Sudan University of Science and Technology
College of Graduate Studies and Scientific

Assessment of Effect dose in CT renal Angiography

تقييم الجرعة المؤثرة اثناء تصويرالاوعية الكلوية بالاشعة المقطعية

A thesis submitted for partial fulfilment for the requirements
of MSc degree in Medical Physics

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صدق الله العظيم

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Dedication

To

My parent

To

My Brothers

To
My friends

And

Finally my family

Dedicate this Research

Acknowledgments

First for most, I would like to express my deepest gratitude to. **Dr.Hussein Ahmed Hassan** for this support and guidance. Without this help this work could not have been accomplished. I also would like to thank Alamal diagnostic center and AlBugaa diagnostic center.

Deep thanks to my friends and finally, I’ would like to sincerely thank my family for their consistent mental support.

Table of Contents

List of Figures:-

	profile were entirely concentrated to are angular of width N.hcol, with N being the number of independent (i.e.non-overlapping) slices that are acquired simultaneously.	
2.11	The average level of total dose profile, which called (Multiple scan Average Dose (MSAD). (Shope 1981), is higher than the peak value of each single dose profile. This increase results from the tails of the single dose profiles	40
2.12	(1).Schematic illustrates the profile of radiation dose delivered during a single CT scan. The CTDI equals the shaded area under the curve divided by the section thinkness (T). (2) Schematic illustrates the profile of radiation dose delivered during multiple CT scan. Represents section thickness, and represent the interval between sections. The MSAD includes the contributions of neighbouring sectionsthe dose of section of interest	41
2.13	Dose length product (DLP) in CT (Total dose profile of a scan series with n=15 sub-sequent rotations. The dose-length product (DLP) is product of the height (dose, i.e.	43

List of Table:-

List of Abbreviations:-

AEC:	Automatic Exposure Control
CT	computed tomography
CTA	computed tomography Angiography
CTDI	computed tomography Dose Index
DLP:	Dose Length Product
MSAD	Multiple Scans Average Dose
MSCT	Multiple Scans computed tomography
UNSCEAR:	The United Nation Scientific Committee on effects Atomic

Radiation

Abstract

Computed Tomography (CT) is diagnostic imaging modality giving higher patient dose in comparison with other radiologic procedures, so the calculation of patient dose in CT exam is very significant . CT improved many diagnoses of diseases. The increasing use of CT in Sudan in recent years is consider to motivated the researchers to reduce the exposure of the patient dose and that the risks Known to X-ray. This study aimed to assessing the radiation dose and estimating the risks resulting from exposure to X-ray during CT angiography (CTA) the 64 slice instruments . A total of 50 patient were examined in Alamal National hospital and AlBugaa Diagnostic hospital using spiral CT Scan 64 slices and general electric 16 slices (in the

period April 2016-May 2016) The average age of patient samples was(46.4000±14.02621)Years .The main effective dose of renal angiography per procedure was (4.4741±1.28744) msv.The patient will exposed to standard dose during the examine of renal CT angiography .The measurement of the dose during renal procedure can be considered as the best method of evaluation of the cancer risks

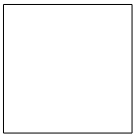
الملخص

الاشعة المقطعية هي تقنية تصوير طبي عند إستخدامها تعطي جرعة إشعاع عالية للمريض بالمقارنة مع الفحوصات الإشعاعية الإخري ، لذلك حساب الجرعات الإشعاعية للمرضي مهم جدا". كما أن الأشعة المقطعية زادت من المقدرة علي تشخيص كثير من الإمراض . تعتبر زيادة إستخدام الأشعة المقطعية في السودان في السنوات الإخيرة من الإسباب التي حفزت الباحثين لخفض الجرعة الإشعاعية والخطر الإشعاعي المصاحب . لذلك هدفت هزة الدراسة الي قياس الإشعاع وتقدير الخطر الإشعاعي الناجم عن فحوصات الأشعة المقطعية للإجهزة

ذات الإربعة وستون شريحة . تم فحص 50 مريضا" بمستشفي الامل الوطني ومستشفي البقعة التشخيصي مستخدمين الشرائح 64و 16 في الفترة من إبريل 2016 وحتي مايو 2016م. بلغ متوسط العمر للمرضي(46.4000±14.02621) سنة . بلغ متوسط الجرعة الفعالة للإوعية الكلوية(4.4741±1.28744) ملي سيفرتيتعرض المريض لجرعة معتبرة أثناء فحص الإوعية الكلوية بالإشعة المقطعية .

يعتبر قياس الجرعة الفعالة للاوعية الكلوية تعتبر امثل طريقة لتقييم المخاطر الناتجة عن السرطان .

Chapter One: Introduction



Chapter One: Introduction

1.1Introduction:

Computed tomography (CT) is an imaging technique which produces a digital to graphic image from diagnostic x-rays. In the early 1970 samajorin innovation was introduced into diagnostic imaging. This innovation, X-rays CT, is recognized today as most significant single event in medical imaging since the discovery of x-ray (William R, E. Russell, 2002).

CT was invented by a British engineer Sir Godfrey Hounsfield Who also won the Nobel Prize because this invention. CT was first introduced in the clinical Practice in 1972 which was only limited to the brain scan.

CT is in its fourth decade of clinical use and has provided in valuable as diagnostic tool for many clinical applications. From cancer diagnostic to traumas to osteoporosis screening. CT was the first imaging modality that made it possible to probe the inner depths of the body, Slice by Slice. 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. The first CT scanner, an EMI1, produced images with 8080 pixel resolution (3-mm pixels) , and

each pair of Slices required approximately 4.5 minutes of Scan time and 1.5 minutes of reconstruction time .

Because of long acquisition time required for the early Scanner and the constraints of Cardiac and respiratory motion , it was originally thought that CT would be Practical only for head Scan (Goldman 2007) CT is one of the many technologies that were made possible by the invention of the computer.

The clinical potential of CT because obvious during its early clinical use, and the excitement forever Solidified the role of computers in medical imaging .Recent advances in acquisition geometry , multiple detector arrays , and x-ray tube design have led to scan times now measured in fraction of a second . Modern computers deliver computational power that allows reconstruction of the image data essentially in real time (Jerrold T,J.antony,Ed wins,Boone,2002) CT has fascinated the world with production of high contrast resolution images for visualizing soft tissues and the ability of producing tomography and three dimensional(3D) volumetric images (IAEA 2007) Thus , it has changed the perception on medical diagnostic quality and as a result it has improved the quality of health care . Now, CT is becoming common diagnostic tool in many major hospital in the whole world.

It is obvious that CT gives a lot of advantages such as faster Scanning procedure, good Spatial resolution and good contrast, compared to other modalities, Nowadays , many medical centres choose to send cases like accident and emergency cases , urology, cardiac imaging and paediatric imaging for CT Scan as their first option for easy diagnosis of symptoms.

In Some countries Sinusitis cases were likely referred to CT compared to the plain radiograph because CT were able to Show important structures (Zammit.Maepel etal.2003) .Having taken notice of that , the manufactures , are also intense introducing the latest technologies and applications of their CT due to high de mind of the CT Scanner .

1.2 Problem of the study:

Computed tomography Radiation dose is a major issue in diagnostic medical imaging because of the high patients dose exposure sometimes it is more than require which give high risk dose for the patient, assessment of the effective dose help to optimise this issue in the different ct diagnostic application e.g. (renal angiography in this study).

1.3 Objectives:

General objective:

The main objective of the study is to estimate effect dose in CT renal angiography (adult)

Specifics objective:

I. Measure effective dose (ED)

ii. Estimate the radiation risks for patients undergoing CTA procedures.

1.4 Out lines:

The objectives of the study are to Thesis outlines:

This thesis is concerned with the assessment of radiation dose for patients during CT angiography

Accordingly, it is divided into the following chapters:

Chapter one is the introduction to this thesis. This chapter presents the historical background and radiation risks, in addition to study problem, objectives and scope of the work. It also provides an outlines of the thesis.

Chapter two contains the background material for the thesis. Specifically it reviews the dose for all absorbed dose measurements and calculations. This chapter also includes a summary previous work performed in this field.

Chapter three describes the materials and methods that used to measure dose for CT machines and explains in details the methods for calculation and optimization.

Chapter four presents the results of this study.

Finally Chapter five presents the discussion, conclusion and recommendations of this thesis and presents the suggestions for future work.

Chapter two
Theoretical Background

Chapter two
Theoretical Background

2.1Anatomy of Kidney:-

The Kidneys are the main part of urinary system, are made up of millions of nephrons that act as individual filtering unit and it complex structures themselves. The ureters, urethra and urinary bladder complete the urinary system.

In the human body the Kidneys are located in abdominal cavity. More specifically in the par vertebral gutter and it lie in retroperitoneal position at slightly oblige position. It’s two Kidneys, one of each side of the spine. The symmetry within the abdominal cavity caused by liver typically results in the right Kidney being slightly lower than the left, and the left Kidney being located more medial than the right. a Left Kidney approximately at the vertebral level TI2 to L3, and the right slightly lower. The sit of right Kidney just below the diaphragm and posterior to the liver. and the left below the diaphragm and posterior to the spleen. Right.(Ciffsnotes. com /study guide/ Anatomy of the Kidney).

Resting on top of each Kidney is an adrenal gland which surrounded by tow layer (the renal and Para renal fat) and the renal fascia. In adult each Kidney weight between 125and 170bgramin males and between 115 and 155 gram in females. The left Kidney is typically

layer than the right. (Ciffsnotes . com / study guide/ Anatomy of the Kidney).

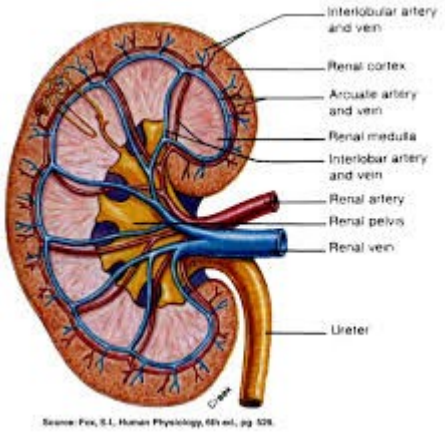


Figure 2.1 shown the structure of the kidney (Radiographic.rsna.org)

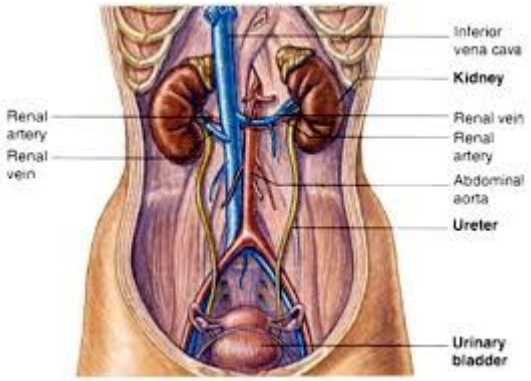


Figure 2:2: position of the Kidney and related organs (Radiographic .rsna.org.2009)

2.2 CT Machine

2.2.1: The CT scanner components

The general structure of CT equipment can be divided in three principle elements:

The Data Acquisition and Transfer system, which encompasses the gantry, the patients table and the power distribution unit and the data transfer unit (Nunes,2010).

The Gantry which is central opening gantry is moveable frame that contains the x-ray tube including collimators and filters ,detectors, data acquisition system (DAS), rotational components including slip ring systems and all associated electronics such as gantry angulations motors and positioning laser lights. A CT gantry can be angled up to 30 degrees toward a forward or backward position (Nunes, 2010).

The Table is where the patients is positioned (Lie down), and it moves through the gantry. The patients table and the gantry constitute CT scanner itself (Nunes, 2010).

The power Distribution unit supplies power to the gantry, the patients table and the computers of the Computing System , which is localized in a separate room as will be explained next (Nunes, 2010).

The computing System (or operators console) is installed in separate room, making it possible for the operator (technician) to control the acquisition process, introducing patient data and selecting several acquisition parameters such as the KVp , mA values the protocol is going to use (Nunes, 2010). Also there is

another operators console for editing and post-processing is also necessary, so it possible to analyze and review previous exam data, without interfering with the current examinations taking place (Nunes, 2010).

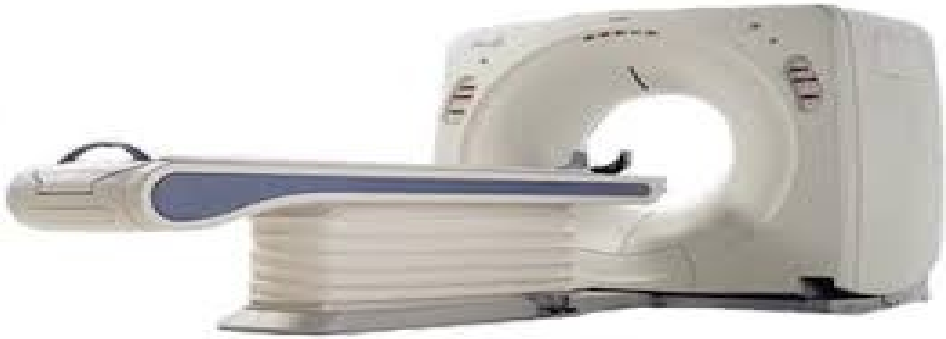


Figure (2.3) CT scanner (Nunes,2010)

3- The image reconstruction system: receives the X-ray transmission data information from the data transfer unit, in a digital format. This gathered data is then corrected to using reconstruction algorithms and later stored (Nunes, 2010).

2.3 CT Generations

2.3.1 First –Generation CT Scanners

The EMI Mark I scanner, the first commercial scanner invented by Hounsfield, was introduced in 1973 (Hounsfield GN, 1973). This scanner acquired data with an x-ray beam collimated to a narrow (pencil) beam directed to a single detector on the other side of the patient; the detector and the beam were aligned in a scanning frame. A single projection was acquired by

moving the tube and detector in a straight-line motion (translation) on opposite side of the patient (Fig 2.4). To acquire next projection, the frame rotated 1, then translated in the other direction. This process of translation and rotation was repeated until 180 projections were obtained. The earliest version required about 4.5 minutes for a single scan and thus were restricted to regions where patient motion could be controlled (the head) . Since procedures consisted of a scan, procedure time was reduced somewhat by using two detectors so that two parallel sections were acquired in one scan. Although the contrast resolution of internal structures was unprecedented, image had poor spatial resolution (on the order of 3 mm for a field of view of 25 cm and 80 80 matrix) and very poor z-axis resolution (13 mm section thickness) (Mahesh,2002).

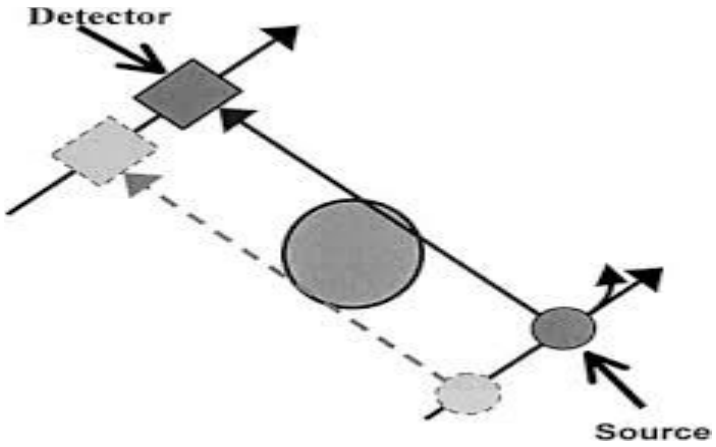


Fig (2.4): Diagram of the first-generation CT scanner, which used a parallel x-ray beam with translate-rotate motion to acquire data (Mahesh, 2002)

2.3.2 Second –Generation CT Scanners

The main impetus for improvement was in reducing scan time ultimately to the point that regions in the trunk could be imaged. By adding detectors angularly displaced, several projections could be obtained in a single translation. For example, one early design used three detectors each displaced by 1. Since each detector viewed the x-ray tube at a different angle, a single translation produced three projections. Hence, the system could rotate 3 to the next projection rather 1 and had to make only 60 translations instead of 180 to acquire a complete section (Fig 2.5). Scan time were reduced by a factor of three. Designs of this type had up to 53 detectors, were ultimately fast enough (tens of seconds) to permit acquisition during a single breath hold, and thus were the first designs to permit scans of the trunk of the body. Because rotating anode tubes could not with stand the wear and tear of rotate-translate motion, this early design required a relatively low output stationary anode x-ray tube. The power limits of stationary anodes for efficient heat dissipation were improved somewhat with the use of a symmetrical

focal spots (smaller in the scan plane than in the z-axis direction), but this resulted in higher radiation doses due to poor beam restriction to the scan plane. Never the less, these scanners required slower scan speeds to obtain adequate x-ray flux at the detectors when scanning thicker or body parts (Mahesh,2002).

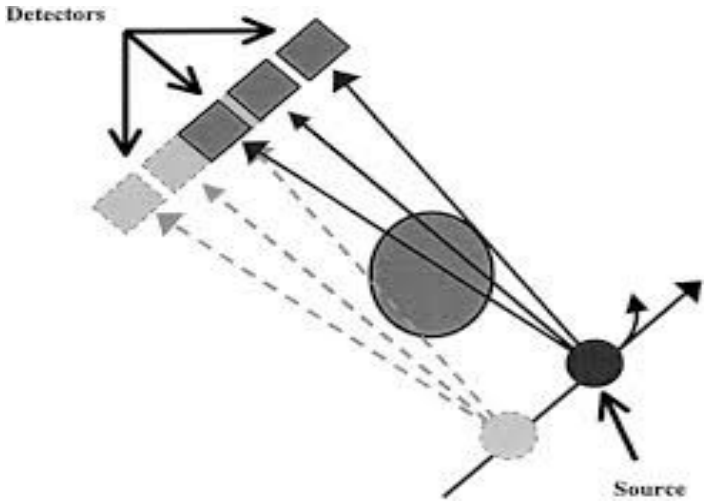


Fig (2.5): Diagram of the second-generation CT scanner, which used translate-rotate motion to acquire data (Mahesh, 2002).

2.3.3 Third-Generation CT Scanners

Designers realized that if Apure rotational scanning motion could be used, then it would be possible to use higher-power, rotating anode x-ray tubes and thus improves scan speeds in thicker body parts. One of the first designs to do so was the so-called third generation or rotate-rotate geometry. In these scanners, the x-ray tube is collimated to wide, fan-shaped x-ray beam and directed toward an arc-shaped row of detectors. During

scanning, the tube and detector array rotate around the patient (Fig 2.6), and different projections are obtained during rotation by pulsing the x-ray source or by sampling the detectors at a very high rate. The number of detectors varied from 300 in early version to over 700 in modern scanners. Since the slam-bang translational motion was replaced with smooth rotational motion, higher-output rotating anode x-ray tubes could be used, greatly reducing scan times. One aspect of this geometry is that rays in a single projection are divergent rather than parallel to each other, as in earlier designs. Beam divergence required some modification of reconstruction algorithms, and sampling considerations required scanning an additional are of one fan angle beyond 180, although most scanners rotate 360 for each scan. Nearly all current helical scanners are based on modifications of rotate-rotate designs. Typical scan times are on the order of a few second or less, and recent versions are capable of sub second scan times (Mahesh, 2002).

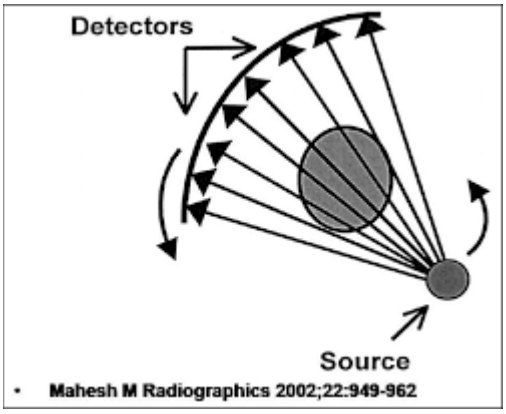


Fig (2.6): Diagram of the third-generation CT scanner, which acquires data by rotating both the x-ray source with wide fan beam geometry and the detectors around the patient. Hence, the geometry is called rotate-rotate motion (Mahesh, 2002).

2.3.4: Fourth-Generation CT Scanners

This design evolved nearly simultaneously with third-generation scanners and also eliminated translate-rotate motion. In this case, only the source rotates within a stationary ring of detectors (Fig 2.7). The x-ray tube is positioned to rotate about the patient within the space between the patient and the detector ring. One clever version, which is no longer produced, moved the x-ray tube out of the detector ring and tilted the ring out of the x-ray beam in a wobbling (mutation) motion as the tube rotated. This design permitted a smaller detector ring with fewer detectors for a similar level of performance. Early fourth-generation scanners had some 600 detectors and later versions had up to 4,800.

Within the same period, scan times of fourth-generation designs were comparable with those of third-generation scanners. One limitation of fourth-generation designs is less efficient use of detectors, since less than one-fourth are used at any point during scanning. These scanners are also more susceptible to scatter artifacts than third-generation types, since they cannot use anti scatter collimators, CT scanners of this design are no longer commercially available except for special-purpose applications.(Mahesh,2002)

Until around 1990, CT technology had evolved to deliver scan plane resolutions of 1-2 1p’mm, but z-axis resolution remained poor and interscan delay was problematic due to the stop-start action necessary for table translation and for cable un winding, which resulted in longer examination times. The z-axis resolution was limited by the choice of section thickness, which ranged from 1 to 10 mm.For thicker sections, the partial volume averaging between different tissues led to partial volume artifacts. These artifacts were reduced to some extent by scanning thinner sections. In addition, even though it was possible to obtain 3D images by stacking thin sections, inaccuracy dominated due to involuntary motion from scan to scan. A typical 3D reconstruction of this era is

shown in (Figure 2.7) the step like contours could be minimized by overlapping of CT sections at the expense of a significant increase in radiation to the patient. Also, the conventional method of section-by-section acquisition produced misregistration of lesions between sections due to involuntary motion of anatomy in subsequent breath holds between scans. It was soon realized that if multiple sections could be acquired in a single breath hold, a considerable improvement in the ability to image structures in regions susceptible to physiologic motion could result. However, this required some technological advances, which led to the development of helical CT scanners. (Mahesh, 2002)

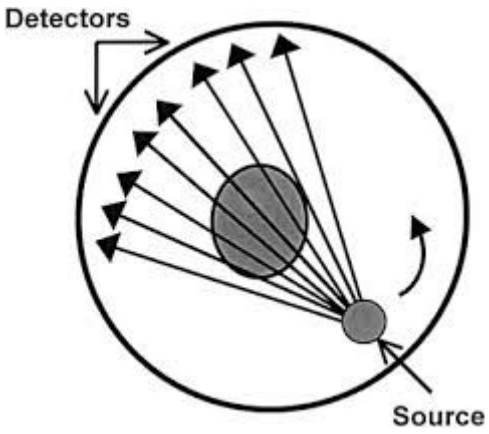


Fig (2.7): Diagram of the fourth-generation CT scanner, which uses a stationary ring of detectors positioned around the patient. Only the x-ray source rotates with wide fan beam motion. From (Mahesh, 2002)

2.4 CT imaging formation

The technique used in CT-scanners share most of its characteristics with conventional X-ray imaging, and the prime differences are seen in projection, detection and acquisition as presented in Figure 2.12 below (Kalra, M. K, et al 2006).

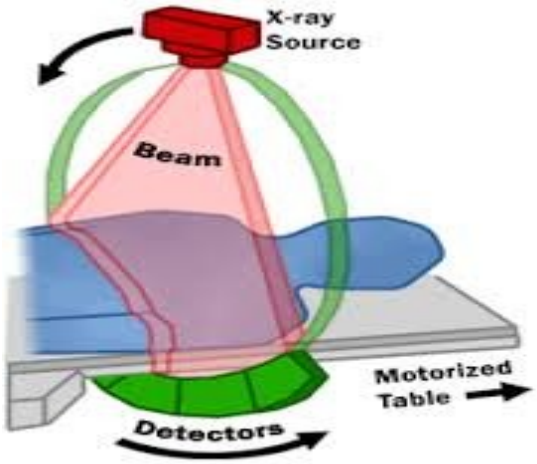


Fig (2.8) Simple overview of a third generation CT-imaging system (Kalra, M.K, et al 2006)

2.4.1 Parameters

In order to properly calculate and compare doses, it is imperative to have a standardized nomenclature to ensure that all data is comparative (Kalra, M. K, et al 2006). Without this, it will be difficult to reproduce measurements, and to develop consistent protocols. When performing a CT examination, a number of parameters are defined by the operator. The thesis will cover the parameters deemed important for correct, uniform dosimeter: tube Voltage, tube current, total scan length, rotation time, slice thickness and pitch.

Automatic exposure control (AEC) and iterative reconstruction will be briefly covered, as their impact on dose and image quality is more of a qualitative influence than a quantitative one (Kalra, K, Et al 2006).

2.4.1.1 Tube Voltage

The tube voltage (KV) determines the voltage across the anode and cathode of the X-ray tube, and therefore the acceleration of the electrodes interior vacum. This determines the Kinetic energy of the electrodes when they reach the anode, and there the number of interactions they can initiate before being absorbed. As a consequence, an increase in tube voltage will increase the dose, all other factors Kept constant, however, the increase is not directly proportional as was the case with current. Voltage determines the energy of the electrons, and therefore the energy distribution of the incident X-rays. It is rarely adjusted from the customary value of 120 KV. Certain examinations use a different voltage, but seldom outside the range of 80 to 140 KV (Kalra, M. K, et al 2006).

2.4.1.2 Tube current

The tube current (mA) influences the number of photons exiting the X-ray tube, as it determines the number of electrons leaving the cathode. The tube

current is directly proportional to radiation dose, and as such is a prime parameter in adjusting the dose. Instead of tube current is some time used the tube-current-time-product (mAs), which is the tube current multiplied with the scan time (Kalra, M. K , et al 2006).

2.4.1.3 Rotation time

The rotation time of the gantry (s) has decreased greatly over the last few decades, with modern scanners, which having a rotation time in the area of 0.4 seconds. The main consequence of the decreased rotation time is an increase in the noise and a reduction in absorbed dose. To avoid the noise, it is customary to increase the tube current accordingly(M. K, Maher, et al 2004).

2.4.1.4 Total Scan Length

It is apparent that the total scan length (cm) influence the absorbed dose, as an increase in scan length will expose a larger part of the patient to radiation. Therefore, it is imperative that scan length is to be limited to cover just the diagnostically relevant part of the patient, otherwise, an unnecessary increase in dose will be seen (ICRP , 2000). This is relatively easy with SSCT; however, the situation is more complicated for MSCT. At the initiation of the scan, the X-ray tube will be activated the moment the first row of detectors reach the diagnostic area. The X-ray beam will irradiate the entire detector-array, but only the first row of detectors will be acquiring image data. The remaining detector rows will not acquire data, but the area will still be irradiated. This is called over scan, and a small degree of over scan is required for correct reconstruction. As the table moves, more rows of detectors are entering the diagnostic area, contributing to the image. At the reverse end of the patient, the

same scenario occurs, and a note worthy part of the dose is absorbed in patient outside the diagnostic area (M. K, Maher, et al 2004).

2.4.1.5 Slice Thickness

In SSCT, with only a single row of detectors, the slice thickness (cm) is determined by simple collimation. The maximum slice thickness is limited by width of the individual detector element (typically 10 mm (M. K, Maher, et al 2004), and by collimating the beam, this thickness can be decreased. In other words, the width of the beam is equal to slice thickness. In MSCT, the width of each individual detector element in the longitudinal direction determines the minimum slice thickness. This has a significant impact on image quality, as thin slices have better spatial resolution compared to thick slices, but lower SNR .To address the decrease in SNR, it is necessary to increase for instance the tube current, resulting in a significant increase in dose to the patient (Kalender, et al,2005).

2.4.1.6 Pitch

With the prevalence of helical MSCT, it is necessary to incorporate the incremental movement of the table, in relation to the irradiated area. This is defined as pitch, being the increment of the table per rotation, divided by the width of the beam. In Figure 2.13 below, a 4-slice MSCT is rotated twice around the patient, resulting in the acquisition of eight slices in pairs of two (indicated by colour). The slices are in reality at an incline, as the patient is moving during exposure (Kalra, M. K, et al 2006).

Pitch = table feed per rotation/collimation

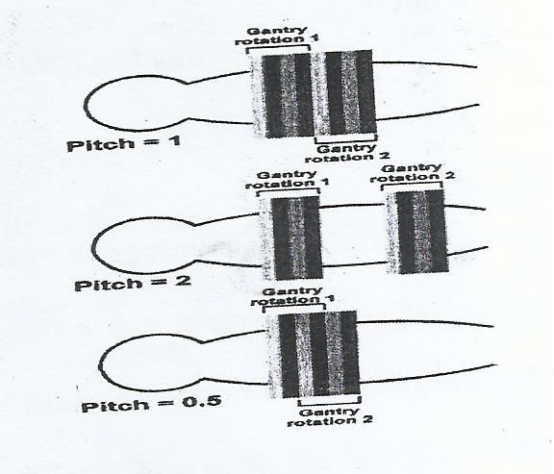


Fig (2.9) the effect of pitch on irradiated area, with a overlap for pitch <1 (23)(Kalra, M.K, et al 2006)

2.4.1.7 Automatic Exposure Control

Technological advances lead to the development of a technique where the tube current is modulated in real-time, in order to minimize the dose while retaining image quality. This technique, Automatic Exposure Control (AEC) varies the tube current during exposure. Variance is relative to patient thickness, optimized to achieve dose distribution defined by a desirable image quality. It is possible to archive a significant reduction in dose based on which type of AEC is used: either the exposure varies within a single slice, in the image plane of the slice, or it is modulated in the longitudinal direction of the patient. It is also possible to combine these two types of AEC (Kalra, M. K, et al 2006).

2.5 In Sudan CT

Te number of CT scan is increasing rapidly. The first ever CT scan was installed in the Military Hospital in 1981 followed another machine installed in Modern Medical centre, Khartoum in 1984.

Since that date, the number of CT Scan are more than 42 scanners, varying between 2 slice and 64 slice and one of them are 128 slice and all the rest are spiral CT (Euro J Radiol.2010).

2.6 Definition of CTA:-

Computed tomography angiography (CTA) uses an injection of iodine-rich contrast material and CT scanning to help diagnose and evaluate blood vessel disease or related conditions, such as aneurysms or blockages.

Tell your doctor if there’s a possibility you are pregnant and discuss any recent illnesses, medical conditions, medications you’re taking, and allergies. You will be instructed to not eat or drink anything several hours beforehand. If you have a known allergy to contrast material, your doctor may prescribe medications to reduce the risk of an allergic reaction. These medications must be taken 12 hours prior to your exam. Leave jewellery at home and wear loose, comfortable clothing. You may be asked to wear a

gown. If you are breastfeeding, talk to your doctor about how to proceed.

Angiography is a minimally invasive medical test that helps physicians diagnose and treat medical conditions. Angiography uses one of three imaging technologies and, in most cases, a contrast material injection is needed to produce pictures of blood vessels in the body.

Angiography is performed using:

-x-rays with catheters

-computed tomography (CT)

-magnetic resonance imaging (MRI)

CT angiography uses a CT scanner to produce detailed images of both blood vessels and tissues in various parts of the body. An iodine-rich contrast material (dye) is usually injected through a small catheter placed in a vein of the arm. A CT scan is then performed while the contrast flows through the blood vessels to the various organs of the body. After scanning, the images will be processed using a special computer and software and reviewed in different planes and projections. (RadiologyInfo.org)

2.7 CTA advantages:-

Speed. The entire length of the ICA can be scanned in under 60 s (the extracrani ICA alone in less than 30 s),

minimizing image misregistration from motion and breathing artifacts, and often reducing contrast requirements.

Accuracy. CTA provides truly anatomic, non-flow dependent data with regard to length of stenoses, residual lumen diameters and areas, and calcifications; flow-dependent techniques such as MR angiography (MRA) and ultrasound (US) are not able to provide these data.

Low Risk. CTA has a lower rate of patient discomfort, is less expensive, and has considerably lower risk of stroke and other vascular complications compared to conventional catheter arteriography. It is also advantageous in situations when MR is contraindicated or cannot be performed. CTA is typically more readily available than MR, especially in emergency settings.

CTA, unlike MRA ,lends itself to the imaging of acutely ill patients, as there are no restrictions on the type and quantity of associated support equipment, such as intravenous pumps, ventilators, or monitoring hardware. Because CT scan acquisition is more rapid than that of MRA, CTA is less prone to motion artifact.

When CTA is combined with CT perfusion (CTP) for the evaluation of acute stroke, quantitative perfusion data

can also be obtained, which is not typically possible with MR perfusion imaging. (RadiologyInfo.org)

2.8 Radiation risk:-

2.8.1 CT radiation risk:-

CT scan uses a high level of ionizing radiation. Ionizing radiation has the capacity to break molecular bonds, and thus alter the molecular structure of the irradiated molecules. The human body cells operation is controlled by the chemical structure of the DNA molecule that they include. Ionizing radiation cause DNA double strand breaks per cell per Gray. And removes apportion of epigenetic markers of the DNA, which regulate the gene expression, at the radiation doses, which typical CT scan impose, a DNA molecule of 40%-100% of the irradiated cells is damaged by one or more double strand breaks. This insult is followed by an effort of the cell in attempt to repair the damaged and broken DNA, however, there pair proce is not perfect and faults that are not properly repaired can cause the cell to stray from its original design of operation. The improper operation can manifest in cell death, cancer, and in other puzzling health conditions, as can be expected from an operation, which randomly alter cell’s DNA, and epigenetic makers (Roxanne Nelson 2009) Aporation of the population possess

flawed DNA repair mechanism and thus suffer a greater insult due exposure to radiation Un like CT, MRI does not use ionizing radiation, and does not cause double strand breaks to the DNA (Khamsi, et al (2007)). The individual risk from radiation associated with a CT scan is quite small compared to the benefits that accurate diagnoses and treatment can prove. Still, unnecessary radiation may be delivered when CT scanner parameters are not appropriate adjusted for the patient size (Anne etal.2001). There is no doubt that many patient have benefited from the rapid diagnoses made possible by CT and from its value for monitoring chronic disease. However is increasing concern regarding the risk of this exposure to radiation. It is well established that radiation can be harmful and has deterministic and stochastic effect. Deterministic effect, Such as hair loss, Skin burns, and cell death, are dose dependent but do not occur below threshold of 150-200msv. Since the typical limited dose associated with proper use of CT is in the range of 2010msv, deterministic effect are not normally aconcerrn.Induction of cancer by radiation is a probabilistic (stochastic) effect, not deterministic effect. That is, higher radiation doses are associated with a higher likelihood of with carcinogeusis, but even low

doses of radiation could potentially induce carcinogenesis and it is more difficult to assess a safe level of exposure (Rounds et al .2003).

CT was always scan sidered (high dose) technique, there is growing realization that image quality in CT often exceeds the level needed for confident diagnosis and patient doses are higher than necessary X-ray procedure , medical personnel can tell if the patient has been over exposed because of the film is over exposed, produce a dark image(ICRP 2006). However, with CT there is no obvious evidence that the patient has been over exposed because the quality of the image may not be compromised. Several recent articles (Kalender et al1999. R ehani M, Berry M 2000, Rehani M 2000).

Stress that is important to use the lowest radiation dose necessary to provide an image from which an a curate diagnosis can be made, and that signification dose reduction can be a achieved without compromising clinical efficacy (Keith et al 2010).

The United Nation Scientific committee on the effect of atomic Radiation (UNSCEAR, 200) has highlighted that the worldwide there about 93 million CT examination performed annually at a rate of about 57 examination per 1000 person.

UN CEAR also estimated that CT constitutes about 5% of all X-ray examination worldwide will accounting for about 34% of resultant collective dose. In the countries that were identified as having the highest level of healthcare, the corresponding figures were 6% and 41% respectively.

New advancement of CT has also led to great increase of the radiation dose to the patient.

The use of multi i-Slice computed tomography (MSCT) has aggravated the scenario with the increasing of collective dose of CT examinations because the MSCT produces higher dose to the patients compared to single slice CT (SSCT) (Hun old et al.2003).

2.8.2 Radiation risk in CTA:-

-There is always a slight chance of cancer from excessive exposure to radiation. However, the benefit of an accurate diagnosis far outweighs the risk.

-If you have a history of allergy to x-ray contrast material, your doctor may advise you to take special precautionary medication, such as a steroid, for a few hours or the day before CT angiography to lessen the chances of allergic reaction. Another option is to undergo a different exam that does not require iodinated contrast material.

-In patients who are at risk for kidney failure and who already have borderline kidney function, administering iodinated contrast material could potentially further damage kidney function. Check with your referring doctor and radiologist to obtain more information regarding this risk.

-If a large amount of x-ray contrast material leaks out from the vein being injected and spreads under the skin where the IV is placed, it may damage the skin, blood vessels and nerves. If you feel any pain or tingling sensation in this area during or immediately after the contrast material injection, you should immediately inform the nurse/technologist.

-Women should always inform their physician and x-ray or CT technologist if there is any possibility that they are pregnant. See the Safety page for more information about pregnancy and x-rays.

-Manufacturers of intravenous contrast indicate mothers should not breastfeed their babies for 24-48 hours after contrast medium is given. However, both the American College of Radiology (ACR) and the European Society of Urogenital Radiology note that the available data suggest that it is safe.

-To continue breastfeeding after receiving intravenous contrast. For further information please consult the ACR Manual on Contrast Media and its references.

-The risk of serious allergic reaction to contrast materials that contain iodine is extremely rare, and hospitals are well-equipped to deal with them (RadiologyInfo.org).

2.9 CT Dose equivalent and unit

2.9.1 Radiation dose units

The specific units of measurement for radiation dose commonly referred to as effective dose (mSv). Other radiation dose measurement units include Rad, Rem, Rontgen, and Sievert. Because different tissues and organs have varying in sensitivity to radiation exposure, the actual effective dose to different parts of the body for X-ray procedure varies. The term effective dose is used when referring to the dose averaged over the entire body. The effective dose accounts for the relative sensitivities of different tissues exposed. More importantly, it allows for qualification of risk and comparison to more familiar sources of exposure that range from natural background radiation to radiographic medical procedure. As with other medical procedures, X-rays are safe when used with care. Radiologists and X-ray technologists have been trained

to use the minimum amount of radiation that is necessary to obtain the needed results. The decision to have an X-ray examination is a medical one, based on the likelihood of benefit from the examination and the potential risk from radiation (ICRP 1990, ICRP 19991).

During the early days of radiological experience there was no precise unit of radiation dose that was suitable either for radiation protection or for radiation therapy. For purposes the radiation protection, a common (dosimeter) was a piece of dental film with a paper clip attached. A daily exposure great enough to just produce a detectable shadow was considered a maximum permissible dose. For greater dose and for therapy purposes the dose unit was frequently the (skin erythema unit). Because of the great energy dependence of the dose units could be biologically meaningful or useful either in quantitative study of the biological effects of radiation of radiation or for radiation protection purposes. Furthermore, since the fraction of the energy in a radiation field that is absorbed by the body is dependent, it is necessary to distinguish between radiation exposure and radiation absorbed dose. (ICRP 60: recommendation)

2.9.1.1 Absorbed doseA absorbed dose is a non-stochastic quantity, defined as the expectation value of

the energy imparted to matter, y, per unit mass of tissue at the point of interest dm (ICRP 60: 1990 recommendation).

$$D=d\,E/dm \qquad 2.1$$

Radiation damage depends on the absorption of energy from the radiation and is approximately proportional to the concentration of absorbed energy in tissue. (ICRP 60: 1990 recommendation).

2.9.1.2 Gray

The basic unit of radiation dose called the gray (Gy) and is defined as: one absorbed radiation dose of one joule per kilogram. The gray is universal applicable to all types of ionizing radiation dosimetry (ICRP 60: 1990 recommendation).

2.9.1.3 Rad

Before the universal absorption of the SI unit, radiation dose easy measured by a unit called the rad (Radiation Absorbed Dose). One rad is an absorbed radiation dose of 100 ergs per gram.

1rad=100ergslg

Since 1 J= 10^7 ergs, and since 1KG= 1000G, 1Gy=100 rads.

Although the gray is the newer unit, and will eventually replace the rad. (ICRP 60: 1990 recommendation).

2.9.1.4 Kerma

Kerma is non-stochastic quantity, defined as the expectation value of the energy transferred (Etr) by uncharged particles (e.g. photons or neutrons) to charge particles per unit mass at the point of interest dm

$$K=dE\ tr/dm \qquad 2.3$$

Kerma has been defined as, and is an acronym for, the sum of the Kinetic energies of all those primary charged particles released by uncharged particles (here photons) per unit mass (Kinetic Energy Released per unit Mass) the unit of kerma is grey (Gy) , where 1 Gy=1j Kg-1.

In a photon field, the Kerma at the point of interest is expressed as

$$K=\int_{E=0}^{Emax} \Psi \quad (E) \quad \frac{\mu tr}{p} \qquad 2.4$$

Where Ψ (E) is the distribution of photon energy fluence and ($\frac{\mu tr}{p}$) is the mass energy –transfer (A ttix, 1986). Photon energy fluence is defined as the product photon fluence and energy E.

Kerma is greater than absorbed dose by a factor of 1/ (1-g). This relation is valid only for irradiation in the condition of charged particle equilibrium i.e. when the number and energies of charged particles leaving is

equal to the number and energies of particles entering this volume.

$$D = (1-g)\,K \qquad 2.5$$

The factor g represent the average fraction of the Kinetic energy of secondary charged particles (produced in all types of interactions) that is subsequently in radioactive (photon emitting) energe-loss processes as the particles slow to rest in the medium. (ICRP 60: 1990 recommendation).

2.9.1.5 Exposure

Exposure is a radiation quantity referring to the intensity of radiation for external radiation of any give energy flux, the absorbed to any point with in an organism depends on the types and the energy of radiation, the depth within the organism of the point at which the absorbed dose is required, and elementary constitution of the absorbing medium at this point. The exposure unit is a measure of photon flux, and is related to the amount of energy transferred from the X-ray field to a unit mass of air. One exposure unit is defined as that quantity of x-or gamma radiation that produces in air, ions carrying 1 coulomb of charge (of either sign) per Kg air.

1x unit= 1c/Kg air.

The exposure unit is based on ionization of air because of the relative ease with which radiation induced ionization can be measured. The exposure unit bay converted in to more fundamental unit of energy absorption per unit mass of air by using the charge on a single ion is 1.6x10-19 coulombs and that the average energy dissipated in the production of a single ion pair in air is 34ev (Cecili Godderidge 1995).

Therefore:

1x unit= $\frac{c}{Kg\,air}$ × $\frac{1\text{ion}}{1.6\times10-19}$ × 34 ev/ion x 1.6 × 10 -19 j/ev × 1Gy/j/Kg = 34Gy (in air)

2.9.1.6 Equivalent dose

Equal doses of all types of ionizing radiation are not equally 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. The equivalent dose (HT) is a measure of the radiation dose to tissue where an attempt has been made to allow for the different relative Biological effects of different types of ionizing radiation. Equivalent dose is therefore a less fundamental quantity than radiation absorbed dose, but is more biologically significant. Equivalent dose has unit of Sieverts (Sv). Another unit, Rontgen equivalent

man (REM or rem), is still in common use in the US ,although regulatory and advisory bodies are encouraging transition to Sieverts (100 Rontgen equivalent man=100 REM=1 sievert).

Equivalent dose (HT) is calculated by multiplying the absorbed dose to the organ or tissue (DT) with the radiation weighting factor, WR. This factor is selected for the type and energy of the radiation incident on the body, or in the case of sources within the body, emitted by the source. The value of WR is 1 for x-ray, gamma rays and beta particles, but higher for protons, neutrons, alpha particles etc…

$$H_{T,R}=W_R X D_{T,R} \qquad 2.6$$

Where $H_{T,R}$ = equivalent dose to tissue T from radiation R

$D_{T,R}$ = absorbed dose D (in Grays) to tissue T from radiation R

The dose in Sv equal to (absorbed dose) multiplied by a (radiation weighting factor) (wr-see Table 2.1 below/0. Prior to 1990, this weight factor was referred to as Quality Factor (QF).

Table2.1 Recommended Radiation Weight Factors (ICRP 60: 1990 recommendation).

Type and energy range	Radiation weighting factor , WR
Gamma rays and X-rays	1
Beta particles	1
Neutrons , energy <10Kev	5
>10 Kev to 100 Kev	10
>100 Ke V to 2Me V	20
>2Me V to 20 Me V	10
>20Me V	5
Alpha particles	5

2.9.1.7 Effective dose

Effective dose equivalent (Now replaced by Effective Dose) is used to compare radiation doses on different body parts on an equivalent basis because radiation dose not affect different parts in the same way . The effective dose is the sum of weighted equivalent doses in all the organs and tissues of the body.)
Effective dose = sum of (organ doses x tissue weighting factor).
The effective dose (E) to an individual is found by calculating a weighted average of the equivalent dose (H) to different body tissues, with the weighting factors (W) designed to reflect the different radio sensitivities of the tissues:

$$E=\sum_i H_i W_i$$

The unit for effective dose is dose is the seivert (Sv) (ICRP 60: 1990 recommendation).

Table (2.2) represent relative sensitivity of organs for developing cancer.

Tissue or Organ	Tissue Weighting Factor
Gonads (test or ovaries)	0.20
Red bone marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Esophagus	0.05
Thyroid gland	0.05
Skin	0.01
Bone surfaces	0.01
Remainder	0.05
Whole body	1.00

One sievert is a large dose. The effects of being exposed to large doses of radiation at one time (a cute exposure) vary with the dose. Here are some.

2.9.1.8 Occupational exposure.

Although CT presents only a small percentage of radiology examinations, it results in a significant portion of the effective radiation dose from medical procedures, (I) with the increasing use of CT for screening procedures, (II) and advances in scanner technology, they tend for increasing numbers of procedures performed with this modality may increase. Although CT is clearly providing many clinical benefits,

the motivation to understand radiation dose in general as well as the specific concepts related to CT grows with prevalence of this modality (ImPACT 2007, Jones et al. 1993).

2.10 CT parameters

2.10.1 CT parameters that influence the radiation dose

The radiation exposure to the patients undergoing CT examination is determined by two factors:

Equipment –related factors, .e. the design of the scanner with respect to dose efficiency, and application-related factors, i.e. the way in which the radiologist and X-ray technologist makes use of the scanner (Nagel 2007). In this chapter the features and parameters influencing patient dose are outlined. First, however, a brief introduction on the dose descriptors applicable to CT is given (Nagel 2007).

2.10.2 CT dose descriptors

The dose qualities used in this projection radiography are not applicable to CT for three reasons (ImPACT 2007, Jones et al.1993)

First, the dose distribution inside the patient is completely different from that of a conventional radiography where the dose decreases continuously from entrance of the X-ray beam to its exit, with the

ratio of between 100 and 1000 to 1. In the case of CT, as a consequence of the scanning procedure that equally irradiates the patient from all directions; the dose is almost equally distribution in the scanning plane .A dose comparison of CT with conventional projection radiography in term of skin dose therefore does not make any sense.

Second, the scan procedure using narrow beams along the longitudinal z-axis of the patient implies that a significant portion of the radiation energy is deposited outside the nominal beam width. This is mainly due to penumbra effects and scattered radiation produced inside the beam.

Third, the situation with CT is further complicated by the circumstances in which-unlike in conventional projection radiography-the volume to be imaged is not irradiated simultaneously.

This often leads to confusion about what dose from a complete series of e.g. 15 slices might be compared with the dose from a single slice (ImPACT 2007, Jones et al.1993).

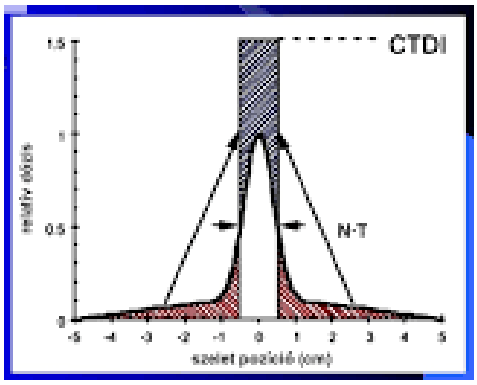
As a conseque, dedicated dose quantities that account for these peculiarities are needed. The (Computed Tomography Dose Index (CTDI), which is a measure of the local dose, and the Dose Length Product (DLP) ,

representing the integral radiation exposure associated with a CT examination. Fortunately, a bridge exists that enables to compare CT with radiation exposure from the other modalities and sources; this can be achieved by the effective dose (E). So there are three dose descriptors in all, which everyone dealing with CT should be familiar with (Nagel 2007).

2.10.2.1 Computed tomography dose index (CTDI)

The (Computed tomography dose index (CTDI) is the fundamental CT dose descriptor. By making use of this quantity, the first two peculiarities of CT scanning are taken into account: The CTDI (unit:Milli gray (mGy) is derived from the dose distribution a long a line which is parallel to the axis of rotation for the scanner (z=axis) and which is recorded for a single rotation of X-ray source (Fig.2.14) illustrates the meaning of the term: CTDI is the equivalent of the dose value inside the irradiated slice (beam) , that would result if the absorbed radiation dose profile were entirely concentrated to a rectangular of width equal to the nominal beam width with N being the number of independent (i.e. non-overlapping) slices that are acquired simultaneously. Accordingly, all dose contributions from outside the nominal beam width, i.e.

the areas under the tails of the dose profile, are added to the area inside the slice (Nagel 2007).



Figer: 2.10: Illustration of term (Computed Tomography Dose Index (CTDI)): is the the equivalent of the dose value inside the irradiated slice (beam) that would result if the absorbed radiation dose profile were entirely concentrated to a rectangular of width equal to the nominal beam width N.hcol, with N being the number of independent (i.e. non-overlapping) slices that are acquired simultaneously (Nagel 2007).

The corresponding mathematical definition of CTDI therefore describes the summation of all dose contributions along the z-axis:

$$CTDI = 1 \div N.hcol. \int_{-\infty}^{+\infty} D\ (Z)\ .dz \qquad (2.2)$$

Where D(z) is the value of the at a given location, z, and N.hcol is the nominal value of the total collimation (beam width) that is used for data acquisition.CTDI is therefore equal to the area of the dose profile (the dose-profile integral) divided by nominal beam width. In

practice, the dose profile is accumulated in range of -50 mm relative to the centre of the beam, i.e. over a distance of 100mm.

The relevancy of CTDI becomes obvious from the total dose profile of a scan series with e.g. n=15 subsequent rotations (Fig.2015). The average level of the total dose profile , which is called Multiple Scans Average Dose (MSAD) (Shape 1981), is higher than the peak value of each single dose profile. This increase results from the tails of the single dose profiles. Obviously MSAD and CTDI are exactly equal of the table feed (TF) is equal to the nominal beam width N.hcol, i.e. if the pitch factor

$$P = \frac{TF}{N.hcol} \qquad (2.3)$$

Is equal to 1. In general (i.e. if pitch factor is not equal to 1, Fig.2016), the relationship between CTDI and MSAD is given by:

$$MSAD = {}^{1}/P.CTDI \qquad (2.4)$$

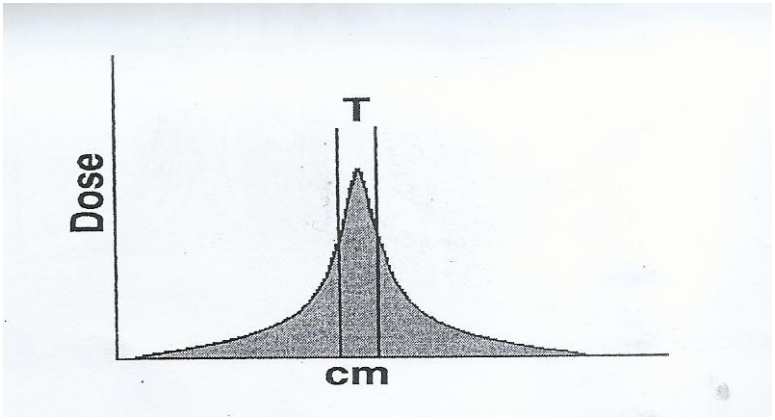


Figure: 2.11: The average level of the total dose profile, which is called (Multiple Scans Average Dose (MSAD) – (Shop 1981), is higher than the peak value of each single dose profile. This increase results from the tails of the single dose profiles (Nagel 2007).

Each pair CTDI (central and peripheral) can be combined into a single are named weighted CTDI ($CTDI_w$) :

$$CTDI_w = \frac{1}{3} CTDI_{100c} + \frac{2}{3} CTDI_{100p} \qquad (2.5)$$

If pitch-related effects on radiation exposure are taken into account at level of local dose (i.e. CTDI) already, a quantity named volume CTDI (CTDI vol), is defined (IEC 2001):

$$CTDIvol = CTDI_w / P \qquad (2.6)$$

So CTDIvol is the pitch-corrected CTDIw. Apart from the integration length, which is limited to 100 mm, CTDIvol is practically to MSAD based on $CTDI_w$ (i.e.$MSAD_w$). Since averaging includes both the cross section and scan length, CTDIvol therefore represents the average dose for a given scan volume. CTDIvol is used as the dose quantity that is displayed at the operator's console of newer scanners (Nagel 2007).

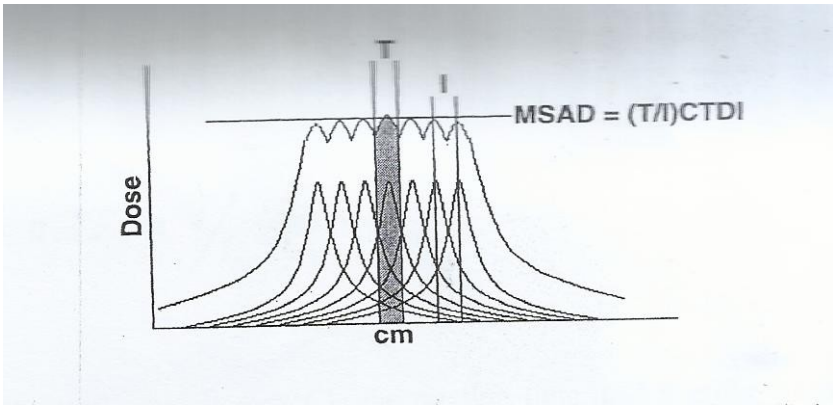


Figure: 2.12: (1) Schematic illustrates the profile of radiation dose delivered during a single CT scan. The CTDI equals the shaded area under the curve divided by the section thickness (T). (2) Schematic illustrates the profile of radiation dose delivered during multiple CT scans represents section thickness, and I represent the interval between sections. The MSAD includes the contributions of neighbouring sections to the dose of the section of interest (D.Tack 2007).

2.10.2.2 Dose length product unit (mGY)

DLP =CTIw.L (mGy-cm). DLP takes both the intensity) represented by $CTDI_{vol}$) and the extension (represented by scan length L) of an into account:

$$DLP = CTDI_{vol}. \text{ Scan length} \qquad (2.7)$$

So DLP increases with number of slices (correctly: with length of irradiated body section), while the dose (i.e. $CTDI_{vol}$) remains the same regardless of the number of slices or length, respectively. The area of the total profile of the scan series represents the DLP.DLP is the

equivalent of the dose-area product (DAP) in projection radiography, a quantity that also combines both aspects (intensity and extension) of patient exposure. In sequential scanning, the scan length is determined by the beam width N.hcol and number of the table feed (TF):

$$L=n*TF + N.hcol \qquad (2.8)$$

While in spiral scanning the scan length only depends on the number (n) of rotations and the table feed (TF):

$$L = n.\ TF = T/t_{rot}.P.N.h_{col} \qquad (2.9)$$

Where T is the total scan time, trot is the rotation time, and P is the pitch factor. While in sequential scanning the scan length L is equal to range from the begin of the first slice till the end of the last, the (gross) scan length for spiral scanning not only comprises the (net) length of the imaged body section but also includes the additional rotations at the begin and the end of the scan (over-ranging) that are required for data interpolations (European Commission 1999). If an examination consists of several sequential or spiral scans, the dose –length product of the complete examination (DLP exam) is the sum of the dose-length products of each single series or spiral scan:

$$DLP_{exam} = \sum_i DLP_i \qquad (2.10)$$

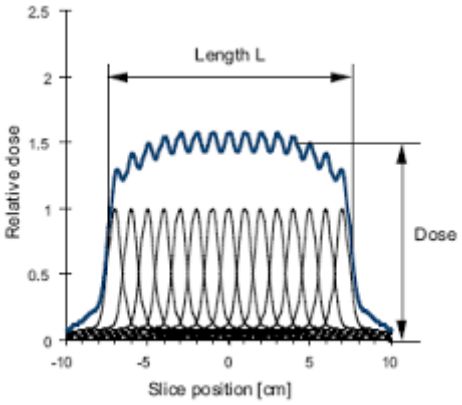


Figure 2.13: Dose length product (DLP) in CT (Total dose profile of a scan series with n=15 sub-sequent rotations. The dose-length product (DLP) is the product of the height (dose, i.e. CTDIvol) and the width (scan length L) of the total dose profile and is equal to the area under the curve (Nagel 2007).

2.10.3 DLP and Effective Dose

CTDI and DLP are CT specific dose descriptors that do not allow for comparisons exposure from others sources, projection radiography, nucler medicine or natural background radiation. The only common denominator to achieve this goal is the (Effective Dose). With effective dose, the organ doses from a partial radiation of the body are converted into an equivalent uniform dose to the entire body (D.Tack 2007).An effective Dose E unit (millisevert, mSv) according to ICRP 60 (ImPACT 2007) is defined as the weighted average of organ dose values HT for a number of specific organs:

E = ∑i WI* (2.11) equation editor

2.11 Previous Studies.

In this study by Sanjay et al (2007), Estimated Risk of cancer Associated with Radiation Exposure from 64-slice computed tomography Coronary Angiography. Computed tomography coronary angiography (CTCA) has become a common diagnostic test, yet there are little data on its associated cancer risk. The recent Biological effects of Ionizing Radiation for (BEIR) VII phase 2 report provides a frame work for estimating lifetime a attributable risk (LAR) of cancer incidence associated with radiation exposure from a CTCA Study ,using the most current data available on health effects of radiation. They study aimed in deter monition the LAR of incidence associated with radiation exposure from a 64-slice CTCA study and evaluate the influence of age, sex, and scan protocol on cancer risk. Organ doses from 64-slice CTCA to standardized phantom (computational model) male and female patients were estimated using Monte carol simulation methods using standard spiral CT protocols. Age and sex specific LARS of individual cancers were estimated using the approach of BEIRVI and summed to obtain whole-body LARS. Main outcome measure whole-body and organ LARS of cancer incidence. Organ doses ranged from 42

to 91 msv for the lungs and 50 to 80 msv for female breast. Life time cancer risk estimates for standard cardiac scans varied from 1 in 143 for a20-year-old woman to 1in 326 for an 80-year-old man. Use of simulated electrocardiographically controlled tube current modulation (ECTCM) decreased these risk estimates to 1 in 219 and 1 in 5017, respectively. Estimated cancer risks using ECTCM for 60-year-oldwoman and a 60-year-old man were 1 in 715 and 1 in 1911, respectively. A combined scan of the heat and aorta had higher LARS, up to l in 114for a 20- year-old. The highest organs LARS were for lung cancer and, in younger women, breast cancer. These estimates derived from our simulation models suggest that use of 64-slice CTCA is associated with angiography negligible LAR of cancer. This risk varies markedly and is considerably greater for women , younger patients, and for combined cardiac and aortic scans.

Jacob Gleans et al (2009) evaluated the radiation Exposure to patients in Multicenter coronary Angiography Trial. The objective of this study was to assess the exposure of patients to radiation for the cardiac CT acquisition protocol of the Multicenter coronary Artery Evaluation using 64-Row Multi detector computed Tomography Angiography (CORE 64)trial.

An algorithm for patient dose assessment with Monte Carlo dosimeter was developed for the aquiline 64-MDCT scanner. During the core 64 study , different acquisition protocols were used depending on patient size and sex, there , six patient models were constructed representing small , normal size , and obese. Organ dose and effective dose resulting from the cardiac CT protocol were assessed for these six patient models.

The average effective dose for coronary CT angiography (CTA) calculated according to Report 103 of the international commission of Radiological Protection (ICRP) is 19msv (range,16-26msv) .The average effective dose for the whole cardiac CT protocol including CT scan grams , bolus tracking, and calcium scoring is slightly higher-22msv (range,18-30msv) .An average conversion factor for the calculation of effective dose from dose-length product of 0.030 msv/mGy . cm was derived for coronary CTA. The current methods of assessing patient dose are not well suited for cardiac CT acquisitions, and published effective dose values tend to under estimated effective dose. The effective dose of cardiac CT is approximately 25% higher when assessed according to the preferred ICRP Report 103 compared with ICRP Report 60.

Underestimation of effective dose by 43%or 53% occurs in coronary CTA according to ICRP Report103 when conversion factor (E/DLP) where E is effective dose and DLP is dose-length product) for general chest CT of 0.017 or 0.014 msv/mGy.cm respectively , is used instead of 0.030msv/mGy.cm.

Chapter three:
Material and Method

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Material and Method

3.1 Material

3.1 .1 Study Groups

This study intended to evaluate the radiation doses from different CT imaging modalities i.e. 64 Slices during CT angiography, The data used in this study was collected from two hospital in the Khartoum state : ALAmal National Hospital, ALBogaa Hospital center, The data collected from April to May 2016.

3.1,2 CT machines

Four CT machines were used to collect data during this study .This machines are installed in to radiological apartments. All quality control test were performed to the machine prior any data collection. The tests were carried out by experts from Sudan Atomic Energy commission (SAEC) .All the data were within acceptable range.

Table 3.1 CT machine

Hospital	Manufacture	Model	Installation	Detected type
ALAmal National hospital	Toshiba 64	Aquition 64	2011	64 Slices
ALBugaa Hospital	GE	Light speed	2010	16 slice

center				

GE: General Electrical

3.2 Data collection:-

Data were collected using a sheet for all patients in order to maintain consistency.

A data collection sheet was designed to evaluta the patients doses and radiation related factor. The collected data included age, tube voltage, tube current, time product settings, and number of sections, In addition we also recorded all scanning parameters, as well as the CT dose descriptors CT volume dose index (in milli sievert) and dose. Length product (in milli sievert-centimeters).All these factors have a direct influence on radiation dose , The entire hospital was passed successfully the extensive quality control tests performed by Sudan atomic energy commission the criteria of this study.

3.3Cancer risk estimation

The risk (RT) of developing cancer in a particular organ(T) following CT exam after irradiation was estimated by multiplying the mean organ equivalent (HT) do dose with the risk coefficients (FT) obtained from (ICRP 60,1990)

$$R_T = H_T F_T \qquad 3.1$$

The overall life time mortality risk(R) per procedure resulting from cancer /heritable was determined by multiplying the effective dose (E) by the risk factors (f).

$$R = E.f = \neg R_T \qquad 3.2$$

The risk of genetic effects in future generation was obtained by multiplying the mean dose to the overies by the risk factor obtained from ICRP 60.

3.4 A analysis of data:-

All dose parameters were registered down and from the display monitor in 64 slices CT Scan and they use in calculation for the effective dose using conversion factor to the renal ,then used as input to statisical soft ware (SPSS) for analysis.

The protocol used in CTA:-

Initial scan without IV contrast, patient should suspended respiration start with scout view to localize start and end position (according to area in question) starts scan area using thin slice thickness, this sequence without injection of contrast media. After that injection IV contrast medium at aflow rate of 4-5 ml/s, CT images are taken and reconstruction, after that post processing technique is applied according to the need.

3.5 CT Dose Measurements:

The patient dose estimate from CT examination using the montecarlo technique requires measurements of

CTDI and conversion coefficient. In theory the CTDI, which is measure of the dose from single- slice irradiation, is defined as integral along a line parallel to the axis of rotation (z) of the dose profiled(z), divided by the nominal slice thickness,(t). In this study dose quantity was obtained (CTDI, DLP) from displayed at the operator's console. CTDI and DLP do not include patient specifics such as size and organ radio sensitivity

Chapter four
Result

Chapter four
Result

4.1: table average value

	Age	Weight	Length	CTDIV	DLP	E	1/E
Mean	46.4000	72.4400	173.8600	7.26880	298.27040	4.4741	.22
Std. Error of Mean	1.98361	1.47887	1.63508	.197434	12.138096	.18207	5.49
Median	46.0000	72.0000	173.0000	7.15000	317.07500	4.7561	.21
Mode	23.00[a]	60.00[a]	180.00	8.270	160.120[a]	2.40[a]	.41
Std. Deviation	14.02621	10.45722	11.56174	1.396073	85.829301	1.28744	.77
Minimum	23.00	55.00	143.00	4.810	160.120	2.40	.41
Maximum	70.00	90.00	195.00	9.810	445.120	6.68	.14

Fig 4.1 : Graph study the average value

4.2Table study group hospital

Hospital name	Frequency	Percent
Almal	30	60.0%
Albugaa	20	40.0%
Total	50	100.0%

Fig 4.2:Graph study group hospital

4.3Table study group gender

	Frequency	Percent
Male	25	50.0%
Female	25	50.0%
Total	50	100.0%

Fig 4.3 Graph study group gender

4.4Study group age distribution

age	Frequency	Percent
21- 30years	8	16.0%

31 – 40years	14	28.0%
41 – 50years	8	16.0%
50- 60years	12	24.0%
61 – 70years	8	16.0%
Total	50	100.0%

Fig : 4.4 Graph Study group age distribution

4.5: Study group age and hospital distribution

			Hospital		Total
			Almal	Albugaa	
Age group	21 – 30years		3	5	8
			10.0%	25.0%	16.0%
	31 – 40year		9	5	14
			30.0%	25.0%	28.0%
	41 – 50year		7	1	8
			23.3%	5.0%	16.0%
	51 – 60year		8	4	12
			26.7%	20.0%	24.0%
	61 – 70years		3	5	8
			10.0%	25.0%	16.0%
Total		N	20	50	
		%	100.0%	100.0%	

4.6: Table study group gender and hospital distribution

		Hospital	Total

		Almal	Albugaa	
Gender	Male	15 50.0%	10 50.0%	25 50.0%
	Female	15 50.0%	10 50.0%	25 50.0%
Total		30 100.0%	20 100.0%	50 100.0%

4.7:Study group age and gender distribution

	Gender		Total
	Male	Female	
Age group	21 – 30years	4 16.0%	4 16.0%	8 16.0%
	31-40years	7 28.0%	7 28.0%	14 28.0%
	41-50years	4 16.0%	4 16.0%	8 16.0%
	51-60years	6 24.0%	6 24.0%	12 24.0%
	61 – 70years	4 16.0%	4 16.0%	8 16.0%
Total		25	25	50

100.0%	100.0%	100.0 %

Chapter Five
Discussion, Conclusion and Recommendation

Chapter Five
Discussion, Conclusion and Recommendation

5.1 Discussion

CT scanning has been recognized as a high radiation dose modality, when compared to other diagnostic X-ray techniques, since its launch into clinical practice more than 30 years ago over that time, as scanner technology has developed and its use has became more widespread, concerns over patient radiation doses from CT have grown, the introduction of multi-slice scanners has focused further attention on this issue, and it is generally believed that it will lead to higher patient doses.

In this study 50 patient adult (over 30 years) are examined by CT Angiography in two hospitals.

Patient dose in this study were measured in different CT technologies, for example Alamal diagnostic center(TOSHIBA Multi-slice 64 helical, mAs and kVp are constant 250 and 120 respectively .And slice thickness was 7mm . And Albugaa diangnostic hospital (siemns 16 electrical general 16 slices, mAs and kVp are constant 250 and 180 respectively.

Patient's demographic data were include 50 patients with in average age (46.4000±14.02621) height(173.8600±11.56174), weight (72.4400±10.45722) CTDIV (7.26880±1.396073) DLP (298.27040 ±85.829301), Effect dose (4.4741±1.28744) are presented in table 4:1.

The most gender of renal is my research was male 50%. Who comparised 50%from samples while femal comprised 50%.That is same with result .

The most Frequency hospital is my research was Alamal diagnostic center is 60% .Who comparised 60% from greater while Frequency Albugaa diangnostic hospital 40%. Thats is smaller with result.

And the frequency age is greater is 28% in average age samples(31 – 40years) these value to estimate the organ equivalent dose using software provided by national protection broad and using impact CT patient dosimetry calculator to calculate the total effective dose .the risk of cancer in a particular organ was estimate by multiplying the mean organ equivalent dose with the risk coefficients (f) obtain from (ICRP) the result were the effective dose is(4.4741mSv) in the present study are the higher compared to their corresponding values in the Previous studies. Cancer probability were for testicles .

Table 5:1 show the previous studies results during CTA.

Author	No of patients	Type of examination	CT machine	CTDIVOL (mGy)	DLP (mGy.cm)	Effective dose(msv)
Sanjay et al (2007)	NA	Coronary Angiography	64-slice	NA	NA	42-91msv(lung) 50-80msv(breast)
Jacob et al (2009)	64	Coronary Angiography	64-slice	NA	NA	22msvfor whole body

NA: not available

Conclusions

Computed tomography to angiography (CTA) has emerged as a useful diagnostic imaging modality in the assessment of renal disease .However, the potential risks due to exposure to ionizing radiation associated with CTA have raised cancers. CTA had been considered of the good image test for evaluation of renal tract system.

In this study measurements of the dose during renal procedure can be consisered as the best method of evaluation of the cancer risk.

Radiation dose can vary considerably between scanner and between institutions. Clinical dose are reported as the dose to standard dosimetry phantom. However due to large variation in patient size these dose may not estimate accurately the deliver to patient during a particular exam.

Recommendations

- Clear justification of examination is highly recommended.
- Limitation of scan length.
- Exposure parameters must based on patient weight and anatomic region of interest.
- It importance to evaluate the risks of the cancer effect due to radiological investigation.
- Considerate ALARA principle.
- Urgent training program is highly recommended to improve patient protection in CT examination.
- Avoided repetition test without clinical justification.

Suggestions for future studies:

A national survey is highly recommended in order to establish a national diagnostic reference level for CTA.

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