To my parents, my family home are make me feeling successful.

my teachers,

and friends

For giving me never-endess gifts of encouragement, love and patience

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Abstract

The use of X-ray radiation in the medical field is increasing steadily since discovered for its great services in the discovery of the disease and in treatment , so this study aimed to work to establish a level of exposure to acceptable according to international standards without prejudice to reduce the presence of medical imaging and desired information from the tests and that called DRLS.

This study was done in the period between 2012 -2015 included 677 unchanged computed tomography average weight of between (65 kg to 75 kg) and with its similarity to the complaint in a single examination and then took the same 10 patients for each examination divided Imager head , chest, abdomen and pelvis, according to the criteria traded on the work DRLS on 17 Cross-Sectional center ray has focused on the study of more centers and more frequency tests request .

The study included all devices CT scan in these centers, which range between (2 slice to 128 Slice)

More than a statistical method used in it to represent the results and data in order to calculate DRLS of the total statistical data which centered on the concept of (DLP) and (CTDIV) basic units to create a diagnostic reference dose for each individual center and then the value located at the account (75%-3rd quartile) DRLS per centers and identify NDRL full range representing .DRL

The study showed follows

First in brain imaging that there is a difference in the level of radiation exposure from center to center in spite of its similarity to the same center and the same device has been found that the difference in the use of exposing the top factors such as current for priming and increasing the

slide area and either increase the area under examination and either of the weakness in the training and calculates the DRL to portray the brain It shows that (75%) corresponding to the value in (1209 mGy.sm)

Second, a CT scan of the chest showed a large study differences are in some of the centers, to a difference in the method used screening and factors used in the exposure to radiation. The DRLS in 75% (650 mGy / cm)

Thirdly number (179) patients of the abdomen and pelvis, especially in patients with urinary tract tests to check routinely The study showed that DRLS (75%) of the data is located in the (978 mGy / cm)

The study concluded I'm there a lot of tests are ordered to incomplete information in the request for examination , leading to a repeat examination more than once as this study an effort to develop a plan and path of the road starts from him and that the lack of previous studies of this area in the Sudan in this area had to be that the other studies deeper and more comprehensive in order to increase the quality of medical imaging , which in turn is to increase its presence in providing highest quality and diagnostic tests less Take and underestimate exposure to radiation damage .

المستخلص

استخدام الأشعه السينيه المؤينه في المجال الطبي في ازدياد مطرد منذ اكتشافها لما تقدمه من خدمات كبيره في اكتشاف المرض وفي العلاج لذا استهدفت هذه الدراسة على العمل على تأسيس مستوي للتعرض المقبول وفقا للمعايير الدوليه دون المساس بتقليل جوده التصوير الطبي والمعلومات المرجوه من الفحوصات . والذي يسمى ب DRLS.

هذه الدراسه اجريت فى الفترة من ٢٠١٢ الى ٢٠١٥ و شملت ٦٧٧ حاله اشعه مقطعيه يتراوح متوسط وزن يتراوح بين (٦٥ كيلوغرام الى ٧٥ كيلوغرام) وذوي تشابهه في الشكوى في الفحص الواحد ثم اخذ عينه ١٠ مرضى لكل فحص مقسمه على تصوير الرأس والصدر والبطن والحوض وفقا للمعايير المتداوله في عمل DRLSوذلك فى ١٧ مركزا للاشعه المقطعيه وقد اهتمت الدراسه باكثر المراكز تردد واكثر الفحوصات طلبا .

وشملت الدراسه كل اجهزه الاشعه المقطعيه الموجوده بتلك المراكز والتي تتراوح موصفاتها بين الاقل (٢ شريحه الى ١٢٨ شريحه)

استخدمت فيه اكثر من طريقه إحصائية لتمثيل النتائج والبيانات وذلك لحساب DRLS من مجموع البيانات الإحصائية والتي تركزت على مفهوم (DLP) و (CTDIV)كوحدات اساسية لإيجاد الجرعة المرجعية التشخيصية لكل مركز على حده ومن ثم حساب القيمة الواقعة عند(٧٥%) DRLSلكل المراكز وتحديد NDRLللمجموعة كامله التي تمثل DRL.

بينت الدراسة الاتي

اولا فى تصوير الدماغ ان هنالك اختلاف في مستوى التعرض للإشعاع من مركز لمركز على الرغم من تشابهه نفس المركز ونفس الجهاز وقد وجد ذلك لاختلاف في استخدام عوامل تعريض اعلى مثل تيارا لفتيله وزيادة مساحة الشريحة واما لزياده المنطقة تحت الفحص واما لضعف في التدريب وبحساب DRL لتصوير الدماغ تبين ان (٧٥%) تقابل القيمة ١٢٠٩ ملى قرى.سم.

ثانيا الاشعة المقطعيه للصدر اوضحت الدراسه الاختلافات وبصوره كبيره في بعض المراكز وذلك لاختلاف في طريقه الفحص المستخدمه والعوامل المستخدمة في التعريض للأشعة . وكانت DRLS في ٧٥% (٦٥٠ ملي قرى /سم)

ثالثا عدد (١٧٩) مرضى الأشعةالمقطعية للبطن والحوض وخاصه في فحوصات المسالك البوليه لفحص روتيني وقد بينت الدراسه ان)75%(DRLS من البيانات تقع في (٩٧٨ملي /سم)

خلصت الدراسة انا هنالك كثير من الفحوصات يتم طلبها لمعلومات غير كامله في طلب الفحص مما يؤدي الى تكرار الفحص اكثر من مره ولما كانت هذه الدراسه مجهود لوضع خطه ومسار

لطريق يبدا منه وذلك لعدم وجود دراسات سابقه لهذا المجال في السودان في هذا المجال كان لابد من ان تقوم دراسات اخرى اعمق واشمل وذلك لزياده جوده التصوير الطبي والذي بدوره هو زياده في جوده تقديم الفحوصات التشخيصيه باعلى جوده واقل تكلفه واقل ضرر للتعرض الاشعاعي.

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List of abbreviations

CT	Computed Tomography
3D	Three dimension
mSv	Ml sevirt
ICRP	Inter National Committee of Radiation protection
UNSCEAR	United Nation Scientific Committee on the Effects of Atomic Radiation.
MSCT	Multi Slice Computed Tomography
DRL	Diagnostic reference level
Kvp	Kilo volt peak
UK	United king
MRP	Multi planer reconstruction
ED	Effected dose
DLP	Dose area product
CTDI	Computed Tomography Dose Index
CTDIv	Computed Tomography Dose Index volume
mGy	Ml gray
CTDIw	Computed Tomography Dose Index weight.
IR(ME)R	Ionization Exposure Medical Regulation.
NDRLs	National Diagnostic Reference Levels.
LDRLs	Local Diagnostic Reference Levels.
SIU	System International Unit.
CPM	Count Per photon Minute.
SIE	Surface Integral Exposure.
DAP	Dose Area Product.

KERMA	Kinetic Energy Released Per unit Mass of Air.

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CHAPTER ONE

INTRODUCTION

1. Introduction

1.1 Medical radiation

X-rays were discovered by Wilhelm Rontgen in 1895. Within six months, they were being used to locate bullets in wounded soldiers and today they form the center of many areas of medical diagnosis and treatment. In modern medicine, medical imaging has undergone major advancements. Today, this ability to achieve information about the human body has many useful clinical applications. Over the years, different sorts of medical imaging have been developed, each with their own advantages and disadvantages .X-ray based methods of medical imaging include conventional X-ray, computed tomography (CT) and mammography. To enhance the X-ray image, contrast agents can be used for example for angiography examinations. Molecular imaging is used in nuclear medicine and uses a variety of methods to visualize biological processes taking place in the cells of organisms. Small amounts of radioactive markers, called radiopharmaceuticals, are used for molecular imaging. Other types of medical imaging are magnetic resonance imaging (MRI) and ultrasound imaging. Unlike conventional X-ray, CT and Molecular Imaging, MRI and ultrasound operate without ionizing radiation. MRI uses strong magnetic fields, which produce no known irreversible biological effects in humans. Diagnostic ultrasound systems use high-frequency sound waves to produce images of soft tissue and internal body organs.

X-ray imaging uses an X-ray beam that is projected on the body. When passing through the body, parts of the x-ray beam are absorbed. On the opposite side of the body, the X-rays are detected, resulting in an image.

Molecular imaging provides detailed information of the biological processes taking place in the body at cellular and molecular levels and can indicate disease in its earliest stages. Computed Tomography (CT) examinations have rapidly increased in number over the last few years due to recent advances such as the spiral, multi-detector-row, CT fluoroscopy and Positron Emission Tomography (PET)-CT technology. This has resulted in a large increase in collective radiation dose as reported by many international organizations. It is also stated that frequently, image quality in CT exceeds the level required for confident diagnosis. This inevitably results in patient radiation doses that are higher than actually required, as also stressed by the US Food and Drug Administration (FDA) regarding the CT exposure of pediatric and small adult patients. However, the wide range in exposure parameters reported, as well as the different CT applications reveal the difficulty in standardizing CT procedures. The purpose of this paper is to review the basic CT principles, outline the recent technological advances and their impact in patient r radiation dose and finally suggest methods of radiation dose optimization.

1. 2 CT imaging (discovery of CT ,development).

Computed Tomography (CT) has emerged as one of the most important imaging techniques of modern times. Starting with a bang in early 1970s with a great promise of exploring inner structure of the organs, it faced challenge from MRI in late 1970s and has emerged not only survivor but rather its clinical applications continue to increase [AAPM/RSNA2002] The recent advances in CT such as multi-detector-row technology, with sub-second acquisition and CT fluoroscopy have boosted CT applications, even more enabling interventional radiological (IR) procedures, which were traditionally performed with C-arm X-ray units. The continual increase in number of slices that can be scanned in one

rotation of the X ray tube has brought multi-detector computed tomography (MDCT) into dynamic imaging. MDCT is all set for playing an important role in angiography where it may be indicated as a replacement for conventional coronary angiography. The development of hybrid systems such as PET/CT, SPECT/CT and CT simulators in radiotherapy, and its incorporation in CT planning and dose delivery systems is moving CT from the domain of diagnostic radiology to other specialties. Comparison of performance between different scanners and techniques [Radiology rounds2003]. DRLs provide the means to improve patient protection, if it is required, identify poor performance and monitor CT performance in periodic measurements [Rehani M2000,UNSCEAR2000]. The foregoing discussion reveals the need for proper management of radiation dose in a CT facility. This paper aims to review the situation with regards to patient exposure in CT examinations, and provide practical advice to manage the radiation dose while maintaining diagnostic confidence.

1.3CT in Sudan.

First CT machines installed in Sudan in 1990 was single slice which from GE company. At last 20years was increased more than 30 machines of computerized tomography and in different specification tools and software applications, so this are increased the clinical used and replaced some radiological investigations. and lead to increased radiation dose to the patients so produced the needs justification .optimization and how reduce the dose.

1.4 Radiation dose in ct examination percent of % collection dose over the world.

Development of CT scanner technology continued through the early years of the 21st century, particularly with multi-slice scanners. At the time of writing, high-end scanners were offering up to 320 slices, dual-source and

dual-energy x-ray sources and iterative reconstruction techniques. Usage of CT has increased dramatically over the last two decades in many countries.

I. An estimated 72 million scans were performed in the United States in 2007.
II. It is estimated that 0.4% of current cancers in the United States are due to CTs performed in the past and that this may increase to as high as 1.5-2% with 2007 rates of CT usage;[i] however, this estimate is disputed.
III. Kidney problems following intravenous contrast agents may also be a concern in some types of studies

In the early 1900s, the Italian radiologist Alessandro Vallebona proposed a method to represent a single slice of the body on the radiographic film. This method was known as tomography. The idea is based on simple principles of projective geometry: moving synchronously and in opposite directions the X-ray tube and the film, which are connected together by a rod whose pivot point is the focus; the image created by the points on the focal plane appears sharper, while the images of the other points annihilate as noise. This is only marginally effective, as blurring occurs in only the "x" plane. There are also more complex devices that can move in more than one plane and perform more effective blurring. Spinning tube, commonly called spiral CT, or helical CT in which an entire X-ray tube is spun around the central axis of the area being scanned. These are the dominant type of scanners on the market because they have been manufactured longer and offer lower cost of production and purchase. The main limitation of this type is the bulk and inertia of the equipment (X-ray tube assembly and detector array on the opposite side of the circle) which limits the speed at which the equipment can spin.

Electron beam tomography is a specific form of CT in which a large enough X-ray tube is constructed so that only the path of the electrons, traveling between the cathode and anode of the X-ray tube, are spun using deflection coils. This type has a major advantage since sweep speeds can be much faster, allowing for less blurry imaging of moving structures, such as the heart and arteries. However, far fewer CTs of this design have been produced, mainly due to the higher cost associated with building a much larger X-ray tube and detector array. Computed Tomography (CT) builds on developments in two fields - X-ray imaging and computing. X-rays were discovered in 1895 and within a few years were an established medical tool. By the 1930s, tomography was being developed, enabling the visualization of sections through a body. By the 1960s, several researchers had worked independently on cross-sectional imaging, culminating in Hounsfield's work at EMI developing computed tomography (CT) for the EMI Scanner. This device relied on the reconstruction of image data by computer, the data being acquired from multiple X-ray transmissions through the object under investigation.

1.4Diagnostic Reference Levels (DRLs) in CT.

The optimization of patient protection in CT requires the application of examination-specific scan protocols tailored to patient age or size, region of imaging and clinical indication in order to ensure that the dose to each patient is as low as reasonably achievable for the clinical purpose of the CT examination. Diagnostic reference levels (DRLs) are a practical tool to promote the assessment of existing protocols and appropriate development of new and improved protocols at each CT centre by facilitating the comparison of doses from present practice. DRLs were first successfully implemented in relation to conventional X rays in the 1980s and subsequently developed for application to CT in the 1990s[ICRP1990].

Surveys of dose estimates from CT highlight the substantial variations in practice between some CT centers for similar types of examination and similar patient group (adults or children of different sizes). Such observations indicate the need for improvement through implementation of measures to keep all doses within acceptable ranges for the clinical purpose of each examination. Examination-specific DRLs for various patient groups can provide the stimulus for monitoring practice to promote improvements in patient protection. Such DRLs can be set not only at a national level (as investigation levels for unusually high typical doses), but also locally by each CT centre (as characterizing its present practice).

1.5 Problem of the study.

CT contributes up to 35% of patient collective doses worldwide. International organizations (ICRP, IAEA, UNSCEAR, WHO) encourage all countries to establish diagnostic reference level in order to optimize patient doses. In Sudan, a total of 38 CT scans were installed up to date. Yet, no study was performed regarding the establishment of DRL. In addition, only one study was conducted by the author for dose optimization in abdominal CT. therefore, there is a great need for a national survey to establish DRL and dose optimization. Furthermore, staff exposed to a significant level of radiation during CT fluoroscopy. No study was conducted in this issue in Sudan and few studies were performed worldwide. Therefore, Optimization of staff doses is important. increasing applications mean increasing collective radiation dose to the population. But that is not bad as long as individual CT examination is clinically justified and doses are optimized to be not more than what is necessary. But experience shows that individual patient doses are increasing [AAPM, Einsten,Goldman2007]In one of the reports from the United States, it was estimated that CT scanning

accounts for more than 10 % of all radiological examinations and about two-thirds of the radiation dose to patients [Gosling2007]. Regarding MDCT, one of the main problems in the initial systems, which were four detector scanners was the width of the X-ray beam in the z-direction. Since more than one row of detectors has to be exposed, a broader beam should be used compared to single row scanners so as to expose the outer detectors of the row, thus increasing the radiation dose. This problem is minimal in 16 detector scanners and above. Large variation in exposure parameters and patient doses even for a single CT examination have been reported [ICRP2000]It is noted that at specific exposure parameters, the radiation dose to the patient from various CT models can be totally different due to changing CT geometry and filtration. There is also growing realization that very often CT image quality is much higher than actually required to produce accurate clinical diagnosis and a number of studies reported large dose reductions using modified exposure parameters [Kalender w.A2005.MartinCJ2007]. Taking all these into consideration, as well as the continuous need to balance between the net benefits and the risks of using such a modality, various international organizations have published guidelines so as to standardize CT examinations and optimize radiation dose [Radiology Rounds2003.Rehani M et-al]. The European guidelines include image quality criteria for the most frequent CT examination, good imaging techniques and use of Diagnostic Reference Levels (DRLs) [Radiology Rounds2003]. Since it is not appropriate to set dose limits on medical exposures, DRL is a useful quantity that facilitates the investigation of dose levels in various CT procedures and permits

1.6 Objectives.

This study will evaluate the effective doses of CT examinations that are commonly practiced in both government and private hospitals throughout

Sudan. This study will be focusing on CT examinations like routine head, routine chest, routine abdomen an routine spine. These data will be compared to other studies from different countries such as the UK (Shrimpton et al. 2005) and Taiwan (Tsai et al. 2007) and also to the European guidelines (Council of European Union 1997). Then, this study will also look into the quality of the CT scanners in Sudan where the measurement of CTDIair will14be compared to that of from accredited source such as mPACT data set (ImPACT 2006a, ImPACT 2006b). The study intended to:

- Estimate effective dose to the patients undergoing common CT examinations in Sudan.
- Establish a Dose Reference Level (DRL) in a national level.
- To estimate the total radiation risk to the patients based on the examination type and scanner specific dosemetric values.
- Optimization of patient doses in CT.
- Measurement of staff doses in fluoroscopic CT.

1.7Thesis outline.

This study intended to provide a national diagnostic reference level in Sudan for certain CT imaging procedures. Accordingly, it is divided into the following chapters:

Chapter one is the introduction to this thesis. This chapter discusses the objectives and scope of work and introduces necessary background. It also provides an outline of the thesis.

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

Chapter three describes the materials and a method used to measure dose for CT machines and explains in details the methods used for dose measurement and dose evaluation.

Chapter four presents the results of this study.

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

1.8 Thesis outcome

The following publications and conference registration are limited to those which are based on work undertaken during the period of registration.

1.8.1 Publications

1. **Abdelrahman. M. Elnour**, Mohamed Yousef, Abdelmoneim Sulieman. Establishment of Local Diagnostic Reference Level for Brain CT Procedures.International Journal of Scientific Research; 4(3):295-298 (2015).
2. A. Sulieman, N. Tammam, K. Alzimami, **A. M. Elnour**, E. Babikir and A. Alfuraih . Dose reduction in chest ct examination. Radiation Protection Dosimetry Journal. Advance Access published April 9, 2015.
3. **Abdelrahman M. Elnour**, Mohamed Yousef, Hiba Omer, Abdelmoneim Sulieman. Survey of Patients Radiation Doses in Computed Tomography Chest Imaging. Proposal of Diagnostic Reference Level. Scholars Journal of Applied Medical Sciences (SJAMS). Sch. J. App. Med. Sci., 2015; 3(2C):684-688.

1.2 Conference Presentations

1. Khalid Alzimami,Nissren, **Abdelrahman M. Elnour**, Tamam,Abdelmoneim Sulieman. Optimization of Radiation Dose in CT Chest Examination . EPRBioDose 2013 International Conference / 24 – 28 March 2013. Leiden, The Netherlands.

2. **Abdelrahman M. Elnour** , Abdelmoneim Sulieman Khalid Alzimami, Nissren Tamam,. Optimization of Radiation Dose in CT Chest

Examination . RPM 2014, 2nd International conference on radiation protection in medicine, 30.05-02.06, 2014.

Chapter Two

Literature Review

During its 25years history, CT has made great improvements in speed, patient contort, and resolution. As CT scan times have got faster more anatomy can be scanned in less time, faster scan helps to eliminated artifacts from patient motion such as breathing or bowel movements.

The radiation type is non ionizing, and ionizing radiation. Non ionizing radiation, is contrast to ionizing radiation is electromagnetic radiation that doses not have sufficient energy to remove electrons from an atom or molecules to from an ion (or changed particle) non ionizing radiation includes frequencies of electromagnetic spectrum ranging from $1 – 3x10^{10}$Hz (300 Gigaherz).

2.1.1 Classification of Radiation:

Radiation is classified into two main categories, non-ionizing, depends on its ability to ionize matter. Ionizing radiation can ionize matter either directly or indirectly: indirectly ionizing radiation (Charged particles) such as electrons, protons, α particles and heavy particles.

Indirectly ionizing radiation (Neutral particles) such as x-rays, x-rays photons and neutrons.

2.1.2 X-ray Beams and X-ray Units:

Clinical x-ray typically range in energy between 10kV and 50MV and are produced when electrons with kinetic energies between 10k eV and 50M eV are decelerated in special metallic targets.

Most of the electron's kinetic energy is transformed in the target into heat and a small fraction of the energy is emitted in the form of x-ray photons, which are divided into two groups: characteristic x-rays and Beams startling x-ray.

2.1.3 Characteristic X-ray:

Characteristic x-rays result from coulomb interactions between the incident electrons and atomic orbital electrons of the target material. In a given coulomb interaction between the incident electron and an orbital electron, the orbital electron is ejected from its shell and an electron from a higher level shell fills the resulting orbital vacancy. The energy difference between the two shells may either be emitted from the atom in the form of a characteristic photon or transferred to an orbital electron that is ejected from the atom as an Auger electron.

2.1.4 Clinical X-ray Beams:

A typical spectrum of a clinical x-ray beam consists of line spectra that are characteristic of the target material and they are superimposed on to the continuous Bremsstrahlung spectrum. The Bremsstrahlung spectrum originates in the x-ray target, while characteristic line spectra originate in the target and in any attenuators placed into the beam. In the diagnostic energy range (10-150kV) most photons are produced at 90° from the direction of electron acceleration, while in the megavoltage energy range (1-50MV) most photons are produced in the direction of electron acceleration[(*)].

2.1.5 Deterministic Effects:

Deterministic or non-stochastic effects are believed to be caused by cell killing, if a sufficient number of cells in an organ or tissue are killed, its function can be impaired.

Deterministic or non-stochastic effects include terratogenic effects to the embryo or fetus, skin damage and cataracts.

A threshold can be defined below which the effect will not occur. For doses greater than the threshold dose, the severity of the effect increases with the dose. To assess the likelihood of a deterministic effect

on an organ from an imaging procedure, the dose to that organ is estimated.

2.1.6 A stochastic Effect:

A stochastic effect is caused by damage to a cell that produces genetically transformed but reproductively viable descendants, cancer and hereditary effects of radiation. Probability of a stochastic effect, instead of its severity increases with dose.

2.2 Computed Tomography:

X-ray computed tomography (CT), computed means calculated, Tomo is a Greek word means cutting or designated layer, graph means to write in Greek.

Computed tomography (CT) is firmly established as a major source of population exposure from diagnostic x-ray examinations and an important tool in diagnostic radiology that provides high quality cross-sectional x-ray images of the body, albeit with relatively large patient doses .

Increasing application of this modality has made a substantial impact on both patient care and also population exposure. The number of scanners in clinical use has risen steady over the past 25 years to reach a global total in 1997 of about 20,000 units, with an associated annual total of some 67 million CT procedures. The distribution of scanners is far from uniform, however, and there are significant variations in frequency of use between countries, even within the European Union. Practice is reported to have grown worldwide at a compound annual rate of about 4% over the period 1993-1995, although national trends differ widely. CT already provides in many countries a substantial proportion of the collective dose from medical x-rays, for example around 35% in Germany and 40% in the UK.

Notwithstanding the potential benefits to the health care of patient from CT, the fundamental concern in radiological protection is the reduction of unnecessary exposures. These are examinations that are either unlikely to be helpful to patient management or involve doses that are not as reasonably practicable in order to meet specified clinical objectives. Potential scope for improvement in the optimization of protection for patient undergoing CT has already been demonstrated in national surveys; for example, variations by factors of 10-40 have been observed in the typical dose between individual scanners for a given general type of procedure in the UK. Such variations are largely due to differences between hospitals in the local scanning technique employed.

The concept of reference doses is recognized as a useful and practical way of promoting optimization of patient protection(*).

2.2.1 CT: Technical Aspects and Theory:

In CT technical aspects different apparatus were used such as, high voltage tube supply, medium frequency generator (Constant potential), microprocessor controlled, x-ray tube, filters, collimators, detectors.

In computed tomography electronics are used, such as amplifiers (20pA – 200nA) and analogue to digital converters (Range 1 – 104). Mechanical apparatus are used as well, such as motorized rotation, support for components and connectors, for example conventional: cabling or spiral: low and high voltage slip rings.

2.2-2 Principles of Helical CT Scanners

The development of helical or spiral CT around 1990 was a truly revolutionary advancement in CT scanning that finally allowed true 3D image acquisition within a single breath hold. The technique involves the continuous acquisition of projection data through a 3D volume of tissue by continuous rotation of the x-ray tube and detectors and simultaneous translation of the patient through the gantry opening (Fig 2.6) (Kalender,

et al, 1990). Three technological developments were required: slip-ring gantry designs, very high power x-ray tubes, and interpolation algorithms to handle the non-coplanar projection data (Beck, 1996).

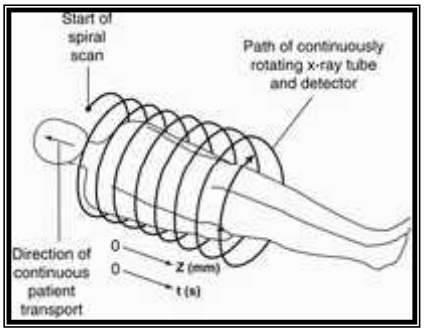


Fig (2.1): Principles of helical CT. As the patient is transported through the gantry, the x-ray tube traces a spiral or helical path around the patient, acquiring data as it rotates. t = time in seconds. From (Mahesh, 2002).

2.2-3 Slip-Ring Technology

Slip rings are electromechanical devices consisting of circular electrical conductive rings and brushes that transmit electrical energy across a moving interface. All power and control signals from the stationary parts of the scanner system are communicated to the rotating frame through the slip ring. The slip-ring design consists of sets of parallel conductive rings concentric to the gantry axis that connect to the tube, detectors, and control circuits by sliding contactors (Fig 2.7). These sliding contactors allow the scan frame to rotate continuously with no need to stop between rotations to rewind system cables (Brunnett, et al., 1994). This engineering advancement resulted initially from a desire to reduce interscan delay and improve throughput. However, reduced interscan delay increased the thermal demands on the x-ray tube; hence, tubes with much higher thermal capacities were required to withstand continuous operation over multiple rotations. (Mahesh, 2002)

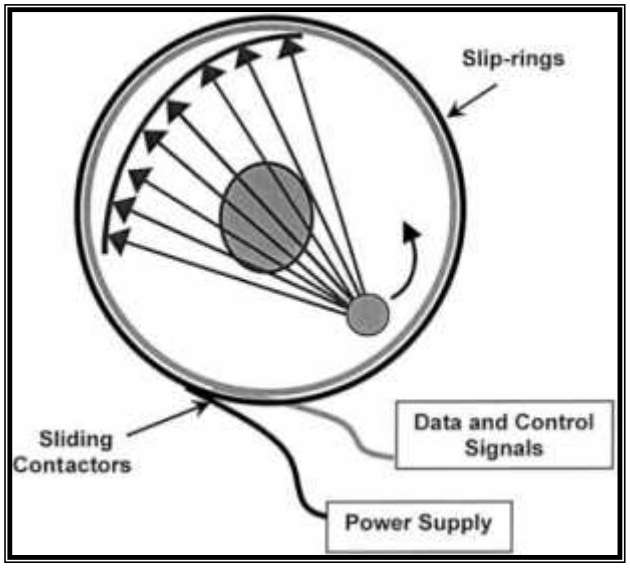


Fig (2.2): Diagram of the slip-ring configuration. Sliding contactors permit continuous rotation of the x-ray tube and detectors while maintaining electrical contact with stationary components.

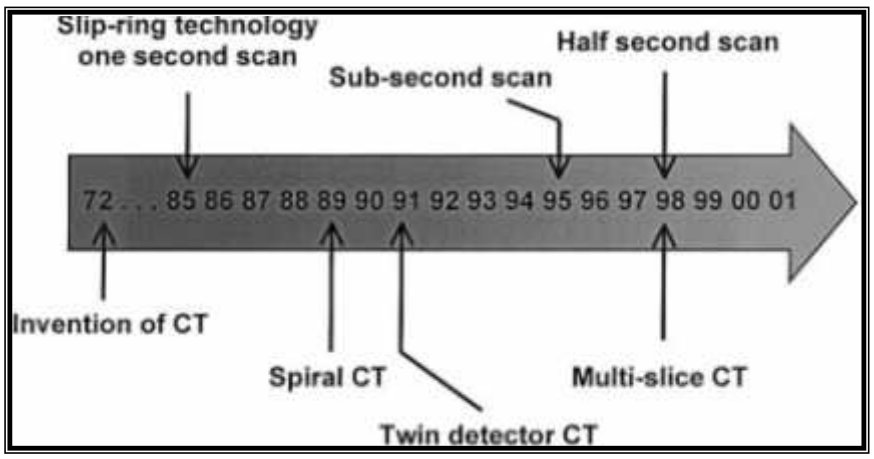


Fig (2.3): Time line of the key technological developments in CT. From (Mahesh, 2002).

2.2.4 Capabilities of Single-Row Detector Helical CT

With the advent of helical CT, considerable progress was made on the road toward 3D radiography. An example of a 3D reconstruction from single-row detector helical scanning is shown in Fig (2.9).Complete organs could be scanned in about 30–40 seconds; artifacts due to patient motion and tissue misregistration due to involuntary motion were

virtually eliminated. It became possible to generate sections in any arbitrary plane through the scanned volume. Significant improvements in z-axis resolution were achieved due to improved sampling, since sections could be reconstructed at fine intervals less than the section width along the z axis. Near-isotropic resolution could be obtained with the thinnest (□1 mm) section widths at a pitch of 1, but this could be done only over relatively short lengths due to tube and breath-hold limitations (Kalender 1995), (Levy, 1995). Higher-power tubes capable of longer continuous operation coupled with faster rotation speeds could scan greater lengths with higher resolution. The practical limit on such brute force approaches, however, became the length of time a sick patient could reliably suspend breathing. This turns out to be no more than 30 seconds. Even though the z-axis resolution for helical CT images far exceeds that of conventional CT images, the type of interpolation algorithm and the pitch still affect the overall image quality. The section sensitivity profiles of helical CT images are different compared with those of conventional CT images, which are influenced by the type of interpolation algorithm and the selected pitch.

2.2.5 Multiple-Row Detector Helical CT

Continued scanner development on the road to a 3D radiograph called for further progress, but single-row detector helical scanners had reached their limits. An obvious improvement would be to make more efficient use of the x rays that are produced by the tube while improving z-axis spatial resolution; this led to the development of multiple-row detector arrays. The principal difference between single- and multiple-row detector helical scanners is illustrated in Figure (2.9). The basic idea actually dates to the very first EMI Mark I scanner, which had two parallel detectors and acquired two sections simultaneously.

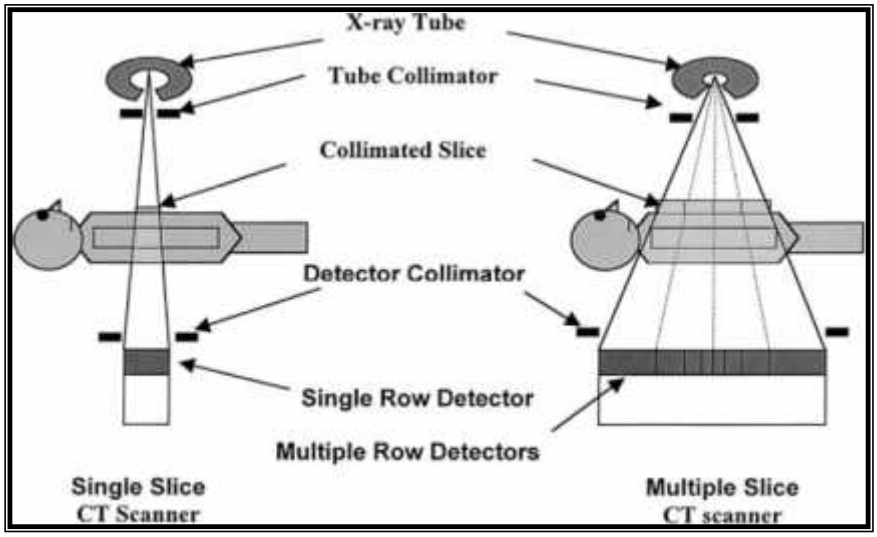


Fig (2.4): Diagram shows the difference between single-row detector and multiple-row detector CT designs. The multiple-row detector array shown is asymmetrical and represents that of one particular manufacturer.

The first helical scanner to use this idea, the CT Twin was launched in 1992. (Mahesh, 2002).This design was so superior to single-row detector designs that all scanner manufacturers went back to the drawing board. By late 1998, all major CT manufacturers launched multiple-row detector CT scanners capable of acquiring at least four sections per rotation. The arrangement of detectors along the z axis and the widths of the available sections vary between the systems. Fig (2.10) illustrates different multiple-row detector array configurations from several manufacturers.

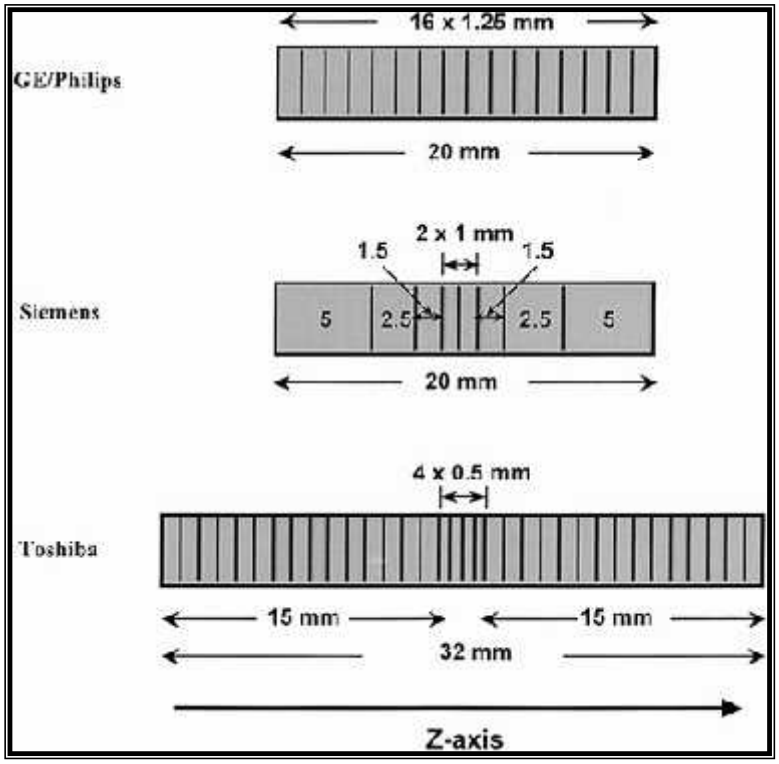


Fig (2-5): Various detector array designs used in multiple-row detector CT scanners.

In single-row detector helical CT designs, scan volume can be increased with an increased pitch at the expense of poorer z-axis resolution, whereas z-axis resolution can be preserved in multiple-row detector designs. For example, if a 10-mm collimation were divided into four 2.5-mm detectors, the same scan length could be obtained in the same time but with a z-axis resolution improved from 10 mm to 2.5 mm. In another example, a multiple-row detector scanner with four 5-mm detectors and a beam width of 20 mm reduces the scan time by a factor of 4–15 seconds for the same z-axis resolution (Mahesh, 2002). By increasing the number of CT scanner detector rows, data acquisition capability dramatically increases while greatly improving the efficiency of x-ray tubes. Further developments in scanner rotational speeds and tube outputs have made isotropic resolution a practical possibility with even better improvements on the

horizon. Current multiple-row detector scanners can scan large 40-cm volume lengths in less than 30 seconds with near-isotropic resolution and image quality that could not be envisioned at the time of Hounsfield's invention.

MDCT systems are CT scanners with a detector array consisting of more than a single row of detectors. The "multi-detector-row" nature of MDCT scanners refers to the use of multiple detector arrays (rows) in the longitudinal direction (that is, along the length of the patient lying on the patient table). MDCT scanners utilize third generation CT geometry in which the arc of detectors and the x-ray tube rotate together. All MDCT scanners use a slip-ring gantry, allowing helical acquisition at rotation speeds as fast as 0.33 second for a full rotation of 360 degrees of the X-ray tube around the patient. A scanner with two rows of detectors (Mahesh, 2002) had already been on the market since 1992 and MDCT scanners with four detector rows were introduced in 1998 by several manufacturers. The primary advantage of these scanners is the ability to scan more than one slice simultaneously and hence more efficiently use the radiation delivered from the X-ray tube (Fig.2.6). The time required to scan a certain volume could thus be reduced considerably.

The number of slices, or data channels, acquired per axial rotation continues to increase, with 64-detector systems now common (Flohr et al., 2005a; Flohr et al., 2005b). It is likely that in the coming years even larger arrays of detectors having longitudinal coverage per rotation > 4 cm will be commercially available. Preliminary results from a 256-detector scanner (12.8 cm longitudinal coverage at the center of rotation) have already been published (Mori et al., 2004). Further, an MDCT system with two x-ray sources is now

commercially available, signaling continued evolution of CT technology and applications (Flohr et al., 2006).

MDCT scanners can also be used to cover a specific anatomic volume with thinner slices. This considerably improves the spatial resolution in the longitudinal direction without the drawback of extended scan times. Improved resolution in the longitudinal direction is of great value in multiplanar reformatting (MPR, perpendicular or oblique to the trans axial plane) and in 3-dimensional (3D) representations. Spiral scanning is the most common scan acquisition mode in MDCT, since the total scan time can be reduced most efficiently by continuous data acquisition and overlapping data sets and this allows improved multi-planar reconstruction (MPR) and 3D image quality to be reconstructed without additional radiation dose to the patient.

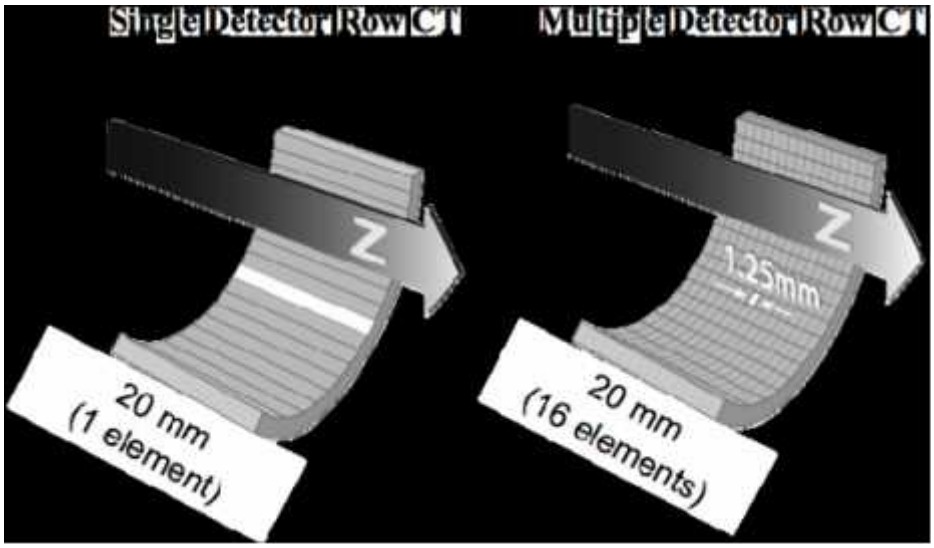


Fig (2.6): single CT detector versus Multi slice CT detector. From (ICRP 32/219,2006).

2. 3.1Radiation Protection:

The international commission on radiological protection, ICPR has developed a framework for radiological protection, including protection against exposures due to artificial sources. Three kinds of exposure are

considered: occupational, medical and public. The system of radiological protection is based on three general principles, i.e., justification, optimization and dose or risk limit [*].

2.3.2 Absorbed Dose (D):

Absorbed dose is a non-stochastic quantity applicable to both indirectly and directly ionizing radiations. For indirectly ionizing radiations, energy is imparted to matter in a two step process. In the first step, the indirectly ionizing radiation transfers energy as kinetic energy to secondary charged particles. In the second step, these charged particles transfer some of their kinetic energy to the medium (Resulting in absorbed dose) and lose some of their energy in the form of radioactive losses.

2.3.3 Equivalent Dose:

The equivalent dose (H_T) is a measure of the radiation dose to tissue where an attempt has been made to allow for the different relative biological effect 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 units of sieverts. Equivalent dose (E) is calculated by multiplying the absorbed dose (D) with the radiation weighting factor.

2.3.4 Effective Dose:

The effective doses are evaluated in this study because it is relevant to risk assessment. The effective dose is calculated by following equation:

$$ED = \sum Wt\ Ht \quad \text{---------- (2-1)}$$

Where ED is effective dose and Wt is the tissue weighting factor for tissue t.

Ht is the equivalent dose in tissue or organ t.

- Effective dose
  - Estimate of stochastic radiation risk
- Dose Length Product (DLP)
  - Related to stochastic radiation risk

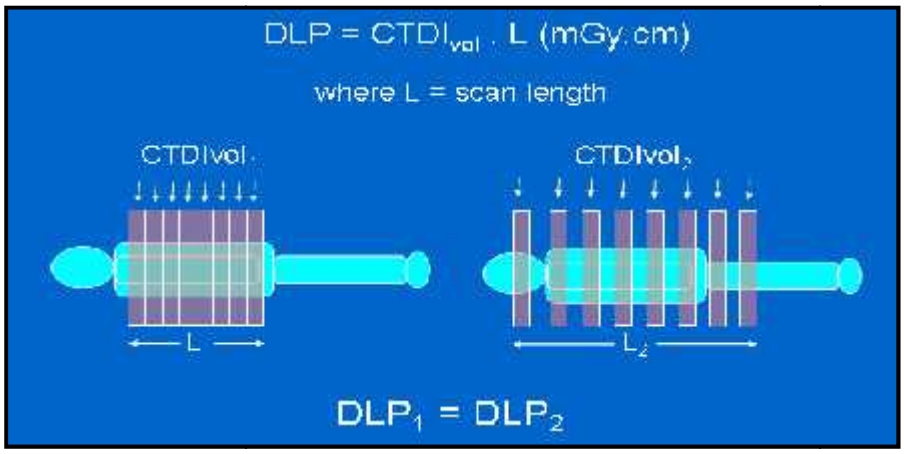


Fig (2.7): showDLP and scan length.

2.3.5 Computed Tomography Dose Index:

In 1981 the United State Food and Drug Administrator introduced the computed tomography dose index (CTDI) as physical dose quantity to describe the absorbed dose delivered by CT[(*)].

CTDI is defined as the integral of a single-scan dose profile along an infinite line perpendicular to the tomographic plane divided by the normal slice thickness:

$$CTDI = \frac{1}{T}\int_{-\infty}^{+\infty} D(z)dz \qquad (2.2)$$

To determine CTDI in a convenient way, an ionization chamber can be used. In most cases, a chamber with an active length of 100mm is used:

Where D (z) is the dose profile along a line z perpendicular to the tomographic plane, where dose is measured as absorbed dose to air, N is

the number of tomographic sections produced in a single rotation of the radiation source and T is the nominal tomographic section (Slice) thickness. $CTDI_{100}$ used to calculate the weighted computed tomography dose index.

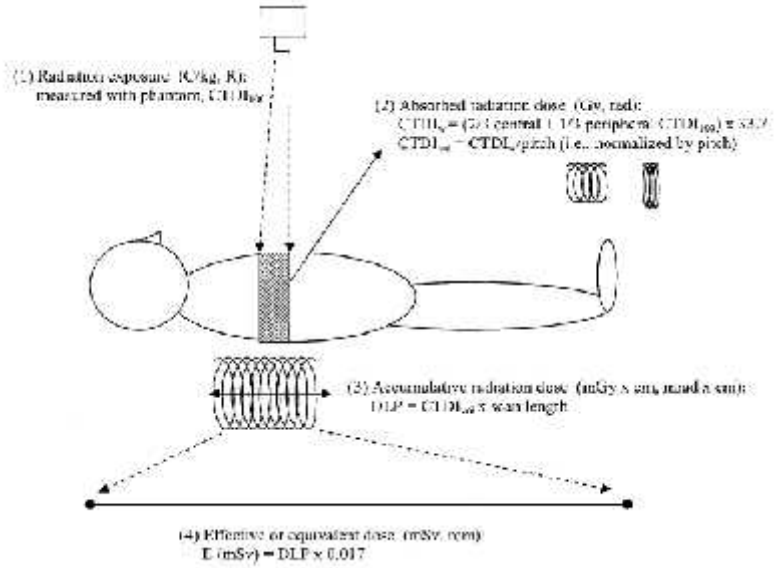


Fig (2.8):effective or equivalent dose (mSv).

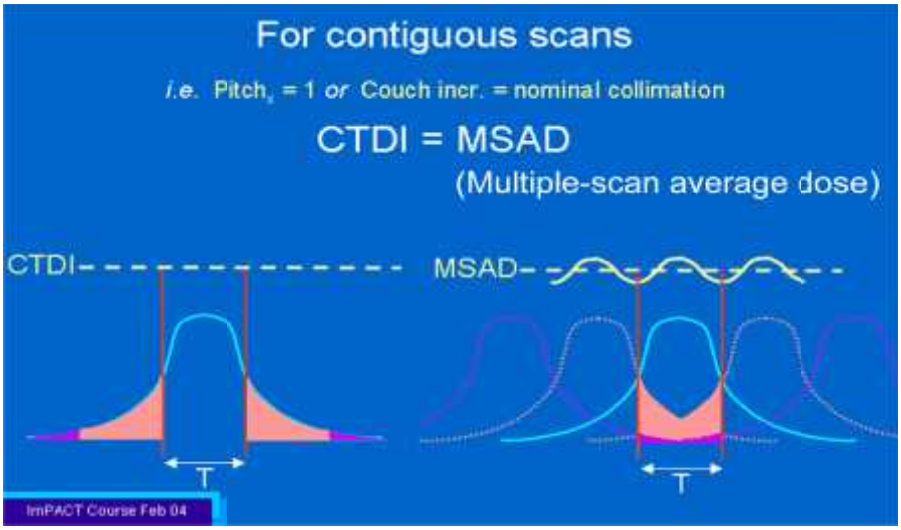


Fig (2.9): show compare between MSAD and CTDI

2.3.6 Weighted Computed Tomography Dose Index:

Weighted computed tomography dose index over a single slice in a CT dosimetry phantom was calculated as the sum of 2/3 of the

peripheral dose and 1/3 of central dose. On the assumption that dose in a particular phantom decreases linearly with radial position from the surface to the centre, then the average dose to the slice for a single exposure is approximated by the weighted CTDI in mGy:

$$CTDIW = 1/3\ CTDI_{100,c} + 2/3\ CTDI_{100,p} \quad \text{---------- (2.3)}$$

Where subscript c means centre and subscript p means periphery (1cm below surface). Accordingly, $CTDI_W$ was calculated for each axial or helical sequence. $CTDI_W$ used to calculate the volume computed tomography dose index.

2.3.7 CT Dosimetry Phantom (ICRU 48, 1992):

The length of the dosimetry phantom is at least 140mm. This conventional phantom contains holes just large enough to accept the pencil-shaped ionization chamber. For dose measurement in cone-beam CT, the length of the phantom should be longer, because of the wider scatter distribution.

2.3.8 CT pitch factor:

In order to calculate the volume computed tomography dose index $CTDI_{vol}$ it is necessary to calculate the pitch factor first:

$$\text{CT pitch factor} = \frac{\Delta d}{N \times T} \quad \text{---------- (2.4)}$$

Where Δd is the patient support travel in horizontal direction, N is the number of tomographic sections produced by a single rotation of the x-ray tube and T is the nominal tomographic section thickness.

2.3.9 Volume Computed Tomography Dose Index ($CTDI_{vol}$):

Volume computed tomography dose index ($CTDI_{vol}$) were calculated on the basis of the reported pitch:

$$CTDI_{vol} = \frac{CTDI_W}{\text{CT pitch factor}} \text{ (mGy)} \quad \text{---------- (2.5)}$$

Corresponding values of $CTDI_{vol}$ were calculated on the basis of the pitch factor.

2.3.10 Dose Length Product (DLP):

Dose-length product was derived from the values of $CTDI_{vol}$ calculated for each scan sequence using the following general approaches, depending on the following equation:

$$DLP = CTDI_{vol} \times L \text{ (mGy.cm)} \quad \text{---------- (2.6)}$$

Where L is the scan length (cm)[(*)].

CTDIW, $CTDI_{vol}$ and DLP form the basis for reference doses set for the purposes of promoting optimization of patient protection (IPEM, 2004; wall, 2004b) and it is an important physical dose quantity which can be used for calculating organ and effective doses by employing conversion factors. In addition, values of effective dose (ICRP, 1991) for complete CT examinations are also useful for comparison with other types of radiological procedure.

2-4 DRLs:

2-4-1 introduction

DRLs were first mentioned by ICRP in 1990 and subsequently recommended in greater detail in 1996 from the 1996 report. The commission now recommend the use of DRLs for patient these levels which are a form of investigation level, apply to an easily measured

quantity, usually the absorbed dose in air or in tissue equivalent material at the surface of simple standard phantom or representative patient.

The diagnostic reference levels will be intended for use as test for identifying situation where the level of patient dose or administered activity is an usually high. There should be a local review of procedures and equivalent in order to determine whether the protection has been adequately optimized.

Diagnostic reference levels are supplement to professional judgment and to not provide a dividing line between good and bad medicine, it is inappropriate to use them for regulatory or commercial purposes.

DRLs apply to medical exposure, not to occupational and public exposure; they have no link to dose limits or constraints. Ideally, they should be result of a generic optimization of protection. In practice, this is unrealistically difficult and it is simple to choose the initial valuses as percentile point on the observer distribution of dose to patients. The values should be selected by professional medical bodies and reviewing at intervals that represent a compromise between the necessary stability and the long term changers in the observed dose distributions. The selected values will be specific to a country or region.

DRLs are not the suggested or ideal dose for a particular procedure or an absolute upper limit for dose. Rather, they present the dose level at which an investigation of the appropriateness of the dose should be initiated.

The a qualified medical physicist should be work with the radiologist and technologist to determine whether or not the required level of image quality could be attained at lower dose level, thus reference levels act as trigger levels.

One of the key issues in the regulations that govern the use of ionising radiation in medicine is the establishment and use of "diagnostic reference levels" (DRLs). The Ionising Radiation (Medical Exposure) Regulations 2000 (IR(ME)R 2000) [1], require employers to establish DRLs and to undertake appropriate reviews if these are consistently exceeded. A multidisciplinary Working Party with representatives from all the professional bodies involved in diagnostic medical exposures was convened by the Department of Health in 2000 to provide broad policy guidance on these IR(ME)R requirements and to formally adopt national DRLs. An employer may decide to adopt national DRLs or to set higher or lower DRLs dependent on the imaging equipment available to them or the patient case-mix of the healthcare establishment. Local DRLs higher than those set nationally would need to be justified. This flexibility enables professionals to provide input at a local level to the DRL setting process. The regular review of these DRLs at national and local level provides a feedback loop that ensures good practice in medical exposures is maintained. More detailed pragmatic advice on how to use DRLs for medical x-ray examinations is available in IPEM Report 88 [2].

2-4-2 The purpose of national DRLs(NDRLs).

National DRLs provide an initial broad check in the optimization process .they are set basis of wide scale surveys of mean doses representing typical practice for a patient group at arrange of representative CT centers for specific CT examination. NDRLs are commonly set at the third quartiles of these national distributions (IPEM,2004).

Quantities that used for setting DRLs:

DRLs should be set in terms of the practical dose quantities used to monitor CT practice: volume weighted CT index (CTDIvol) and dose-length product (DLP in mGy.cm) as commonly displayed by CT

scanners. Each CT centre should determine its typical levels of dose (CTDIvol and DLP) for each type of examination associated to clinical indication for each patient group (adult and children of different size)[IPEM,2004].these mean doses should be compared with the relevant NDRLs .mean value above the NDRLs should be investigated and either justified as to being clinical necessary or reduced through appropriate changes in practice to improve patient protection.

2.4.3 Local DRLs (LDRLs):

For subsequent comparison with practice at other CT centres in pursuit of improved patient protection.LDRLs should be reviewed annually and revised as necessary following periodic.

DRLs are not apply to individual patients.DRLs relate to typical practice for specific CT examination (e.g., brain in relation to acute stroke) and patient group (e.g., by age or gender).NDRLs for each examination and patient group are set on the basic of distribution of the typical doses observed in wide scale (national surveys).LDRLs represent the typical local practice at a CT centre, as the mean doses determined from samples of patients. Dose notification values can be set locally.

2-4-**4Radiation quantities**:

There are many different physical quantities that can be used to express the amount of radiation delivered to human body. Generally there are advantages and applications as well as disadvantages and limitations for each of the quantities. They are tow types of radiations quantities. Those are express the concentration of radiation at some point, or to the specific tissues or organs, there are also quantities that express the total radiation delivered to a body.

2-4-5 .Radiation units:

In more recent times the metric system has gradually replaced some of the other more traditional or classic system.

2-4-6 Conventional units:

These are such units as the three RS the Roentgen, Rad, and Rem.all of these were very practical units and have several their purpose well.

2-4-6-1 SI units (System International units):

The SI radiation units have been adapted by most organizations and publication, however become of their practicality, and familiarity.

2-4-6-2 Photons:

The physical difference between the different types of radiation, like light, and x-rays is the amount of energy packaged in each photon. Therefor, it is logical to consider expressing the amount of radiation delivered to an organ, object, such as human body. In medical imaging there are two situations in which we are concerned with the number of photons:

1-Total photons: Count the photons that emitted with proper calibration factors(CPM) The count per minute can be converted into units of radioactivity, Curies, Becquerel.

2-photon concentration (fluency) a factor in image quality:

I n all forms of medical imaging using the concentration of photons absorbed in the image forming process in a very critical factors this is the principle factors that determines the amount of visual noise in image that is so called quantum (photon) noise. In CTit is the concentration of photons absorbed in each tissue voxel that determines the noise is an important factor in producing good quality images.

2-4-6-3 Energy:

The radiation used for all types of medical imaging deposits energy in patient’s body .this would be an appropriate quality for expressing the amount of radiation delivered to body. Absorbed dose, total energy absorbed in the body is the integral dose.

2-4-6-4Exposure

Is the radiation quantity that expresses the concentration of radiation delivered to specific point such as the surface of human body. There are two units for expressing exposure;

1-Coulmb/kg of air (1kgof air):

1R=2.58X10-4 C per kg of air.

Entrance Surface Exposure Dose not give a complete description of the radiation delivered to all tissues it does provide to all information for several purposes. And can be used to:

1-compare different imaging technique with respect to radiation delivered to patient especially for the same anatomical coverage.

2-calculate the absorbed dose to under lying tissue and organs.

2-4-6-5 Air Kerma:

Radiation quantity used to express the radiation concentration delivered to point, such as the entrance surface of a patient's body.

Kerma Kinetic Energy Released per unit Mass of Air and is expressed in unit of J/Kg.

2-4-6-6 Surface Integral Exposure (SIE):

The unit of SIE is the R/cm2, and alternate name for this quantity is sometimes used is Exposure Area Product (EAP).The value of SIE compeered to just surface entrance exposure it that gives information about the total radiation.

2-4-6-7 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 the patient.the principle difference is in the units used.

DAP is dose unit such as Gy-cm2 for an uniformly exposure. the DAP is just the product of air kerma in Gy or mGyand the exposed area in cm2.

DAP provides a good estimation of the total radiation energy delivered to a patient during aprocedure. Both radiographic and fluoroscopic machines can be equipped with devices(DAP meter)or computer programs that measure or calculate the DAP for each procedure.

Absorbed Dose:is radiation quantity used to express the concentration of radiation energy actually absorbed in specific tissues.

1grayGy= 100rads.

10mGy = 1rad.

1mGy = 100m rad.

The quantity relating to radiation outside of a human body, such as (Exposure,Air Kerma,SIE,and DAP meter)

- Can be placed at the location of interst,
- And is tissue dosimeters, can be placed on the surface.
- Not responsible to insert them into most internal tissues or organs.

Another method used to determine dose is to actually measure the dose in a"phantom".Phantom is block of some material that have the same radiation absorption properties as tissue ,the phantom should be approximately the same size and shape as the body section in which the dose is to be determined .

A dosimeter is inserted into the phantom and it is then exposed to radiation using known exposure factors. these measured dose value in the phantom can be then used to estimate patient dose value by applying appropriate factors to account for different exposure condition.

It is not always easy to determine the absorbed dose at specific location or organs in patient undergoing an imaging procedure due to:

1 -Variations in organ size and location.

2- Variations in the body size and composition.

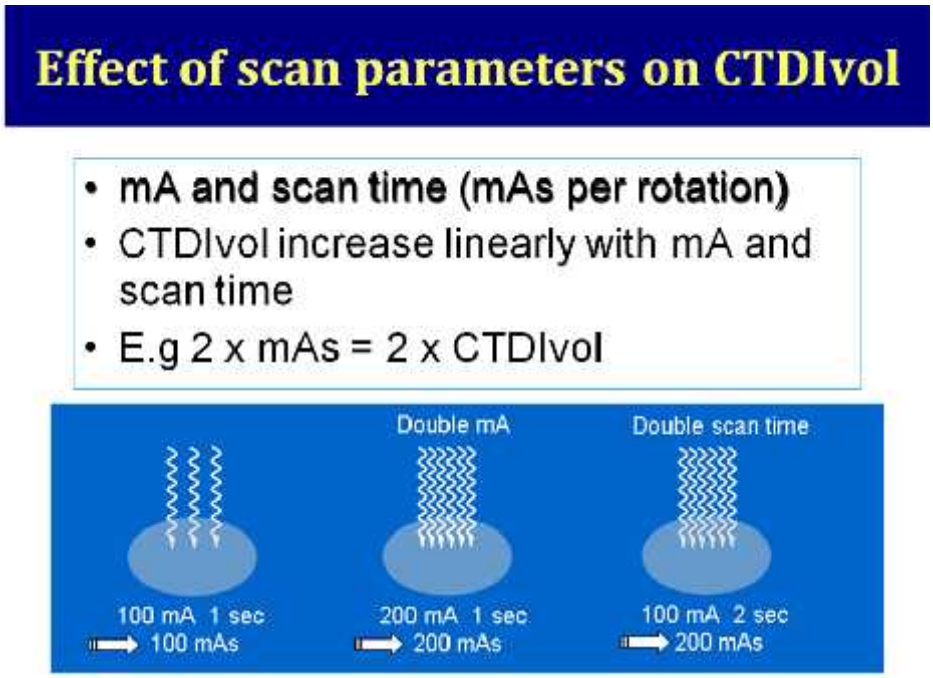
3- Non uniformity of radiation distribution within the body.

To overcome some of these difficulties several specific radiation dose quantities have been developed for specific imaging procedures(CT and mammography).

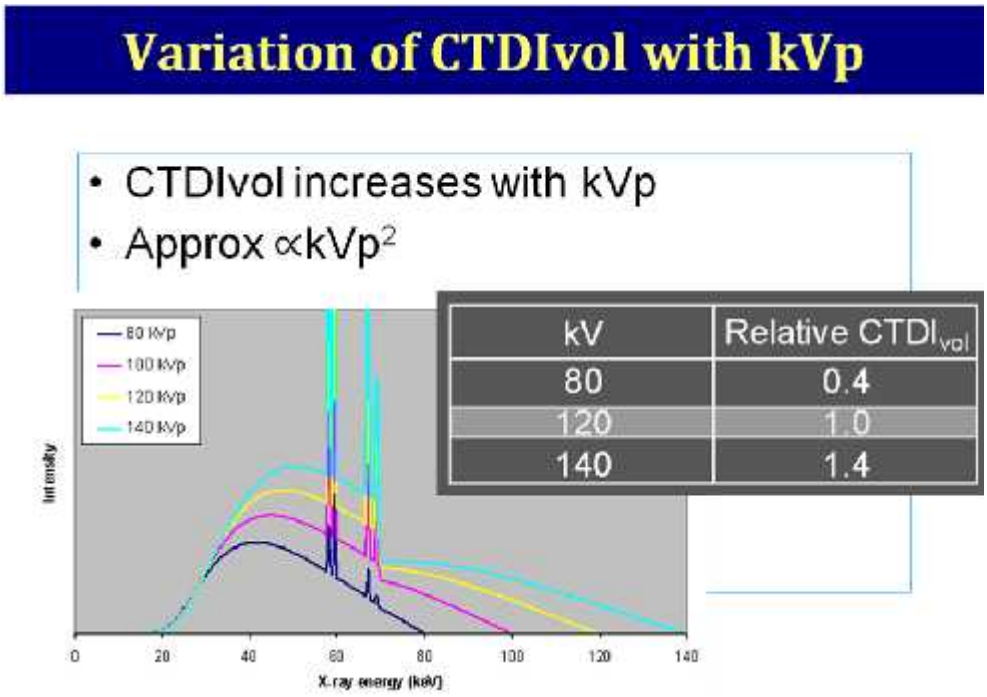
These special dose quantities are usually determined by fallowing well established measurement and calculation protocols. This makes it possible to compare dose values for different imaging techniques, among institutions, and from county to country

The exposure to radiation of patients undergoing CT examinations is determined by two factors:-

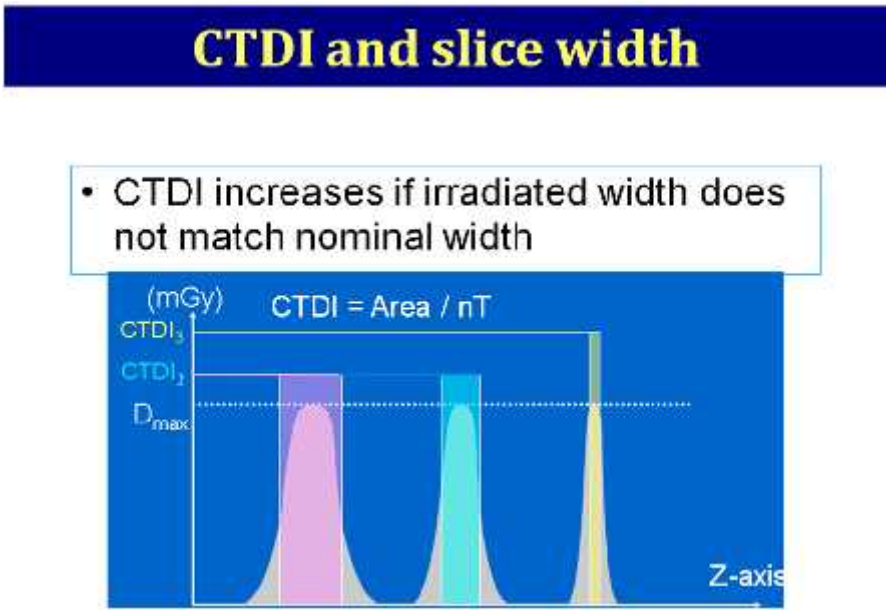
- Equipment – related factors, i.e. design of the scanner with respect to dose efficiency. Several form of ionization radiation .
- The applications – related factors i.e. the way in which the radiologist and technologist makes use of the scanner.



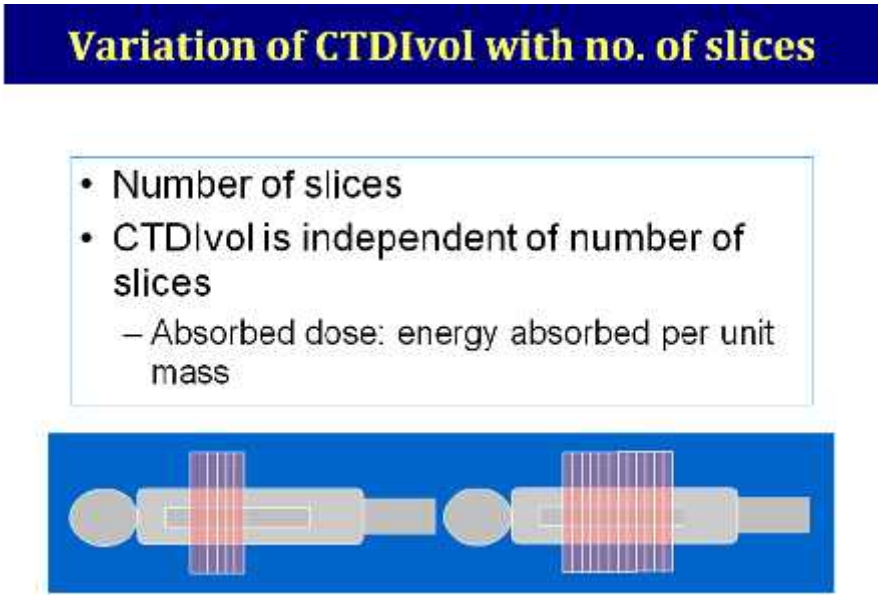
Fig(2.10)effect of mAs to the output of the photon.



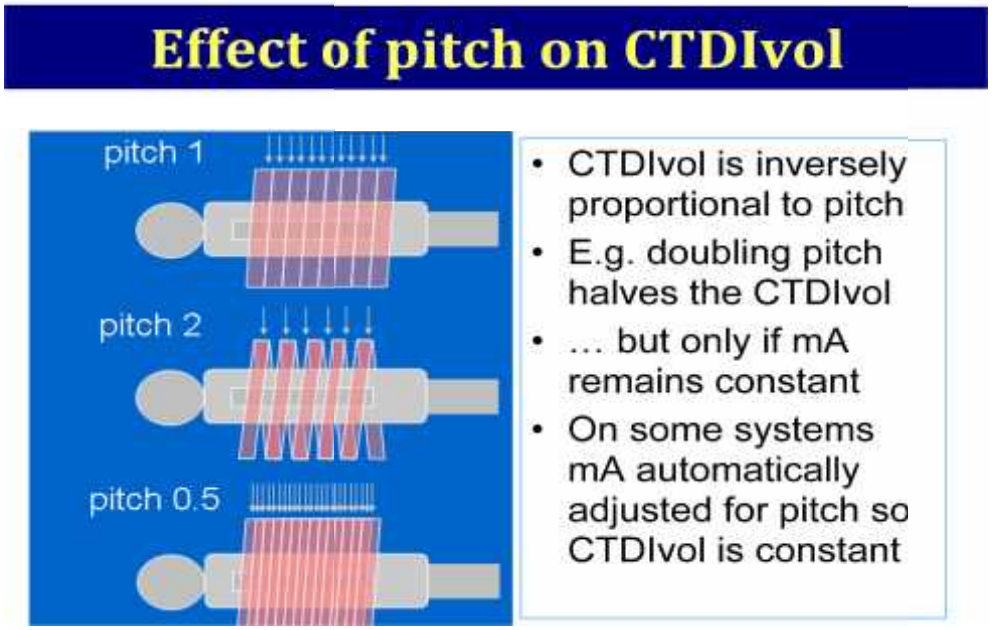
Fig(2-11) show comparison of CTDIvol and kVp.



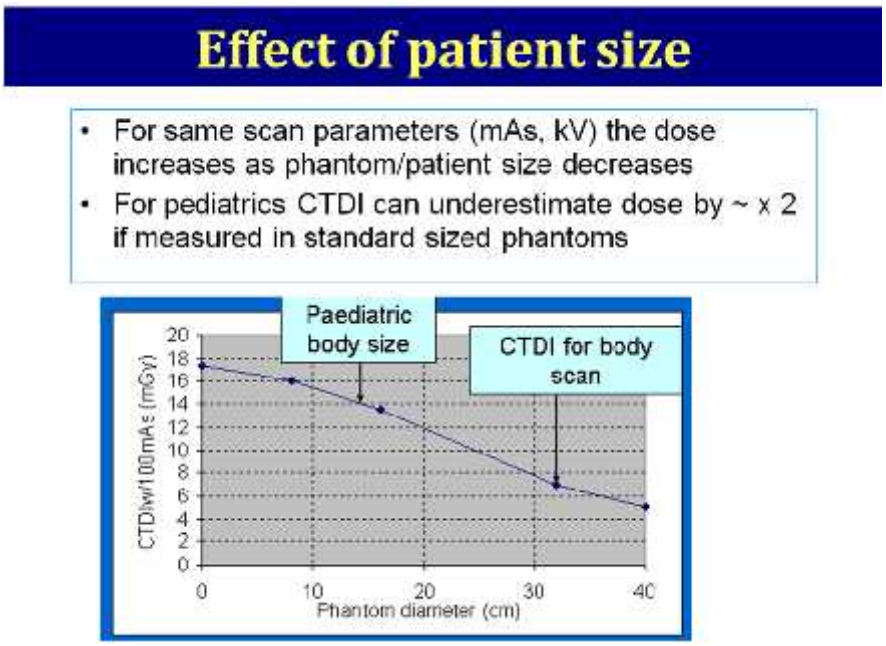
Fig(2-12) show comparison of CTDIvol and slice width.



Fig(2.13)show comparison of CTDIvol and number of slices.



Fig(2.14): effect of pitch on CTDIvol.



Fig(2.15): effect of patient size.

2-5 Previous studies:

2-5-1-1S J FOLEY,et –al British Journal of Radiology May 17, 2012 Establishment of CT diagnostic reference levels in Ireland collected data from 40CT in Ireland the study collected data (CTDIvol and DLP)data collected from3305 patients, and the authors represented 54% of national total .and noted that all equipment had capability (2-128)the study reported the CTDIvol and DLP for head ,sinuses, cervical spine, thoracic high resolution,CTA pulmonary, multiphase abdomen, routine abdomen/pelvis and trunk examinations.the study represented these values were lower than current DRLs and comparabled to the other international studies .

The studied recommended the variation in dose between CT departments and suggested a large potential for optimization of examination.

2-5-2-R. Treier et-al Radiation Protection Dosimetry (2010), Vol. 142, No. 2–4, pp. 244–254 doi:10.1093/rpd/ncq279

Advance Access publication 6 October 2010, patient dose in CT investigations in Switzerland implementation of national diagnostic reference levels

. Diagnostic reference levels (DRLs) were established for 21 indication-based CT examinations for adults in Switzerland. One hundred and seventy-nine of 225 computed tomography (CT) scanners operated in hospitals and private radiology institutes were audited on-site and patient doses were collected. For each CT scanner, a correction factor wascalculated expressing the deviation of the measured weighted computed tomography dose index (CTDI) to the nominal weighted CTDI as displayed on the workstation. Patient doses were corrected by this factor providing a realistic basis for establishing national DRLs. Results showed large variations in doses between different radiology departments in Switzerland, especially for examinations of the petrous bone, pelvis, lower limbs and heart. This indicates that the concept of DRLs has not yet been correctly applied for.

CT examinations in clinical routine. A close collaboration of all stakeholders is mandatory to assure an effective radiation

Protectionof patients. On-site audits will be intensified to further establish the concept of DRLs in Switzerland.

2-5-3 Federica et al .9-september 2013, European society of radiology studied the adult exposures from MDCT included multiphase studies first Italian nationwide dose in routine MDCT examination in Italian population, the study was retrospective study included 5668 patients from 65 radiology departments in common CT protocol. The study finished to result that could help to definition of updated DRL and recommended, radiation dose associated with MDCT is an important health issue.

2-5-4 PATIENT DOSES IN CT EXAMINATIONS IN SWITZERLAND:

IMPLEMENTATION OF NATIONAL DIAGNOSTIC REFERENCE LEVELS

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Diagnostic reference levels (DRLs) were established for 21 indication-based CT examinations for adults in Switzerland. One hundred and seventy-nine of 225 computed tomography (CT) scanners operated in hospitals and private radiology institutes were audited on-site and patient doses were collected. For each CT scanner, a correction factor was calculated expressing the deviation of the measured weighted computed tomography dose index (CTDI) to the nominal weighted CTDI as displayed on the workstation. Patient doses were corrected by this factor providing a realistic basis for establishing national DRLs.

Results showed large variations in doses between different radiology departments in Switzerland, especially for examinations of the petrous bone, pelvis, lower limbs and heart. This indicated that the concept of DRLs has not yet been correctly applied for CT examinations in clinical routine. A close collaboration of all stakeholders is mandatory to assure an effective radiation protection of patients. On-site audits will be intensified to further establish the concept of DRLs in Switzerland.

2-5-5 Roshan-S et—al in Jan-mar 2011-journal of medical physics-volume36/no1studed the CT scanner in India .the study intended to and evaluated radiation doses imported to patient undergoing Thoracic, abdomen and pelvic CT examination formulated regional DRLs in Tamil Nadu, South India. The study informed 127CT scanner, CTDIvol was measured used 32cm (PMMA) body phantom in each CT scanner.DLP

for different anatomical regions was generated using mean effective dose was estimated, the regional DRLs for thoracic, abdomen and pelvic examined were 557.521, 294mGy.cm respectively the study was recommended that establishment of DRLs is the first steps toward optimization of CT dose in India context.

2-5-6- A.Saravana.Kumar.et al, Journal medical physics 2014Jan-mar 39/1/50-55.studed to establishment of DRLs in CT for selected procedures in puchuchary,India.

In this context weighted dose index (DTDIw),CTDIv and DLP were used to assess procedures in CT imaging ,the aimed was to established the exiting dose level of six CT scanner in six deferent radiological department using 100mm long pencil ionization chamber and (PMMA) phantom and data collected from 50 head,50 abdomen over one year,the DRLs was established based on third quartile value of CTDIv and DLP which was 32mGy,925mGy.cm for head and 12mGy,456 mGy.cm for chest and 16mGy,482cm for abdomen procedures. These values well below European commission dose reference level (ERDRL)and comparable with the third quartile value reported for Tamil Nadu in India the study recommended similar studies in other regions of India to establish NDRLs.

2-5-7-T sapaki et al Br J Radio 2001 sep;74(885);836-4application of European commission reference dose level in CT examination in Grele,Greece.

The study applied ECDRLs to routine CT examination used the dosimetric quantities CTDIw, CTDIv, and DLP and patient related data as technical parameter for brain, chest, abdomen and pelvis data were collected for four CT scanner in Euromedica medical center.

CTDIv, and CTDIw, DLP dose were collected and the effective dose was estimated from each type of examinations, random sample from 10 typical patients.

CTDIw had range of (27-52mGy) for brain, (13.9-26.9) for chest, abdomen and pelvis, mean value of DLP had range of (430-758mGy) brain and (348-807mGy)for chest(78-592mGy)abdomen, and (306-592mGy)for pelvis. Effective dose were calculated as 1.4mSv for brain, 10.9mSv for chest, 7.1mSv for abdomen and 9.3mSv for pelvis. The results confirmed that the Euromedica Medical centre meet ECDRLs for brain, abdomen, and pelvis as term of radiation dose and technique.

As for as chest examination in concerned, DPL is concederelly exceeded because of large irradiation volume length (L). The study recommended reduction the length of scan or mAs .

2-5-8- Ngaile JE,et-al;J Radiol prot 2006.Jan:26(2):213-25 E pub 2006 May 26 established of NDRLs for CT exam in Tanzania.

The study assessed the radiation dose levels from CT examination according to EC guideline used dosimetric quantities CTDIv, CTDIw, and DLP from five common CT examinations from eight hospital CTDIw for head ,lumber spine had range of 25-77mGy and 18-47mGy while from chest abdomen and pelvis had range 11-25mGy.the mean values of DLP for head, chest, and abdomen had range of 610-1684 mGy-cm,495-922 mGy-cm, and 717-1428 mGy-cm in respectively, while L/S and pelvis had range 200-382mGy-cm 526-1302 mGy-cm.

The study observed the wide variation of mean CTDIw and DLP values among hospitals for similar examinations. Mean DLP values of examinations almost above the proposed RDLs. and recommended future investigation of scanning protocols is needed.

CHAPTER THREE:

METHODOLOGY AND RELATED BACKGROUND

This Section summarizes the list of participating centers, the equipment and methodology employed and some theoretical background. And the methods of the data analysis

3.1. PARTICIPATING CENTRES

3.1.1. Identification of hospitals

The study employed a convenience, as opposed to a randomly selected, sample. This limitation was accepted because of practical constraints on the time and resources available to the project. Within this limitation, it was important that the participating centers:

Be experienced in clinical CT work, or have access to institutions so involved; Have a capacity for dissymmetry and image quality analysis, or have access to a team. Consisting of radiologists, technologist and physicists, with such capacity; provide as wide a geographic distribution as possible.

- A lot of patient's frequency.

The first two requirements were essential either to develop methodology for patient dose optimization linked to image quality, or to provide evidence that might have potential for widespread application. The regions involved included Khartoum state and any CT centers which system machine involved dosimetric displayed on the console in anywhere of Sudan.

3.2 **Examinations should have DRLs?**

DRLs are intended to promote improvements in patient protection by allowing comparison of current practice. National and local DRLs should (ideally) be set for each examination and each patient group

(adults and children of different sizes). In order to allow meaningful comparison of truly similar examinations conducted for similar purpose and requiring similar scan technique, it is crucial to specify detailed descriptions of CT procedures, including a clinical indication (such as CT abdomen in relation to liver metastases), rather than simply broad categories of examination (such as CT abdomen). This usefully allows the comparison of 'apples with apples' rather than a mixed bag of fruit. so for these reasons the study chose same adult patients have average range of weight between 65kg-75kg or 75kg+/-10kg.and for National and local DRLs should also be established with similar regard to patient size. It is important to know the reference CT dissymmetry phantom (diameter of 16 cm or 32 cm) for the values of $CTDI_{vol}$ and DLP displayed for each protocol in order to allow meaningful comparison of doses. And study included about 677 patients for main CT examinations (Abdomen for KUB as abdomen pelvic, abdomen multie- phases, and tri-phases)(Brain routine,PNS)(Chest routine and HRCT).

3-3 .**The dose quantities are used for setting DRLs for CT:**

DRLs should be set in terms of the practical dose quantities used to monitor CT practice: volume weighted CT dose index ($CTDI_{vol}$, expressed in mGy) and dose-length product (DLP in mGy•cm), as commonly displayed by CT scanners.

. The institutions involved are listed in Table 1.

TABLE 3-1. Participating hospitals

HOSPITAL	CT configurations	Installation date	Classifications G/p	company	Frequncey
1	64	2010	g	Toshiba	
2	16	2005	g	Seimens	
3	16	2014	g	New soft	
4	64	2010	p	Toshiba	
5	64	2012	p	Phillips	
6	64	2011	p	Toshiba	
7	16	2010	g	GE	
8	16	2012	p	Toshiba	
9	16	2012	g	Toshiba	
10	64	2014	p	New soft	
11	128	2012	p	Toshiba	
12	16	2005	p	Seimens	
13	16	2012	g	New soft	
14	4	2012	p	Toshiba	
15	4	2012	p	Toshiba	
16	2	2009	g	Phillips	

The key p=privet centers=governmental centers.

Qualification test pre

4. Chapter Four: Results

4.1 Introduction

The objective of this thesis is to establish national DRL that can be used by Sudan Atomic Energy Commission and local radiology department in order to assess the patients doses and imaging protocol. The use of DRL as a practical tool in medical imaging is important. Accomplishing satisfactory image quality or adequate diagnostic finding, consistent with the medical imaging task, is the main purpose of radiation imaging. DRL are then used to help deal with the radiation dose to patients so that the dose is commensurate with the clinical purpose. This thesis extensively assessed patient doses in 18 radiology department equipped with different CT modalities. In order to provide reasonable DRL values, The $CTDI_{vol}$ (mGy) and DLP (mGy.cm) were used to establish doses reference level for certain investigations. The dose values were compared with reference doses and previous studies which would should optimizing radiography examination in these hospitals, the result presented will serves as baseline data, in addition to other studies, needed for deriving reference dose levels (DRLs) for CT examination in Sudan. All patient dose data were calculated using operator console data after careful calibration of the CT machine (Chapter 3).The data was analyzed using Statistical Package for the Social Sciences (SPSS) version. 16.0 Chicago, Illinois, USA, SPSS

Inc.). Descriptive statistics, Bivariate statistics (t-test, ANOVA). DLP (mGy.cm) and CTDIvol (mGy) were analyzed to obtain the third quartile value as a reference value for DRL for each hospital and the overall average.

The following statistical methods were used : Mean, Std. Deviation, Maximum, Minimum, Range, Test (One Way ANOVA):To know significance of the differences in the variables (Age, kVp, mAs, DLP, CTDI) according to (Hospital and CT Modality), Scheffe test: used to know the differences in favor, existing in the analysis of variance, Independent samples T test: To know significance of the differences in the variables (Age , kVp, mAs, DLP, CTDI) according to gender.

The results were tabulated in the tables (mean ± standard deviation (sd) and the range of the readings in parenthesis. The dose values in diagnostic radiology are small, therefore the dose were presented in milli-Gray for CTDIvol and mGy.cm for DLP. The mean and the standard deviation were calculated using SPSS software (Chapter 3).

For radiation dose evaluation, patient individual exposure parameters were recorded (tube voltage (kV), tube current and exposure time product (mAs) and pitch. Patient demographic data (age, gender, weight, height) were presented per hospital.

Table 4.1: CT systems			
No	Hospital	Manufacture	Modality (number of slice/detectors
1	SHN	Philips	2
2	RIB	Siemens	16
3	KHB	Neosoft	16
4	ALB	G.E	16
5	YAS	Toshiba	16
6	ROY	Toshiba	64
7	ALA	Toshiba	64
8	DAR	Philips	64
9	DOC	Tosiba	64
10	GAR	Philips	128
11	FAS	Tosiba	16
12	KRS	Neosoft	16
13	ELG	Tosiba	16
14	ELZ	Toshiba	64
15	IBh	Tosiba	4
16	NSF	Tosiba	16

Concerning CTDIvol (mGy) and DLP (mGy.cm) in all hospitals, the dose are high in many hospitals equipped with 64 slices shown in table 4.1 due to exposure factors (kV ,mAs) because the unit need more mAs to produce the same number of photons that produced by constant potential. For this reason it is recommended to use the machines wisely, in addition there are several factors contribute to dose variation such as variation in technique, exposure factor used, difference in technologist experience. A comparison was made between DLPs obtain between in this work and with some international reference.

4. 2Results

4.2.1 CT Brain Results

A total of 244 CT brain procedures were performed over one year in 16 different hospitals. Patient age per hospital was presented in Table 4. 2. Radiation exposure parameters were presented in Table 4.3 for tube voltage (kVp) and tube current time product (mAs), respectively. Patient dose in terms of DLP (mGy.cm) and CTDIvol were presented in Tables 4.2 and 4.3 in that order. Table 4.4 presented the comparison between different measured parameters according to the gender. Although substantial variations were noticed in patient doses, no significant difference in patient populations in terms of age, tube voltage and tube current and gender.

4.2.2 CT Chest Results

A total of 78 chest CT imaging procedures (34 females and 44 males) were performed over one year in 6 different hospitals. Patient age per hospital was presented in Table 4.5. Radiation exposure parameters (tube voltage (kVp) and tube current time product (mAs)) were presented in the same Table. Patient dose in terms of DLP (mGy.cm) and CTDIvol were presented in Tables 4.6. Table 4.6, shows the results of the variables (Age, kVp, mAs, DLP, CTDI) according to CT system (mean , std. deviation, maximum, minimum, range). Table 4.7. shows the results of

(One Way ANOVA),to determine the significance of the differences in the variablesc(Age,mAs,DLP,CTDI) according to CT modality(Daul slices, 16 slices and 64 Slices). There are statistically significant differences at the level of significance (0.05) or less in the variables (mAs, DLP, CTDI) attributable to Hospitals.There are not statistically significant differences at the level of significance (0.05) or less in the variable (Age) attributable to Hospitals.

4.2.3 Paranasal Sinuses CT procedures

A total of 66 CT Para nasal sinuses (PNS) procedures were performed over two years in 7 different hospitals equipped with different multi detector CT modality. Patient age per hospital, radiation exposure parameters were presented in Table 4.8 for tube voltage (kVp) and tube current time product (mAs), respectively. Patient dose in terms of DLP (mGy.cm) and CTDIvol were presented in Table 4.9. Table 4.10 shows the Results of (One Way ANOVA), To know significance of the differences in the variables(AGE,MAS,DLP,CTDI) according to Hospital. Table 4.11 shows the results of the Scheffe test to the variables mAs, DLP,CTDIvol) according to Hospitals.

Table4.12 shows the results of (One Way ANOVA),To know significance of the differences in the variables(Age ,mAs ,DLP,CTDIvol) according to CT modality. Table 4.13 shows the results of the Scheffe

test to the variables (CTDI) according to No of CT device. And finally Table 4.14. Shows the results of independent samples T test, to know significance of the differences in the variables (Age, mAs,DLP, CTDIvol) according to gender.

4.2.4 CT Abdomen

4.2.4.: CT abdomen (Routine)

A total of 73 CT abdomen (routine) procedures were performed in two different hospitals equipped with different multi detector CT modality. Table 4.15 shows the results of Mean, Std. Deviation, Maximum, Minimum of the variables (Age, kVp, mAs, DLP, CTDIvol) according to Hospital. Table4.16 shows the results of Mean, Std. Deviation, Maximum, and Minimum of the variables (Age, kVp, mAs, DLP, CTDIvol) according to No. device. Table 4.17 shows the Results of (One Way ANOVA), To know significance of the differences in the variables (Age, kVp, mAs,DLP, CTDIvol) according to Hospital. Table 4.18 shows the results of (One Way ANOVA), to know significance of the differences between the variables(Age ,kVp, mAs ,DLP,CTDIvol) according to No. device: Table 4.19 shows the results of the Scheffe test to the variables (DLP) according to No. Device. Table 4.20 shows the results of independent samples T test, to know significance of the

differences in the variables (Age, kVp, mAs,DLP, CTDIvol) according to gender.

4.2.4.1: CT abdomen-pelvis procedures

A total of 175 CT abdomen-pelvis procedures were performed for CT abdomen-pelvis procedures over two year in 15 different hospitals. Table 4.21 shows the results of Mean, Std. Deviation, Maximum, Minimum, Range of the variables (Age, kVp, mAs, DLP, CTDIvol) according to Hospital. Table 4.22 shows the results of Mean, Std. Deviation, Maximum, Minimum, and Range of the variables (Age, kVp, mAs, DLP, CTDIvol) according to No. device. Table 4.23 shows the results of (One Way ANOVA), to know significance of the differences in the variables (Age, kVp, mAs, DLP, CTDI) according to Hospital. 4.24. Table 4.25 shows the results of the Scheffe test to the variables (Age, kVp, mAs, DLP, CTDIvol) according to Hospitals. Table 4.26 shows the results of (One Way ANOVA),to know significance of the differences in the variables(Age ,kVp,mAs,DLP,CTDIvol) according to No. device. Table 4.27 shows the results of the Scheffe test to the variables (AGE, KVP, MAS, DLP, and CTDI) according to No. Device. Table 4.28shows the results of independent samples T test, to know significance of the differences in the variables (Age, kVp, mAs, DLP, CTDIvol) according to gender:

4.2.4.2: CT abdomen-tri phase procedures

A total of 73 CT abdomen tri-phase procedures were performed for CT abdomen-pelvis procedures over two year in 15 different hospitals. Table 4.29 shows the results of Mean, Std. Deviation, Maximum, Minimum, range of the variables(Age, kVp, mAs, DLP, CTDIvol) according to Hospital. Table 4.30 shows the results of Mean, Std. Deviation, Maximum, Minimum, range of the variables (Age, kVp, MAS, DLP, CTDI) according to No. device. Table 4.31 shows the results of (One Way ANOVA),to know significance of the differences in the variables(mAs,DLP,CTDIvol) according to Hospital. Table 4.32 shows the results of the Scheffe test tothe variables (mAs, DLP, CTDIvol) according to Hospitals. Table 4.33 shows the results of (One Way ANOVA),To know significance of the differences in the variables(mAs,DLP,CTDIvol) according to No. device Table 4.34 shows the results of the Scheffe test to the variables(mAs,DLP,CTDIvol) according to numberdevice. Table 4.35shows the results of independent samples T test, To know significance of the differences in the variables (mAs,DLP,CTDIvol) according to gender.

4.2.4,3 : CTU procedures

A total of 27 CTU procedures were performed for CT in two different hospitals. Table 4.36 shows the results of Mean, Std. Deviation,

Maximum, Minimum, and Range of the variables (AGE, KVP, MAS, DLP, and CTDI) according to Hospital. Table 4.37 shows the results of Mean, Std. Deviation, Maximum, Minimum, Range of the variables (AGE, KVP, MAS, DLP, CTDI) according to No. device. Table 4.38 shows the results of (One Way ANOVA) to know significance of the differences in the variables (AGE, MAS, DLP, CTDI) according to Hospital. Table 4.39 shows the results of the Scheffe test to the variables (MAS, DLP, CTDI) according to Hospitals. Table 4.40 shows the results of independent samples T test, To know significance of the differences in the variables(AGE,MAS,DLP,CTDI) according to gender:

4.2.4,4: CT KUB procedures

A total of 139 CT KUB procedures were performed for CT in 3 different hospitals. Table 4.41 shows the results of Mean, Std. Deviation, Maximum, Minimum, Range of the variables (Age,kVp, mAs, DLP, CTDIvol) according to Hospital. Table 4.42 shows the results of Mean, Std. Deviation, Maximum, Minimum, Range of the variables (Age, kVp, mAs, DLP, CTDIvol) according to No. device. Table 4.43 shows the results of (One Way ANOVA),to know significance of the differences in the variables(Age ,mAs,DLP,CTDIvol) according to Hospital. Table 4.44 shows the results of the Scheffe test to the variables (mAs, DLP, CTDIvol) according to Hospitals. Table 4.45 shows the results of (One

Way ANOVA), to know significance of the differences in the variables(Age ,mAs,DLP,CTDIvol) according to No. device. Table 4.46 shows the results of the Scheffe test to the variables (mAs) according to No. Device. Table 4.47 shows the results of independent samples T test, to know significance of the differences in the variables(Age ,mAs,DLP,CTDIvol) according to gender.

Table 4.2: Brain dose and DRL per hospital

Variables	Hospital	Mean	Std. Deviation	Maximum	Minimum	3rd quartile
DLP (mGy.cm)	SHN	831.20	274.767	1358	414	950
	RIB	1355.16	631.652	3573	414	2085
	KHB	978.70	65.074	1073	938	1015
	ALB	1159.37	126.770	1436	1037	1250
	YAS	1021.08	120.529	1179	826	1012
	ROY	1371.50	165.471	1504	1056	1284
	ALA	1442.73	86.309	1624	1360	1420
	DAR	1140.50	119.483	1451	1003	1174
	DOC	1007.20	119.325	1208	887	1076
	GAR	1329.10	120.381	1520	1166	1400
	FAS	991.30	159.762	1258	752	912
	KRS	1208.67	236.586	1599	707	1240
	ELG	993.10	108.519	1205	888	1162
	ELZ	1686.91	143.548	2055	1544	1670
	IBN	958.60	59.003	1055	874	914
	NSF	1107.56	66.707	1220	1024	792

Table 4.3: CTDI vol and DRL for Brain procedure						
Variables	Hospital	Mean	Std. Deviation	Maximum	Minimum	3rd quartile
CTDIvol (mGy)	SHN	54.23	15.584	69	31	44
	RIB	77.36	31.873	225	31	81
	KHB	74.50	.000	75	75	75
	ALB	76.58	2.678	83	72	77
	YAS	52.90	.000	53	53	53
	ROY	79.80	1.581	81	77	79
	ALA	78.06	1.308	80	77	78
	DAR	70.70	.675	71	69	70
	DOC	57.66	2.789	61	56	59
	GAR	67.40	.000	67	67	67
	FAS	54.40	5.502	57	43	48
	KRS	61.87	11.262	76	37	52
	ELG	52.90	.000	53	53	53
	ELZ	78.36	1.567	80	77	79
	IBN	57.50	.000	58	58	58
	NSF	75.30	.000	75	75	75

Table 4.4. shows the Results of independent samples T test,To know significance of the differences in the variables (age, kVp, mAs, DLP, CTDIvol) according to gender.						
Variables	Gender	N	Mean	standard deviation	T-Test	Sig
Age	Female	98	49.35	19.502	1.922	.056
	Male	146	44.55			
kVp	Female	98	123.47	7.612	-1.475	.141
	Male	146	125.07			
mAs	Female	98	250.28	104.877	.561	.575
	Male	146	242.49			
DLP	Female	98	1195.68	378.646	.181	.857
	Male	146	1185.61			
CTDIvol	Female	98	69.68	17.338	.790	.430

4.1 Chest CT procedures

Table4.5 : Patient mean and range of age and image acquisition parameters during chest CT procedures						
Parameter/Hospital	SHN	RIB	ALB	YAS	ALA	NSF
Age (year)	44.9±15.6 (18-70)	58.6±16.2 (28-80)	49.6±16.3 (30-75)	62.6±23 (25-92)	54.8±15.2 (40-83)	49.93±19.4 (20-83)
Tube voltage (kVp)	120*	120*	120*	120*	120*	120*
Tube current-time product (mAs)	90.7±46 (44-180)	101.9±29 (34-125)	153.3±44 (66-187)	70.4±19 (43-115)	225.6±48 (200-299)	204.9±78.8 (44-249)
DLP (mGy.cm)	245.6±128 126-546)(	681.5±240 202-1104)(	487.6±182 177-746)(	226.3±100 120-443)(	632.4±171 450-939)(	615.9±83 409-734)(
CTDIvol (mGy)	7.23±4.23 3.0-15.0)(	12.7±7.0 3.0-19.0)(	15.6±5. 3 5.0-19.0)(	5.1±1.4 3.0-8.0)(	16.7±3.2 13.0-20.0)(	18.0±3.7 7.0-20.0)(

*Constant tube potential

Table 4.6. shows the results of the variables (Age, kVp, mAs, DLP, CTDI) according to CT system (mean , std. deviation, maximum, minimum, range).							
Variables	CT modality	Mean	Std. Deviation	Maximum	Minimum	Range	N
Age	2S	44.93	15.572	70	18	52	15
Age	16S	54.44	18.962	92	20	72	55
Age	64S	54.75	15.239	83	40	43	8
kVp	2S	120.00	.000	120	120	0	15
kVp	16S	120.00	.000	120	120	0	55
kVp	64S	120.00	.000	120	120	0	8
mAs	2S	90.67	46.021	180	44	136	15
mAs	16S	141.69	75.181	249	34	215	55
mAs	64S	255.63	48.922	299	200	99	8
DLP	2S	245.60	128.265	546	126	420	15
DLP	16S	554.98	227.823	1104	120	984	55
DLP	64S	632.38	171.763	939	450	489	8
CTDI	2S	7.23	4.233	15	3	12	15
CTDI	16S	13.79	6.634	20	3	17	55
CTDI	64S	16.73	3.168	20	13	6	8

Table 4.7. shows the results of (One Way ANOVA),to determine the significance of the differences in the variablesc(Age,mAs,DLP,CTDI) according to CT modality(Daul slices, 16 slices and 64 Slices)

Variables	Source of variation	Mean Square	F	Sig.
Age	Between Groups	470.420	1.488	.194
	Within Groups	316.125		
	Total			
mAs	Between Groups	49818.867	18.271**	.000
	Within Groups	2726.690		
	Total			
DLP	Between Groups	481856.612	10.251**	.000
	Within Groups	47004.266		
	Total			
CTDI	Between Groups	169551.220	4.944**	.000
	Within Groups	34291.398		
	Total			

4.3 Para nasal Sinuses

Table 4.8 shows the results of Mean, Std. Deviation, Maximum, Minimum, Range of the variables (Age,kVp, mAs, DLP, CTDIvol) according to Hospital:

Variables	Hospital	Mean	Std. Deviation	Maximum	Minimum	Range	N
Age	RIB	42.88	15.866	65	19	46	16
	KHB	37.45	11.784	65	22	43	11
	ALB	35.50	14.707	53	18	35	6
	BAH	37.20	15.241	65	18	47	20
	ELN	42.00	.	42	42	0	1
	FAS	48.86	11.202	70	37	33	7
	ELG	31.60	7.797	41	25	16	5
kVp	RIB	120.00	.000	120	120	0	16
	KHB	120.00	.000	120	120	0	11
	ALB	120.00	.000	120	120	0	6
	BAH	120.00	.000	120	120	0	20
	ELN	120.00	.	120	120	0	1
	FAS	120.00	.000	120	120	0	7
	ELG	120.00	.000	120	120	0	5
mAs	RIB	164.00	76.566	248	88	160	16
	KHB	60.00	.000	60	60	0	11
	ALB	150.00	.000	150	150	0	6
	BAH	224.25	43.982	249	150	99	20
	ELN	112.00	.	112	112	0	1
	FAS	112.00	.000	112	112	0	7
	ELG	112.00	.000	112	112	0	5
DLP	RIB	464.06	242.715	990	206	784	16
	KHB	185.73	12.109	211	167	44	11
	ALB	713.83	78.492	853	619	234	6
	BAH	375.45	52.334	498	314	184	20
	ELN	389.00	.	389	389	0	1
	FAS	446.71	60.019	498	329	169	7
	ELG	547.80	94.099	650	431	219	5
CTDIvol	RIB	28.99	9.120	39	21	18	16
	KHB	12.60	.000	13	13	0	11
	ALB	55.00	.000	55	55	0	6
	BAH	35.72	5.838	39	26	13	20
	ELN	42.00	.	42	42	0	1
	FAS	42.00	.000	42	42	0	7
	ELG	37.70	.000	38	38	0	5

Table 4.9 shows the results of Mean, Std. Deviation, Maximum, Minimum, and Range of the variables (AGE, KVP, MAS, DLP, and CTDI) according to CT modality:

Variables	No. device	Mean	Std. Deviation	Maximum	Minimum	Range	N
Age	4S	48.00	10.650	70	37	33	8
	16S	38.77	14.585	65	18	47	53
	64S	31.60	7.797	41	25	16	5
kVp	4S	120.00	.000	120	120	0	8
	16S	120.00	.000	120	120	0	53
	64S	120.00	.000	120	120	0	5
mAs	4S	112.00	.000	112	112	0	8
	16S	163.57	78.131	249	60	189	53
	64S	112.00	.000	112	112	0	5
DLP	4S	439.50	59.195	498	329	169	8
	16S	401.13	202.940	990	167	823	53
	64S	547.80	94.099	650	431	219	5
CTDIvol	4S	42.00	.000	42	42	0	8
	16S	31.07	13.576	55	13	42	53
	64S	37.70	.000	38	38	0	5

Table 4.10 shows the results of (One Way ANOVA),To know significance of the differences in the variables(Age ,mAs,DLP,CTDIvol) according to Hospital

Variables	Source of variation	Sum of Squares	Df	Mean Square	F	Sig.	Interpretation
Age	Between Groups	1359.750	6	226.625	1.147	.347	There are not statistically significant differences
	Within Groups	11655.234	59	197.546			
	Total	13014.985	65				
mAs	Between Groups	220502.205	6	36750.367	17.389**	.000	There are statistically significant differences
	Within Groups	124689.750	59	2113.386			
	Total	345191.955	65				
DLP	Between Groups	1279491.126	6	213248.521	12.275**	.000	There are statistically significant differences
	Within Groups	1025001.131	59	17372.901			
	Total	2304492.258	65				
CTDI	Between Groups	8644.536	6	1440.756	44.856**	.000	There are statistically significant differences
	Within Groups	1895.043	59	32.119			
	Total	10539.579	65				

(**) Means the difference is statistically significant at the level of significance (0.01) or less
(*) Means the difference is statistically significant at the level of significance (0.05) or less

Table 4.11 shows the results of the Scheffe test tothe variables (mAs,DLP,CTDIvol) according to Hospitals:

Variables	Hospital	Mean	RIB	KHB	ALB	BAH	FAS	ELG
mAs	RIB	164.00	-					
	KHB	60.00	**	-				
	ALB	150.00		**	-			
	BAH	224.25	**	**	*	-		
	FAS	112.00	*	*		**	-	
	ELG	112.00	*	*		**		-
DLP	RIB	464.06	-					
	KHB	185.73	**	-				
	ALB	713.83	**	**	-			
	BAH	375.45	*	**	**	-		
	FAS	446.71		**	**		-	
	ELG	547.80		**	*	*		-
CTDIvol	RIB	28.99	-					
	KHB	12.60	**	-				
	ALB	55.00	**	**	-			
	BAH	35.72	**	**	**	-		
	FAS	42.00	**	**	**	**	-	
	ELG	37.70	**	*	**			-

Seen from the Table () as follows:

- (**) Means the presence of statistically significant differences at the level of significance (0.01) or less between averages of hospitals in favor of the largest average.
- (*) Means the presence of statistically significant differences at the level of significance (0.05) or less between averages of hospitals in favor of the largest average.

Table 4.12 shows the results of **(One Way ANOVA),**To know significance of the differences in the variables(Age, mAs ,DLP,CTDIvol) according to No. device:

Variables	Source of variation	Sum of Squares	Df	Mean Square	F	Sig.	Interpretation
Age	Between Groups	916.502	2	458.251	2.386	.100	There are no statistically significant differences
	Within Groups	12098.483	63	192.039			
	Total	13014.985	65				
mAs	Between Groups	27758.936	2	13879.468	2.755	.071	There are statistically significant differences
	Within Groups	317433.019	63	5038.619			
	Total	345191.955	65				
DLP	Between Groups	102937.382	2	51468.691	1.473	.237	There are statistically significant differences
	Within Groups	2201554.875	63	34945.315			
	Total	2304492.258	65				
CTDIvol	Between Groups	955.208	2	477.604	3.139*	.050	There are statistically significant differences
	Within Groups	9584.372	63	152.133			
	Total	10539.579	65				

(**) Means the difference is statistically significant at the level of significance (0.01) or less
(*) Means the difference is statistically significant at the level of significance (0.05) or less

Seen from the Table () as follows:

- There are statistically significant differences at the level of significance (0.05) or less in the variable (CTDI) attributable to No. device.
- There are not statistically significant differences at the level of significance (0.05) or less in the variables (AGE,MAS, DLP) attributable to No. device.
- To know the differences in favor of using Scheffe test as follows:

Table 4.13 shows the results of the Scheffe test to the variables (CTDI) according to number of device:

Variables	No. device	Mean	4S	16S	64S
CTDI	4S	42.00	-		
CTDI	16S	31.07	*	-	
CTDI	64S	37.70			-

Seen from the Table () as follows:

- (**) Means the presence of statistically significant differences at the level of significance (0.01) or less between averages types of devices in favor of the largest average.
- (*) Means the presence of statistically significant differences at the level of significance (0.05) or less between averages types of devices in favor of the largest average

Table 4.14 shows the results of independent samples T test, To know significance of the differences in the variables(Age ,mAs,DLP,CTDIvol) according to gender:

Variables	Gender	N	Mean	standard deviation	T-Test	Sig	Interpretation
Age	Female	43	38.91	14.010	-.344	.732	The difference is statistically significant
	Male	23	40.17	14.690			
mAs	Female	43	163.79	74.484	1.601	.114	The difference is not statistically significant
	Male	23	134.00	67.043			
DLP	Female	43	433.72	199.221	.993	.325	The difference is not statistically significant
	Male	23	385.43	165.505			
CTDIvol	Female	43	33.99	12.451	.949	.346	The difference is not statistically significant
	Male	23	30.86	13.283			

Seen from the Table () as follows:

- There are not statistically significant differences at the level of significance (0.05) or less in the variables (AGE,MAS, DLP, CTDI) attributable to gender.

4.4 CT Abdomen Procedures

4.4.1 Routine CT Abdomen

Table 4.15 shows the results of Mean, Std. Deviation, Maximum, and Minimum of the variables (AGE, KVP, MAS, DLP, and CTDI) according to Hospital:

Variables	Hospital	Mean	Std. Deviation	Maximum	Minimum	Range	N
Age	SHN	41.57	13.138	65	25	40	7
	RIB	46.62	16.788	80	18	62	66
kVp	SHN	120.00	.000	120	120	0	7
	RIB	120.30	2.462	140	120	20	66
mAs	SHN	180.00	.000	180	180	0	7
	RIB	161.39	47.180	250	46	204	66
DLP	SHN	1330.57	234.903	1707	918	789	7
	RIB	3171.88	2099.368	7041	124	6917	66
CTDIvol	SHN	29.66	4.688	34	23	12	7
	RIB	266.67	324.494	1330	3	1327	66

Table 4.16 shows the results of Mean, Std. Deviation, Maximum, and Minimum of the variables (AGE, KVP, MAS, DLP, and CTDI) according to No. device:

Variables	No. device	Mean	Std. Deviation	Maximum	Minimum	Range	N
Age	2S	41.57	13.138	65	25	40	7
	16S	46.62	16.788	80	18	62	66
kVp	2S	120.00	.000	120	120	0	7
	16S	120.30	2.462	140	120	20	66
mAs	2S	180.00	.000	180	180	0	7
	16S	161.39	47.180	250	46	204	66
DLP	2S	1330.57	234.903	1707	918	789	7
	16S	3171.88	2099.368	7041	124	6917	66
CTDI	2S	29.66	4.688	34	23	12	7
	16S	266.67	324.494	1330	3	1327	66

Table 4.17 shows the results of (One Way ANOVA),To know significance of the differences in the variables(AGE,KVP,MAS,DLP,CTDI) according to Hospital

Variables	Source of variation	Sum of Squares	Df	Mean Square	F	Sig.	Interpretation
AGE	Between Groups	161.386	1	161.386	.592	.444	There are not statistically significant differences
	Within Groups	19355.245	71	272.609			
	Total	19516.630	72				
KVP	Between Groups	.581	1	.581	.105	.747	There are statistically significant differences
	Within Groups	393.939	71	5.548			
	Total	394.521	72				
MAS	Between Groups	2190.927	1	2190.927	1.075	.303	There are statistically significant differences
	Within Groups	144685.758	71	2037.828			
	Total	146876.685	72				
DLP	Between Groups	21457133.009	1	21457133.009	5.312*	.024	There are statistically significant differences
	Within Groups	286808466.745	71	4039555.870			
	Total	308265599.753	72				
CTDI	Between Groups	355505.000	1	355505.000	3.688		There are statistically significant differences
	Within Groups	6844384.449	71	96399.781			
	Total	7199889.449	72				

(**) Means the difference is statistically significant at the level of significance (0.01) or less

(*) Means the difference is statistically significant at the level of significance (0.05) or less

Table 4.18 shows the results of the Scheffe test tothe variables (CTDI) according to Hospitals:

Variables	Hospital	Mean	SHN	RIB
CTDI	SHN	29.66	-	
CTDI	RIB	266.67	**	-

Table 4.19 shows the r esults of (One Way ANOVA),To know significance of the differences between the variables(AGE,KVP,MAS,DLP,CTDI) according to No. device:

Variables	Source of variation	Sum of Squares	Df	Mean Square	F	Sig.	Interpretation
AGE	Between Groups	161.386	1	161.386	.592	.444	There are no statistically significant differences
	Within Groups	19355.245	71	272.609			
	Total	19516.630	72				
KVP	Between Groups	.581	1	.581	.105	.747	There are statistically significant differences
	Within Groups	393.939	71	5.548			
	Total	394.521	72				
MAS	Between Groups	2190.927	1	2190.927	1.075	.303	There are statistically significant differences
	Within Groups	144685.758	71	2037.828			
	Total	146876.685	72				
DLP	Between Groups	21457133.009	1	21457133.009	5.312*	.024	There are statistically significant differences
	Within Groups	286808466.745	71	4039555.870			
	Total	308265599.753	72				
CTDI	Between Groups	355505.000	1	355505.000	3.688	.059	There are statistically significant differences
	Within Groups	6844384.449	71	96399.781			
	Total	7199889.449	72				

(**) Means the difference is statistically significant at the level of significance (0.01) or less

(*) Means the difference is statistically significant at the level of significance (0.05) or less

Table4.20 shows the results of the Schaffer test to the variables (DLP) according to number device:

Variables	No. device	Mean	2S	16S
DLP	2S	1330.57	-	
DLP	16S	3171.88	**	-

Seen from the Table () as follows:

- (**) Means the presence of statistically significant differences at the level of significance (0.01) or less between averages types of devices in favor of the largest average.

Table 4.21 shows the Results of independent samples T test, To know significance of the differences in the variables(AGE,KVP,MAS,DLP,CTDI) according to gender:

Variables	**Gender**	**N**	**Mean**	**standard deviation**	**T-Test**	**Sig**	**Interpretation**
AGE	Female	39	43.62	14.578	-1.411	.163	The difference is not statistically significant
	Male	34	49.03	18.182			
KVP	Female	39	120.51	3.203	.933	.354	The difference is not statistically significant
	Male	34	120.00	.000			
MAS	Female	39	160.85	41.547	-.470	.640	The difference is not statistically significant
	Male	34	165.85	49.491			
DLP	Female	39	2720.59	2047.368	-1.219	.227	The difference is not statistically significant
	Male	34	3310.44	2079.194			
CTDI	Female	39	176.29	252.576	-1.998*	.050	The difference is not statistically significant
	Male	34	321.53	364.838			

Seen from the Table () as follows:

- There are not statistically significant differences at the level of significance (0.05) or less in the variables (AGE,KVP, MAS, DLP) attributable to gender.
- There are statistically significant differences at the level of significance (0.05) or less in the variable (CTDI) Between the average male and female in favor of average male.

4.4.2 CT Abdomen: Tri-phase

Table 4.22 shows the results of Mean, Std. Deviation, and Maximum, and Minimum, range of the variables (AGE, KVP, MAS, DLP, and CTDI) according to Hospital:

Variables	Hospital	Mean	Std. Deviation	Maximum	Minimum	Range	N
KVP	SHN	120.00	.000	120	120	0	24
KVP	BAH	120.00	.000	120	120	0	9
KVP	DAR	120.00	.000	120	120	0	10
KVP	NSF	120.00	.000	120	120	0	30
MAS	SHN	83.96	14.834	100	57	43	24
MAS	BAH	249.00	.000	249	249	0	9
MAS	DAR	250.00	.000	250	250	0	10
MAS	NSF	249.00	.000	249	249	0	30
DLP	SHN	1184.67	247.284	1859	892	967	24
DLP	BAH	4064.67	579.648	5418	3653	1765	9
DLP	DAR	4415.70	595.168	5776	3643	2133	10
DLP	NSF	4057.47	616.185	5418	3067	2351	30
CTDI	SHN	25.00	3.683	34	17	16	24
CTDI	BAH	19.80	.000	20	20	0	9
CTDI	DAR	16.30	.000	16	16	0	10
CTDI	NSF	19.80	.000	20	20	0	30

Table 4.23 shows the results of Mean, Std. Deviation, Maximum, Minimum, and Range of the variables (AGE, KVP, MAS, DLP, and CTDI) according to No. device:

Variables	No. device	Mean	Std. Deviation	Maximum	Minimum	Range	N
KVP	2S	120.00	.000	120	120	0	25
KVP	16S	120.00	.000	120	120	0	48
MAS	2S	90.56	36.061	249	57	192	25
MAS	16S	249.21	.410	250	249	1	48
DLP	2S	1319.88	718.100	4565	892	3673	25
DLP	16S	4122.88	613.806	5776	3067	2709	48
CTDI	2S	24.79	3.752	34	17	16	25
CTDI	16S	19.07	1.436	20	16	4	48

Table 4.24 shows the results of (One Way ANOVA), to know significance of the differences in the variables (MAS, DLP, CTDI) according to Hospital:

Variables	Source of variation	Sum of Squares	Df	Mean Square	F	Sig.	Interpretation
MAS	Between Groups	439898.932	3	146632.977	1999.162**	.000	There are statistically significant differences
	Within Groups	5060.958	69	73.347			
	Total	444959.890	72				
DLP	Between Groups	140942982.881	3	46980994.294	177.207**	.000	There are statistically significant differences
	Within Groups	18293214.900	69	265119.057			
	Total	159236197.781	72				
CTDI	Between Groups	660.200	3	220.067	48.680**	.000	There are statistically significant differences
	Within Groups	311.930	69	4.521			
	Total	972.130	72				

(**) Means the difference is statistically significant at the level of significance (0.01) or less
(*) Means the difference is statistically significant at the level of significance (0.05) or less

Table 4.25 shows the results of the Scheffe test tothe variables(MAS,DLP,CTDI) according to Hospitals:

Variables	Hospital	Mean	SHN	BAH	DAR	NSF
MAS	SHN	83.96	-			
MAS	BAH	249.00	**	-		
MAS	DAR	250.00	**		-	
MAS	NSF	249.00	**			-
DLP	SHN	1184.67	-			
DLP	BAH	4064.67	**	-		
DLP	DAR	4415.70	**		-	
DLP	NSF	4057.47	**			-
CTDI	SHN	25.00	-			
CTDI	BAH	19.80	**	-		
CTDI	DAR	16.30	**	**	-	
CTDI	NSF	19.80	**		**	-

(**) Means the presence of statistically significant differences at the level of significance (0.01) or less between averages of hospitals in favor of the largest average.
(*) Means the presence of statistically significant differences at the level of significance (0.05) or less between averages of hospitals in favor of the largest average

Table 4.26 shows the results of (One Way ANOVA),to know significance of the differences in the variables(MAS,DLP,CTDI) according to No. device:

Variables	Source of variation	Sum of Squares	Df	Mean Square	F	Sig.	Interpretation
MAS	Between Groups	413741.814	1	413741.814	940.983**	.000	There are statistically significant differences
	Within Groups	31218.077	71	439.691			
	Total	444959.890	72				
DLP	Between Groups	129152563.891	1	129152563.891	304.811**	.000	There are statistically significant differences
	Within Groups	30083633.890	71	423713.153			
	Total	159236197.781	72				
CTDI	Between Groups	537.304	1	537.304	87.733**	.000	There are statistically significant differences
	Within Groups	434.826	71	6.124			
	Total	972.130	72				

(**) Means the difference is statistically significant at the level of significance (0.01) or less

(*) Means the difference is statistically significant at the level of significance (0.05) or less

Seen from the Table () as follows:

- There are statistically significant differences at the level of significance (0.05) or less in the variables (MAS , DLP, CTDI) attributable to No. device.
- To know the differences in favor of using Scheffe test as follows:

Table 4.27 shows the results of the Scheffe test tothe variables(MAS,DLP,CTDI) according to Number device:

Variables	No. device	Mean	2S	16S
MAS	2S	90.56	-	
MAS	16S	249.21	**	-
DLP	2S	1319.88	-	
DLP	16S	4122.88	**	-
CTDI	2S	24.79	-	
CTDI	16S	19.07	**	-

- (**) Means the presence of statistically significant differences at the level of significance (0.01) or less between averages types of devices in favor of the largest average.
- (*) Means the presence of statistically significant differences at the level of significance (0.05) or less between averages types of devices in favor of the largest average

Table 4.28 shows the results of independent samples T test, to know significance of the differences in the variables (MAS, DLP, and CTDI) according to gender:

Variables	Gender	N	Mean	standard deviation	T-Test	Sig	Interpretation
MAS	Female	27	216.30	70.383	1.812	.074	The difference is not statistically significant
	Male	46	182.30	81.172			
DLP	Female	27	3508.81	1270.409	1.537	.129	The difference is not statistically significant
	Male	46	2959.93	1578.664			
CTDI	Female	27	19.84	2.340	-2.170**	.033	The difference is not statistically significant
	Male	46	21.73	4.135			

- There are not statistically significant differences at the level of significance (0.05) or less in the variables (MAS, DLP,) attributable to gender.
- There are statistically significant differences at the level of significance (0.05) or less in the variable (CTDI) Between the average male and female in favor of average male.

4.4.3 CT Abdomen- pelvis procedure

Table 4.29 shows the Results of Mean, Std. Deviation, Maximum, Minimum, and Range of the variables (AGE, KVP, MAS, DLP, and CTDI) according to Hospital:

Variables	Hospital	Mean	Std. Deviation	Maximum	Minimum	Range	N
AGE	RIB	38.17	13.581	67	18	49	29
AGE	KHB	39.00	10.739	58	20	38	10
AGE	ALB	50.77	15.605	70	22	48	13
AGE	YAS	41.91	10.084	53	27	26	11
AGE	ROY	41.00	11.754	61	20	41	13
AGE	ALA	37.60	11.843	60	20	40	15
AGE	DAR	49.47	20.067	78	20	58	15
AGE	DOC	51.50	19.092	65	38	27	2
AGE	GAR	54.83	14.825	75	24	51	12
AGE	FAS	47.00	.	47	47	0	1
AGE	KRS	33.36	10.538	50	20	30	11
AGE	ELG	47.89	14.912	73	27	46	9
AGE	ELZ	42.18	24.879	90	20	70	11
AGE	IBN	52.00	17.003	77	28	49	10
AGE	NSF	46.44	19.635	77	22	55	9
KVP	SHN	120.00	.000	120	120	0	9
KVP	RIB	123.72	7.875	140	120	20	43
KVP	KHB	120.00	.000	120	120	0	10
KVP	ALB	120.00	.000	120	120	0	13
KVP	YAS	120.00	.000	120	120	0	11
KVP	ROY	120.00	.000	120	120	0	13
KVP	ALA	120.00	.000	120	120	0	15
KVP	DAR	120.00	.000	120	120	0	15
KVP	DOC	120.00	.000	120	120	0	2
KVP	GAR	120.00	.000	120	120	0	12
KVP	FAS	120.00	.000	120	120	0	10
KVP	KRS	120.00	.000	120	120	0	11
KVP	ELG	120.00	.000	120	120	0	9
KVP	ELZ	120.00	.000	120	120	0	11
KVP	IBN	120.00	.000	120	120	0	10
KVP	NSF	120.00	.000	120	120	0	9
MAS	SHN	197.78	6.667	200	180	20	9
MAS	RIB	164.81	64.508	250	56	194	43
MAS	KHB	249.00	.000	249	249	0	10
MAS	ALB	226.38	84.099	429	89	340	13
MAS	YAS	112.00	.000	112	112	0	11
MAS	ROY	175.00	10.206	200	150	50	13
MAS	ALA	150.00	.000	150	150	0	15
MAS	DAR	249.93	.258	250	249	1	15
MAS	DOC	125.00	.000	125	125	0	2
MAS	GAR	130.17	17.898	187	125	62	12

MAS	FAS	205.00	57.975	260	150	110	10
MAS	KRS	90.64	14.555	117	67	50	11
MAS	ELG	42.67	10.440	67	37	30	9
MAS	ELZ	226.64	5.427	243	225	18	11
MAS	IBN	200.00	.000	200	200	0	10
MAS	NSF	446.44	73.667	471	250	221	9
DLP	SHN	447.22	44.186	528	388	140	9
DLP	RIB	645.08	303.987	1107	178	929	43
DLP	KHB	926.90	44.899	981	872	109	10
DLP	ALB	278.15	210.832	922	89	833	13
DLP	YAS	370.18	95.932	511	268	243	11
DLP	ROY	1267.85	129.530	1543	992	551	13
DLP	ALA	609.00	48.019	672	525	147	15
DLP	DAR	788.00	57.136	874	668	206	15
DLP	DOC	922.50	316.077	1146	699	447	2
DLP	GAR	978.92	180.083	1421	731	690	12
DLP	FAS	894.80	237.499	1262	516	746	10
DLP	KRS	309.00	87.420	537	222	315	11
DLP	ELG	259.89	94.087	473	168	305	9
DLP	ELZ	1686.91	143.548	2055	1544	511	11
DLP	IBN	958.60	59.003	1055	874	181	10
DLP	NSF	1107.56	66.707	1220	1024	196	9
CTDI	SHN	11.44	.606	12	10	1	9
CTDI	RIB	19.29	10.939	61	4	58	43
CTDI	KHB	19.80	.000	20	20	0	10
CTDI	ALB	13.97	4.851	23	7	15	13
CTDI	YAS	8.42	2.219	12	5	7	11
CTDI	ROY	26.52	1.387	27	22	5	13
CTDI	ALA	12.20	.000	12	12	0	15
CTDI	DAR	16.30	.000	16	16	0	15
CTDI	DOC	20.55	3.182	23	18	5	2
CTDI	GAR	22.79	14.054	67	18	49	12
CTDI	FAS	21.28	5.386	27	15	12	10
CTDI	KRS	6.82	1.855	12	5	7	11
CTDI	ELG	5.70	.994	8	4	3	9
CTDI	ELZ	78.36	1.567	80	77	3	11
CTDI	IBN	57.50	.000	58	58	0	10
CTDI	NSF	75.30	.000	75	75	0	9

Table 4.30 shows the results of Mean, Std. Deviation, Maximum, Minimum, and Range of the variables (Age, kVp, mAs, DLP, CTDIvol) according to No. device:

Variables	No. device	Mean	Std. Deviation	Maximum	Minimum	Range	N
AGE	4S	51.55	16.201	77	28	49	11
AGE	16S	41.66	14.502	77	18	59	91
AGE	64S	42.96	17.465	90	20	70	57
AGE	128S	54.83	14.825	75	24	51	12
KVP	2S	120.00	.000	120	120	0	9
KVP	4S	120.00	.000	120	120	0	20
KVP	16S	121.52	5.332	140	120	20	105
KVP	64S	120.00	.000	120	120	0	57
KVP	128S	120.00	.000	120	120	0	12
MAS	2S	197.78	6.667	200	180	20	9
MAS	4S	202.50	39.984	260	150	110	20
MAS	16S	181.90	112.753	471	37	434	105
MAS	64S	194.19	46.982	250	52	198	57
MAS	128S	130.17	17.898	187	125	62	12
DLP	2S	447.22	44.186	528	388	140	9
DLP	4S	926.70	171.578	1262	516	746	20
DLP	16S	572.93	337.960	1220	89	1131	105
DLP	64S	1018.98	427.589	2055	244	1811	57
DLP	128S	978.92	180.083	1421	731	690	12
CTDI	2S	11.44	.606	12	10	1	9
CTDI	4S	39.39	18.947	58	15	43	20
CTDI	16S	19.99	19.232	75	4	72	105
CTDI	64S	29.51	24.722	80	7	73	57
CTDI	128S	22.79	14.054	67	18	49	12

Table 4.31 shows the results of (One Way ANOVA),To know significance of the differences in the variables(AGE,KVP,MAS,DLP,CTDI) according to Hospital:

Variables	Source of variation	Sum of Squares	Df	Mean Square	F	Sig.	Interpretation
AGE	Between Groups	6678.496	14	477.035	2.014*	.020	There are statistically significant differences
	Within Groups	36948.148	156	236.847			
	Total	43626.643	170				
KVP	Between Groups	469.240	15	31.283	2.246**	.006	There are statistically significant differences
	Within Groups	2604.651	187	13.929			
	Total	3073.892	202				
MAS	Between Groups	1187811.820	15	79187.455	43.333**	.000	There are statistically significant differences
	Within Groups	341723.057	187	1827.396			
	Total	1529534.877	202				
DLP	Between Groups	26338820.948	15	1755921.397	52.925**	.000	There are statistically significant differences
	Within Groups	6204182.292	187	33177.445			
	Total	32543003.240	202				
CTDI	Between Groups	83356.145	15	5557.076	131.644**	.000	There are statistically significant differences
	Within Groups	7893.799	187	42.213			
	Total	91249.945	202				

(**) Means the difference is statistically significant at the level of significance (0.01) or less

(*) Means the difference is statistically significant at the level of significance (0.05) or less

Table 4.32 shows the results of the Scheffe test tothe variables(AGE,KVP,MAS,DLP,CTDI) according to **Hospital**s:

Variables	Hospital	Mean	SHN	RIB	KHB	ALB	YAS	ROY	ALA	DAR	DOC	GAR	FAS	KRS	ELG	ELZ	IBN	NSF
AGE	RIB	38.17	-															
AGE	KHB	39.00	**	-														
AGE	ALB	50.77	**	**	-													
AGE	YAS	41.91	**	**		-												
AGE	ROY	41.00	**	**		**	-											
AGE	ALA	37.60	**	**	**	**		-										
AGE	DAR	49.47	**	**	**	**			-									
AGE	DOC	51.50	**	**	**	**	**	**	**	-								
AGE	GAR	54.83	**	**	**	**	**	**	**		-							
AGE	FAS	47.00	**	**	**	**	**	**	**	**	**	-						
AGE	KRS	33.36	**	**	**	**	**	**	**	**	**	**	-					
AGE	ELG	47.89	**	**	**	**	**	**	**	**	**	**		-				
AGE	ELZ	42.18	**	**	**	**	**	**	**	**	**	**			-			
AGE	IBN	52.00	**	**		**	**	**	**	**	**	**				-		
AGE	NSF	46.44	**	**		**	**	**	**	**	**	**					-	
KVP	SHN	120.00	-															
KVP	RIB	123.72		-														
KVP	KHB	120.00	**	**	-													
KVP	ALB	120.00	**	**	**	-												
KVP	YAS	120.00	**	**	**		-											
KVP	ROY	120.00			**	**	**	-										
KVP	ALA	120.00			**	**	**		-									
KVP	DAR	120.00	**	**	**	**	**	**	**	-								
KVP	DOC	120.00	**	**	**	**	**	**	**		-							
KVP	GAR	120.00	**		**	**	**			**	**	-						
KVP	FAS	120.00			**					**	**		-					
KVP	KRS	120.00	**	**	**		**	**	**	**	**	**	**	-				
KVP	ELG	120.00	**	**	**	**		**	**	**	**			**	-			
KVP	ELZ	120.00			**		**			**	**			**	**	-		
KVP	IBN	120.00			**	**	**			**	**			**			-	
KVP	NSF	120.00	*		*	**		**		**		**		**	*	**	**	-
MAS	SHN	197.78	-															
MAS	RIB	164.81	**	-														
MAS	KHB	249.00		**	-													
MAS	ALB	226.38	*			-												
MAS	YAS	112.00		**			-											
MAS	ROY	175.00	**		*		**	-										
MAS	ALA	150.00	**		**	**	**		-									
MAS	DAR	249.93	*			**	**			-								
MAS	DOC	125.00		**		**	**		**		-							
MAS	GAR	130.17	**		*	**	**					-						
MAS	FAS	205.00		**		**	**		**			*	-					
MAS	KRS	90.64	**			**	**							-				
MAS	ELG	42.67		**		**	**		**			*			-			
MAS	ELZ	226.64	**	**	**	**	**			**	**	*	**	**	**	-		
MAS	IBN	200.00		**				*	**			*				**	-	
MAS	NSF	446.44	*	**		*	*		**		*	*	**	**		*		
DLP	SHN	447.22	-															
DLP	RIB	645.08		-														
DLP	KHB	926.90	**	**	-													
DLP	ALB	278.15			**	-												
DLP	YAS	370.18			*	**	-											

DLP	ROY	1267.85				**		-										
DLP	ALA	609.00	**	*			*		-									
DLP	DAR	788.00				**				-								
DLP	DOC	922.50	**	**			**				-							
DLP	GAR	978.92		*		*						-						
DLP	FAS	894.80	**	**			**	*					-					
DLP	KRS	309.00			**		**		*		*	*		-				
DLP	ELG	259.89	**	**		**	**							**	-			
DLP	ELZ	1686.91				**	**									-		
DLP	IBN	958.60				**											-	
DLP	NSF	1107.56																-
CTDI	SHN	11.44	-															
CTDI	RIB	19.29	**	-														
CTDI	KHB	19.80		**	-													
CTDI	ALB	13.97	*			-												
CTDI	YAS	8.42		**			-											
CTDI	ROY	26.52	**		*	**	**	-										
CTDI	ALA	12.20	**		**	**	**	**	-									
CTDI	DAR	16.30	*		**	**	**	**		-								
CTDI	DOC	20.55		**	**	**	**	**	**	**	-							
CTDI	GAR	22.79	**		**	**	**	**		**		-						
CTDI	FAS	21.28		**	**	**	**	**	**	**		*	-					
CTDI	KRS	6.82	**		**	**	**	**		**				-				
CTDI	ELG	5.70		**	**	**	**	**	**	**		*			-			
CTDI	ELZ	78.36	**	**	**	**	**	**		**	**	*	**	**	**	-		
CTDI	IBN	57.50		**	**			*	**	**		*				**	-	
CTDI	NSF	75.30	8	*		**		*		**	*		**		**	*	**	-

- (**) Means the presence of statistically significant differences at the level of significance (0.01) or less between averages of hospitals in favor of the largest average.
- (*) Means the presence of statistically significant differences at the level of significance (0.05) or less between averages of hospitals in favor of the largest average.

Table 4.33 shows the results of **(One Way ANOVA),**To know significance of the differences in the variables(AGE,KVP,MAS,DLP,CTDI) according to No. device:

Variables	Source of variation	Sum of Squares	Df	Mean Square	F	Sig.	Interpretation
AGE	Between Groups	2573.880	3	857.960	3.490*	.017	There are statistically significant differences
	Within Groups	41052.763	167	245.825			
	Total	43626.643	170				
KVP	Between Groups	117.701	4	29.425	1.971	.100	There are statistically significant differences
	Within Groups	2956.190	198	14.930			
	Total	3073.892	202				
MAS	Between Groups	49503.930	4	12375.982	1.656	.162	There are statistically significant differences
	Within Groups	1480030.947	198	7474.904			
	Total	1529534.877	202				
DLP	Between Groups	9494135.027	4	2373533.757	20.390**	.000	There are statistically significant differences
	Within Groups	23048868.213	198	116408.425			
	Total	32543003.240	202				
CTDI	Between Groups	9563.608	4	2390.902	5.795**	.000	There are statistically significant differences
	Within Groups	81686.337	198	412.557			
	Total	91249.945	202				

(**) Means the difference is statistically significant at the level of significance (0.01) or less

(*) Means the difference is statistically significant at the level of significance (0.05) or less

Table 4.34 shows the results of the Schaffer test to the variables(AGE,KVP,MAS,DLP,CTDI) according to Number device:

Variables	No. device	Mean	2S	4S	16S	64S	128S
AGE	4S	51.55					
AGE	16S	41.66		**			
AGE	64S	42.96		**			
AGE	128S	54.83			**	**	-
KVP	2S	120.00	-				
KVP	4S	120.00		-			
KVP	16S	121.52	**	**	-		
KVP	64S	120.00				-	
KVP	128S	120.00			**	**	-
MAS	2S	197.78	-				
MAS	4S	202.50	**	-			
MAS	16S	181.90	*	**	-		
MAS	64S	194.19				-	
MAS	128S	130.17	**	**	**	**	-
DLP	2S	447.22	-				
DLP	4S	926.70	**	-			
DLP	16S	572.93	*	*	-		
DLP	64S	1018.98	**	**	**	-	
DLP	128S	978.92	**	**	**	**	-
CTDI	2S	11.44	-				
CTDI	4S	39.39	**	-			
CTDI	16S	19.99	**	**	-		
CTDI	64S	29.51	**	*	*	-	
CTDI	128S	22.79	**	**	*	**	-

(**) Means the presence of statistically significant differences at the level of significance (0.01) or less between averages types of devices in favor of the largest average.

(*) Means the presence of statistically significant differences at the level of significance (0.05) or less between averages types of devices in favor of the largest average

Table 4.35 shows the results of independent samples T test, to know significance of the differences in the variables(AGE,KVP,MAS,DLP,CTDI) according to gender:

Variables	Gender	N	Mean	standard deviation	T-Test	Sig	Interpretation
AGE	Female	58	44.48	16.817	.483	.630	The difference is not statistically significant
	Male	113	43.23	15.654			
KVP	Female	72	120.00	.000	-2.153*	.032	The difference is statistically significant
	Male	131	121.22	4.808			
MAS	Female	72	179.96	81.600	-.614	.540	The difference is not statistically significant
	Male	131	187.81	90.039			
DLP	Female	72	752.18	418.437	.019	.985	The difference is not statistically significant
	Male	131	751.06	393.325			
CTDI	Female	72	24.82	22.356	.228	.820	The difference is not statistically significant
	Male	131	24.11	20.707			

- There are not statistically significant differences at the level of significance (0.05) or less in the variables (AGE ,MAS, DLP, CTDI) attributable to gender.
- There are statistically significant differences at the level of significance (0.05) or less in the variable (KVP) Between the average male and female in favor of average male.

4.4.5 CTU Procedures

Table 4. 36 shows the results of Mean, Std. Deviation, Maximum, Minimum, Range of the variables (AGE, KVP, MAS, DLP, CTDI) according to Hospital:

Variables	Hospital	Mean	Std. Deviation	Maximum	Minimum	Range	N
AGE	RIB	42.41	15.070	73	19	54	27
KVP	RIB	120.00	.000	120	120	0	27
KVP	NSF	120.00	.000	120	120	0	15
MAS	RIB	172.15	80.963	435	71	364	27
MAS	NSF	249.00	.000	249	249	0	15
DLP	RIB	2472.42	1171.574	5091	647	4444	27
DLP	NSF	4226.40	671.486	5301	3494	1807	15
CTDI	RIB	57.62	28.935	136	15	121	27
CTDI	NSF	19.80	.000	20	20	0	15

Table 4.37 shows the results of Mean, Std. Deviation, Maximum, Minimum, range of the variables (AGE, KVP, MAS, DLP, CTDI) according to No. device:

No. device	Variables	Std. Deviation	Mean	Maximum	Minimum	Range	N
16S	AGE	15.070	42.41	73	19	54	27
	KVP	.000	120.00	120	120	0	42
	MAS	74.471	199.60	435	71	364	42
	DLP	1322.098	3098.84	5301	647	4654	42
	CTDI	29.449	44.11	136	15	121	42

Table 4.38 shows the results of (One Way ANOVA),To know significance of the differences in the variables(AGE,MAS,DLP,CTDI) according to Hospital:

Variables	Source of variation	Sum of Squares	Df	Mean Square	F	Sig.	Interpretation
MAS	Between Groups	56952.712	1	56952.712	13.367**	.001	There are statistically significant differences
	Within Groups	170431.407	40	4260.785			
	Total	227384.119	41				
DLP	Between Groups	29665878.088	1	29665878.088	28.253**	.000	There are statistically significant differences
	Within Groups	41999767.369	40	1049994.184			
	Total	71665645.457	41				
CTDI	Between Groups	13789.442	1	13789.442	25.339**	.000	There are statistically significant differences
	Within Groups	21768.004	40	544.200			
	Total	35557.446	41				

(**) Means the difference is statistically significant at the level of significance (0.01) or less
(*) Means the difference is statistically significant at the level of significance (0.05) or less

Seen from the Table () as follows:

- There are statistically significant differences at the level of significance (0.05) or less in the variables (MAS, DLP, CTDI) attributable to Hospitals.
- To know the differences in favor of using Scheffe test as follows:

Table 4.39 shows the results of the Scheffe test tothe variables (MAS,DLP,CTDI) according to Hospitals:

Variables	Hospital	Mean	RIB	NSF
MAS	RIB	172.15	-	
MAS	NSF	249.00	**	-
DLP	RIB	2472.42	-	
DLP	NSF	4226.40	**	-
CTDI	RIB	57.62	-	
CTDI	NSF	19.80	**	-

Seen from the Table () as follows:

- (**) Means the presence of statistically significant differences at the level of significance (0.01) or less between averages of hospitals in favor of the largest average.
- (*) Means the presence of statistically significant differences at the level of significance (0.05) or less between averages of hospitals in favor of the largest average.

Table4.40 shows the Results of independent samples T test, To know significance of the differences in the variables(AGE,MAS,DLP,CTDI) according to gender:

Variables	Gender	N	Mean	standard deviation	T-Test	Sig	Interpretation
AGE	Female	14	45.43	13.698	1.085	.288	The difference is statistically significant
	Male	13	39.15	16.329			
MAS	Female	19	179.74	86.688	-1.600	.117	The difference is not statistically significant
	Male	23	216.00	59.710			
DLP	Female	19	2602.28	1165.500	-2.329**	.025	The difference is not statistically significant
	Male	23	3509.04	1325.619			
CTDI	Female	19	41.64	23.246	-.490	.627	The difference is not statistically significant
	Male	23	46.15	34.125			

Seen from the Table () as follows:

- There are not statistically significant differences at the level of significance (0.05) or less in the variables (AGE,MAS, CTDI) attributable to gender.
- There are statistically significant differences at the level of significance (0.05) or less in the variable (DLP) Between the average male and female in favor of average male.

KUB procedure

Table 4.41 shows the Results of Mean, Std. Deviation, Maximum, Minimum, range of the variables(AGE, KVP, MAS, DLP, CTDI) according to Hospital:

Variables	Hospital	Mean	Std. Deviation	Maximum	Minimum	Range	N
AGE	SHN	43.33	15.716	65	22	43	9
AGE	RIB	38.69	12.102	65	19	46	103
AGE	BAH	34.59	10.312	50	19	31	27
KVP	SHN	120.00	.000	120	120	0	9
KVP	RIB	120.00	.000	120	120	0	103
KVP	BAH	120.00	.000	120	120	0	27
MAS	SHN	197.78	6.667	200	180	20	9
MAS	RIB	157.88	76.259	440	53	387	103
MAS	BAH	100.26	23.792	158	54	104	27
DLP	SHN	447.09	44.236	528	388	140	9
DLP	RIB	678.99	465.989	2804	140	2664	103
DLP	BAH	346.44	106.339	596	171	425	27
CTDI	SHN	11.57	.464	12	10	1	9
CTDI	RIB	14.19	8.933	53	4	50	103
CTDI	BAH	7.36	1.970	12	4	8	27

Table 4.42 shows the results of Mean, Std. Deviation, Maximum, Minimum, range of the variables (AGE, KVP, MAS, DLP, and CTDI) according to No. device:

Variables	No. device	Mean	Std. Deviation	Maximum	Minimum	Range	N
AGE	2S	43.33	15.716	65	22	43	9
AGE	16S	37.84	11.833	65	19	46	130
KVP	2S	120.00	.000	120	120	0	9
KVP	16S	120.00	.000	120	120	0	130
MAS	2S	197.78	6.667	200	180	20	9
MAS	16S	145.92	72.546	440	53	387	130
DLP	2S	447.09	44.236	528	388	140	9
DLP	16S	609.92	438.537	2804	140	2664	130
CTDI	2S	11.57	.464	12	10	1	9
CTDI	16S	12.77	8.463	53	4	50	130

Table 4.43 shows the results of (One Way ANOVA),To know significance of the differences in the variables(AGE,MAS,DLP,CTDI) according to Hospital:

Variables	Source of variation	Sum of Squares	Df	Mean Square	F	Sig.	Interpretation
AGE	Between Groups	613.179	2	306.589	2.119	.124	There are not statistically significant differences
	Within Groups	19678.577	136	144.695			
	Total	20291.755	138				
MAS	Between Groups	93674.269	2	46837.134	10.473**	.000	There are statistically significant differences
	Within Groups	608245.343	136	4472.392			
	Total	701919.612	138				
DLP	Between Groups	2588887.566	2	1294443.783	7.839**	.001	There are statistically significant differences
	Within Groups	22458555.081	136	165136.434			
	Total	25047442.646	138				
CTDI	Between Groups	1011.020	2	505.510	8.341**	.000	There are statistically significant differences
	Within Groups	8242.376	136	60.606			
	Total	9253.396	138				

(**) Means the difference is statistically significant at the level of significance (0.01) or less

(*) Means the difference is statistically significant at the level of significance (0.05) or less

Seen from the Table () as follows:

- There are statistically significant differences at the level of significance (0.05) or less in the variables (MAS, DLP, CTDI) attributable to Hospitals.
- There are not statistically significant differences at the level of significance (0.05) or less in the variable (AGE) attributable to Hospitals.
- To know the differences in favor of using Scheffe test as follows:

Table .4.44 shows the results of the Scheffe test tothe variables (MAS,DLP,CTDI) according to Hospitals:

Variables	Hospital	Mean	SHN	RIB	BAH
MAS	SHN	197.78	-		
MAS	RIB	157.88		-	
MAS	BAH	100.26	**	**	-
DLP	SHN	447.09	-		
DLP	RIB	678.99		-	
DLP	BAH	346.44		**	-
CTDI	SHN	11.57	-		
CTDI	RIB	14.19		-	
CTDI	BAH	7.36		**	-

- (**) Means the presence of statistically significant differences at the level of significance (0.01) or less between averages of hospitals in favor of the largest average.
- (*) Means the presence of statistically significant differences at the level of significance (0.05) or less between averages of hospitals in favor of the largest average.

Table 4.45 shows the results of (One Way ANOVA),To know significance of the differences in the variables(AGE,MAS,DLP,CTDI) according to No. device:

Variables	Source of variation	Sum of Squares	Df	Mean Square	F	Sig.	Interpretation
AGE	Between Groups	254.148	1	254.148	1.738	.190	There are no statistically significant differences
	Within Groups	20037.608	137	146.260			
	Total	20291.755	138				
MAS	Between Groups	22639.987	1	22639.987	4.566*	.034	There are statistically significant differences
	Within Groups	679279.625	137	4958.245			
	Total	701919.612	138				
DLP	Between Groups	223183.373	1	223183.373	1.232	.269	There are statistically significant differences
	Within Groups	24824259.273	137	181198.973			
	Total	25047442.646	138				
CTDI	Between Groups	12.185	1	12.185	.181	.671	There are statistically significant differences
	Within Groups	9241.210	137	67.454			
	Total	9253.396	138				

(**) Means the difference is statistically significant at the level of significance (0.01) or less

(*) Means the difference is statistically significant at the level of significance (0.05) or les

Table 4.46 shows the results of the Scheffe test to the variables (mAs) according to No. device:

Variables	No. device	Mean	2S	16S
MAS	2S	197.78	-	
MAS	16S	145.92	**	-

Seen from the Table () as follows:

- (**) Means the presence of statistically significant differences at the level of significance (0.01) or less between averages types of devices in favor of the largest average.
- (*) Means the presence of statistically significant differences at the level of significance (0.05) or less between averages types of devices in favor of the largest average.

Table 4.47 shows theResults of independent samples T test,To know significance of the differences in the variables(AGE,MAS,DLP,CTDI) according to gender:

Variables	Gender	N	Mean	standard deviation	T-Test	Sig	Interpretation
AGE	Female	50	37.12	13.430	-.782	.436	The difference is statistically significant
	Male	89	38.80	11.364			
MAS	Female	50	141.98	64.164	-.903	.368	The difference is not statistically significant
	Male	89	153.37	75.078			
DLP	Female	50	527.48	301.127	-1.498	.136	The difference is not statistically significant
	Male	89	639.77	479.116			
CTDI	Female	50	11.41	5.869	-1.390	.167	The difference is not statistically significant
	Male	89	13.41	9.193			

Seen from the Table () as follows:

- There are not statistically significant differences at the level of significance (0.05) or less in the variables (AGE,MAS, DLP, CTDI) attributable to gender.

Chapter five

Discussion ,Conclusion and Recommendation

5-1 Discussion

CT has been the highest growing medical imaging system since it emergence in 1971. CT enabled diagnosis of various diseases due short scanning time and volumetric acquisition. CT expose population to a high radiation dose compared with other imaging modalities. A pivotal study revealed that as much as 0.4% of all current cancers in the United States may be attributable to the radiation from CT studies based on CT usage data from 1991–1996 (Brenner et al., 2007). When organ specific cancer risk was adjusted for current levels of CT usage, it was determined that 1.5–2% of cancers may eventually be caused by the ionizing radiation used in CT. Therefore, to increase the benefit of the imaging procedure, it is mandatory to evaluate the parameters that affect CT dose for the patient. Diagnostic reference levels were first mentioned by the International Commission on Radiological Protection (ICRP) in 19901 and subsequently recommended in greater detail in 1996 (ICRP. 1996). Diagnostic reference levels (DRL) are supplements to professional judgment and do not provide a dividing line between good and bad medicine. It is inappropriate to use them for regulatory or commercial purposes. DRL apply to medical exposure, not to occupational and public

exposure. Thus, they have no link to dose limits or constraints. Ideally, they should be the result of a generic optimization of protection. In practice, this is unrealistically difficult and it is simpler to choose the initial values as a percentile point on the observed distribution of doses to patients (Jessen et al., 2000). The values should be selected by professional medical bodies and reviewed at intervals that represent a compromise between the necessary stability and the long-term changes in the observed dose distributions. The selected values will be specific to a country or region (Jessen et al., 2000).

DRL are not the suggested or ideal dose for a particular procedure or an absolute upper limit for dose. Rather, they represent the dose level at which an investigation of the appropriateness of the dose should be initiated. In conjunction with an image quality assessment, a qualified medical physicist should work with the radiologist and technologist to determine whether or not the required level of image quality could be attained at lower dose levels. Thus, reference levels act as “trigger levels” to initiate quality improvement. Their primary value is to identify dose levels that may be unnecessarily high – that is, to identify those situations where it may be possible to reduce dose without compromising the required level of image quality(ICRP,1996).

Consequently, establishment of DRL is a crucial part of the radiation dose reduction and optimization in medical imaging, without compromising the diagnostic findings. Concern has increased regarding radiation exposure during medical procedures, especially CT, which involves greater radiation doses than radiography. The radiology community has become more cognizant of radiation exposure to patients, and techniques to reduce dose are commonly used

5.1.1 Role of DRL in dose reduction

DRL has an important role in radiation dose optimization tool and much international organization recommended the use of DRL, including the ICRP, American College of Radiology (ACR), American Association of Physicists in Medicine (AAPM), United Kingdom (U.K.) Health Protection Agency, International Atomic Energy Agency (IAEA), and European Commission (EC). DRL are typically set at the 3rd quartile of the dose distribution from a survey conducted across a broad user base (i.e., large and small facilities, public and private, hospital and out-patient) using a specified dose measurement protocol and phantom. They are established both regionally and nationally, and considerable variations have been seen across both regions and countries (McCollough, 2006). Dose surveys should be repeated periodically to establish new reference levels, which can demonstrate changes in both the mean and standard deviation of the dose distribution. The use of diagnostic reference levels

has been shown to reduce the overall dose and the range of doses observed in clinical practice. For example, U.K. national dose surveys demonstrated a 30% decrease in typical radiographic doses from 1984 to 1995 and an average drop of about 50% between 1985 and 2000(McCollough et al., 2006) . While improvements in equipment dose efficiency may be reflected in these dose reductions, investigations triggered when a reference dose is exceeded can often determine dose reduction strategies that do not negatively impact the overall quality of the specific diagnostic exam. Thus, data points above the 75th percentile are, over time, moved below the 75th percentile – with the net effect of a narrower dose distribution and a lower mean dose.

5.1.2 Radiation dose from CT brain Procedure

In this study a total of 16 CT machines were involved as illustrated in Table 4.1. 50% of the equipment is 16 slice CT machines, 32% are 64 slice and dual slice, four slices and 128 slices are 6% each. Most of patients are mid aged patients, except ALB and YAS hospitals. It is important to note that there is significant number of young patients with age range from 20 to 25. Patients in these age groups are more sensitive than older ones, due to long life expectancy. In CT imaging, there are a number of scan parameters and patient attributes that influence the dose and image quality in a CT exam. Some are user controlled (e.g. kV,

mAs, pitch). Other factors are inherent to the scanner (e.g. ,detector efficiency, geometry). Still others are patient dependent (e.g., patient size ,anatomy scanned). All these parameters are interrelated. A solid understanding of how each parameter relates to the others and affects both dose and image quality is essential to maintaining the dose as low as reasonably achievable (ALARA). Therefore, a careful evaluate the factors affecting patient dose is necessary.

Table 4.4 presents the tube current time product (mAs) per hospital; it is well know that the radiation dose is proportional to patient doses ($CTDI_{vol}$) during the radiological procedures. Table 4.4 illustrates that many hospitals, especially machines equipped with 64 CT machines and 4 slice machines, used fixed tube current. In spite of the fact that no significant difference of the most of people head, using fixed tube current is not is not justified due to the wide variation of patients age group. This fact proof that patients in these hospitals may be exposed the patients to avoidable radiation. The use of very high tube current time product is presents in two hospitals (NSF, KHB). Patients are exposed to a high dose up 450 mAs. When all factors held constant, the dose is proportional to tube current time product. Table 4.4 presents the tube voltage, mAs and DPL per hospital. In this study, it was estimated that 13 hospitals out of 16 used a constant tube potential of 120 kVp. Three hospitals used

a higher values up to 140 per CT brain. Tube potential determines penetration power of the X ray beam. Therefore, higher energy x-rays have a greater probability than lower energy x-ray of passing through the body and creating signal at the detector. With all else being equal, higher kV will increase signal to noise ratio (S/N). For the same scan parameters, changing the kV from 120 to135 increases the dose by about 33% (Downes,et al 2009), Horiguchi et al., 2009). The image noise is reduced since the dose is higher and more photons are reaching the detectors, but the tissue contrast is compromised as well (Horiguchi et al., 2009). In this study, there was large variation in the radiation dose to the patients as illustrated in Table 4.3. In general these variations of doses are due to differences in, tube voltages, number of scan, tube current and repeated scans. The mean dose in terms of DLP is ranged between 958.6 mGy.cm to 1442.0 mGy.cm for 4 slice and 64 slice respectively. Patient dose in Table 4.2 showed wide variation between different hospitals and even in the same hospital. There may be reasonable causes for this discrepancies in clinical environment, of which the most important reasons for these difference were due to clinical indication and CT scan modality and imaging protocol. This discrepancy is greater if the technologists are inadequately trained in CT imaging protocols and radiation dose reduction aspects. These factors indicate strongly against

measures to provide effective radiation protection. Therefore, It is necessary to establish the minimum exposure threshold that will deliver adequate image quality in each application, preferably expressed in terms of clinical effectiveness. Table 4.4 illustrate there is a significant variation of patients doses between the two genders. This can be attributed to the clinical indication for CT brain. Therefore, Careful analysis of patient doses might reveal the reason for this discrepancy.

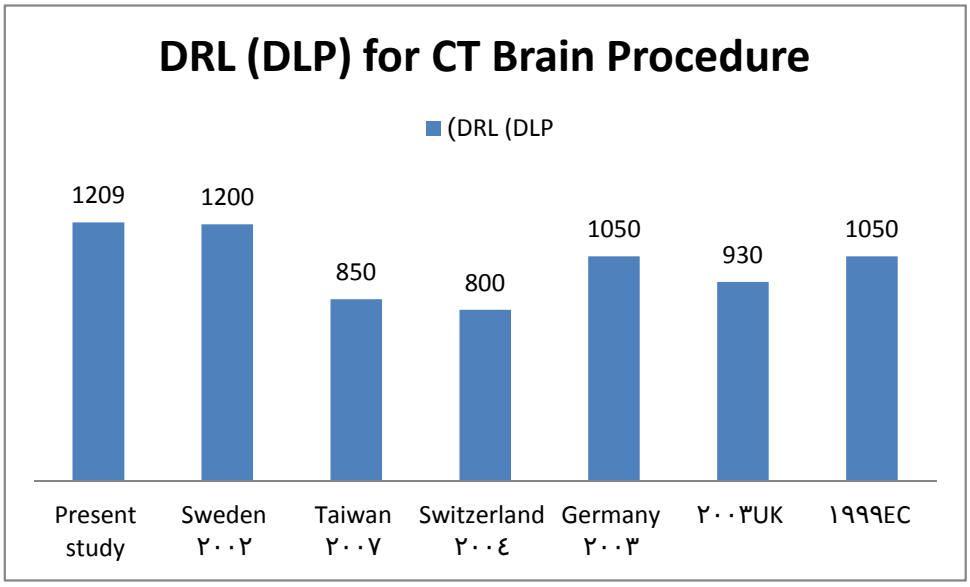

Figure 5.1. Comparison between current study and DRL in other countries for CT Brain Procedure

Figure 5.1 present a comparison of patient DRL for CT brain procedures. The value of DRL is comparable with Sweden DRL while is higher by 30% compared to recent studies. This value is preliminary results, initiated to increase the attention about the avoidable or unnecessary radiation dose for patients in CT imaging. Figure 5.1 showed that there is

a substantial variations in DRL in various countries, and even at the same country from time to time due to advancement in imaging technique. This study must be expanded to include all other investigations. The available data can be used to establish DRL, but this could be a baseline for further studies concerning dose optimization. To the best of our knowledge, no values have been proposed to date for DLP during CT abdomen procedure. Therefore, a third quartile value of 1209 mGy.cm can be used as DRL in a local basis for CT brain procedure for adults.

5.1.3 Radiation dose and DRL for CT chest Procedure

For CT chest procedure, four CT machines (66%) were 16 slice CT machines, while the rest two were dual and 64 slice CT machines. Patient radiation dose during CT examinations is affected by two main sources, the CT modality and imaging protocol. The recent CT modalities can potentially result in higher radiation exposure and hence a higher radiogenic risk to the patient due to increased capabilities of X ray tube which enable long scan lengths at high tube currents. Therefore, significant variation of patient doses is expected. Patient mean ages were comparable, while the variation between minimum and maximum is great. Pediatrics and females have higher radiation sensitivity compared to adult male (ICRP 1991). Image acquisition parameters are constant in CT imaging, there are a number of scan parameters and patient attributes

that influence the dose and image quality in a CT exam. Some are user controlled (e.g. kV, mAs, pitch). Other factors are inherent to the scanner (e.g., detector efficiency, geometry). Still others are patient dependent (e.g., patient size, anatomy scanned). All these parameters are interrelated. A solid understanding of how each parameter relates to the others and affects both dose and image quality is essential to maintaining the dose as low as reasonably achievable (ALARA). Therefore, a careful evaluate the factors affecting patient dose is necessary.

All hospitals used a fixed tube voltage (120 kVp), in spite of the patient weight or BMI, suggesting that patients may exposed to unnecessary radiation dose. Patient doses in terms of DLP and CTDI showed wide differences across the hospitals. As previously mentioned this variation may be attributed to depending on CT scanner configuration and imaging protocols (ImPact, 2007). In this study, the patients doses (mGy.cm) during chest CT procedures lowest at CT machines with dual slices due to use of sequential techniques. Slight dose variation between 16 slices and 64 slices was noticed in this study. From Table 4.6, the variation between CT scanners of the same modality and the same manufacture, may be attributed to the imaging protocol, if all other factors were held constant. Therefore, optimization and setting DRL will reduce these discrepancies in patient doses.

Image acquisition factors affect patient doses include tube voltage, tube current, scan length and imaging technique (helical or sequential). However, the wide variation in patient doses can be minimized if proper exposure factors were selected, and patients will exposed to radiation to justifiable radiation doses consistent with the diagnostic purposes.

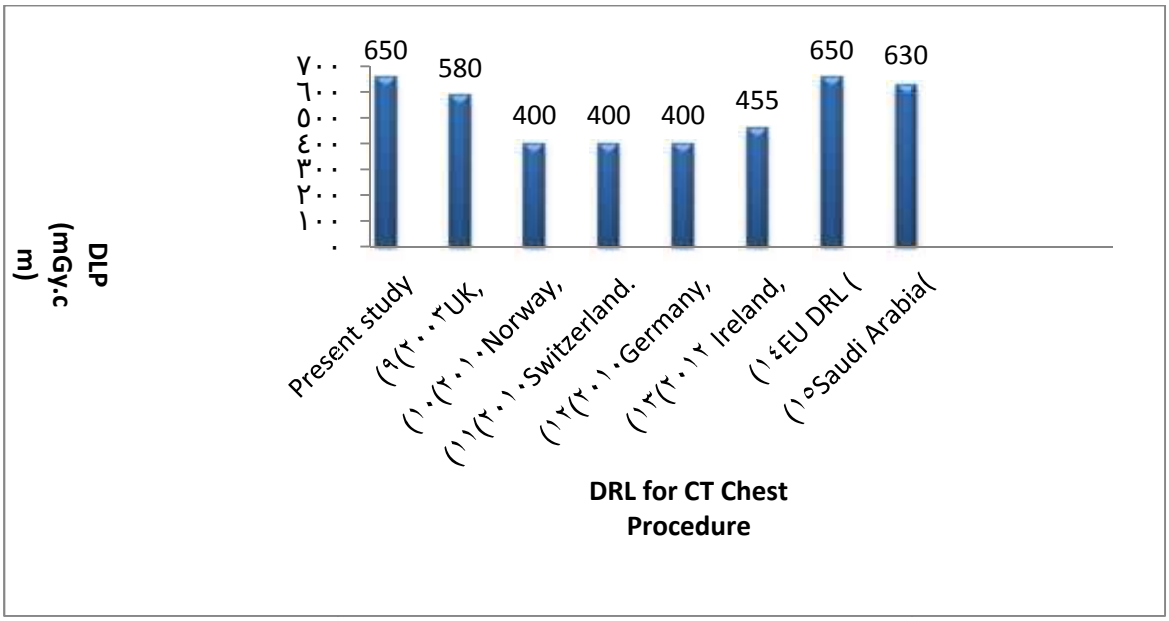

Figure 5.2 Comparison between current study and DRL in other countries

Figure 5.2 showed that there is DRL decreased in European countries in recent years. this can be attributed to CT technology development and image acquisition protocols. In addition to that, the increase of the awareness regarding CT dose and related riks is a factor cannot be ignored. The DRL vales in Germany, Switzerland and Norawy (**Friberg et al, 2009** et al., 2009, **Treier** et al., 2010, Brix, 2003) have an equal value (400 mGy.cm). The dose level in this study is comparable with the European data before 10 years ago, and dose values in Saudi Arabia

(Qurashi et al., 2014). This study illustrates that the develop in CT technology, awareness and image acquisition protocol will reduce the patient doses significantly

5.1.4 CT dose during par nasal sinuses

Sinusitis is considered one of the most common diseases worldwide with established evidence that it is increasing in both incidence and prevalence (Lam et al., 2009). CT has become the method of choice for diagnosis and staging of different sinus pathologies including inflammatory disease thus it is a preferred examination for the diagnosis of chronic sinusitis (Zinreich et al., 2009, Harnsberger 1995). There has been an increase in the use of Computed Tomography (CT) as a clinical diagnostic imaging modality worldwide, therefore radiation exposure to the public has also increased (linton et al., 2003). CT dose for par nasal sinuses were collected from three CT modalities 4 sleices, 16 slices and 64 slices. Currently CT is widely regarded as the optimal imaging technique for the nose and paranasal sinuses. The technique however, involves exposing the lens of the eye to ionizing radiation, risking cataract formation (Cathcart et al., 2002). Accordingly, it is important to minimize the radiation dose, whilst at the same time delivering high quality images. Table 4.9 showed that wide variation in exposure factors were used while constant potential was used in ceratin hospitals. Significance of the

differences in the variables (Age, mAs, DLP,CTDIvol) according to Hospital were presented in Table 4.10. No significance difference was detected between different variables as illustrated in Table 4.10. on the other hand, Table 4.11, showed the presence of statistically significant differences at the level of significance (0.01) or less between averages of hospitals. There are statistically significant differences at the level of significance (0.05) or less in the variable (CTDI) attributable to No. device. There are not statistically significant differences at the level of significance (0.05) or less in the variables (age ,mAs, DLP) attributable to number of CT scanners.

Table 4.13 showed that the radiation dose from three CT scanners 4 , 16 and 64 slices. Patients were exposed to a higher radiation doses compared with the other imaging modalities (CTDIvol= 42 mGy while the dose was 31 mGy for 16 slice and 37 mGy for 64 slices. If we assumed that the clinical indication and patient charactersitics (weight) are the same, patients were overexposued in 4slices and 64 slices. Table 5.1 shows that patients radiation doses in this study is higher compared to other published studies in the literature. The dose values ranged from 1.5 times to four times compared with the european studies. This indicate the need for harmonisation of patient doses in Sudan

Table 5.1 Comparison of patient Radiation dose in terms of DRL ($CTDI_{vol}$ (mGy) and DLP (mGy cm)) for certain countries

Country	CTDIvol	DLP(mGy.cm)
Switzerlan,2010	25	350
Germany,2010	9	100
Irelaand, 2012	12.7	170
Current study	37	462

5.1.5 CT Abdomen Procedures

For CT abdomen procedure, a total of 66 adult patients suffer from abdominal disturbances and the abdominal CT scanning exams were examined. The CT abdomen procedures were performed in two departments equipped with dual and 16 slices CT machines. Table 4.15 shows the results of mean, Std. deviation, maximum, and minimum of the variables (age, kVp, mAs, DLP, and CTDIvol) according to Hospital. As previously mentioned, the exposure parameters are not well adjusted resulting in a high radiation doses compared with the previous studies illustrated in Table 5.2

Table 5.2 Comparison of patient Radiation with previous studies

Author	Country	DLP
Shrimpton et al. 2005)	UK	472
Tsapaki et al. 2006)	USA	549
McCollough(2006).	USA	382
Breiki (	Egypt	242-1200
This study	Sudan	753.48

5.1.6 CT Abdomen: Tri-phase

A total of 30 procedures were performed for CT abdomen procedure (triphase). The procedures were performed with two and 16 CT slices CT machines. In agreement with other examination, the radiation dose during CT abdomen is higher four times in 16 slice CT machines compared to dual slices as illustrated in Table 4.22- 4.28. Table 4.28 shows that no significance differences in the variables (mAs,DLP,CTDIvol) according to gender.

Table 5. 3. shows comparison of the variables (mAs, DLP, and CTDIvol) according to number of slice

Variables	No. device	Mean
mAs	2S	90.56
	16S	249.21
DLP	2S	1319.88
	16S	4122.88
CTDIvol	2S	24.79
	16S	19.07

5.1.7 CT Abdomen- pelvis procedure

A total of 105 CT abdomen pelvis procedures were performed over one year in 4 different hospitals equipped with dual, 16, 64 and 128 CT slices. Patient age per hospital were presented in Table 4.30 presents the radiation exposure parameters (tube voltage (kVp) and tube current time product (mAs), respectively. Patient dose in terms of DLP (mGy.cm) and CTDIvol). Table 4.31 presented the comparison between different

measured parameters according to the gender. Although substantial variations were noticed in patient doses, no significant difference in patient populations in terms of age , tube voltage and tube current and gender.

Table 5.4 Comparison of poatient doses with different CT modalities for CT abdomen and pelvis

DLP (mGy.cm)	2S	447.22
	4S	926.70
	16S	572.93
	64S	1018.98
	128S	978.92

Table 5.5: Patient doses comparison during CT abdomen and pelvis

Country	Abdomen		Abdomen & Pelvis			
	Whole Exam		Pelvis		Whole Exam	
	CTDIw	DLP	CTDIw	DLP	CTDIw	DLP
EC 1999	35	900	-	-	35	780
ACR 2002	35	-	-	-	-	-
UK 2003	20	470	-	-	20	560
Germany 2003	25	770	-	-	24	1500
Switzerland 2004	20	710	30	540	-	-
Taiwan 2007	31	680	28	520	-	-

5.6: CTU procedure

The mean patient doses from CTU procedures was measured in two hospitals equipped with 16 slices CT modality. The patient's doses were higher compared to previous studies . This can be attributed to the high pitch factor used and optimum exposure factors used in this study. In general, CTU protocol may be performed with substantially different scanning techniques from one institution to another (Nawfel et al.,2004). Thus, it is important to harmonize the procedure protocol in order to improve the technique and reduce the unnecessary radiation exposure. For conventional urography, a patient dose depends mainly into three factors most likely contributed to the wide range of doses at conventional urography: the number of images acquired, exposure technique factors used by technologists, and patient size. It is important to harmonize the procedure protocol in order to improve the technique and reduce the unnecessary radiation exposure. Optimization of these factors will decrease significantly the radiation dose to patients. In the light of the fact that conventional diagnosis using sonography and intravenous urography yields comparable results (Strohmaier and Bartunek., 2008). IVU can be used as primary method due to the lower radiation dose compared to CTU.

Table 5.6: comparison of patient doses during CTU procedures

Variables	Hospital	Mean
mAs	RIB	172.15
	NSF	249.00
DLP(mGy.cm)	RIB	2472.42
	NSF	4226.40
CTDIvol	RIB	57.62
	NSF	19.80

5.1.8. KUB procedure

A total of 130 patients referred for CT KUB imaging procedure were performed during using dual and 16 CT slices. Patient demographic data (e.g., age, gender, diagnostic purpose of examination, body region, and use of contrast media) and patient dose were collected in terms of DLP(mGy.cm) and $CTDI_{vol}$ (mGy) as illustrated in Table 4.42. In addition to that, radiation dose -related factors (exposure factors (kilovoltage (kVp), tube current (mA), exposure time (s)), slice thickness (mm), table increment (mm/s), number of slices, and start and end positions of scans) were registered for all patients using standard data collection sheet (4.43).

Table 5.7 shows patient doses according to the gender

Variables	Gender	N	Mean
Age	Female	50	37.12
	Male	89	38.80
mAs	Female	50	141.98
	Male	89	153.37
DLP(mGy.cm)	Female	50	527.48
	Male	89	639.77
CTDIvol(mGy)	Female	50	11.41
	Male	89	13.41

5.1 .9 CT Diagnostic Reference Levels From Other Countries

Diagnostic reference levels must be defined in terms of an easily and reproducibly measured dose metric using technique parameters that reflect those used in a site's clinical practice. In radiographic and fluoroscopic imaging, typically measured quantities are entrance skin dose for radiography and dose area product for fluoroscopy. Dose can be measured directly with TLD or derived from exposure measurements.

Some authors survey typical technique factors and model the dose metric of interest. In CT, published diagnostic reference levels use CTDI-based metrics such as CTDIw, CTDIvol, and DLP. Normalized CTDI values (CTDI per mAs) can be used by multiplying them by typical technique factors, or CTDI values can be measured at the typical clinical technique factors. Tables 1 and 2 below provide a summary of CT reference levels from a variety of national dose surveys. The use of DRL has been shown to decrease radiation dose to the patients. A reduction of radiation doses up to 30% was reported for certain imaging procedures from 1984 to 1995 and an average drop of about 50% between 1985 and 2000 in UK due to advancement in imaging technology and staff awareness. [13,14] .

Table 5.8: Diagnostic Reference Levels for CTDIvol (mGy) and DLP (mGy·cm)

	Head		Abdomen		Abdomen & Pelvis			
	Whole Exam		Whole Exam		Pelvis		Whole Exam	
	CTDIvol	DLP	CTDIvol	DLP	CTDIvol	DLP	CTDIvol	DLP
Sweden 2002 [12]	75	1200	25	-	-	-	-	-
UK 2003 [8]	65 - 100	930	14	470	-	-	14	560
Netherlands 2008 [13]	-	-	-	-	-	-	15	700
EC 2004 [14]	60	-	25	-	-	-	15	700
ACR 2008 [15]	75	-	25	-	-	-	-	-

EC = European Commission; ACR = American College of Radiology; UK = United Kingdom

5.1 .10 Clinical Scanning Factors Affecting CT Radiation Dose

Dose in CT generally depend on the choice of technique factors that are used to perform abdomen CT examinations .The most important of the parameters that are under the control of the CT operator. These factors are , tube current (amperage), slice scan time, and tube peak kilo voltage (kVp) , pitch in multi-slice CT ,slice thickness, and filtration. Tube current and slice scan time are taken together as mAs in relation to radiation dose. As found in literature from previous studies (Table 5.8), the mAs is proportional to the number of photons directed at the patient. Therefore, dose is directly proportional to the mAs. Increasing the mAs (by increasing tube current or slice scan time) increases the dose, in previous studies the $CTDI_w$ values increase linearly with milliampere-seconds but to verify this relationship more values . Thus, CT radiation dose is often expressed as dose per mAs (or per 100 mAs). The kVp (kilo voltage-peak) of the x-ray beam determines how well the beam penetrates the patient. The higher the kVp, the more penetrating is the x-ray beam and the more uniformly the dose is distributed in the patient. If all other parameters remain the same, higher kVp causes higher dose. Changing

from 120 to 140 kVp will increase the dose by about 40%.Increasing peak kilo voltage (with all else held constant) increase the average photon energy , as a result it increases radiation dose, because the beam carries more energy as reported in previous studies which found the relation between kVp and dose . However, increasing peak kilovoltage significantly increases the intensity of the x-rays penetrating the patient to reach the detectors. Therefore, significantly lower mAs are needed to achieve similar image quality. Consequently, a higher peak kilo voltage does not necessarily mean an increased patient dose and, in fact, may allow the dose to be reduced (ICRP,2009).

The contrast in values of DLP in the same peak voltage and slice thickness was due to variation in number of slices, the greater number of slice the greater DLP. The dose is inversely proportional to pitch. Going from a pitch of 1 to a pitch of 2 by doubling the table speed means that the x-ray is on for half as long, and so the dose is halved. Pitches greater or less than 1 again affect CTDI values proportionally. In this study the pitch was 1, and didn't cause increase in dose. Slice thickness does not necessarily affect the dose directly. However, for the same scan parameters, thin slices are reconstructed from less data than thick slices and therefore have more noise. A higher mAs is usually required for thin

slices to keep the image noise reasonable. Therefore, in practice thin slices are associated with higher dose.

5.2 Conclusions

Patient doses during CT procedures are vary among different department and even at the same department. Wide variation of technical setting, suggest that there is a great need for staff training. Patient doses are higher compared to other studies worldwide. Diagnostic reference level was proposed for brain CT procedures. Patient doses showed wide variation due to patient clinical indication, CT system modality and image acquisition parameters. Local DRLs for chest CT procedures was proposed. Proposed DRLs were up to 40% higher than the current values in certain European countries and were analogous to other international work. Patient doses showed a great discrepancy in CT doses among the departments and at the same department, suggesting that patients are exposed to unnecessary radiation exposure.

5.3 Recommendations

- CT operators must optimize the patient dose for patient to reduce patient cancer risks. Some of the best strategies available for reducing radiation dose are:

(i) technique chart utilization to allow for mAs reduction in relation to the patient's size and weight , adapted tube current based on patient size (such as weight with fixed tube current scanning; and

(ii) Implementation of automatic exposure control systems by the manufacturers.

(iii) Achieve optimization through; the design of dose efficient equipment, the optimization of scan protocol and improvement of referring criteria.

(iv) Implementation of DRL in local and national levels

(v) Staff training regarding image acquisition in advance CT protocols.

- The radiologists and CT technologists must be trained to adapt CT scanning techniques based on clinical indications and to assess associated radiation doses with different scanning parameters.

Suggestion for future work:

Further studies are highly encouraged in this field with larger samples after conducting a training program in CT dose reduction and radiation protection aspects for different CT modalities.

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