Sudan University of science and technology

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Assessment of abdominal patients dose during CT examinations in Oman

A thesis submitted for partials fulfillments of the requirements of the M.Sc. degree in medical physics

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الايـــــــــــة

قال تعالى :

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صدق الله العظيم

سورة المجادلة الاية 1

I

DEDICATION

TO MY PARENTS MY BROTHERS MY FRIENDS AND MY LOVELY DAUGHTER

II

Acknowledgments

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ABSTRACT

Computed tomography (CT), is an X-ray procedure that generates high quality cross-sectional images of the body, and by comparison to other radiological diagnosis, CT is responsible for higher doses to patients. The radiation dose was measured in two hospitals in Sultanat of Oman during (Januray,2014- January 2015) using different CT modalities. The radiation dose higher Sultan Qaboos hospital than the Nizwa national hospitals. MSCT scanners 128 slice exposed patients to a higher dose than 64 slice scanners.

In this study, the mean effective dose for Nizwa national hospital was 18.2±13.1mSv, and 36.9±20.6mSv for the Qaboos University hospital.

ملخص البحث

التصوير المقطعي (CT)، هو عملية التصوير بالأشعة السينية التي تنتج صور لمقاطع جسم المريض بجودة عالية، وبالمقارنة مع التشخيص الإشعاعية الأخرى، الاشعه المقطعية ذات جرعات اكبر للمرضى. تم قياس الجرعة الإشعاعية للمرضى في مستشفيين في سلطنة عمان خلال الفترة (يناير 2014 - يناير 2015) باستخدام تقنيات مختلفة من جهاز تصوير الاشعه المقطعية. وجدنا ان الجرعة الاشعاعية عالية في مستشفى السلطان قابوس الجامعي، مقارنة بالجرعة الاشعاعية من مستشفى نزوى الوطني. جهاز الأشعة المقطعية متعدد الشرايح ذو 128 شريحة يعطي جرعة أعلى للمريض من جهاز الاشعة المقطية ذو 64 شريحة. في هذه الدراسة، كان متوسط الجرعة الفعالة للمرضى في مستشفى نزوى الوطني 13.1 ± 18.2 ملي سيفرت. وكان متوسط الجرعة الفعالة في مستشفى السلطان قابوس الجامعي20.6 ± 36.9 ملي سيفرت،

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Chapter one:

1.1 Introduction

1.1.1 Radiation:-

In physics radiation is a process in which energetic particlesor energetic waves travel through a medium or space. Two types of radiation are commonly differentiated in the way they interact with normal chemical matter : ionizing and non-ionizing radiation, both ionizing and non-ionizing radiation can be harmful to organisms and can result in changes to the natural environment. In general, however ionizing radiation is far more harmful to living organisms per unit of energy deposited than non-ionizing radiation, since the ions that are produced by ionizing radiation, even at low radiation powers, have the potential to cause DNA damage. By contrast most non-ionizing radiation is harmful to organisms only in proportion to the thermal energy deposited and is conventionally considered harmless at low powers which do not produce significant temperature rise.

1.1.2 Ionizing radiation:-

Radiation with sufficiently high energy can ionize atoms. Most often, this occurs when an electron is stripped from an electron shell, which leaves the atom with a net positive charge. Because cells and more importantly the DNA can be damaged, this ionization can result in an increased chance of cancer. An individual cell is made of trillions of atoms. The probability of ionizing radiation causing cancer is dependent upon the absorbed dose of the radiation, as adjusted for the damaging tendency of the type of radiation (equivalent dose) and the sensitivity of the organism or tissue being irradiated (effective dose). The more rapidly a cell is diving the greater its sensitivity.

Photons and particles with energies above 10ev are ionizing. Alpha particles, beta particles, cosmic rays, and x-rays radiation all carry energy high enough to ionizesatoms. Ionizing

radiation comes from radioactive materials, x-ray tubes, particle accelerators and is present in the environment.

1.1.3 CT SCAN

A CT scan stands of Computed Tomography scan. It is also known as a CAT Computed Axial Tomography scan. It is a medical imaging method that employs tomography. Although most common in medicine, CT is also used in other fields such as NDT nondestructive materials testing, Tomography is the process of a two-dimensional image of slice or section through a 3-dimensionalobject (a tomogram).The medical device (the machine) is called a CTG scanner ,it is a large machine and use X-rays, CT scanner is a special kind of x-ray machine. Instead of sending out a single x-ray through your body as with ordinary x-rays, several beams are sent simultaneously from different angles.

The x-rays from the beams is detected after they have passed through the body and their strength is measured, each set of measurement made by the scanners is in effect, a cross-section through the body.

The computer process the result, displaying them as a two dimensioned picture shown on monitor. The information from the two dimensional computer images can be reconstructed to produce 3-dimensional images by some modern CT scanners. They can be used to produce virtual images that show what a surgeon would see during an operation. CT scan have already allowed doctors to inspect the inside of the body without having to operate or perform unpleasant examinations, CT scanning has also proven invaluable in pinpointing tumors and planning treatment with radiotherapy.

1-2-1 Development of CT:

The first clinical CT scanners were installed between 1974 and 1976. The original systems were dedicated to head imaging only, but (wholebody) systems with larger patient opening became available in 1976. CT became widely available by about 1980.

The first CT scanner developed by Haounsfield in his lap at EMI took several hours to acquire the raw data for a single scan or slice and took days to reconstruct a signal image from this row data. The lastest multi-slice CT systems can collect up to 4 slices of data in about 350 ms and reconstruct a 512 x512-matrix image from millions of data points in less than a second. An entire chest (forty 8mm slice) can be scanned in five to ten seconds using the most advanced multi-slice CT system.

During its 25-years history, CT has made great improvements in speed, patient comfort, and resolution.

1.2.2 CT scan risk:

As in many aspects of medicine, there are risks associated with the use of CTthe main risks associated with CT are: an increased lifetime risk of cancer due to x-ray radiation exposure, possible allergic reactions or kidney failure due to contrast agent, or "dye" that may be used in some cases to improve visualization. The need for additional follow-up tests after receiving abnormal test results or to monitor the effect of a treatment on disease, such as to monitor a tumor after surgical removal, some of these tests may be invasive and present additional risks, under some rare circumstances of prolonged, high-dose exposure, x-rays can cause other adverse health effects, such as skin reddening (erythema), skin tissue injury, hair loss, cataracts, and potentially, birth defects (if scanning is done during pregnancy, radiation exposure is a concern in both adults and children. However, these concerns are greater for children because they are more sensitive to radiation and have a longer life expectancy than adults. As a result, accumulated exposures over a child's lifetime are more likely to result in an adverse health effect. A child's smaller size also has an impact on the radiation dose they receive. For example, if a CT scan is performed on a child using the

same parameters as those used on an adult, an unnecessarily large dose will be delivered to the child, CT equipment settings (exposure parameters such as, x-ray tube current, slice thickness, or pitch) can be adjusted to reduce dose significantly while maintaining diagnostic image quality.

1.3 Objective of study :

The use of CT in medical diagnosis delivers radiation doses to patients that are higher than those from other radiological procedures, lake of optimized protocols could be an additional source of increased dose in developing

1.3.1 General objective:

- To determine the magnitude of radiation doses received by the patients undergoing abdomen CT examinations and compare them with other studies.
- To assess how CT scanning protocols in practice affect patient doses.

1.3.2 Specific objective

It is generally recommended that dosimeter should be performed regularly to evaluate the level of radiation dose for optimization the radiation dose received by the patients.

The current study intends to:

1. Quantify the patient dose in CT examination for abdominal.
2. Evaluate the outcome of protocols.
3. Estimate the patient effective dose.

1.4 Thesis outline

This thesis is concerned with the assessment of radiation dose for patients during abdominal CT examinations for different CT Modalities:

Accordingly, it is divided into the following chapters:

- Chapter one is the introduction to this thesis. This chapter presents the historical

background and radiation risks, in addition to study problem, objectives and scope of the work. It also provides an outlines of the thesis.

- Chapter two contains the background material for the thesis. This chapter also includes a summary previous work performed in this field.
- Chapter three describes the materials and methods that used to measure dose for CT machines and explains in details the methods for calculation and optimization.

- Chapter four presents the results of this study.
- Chapter five presents the discussion, conclusion and recommendations of this thesis and presents the suggestions for future work

Chapter two:

Theoretical Background

2.1 CT Machine

The invention of computed tomography is considered to be the greatest innovation in the field of radiology since the discovery of X-rays**, t**his cross-sectional imaging technique provided diagnostic radiology with better insight into the pathogenesis of the body, thereby increasing the chances of recovery, in 1979, G.N. Hounsfield and A.M. Cormack were awarded the Nobel Prize in medicine for the invention of CT (Henkestr , et al 2002).

Today, CT is one of the most important methods of radiological diagnosis. It delivers non-superimposed, cross-sectional images of the body, which can show smaller contrast differences than conventional X-ray images, this allows better visualization of specific differently structured soft-tissue regions, for example, which could otherwise not be visualized satisfactorily, since the introduction of spiral CT in the nineties, computed tomography has seen a constant succession of innovations, the development of slip ring technology allowed for a continuously rotating gantry – the prerequisite for spiral CT ,the first spiral CT scanner was

a Siemens SOMATOM Plus system, today this technology is widely used (Henkestr , et al 2002).

2.2 CT Generations

2.2.1First-Generation CT Scanners

The EMI Mark I scanner, the first commercial scanner invented by Houns field, was introduced in 1973. This scanner acquired data with an x-ray beam collimated to a narrow pencil beam directed to a single detector on the other side of the patient; the detector and the beam were aligned in a scanning frame. A single projection was acquired by moving the tube and detector in a straight-line motion (translation) on opposite sides of the patient (Mahadevappa Mahesh, 2002). To acquire the next projection, the frame rotated 1, and then translated in the other direction. This process of translation and rotation was repeated until 180 projections were obtained. The earliest versions required about 4.5 minutes for a single scan and thus were restricted to regions where patient motion could be controlled (the head). Since procedures consisted of a series of scans, procedure time was reduced somewhat by using two detectors so that two parallel sections were acquired in one scan (Mahadevappa Mahesh, 2002).

Although the contrast resolution of internal structures was unprecedented, images had poor spatial resolution (on the order of 3 mm for a field of view of 25 cm and 80 matrixes) and very poor z-axis resolution (13-mm section thickness) (Mahadevappa Mahesh, 2002).

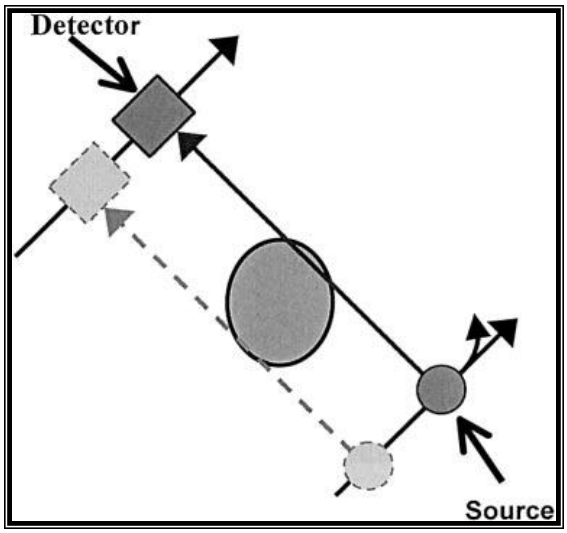


Fig (2.1): Diagram of the first-generation CT scanner, which used a parallel x-

2.2.2 Second-Generation CT Scanners

The main impetus for improvement was in reducing scan time ultimately to the point those regions in the trunk could be imaged. By adding detectors angularly displaced, several projections could be obtained in a single translation. For example, one early design used three detectors each displaced by 1

Since each detector viewed the x-ray tube at a different angle, a single translation produced three projections. Hence, the system could rotate3 to the next projection rather than 1and had to make only 60 translations instead of 180 to ac- quire a complete section (Mahadevappa Mahesh, 2002).

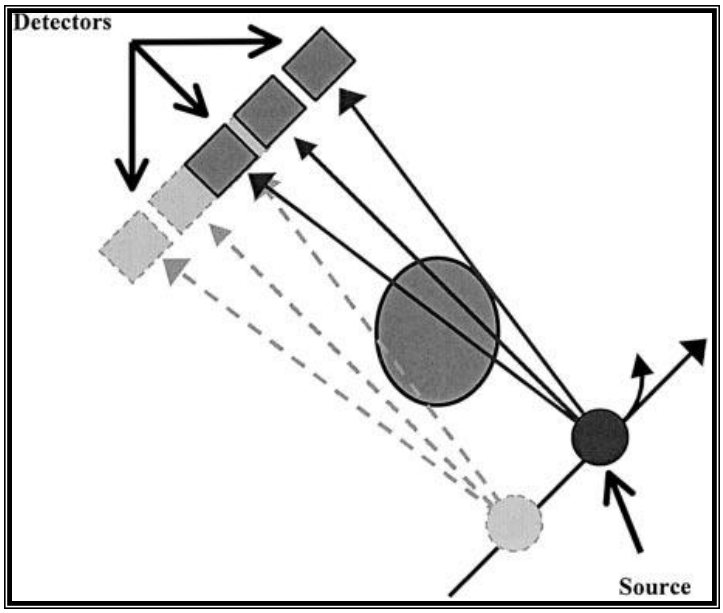


Fig (2.2): Diagram of the second-generation CT scanner, which used

Scan times were reduced by a factor of three. Designs of this type had up to 53 detectors, were ultimately fast enough (tens of seconds) to permit acquisition during a single breath hold, and thus were the first designs to permit scans of the trunk of the body(Mahadevappa Mahesh, 2002).

Because rotating anode tubes could not withstand the wear and tear of rotate-translate motion, this early design required a relatively low output stationary anode x-ray tube. The power limits of stationary anodes for efficient heat dissipation were improved somewhat with the use of asymmetrical focal spots (smaller in the scan plane than in the z-axis direction), but this resulted in higher radiation doses due to poor beam restriction to the scan plane. Nevertheless, these scanners required slower scan speeds to obtain adequate x-ray flux at the detectors when scanning thicker patients or body parts (Mahadevappa Mahesh, 2002).

2.2.3 Third-Generation CT Scanners

Designers realized that if a pure rotational scanning motion could be used, then it would be possible to use higher-power, rotating anode x-ray tubes and thus improves scan speeds in thicker body parts(Mahadevappa Mahesh, 2002).

One of the first designs to do so was the so-called third generation or rotate-rotate geometry. In these scanners, the x-ray tube is collimated to a wide, fan-shaped x-ray beam and directed toward an arc-shaped row of detectors (Mahadevappa Mahesh, 2002).

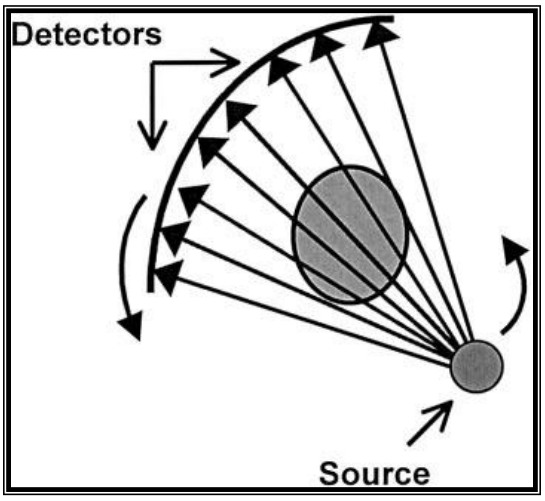


Fig (2.3): Diagram of the third-generation CT scanner, which acquires data by

During scanning, the tube and detector array rotate around the patient, and different projections are obtained during rotation by pulsing the x-ray source or by sampling the detectors at a very high rate (Mahadevappa Mahesh, 2002).

The number of detectors varied from 300 in early versions to over 700 in modern scanners. Since the slam-bang translational motion was replaced with smooth rotational motion, higher-output rotating anode x-ray tubes could be used, greatly reducing scan times. One aspect of this geometry is that rays in a single projection are divergent rather than parallel to each other, as in earlier designs (Mahadevappa Mahesh, 2002).

Beam divergence required some modification of reconstruction algorithms, and sampling considerations required scanning an additional arc of one fan angle beyond 180 although most scanners rotate 360 for each scan (Mahadevappa Mahesh, 2002).

Nearly all current helical scanners are based on modifications of rotate-rotate designs. Typical scan times are on the order of a few seconds or less, and recent versions are capable of sub second scan times (Mahadevappa Mahesh, 2002).

2.2.4 Fourth-Generation CT Scanners

This design evolved nearly simultaneously with third-generation scanners and also eliminated translate-rotate motion. In this case, only the source rotates within a stationary ring of detectors (Mahadevappa Mahesh, 2002).

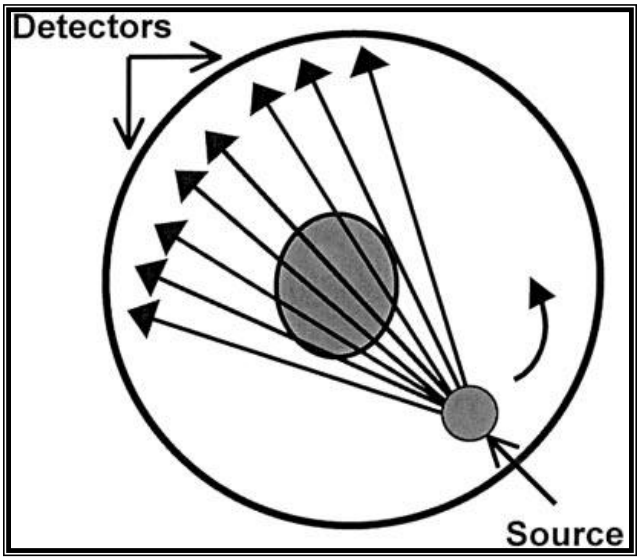


Fig (2.4): Diagram of the fourth-generation CT scanner

The x-ray tube is positioned to rotate about the patient within the space between the patient and the detector ring. One clever version, which is no longer produced, moved the x-ray tube out of the detector ring and tilted the ring out of the x-ray beam in a wobbling (nutation) motion as the tube rotated. This design permitted a smaller detector ring with fewer detectors for a similar level of performance. Early fourth-generation scanners had some 600 detectors and later versions had up to 4,800 (Mahadevappa Mahesh, 2002).

Within the same period, scan times of fourth-generation designs were comparable with those of third-generation scanners (Mahadevappa Mahesh, 2002).

One limitation of fourth-generation designs is less efficient use of detectors, since less than one-fourth are used at any point during scanning (Mahadevappa Mahesh, 2002).

These scanners are also more susceptible to scatter artifacts than third-generation types, since they cannot use anti scatter collimators. CT scanners of this design are no longer commercially available except for special-purpose applications (Mahadevappa Mahesh, 2002).

Until around 1990, CT technology had evolved to deliver scan plane resolutions of 1-2lp/mm, but z-axis resolution remained poor and interscan delay was problematic due to the stop- start action necessary for table translation and for cable unwinding, which resulted in longer examination times (Mahadevappa Mahesh, 2002).

The z-axis resolution was limited by the choice of section thickness, which ranged from 1 to 10 mm. For thicker sections, the partial volume averaging between different tissues led to partial volume artifacts (Mahadevappa Mahesh, 2002).

These artifacts were reduced to some extent by scanning thinner sections. In addition, even though it was possible to obtain 3D images by stacking thin sections, inaccuracy dominated due to involuntary motion from scan to scan(Mahadevappa Mahesh, 2002).

The step like contours could be minimized by overlapping of CT sections at the expense of a significant increase irradiation to the patient. Also, the conventional method of section-by-section acquisition produced misregistration of lesions between sections due to involuntary motion of anatomy in subsequent breath holds between scans (Mahadevappa Mahesh, 2002).

It was soon realized that if multiple sections could be acquired in a single breath hold, a considerable improvement in the ability to image structures in regions susceptible to physiologic motion could (Mahadevappa Mahesh, 2002).

2.3 Quality assurance program goals

The goals of a CT-simulation QA program are to assure safe and accurate operation of the CT-simulation process as a whole. The QA program design should include tests which will

assure accurate target and critical structure localization and accurate placement of treatment beams with respect to a volumetric CT-scan of a patient (SasaMutic, et al, 2003).

While CT-scanners are generally regarded as ‘‘safe’’ medical devices they are radiation producing equipment and as such capable of harming patients, staff, and public. The QA program must assure that radiation levels from the CT- scanner are safe, and that they comply with applicable regulatory limits (SasaMutic, et al, 2003).

2.3.1 Accurate target localization and treatment simulation

For accurate patient treatment planning, the CT-scanner must provide high quality images, with geometrical and spatial integrity, and with a known CT number Hounsfield unit! 20 to electron density relationship. The CT-scanner QA program should include tests to verify that all three of the above conditions are met (SasaMutic, et al, 2003).

The primary areas of focus for the CT-simulation QA program should be the imaging performance and geometric accuracy of the CT-scanner, the geometric accuracy and utility of the CT-simulation software, accuracy and image quality of DRRs, and accuracy and integrity of information transfer between the various treatment planning and treatment delivery systems. The tests outlined in Secs (SasaMutic, et al, 2003).

The suggested frequency of these tests should ensure that critical problems are detected in a timely fashion. The tolerance limits for QA tests recommended in this report were designed to satisfy accuracy requirements of conformal radiation therapy. They are in accordance with AAPM Report No. 39, TG53, and NCRP Report No. 99 recommendations and have been shown to be achievable in a routine clinical setting. Depending on the goals and prior clinical experience of a particular CT- simulation program, these tests, frequencies, and tolerances may be modified by the medical physicist. Radiation therapy procedures which require higher precision ~ i.e., intensity modulated radiation therapy! May demand more stringent tolerance limits and testing frequency (SasaMutic, et al, 2003).

Likewise, QA of CT-scanners which are primarily used for less demanding procedures can be based on less stringent limits. The modified QA program should still ensure that the QA goals

and objectives outlined in this report are satisfied and that the quality of patient care is not compromised (SasaMutic, et al, 2003).

2.3.2 QUALITY ASSURANCE FOR CT-SCANNERS USED FOR CT-SIMULATION AND ITS FREQUENCY

For a successful CT-simulation process, the CT-scanner should consistently produce patient images with the highest possible quality and accurate geometrical information. Image quality directly affects the physician's ability to define target volumes and critical structures, and the spatial integrity of the CT study establishes how accurately radiation can be delivered to target volumes. The CT-scanner evaluation process consists of an evaluation of patient dose from the CT- scanner, radiation safety, electromechanical components, and image quality. Testing procedures and QA devices described here are just for illustration purposes. They are intended to describe a general approach to CT-simulation QA. Alternative testing methods and phantoms exist and can certainly be used in place of methods described here (SasaMutic, et al, 2003).

2.4 CT Dose equivalent and unit

2.4.1 Radiation dose units

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

on the likelihood of benefit from the examination and the potential risk from radiation (ICRP 1990, ICRP 1991).

2.4.2 Effective dose

Effective dose is becoming a very useful radiation quantity for expressing relative risk to humans, both patients and other personnel. It is actually a simple and very logical concept. It takes into account the specific organs and areas of the body that are exposed. The point is that all parts of the body and organs are not equally sensitive to the possible adverse effects of radiation, such as cancer induction and mutations (Perry Sprawls.org, Online).

For the purpose of determining effective dose, the different areas and organs have been assigned tissue weighting factor (WT) values. For a specific organ or body area the effective dose is:

$$\text{Effective Dose (Gy)} = \text{Absorbed Dose (Gy)} \times WT \qquad (2.1)$$

If more than one area has been exposed, then the total body effective dose is just the sum of the effective doses for each exposed area. It is a simple as that. Now let's see why effective dose is such a useful quantity. There is often a need to compare the amount of radiation received by patients for different types of x-ray procedures, for example, a chest radiograph and a CT scan. The effective dose is the most appropriate quantity for doing this. Also, by using effective dose it is possible to put the radiation received from diagnostic procedures into perspective with other exposures, especially natural background radiation (Perry Sprawls.org, Online).

It is generally assumed that the exposure to natural background radiation is somewhat uniformly distributed over the body. Since the tissue weighting factor for the total body has the value of one (1), the effective dose is equal to the absorbed dose. This is assumed to be 300 mrad in the illustration.

Let's look at an illustration. If the dose to the breast, MGD, is 300 mrad for two views, the effective dose is 45 mrad because the tissue weighting factor for the breast is 0.15.

What this means is that the radiation received from one mammography procedure is less than the typical background exposure for a period of two months.

Table: 2.1 Tissue Weighting Factors (UNSCEAR 2008):

Weighting factors for different organs			
Organs	Tissue weighting factors		
	ICRP30(I36) 1979	ICRP60(I3) 1991	ICRP103(I6) 2008
Gonads	0.25	0.20	0.08
Red Bone Marrow	0.12	0.12	0.12
Colon	-	0.12	0.12
Lung	0.12	0.12	0.12
Stomach	-	0.12	0.12
Breasts	0.15	0.05	0.12
Bladder	-	0.05	0.04
Liver	-	0.05	0.04
Esophagus	-	0.05	0.04
Thyroid	0.03	0.05	0.04
Skin	-	0.01	0.01
Bone surface	0.03	0.01	0.01
Salivary glands	-	-	0.01
Brain	-	-	0.01

Remainder of body	0.30	0.05	0.12

2.5 CT dose measurements

Although CT presents only a small percentage of radiology examinations, it results in a significant portion of the effective radiation dose from medical procedures; (I) with the increasing use of CT for screening procedures, (II) and advances in scanner technology, they tend for increasing numbers of procedures performed with this modality may increase. Although CT is clearly providing many clinical benefits, the motivation to understand radiation dose in general as well as the specific concepts related to CT grows with prevalence of this modality (ImPACT 2007, Jones et al. 1993).

2.5.1 CT parameters that influence the radiation dose

The radiation exposure to the patients undergoing CT examinations is determined by two factors: equipment-related factors, .e. the design of the scanner with respect to dose efficiency, and applications-related factors, i.e. the way in which the radiologist and X-ray technologist makes use of the scanner (Nagel 2007). In this chapter the features and parameters influencing patient dose are outlined. First, however, a brief introduction on the dose descriptors applicable to CT is given (Nagel 2007).

2.5.2 CT dose descriptors

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

First, the dose distribution inside the patient is completely different from that of a conventional radiography where the dose decreases continuously from entrance of the X-ray beam to its exit, with the ratio of between 100 and 1000 to 1. In the case of CT, as a consequence of the scanning procedure that equally irradiates the patient from all directions; the dose is almost equally distribution in the scanning plane. A dose comparison of CT with conventional projection radiography in term of skin dose therefore does not make any sense, second the scan procedure using narrow beams along the longitudinal z-axis of the patient implies that a significant portion of the radiation energy is deposited

outside the nominal beam width.

This is mainly due to penumbra effects and scattered radiation produced inside the beam, third the situation with CT is further complicated by the circumstances in which-unlike in conventional projection radiography-the volume to be imaged is not irradiated simultaneously. This often leads to confusion about what dose from a complete series of e.g. 15 slices might be compared with the dose from a single slice (ImPACT 2007, Jones et al. 1993).

As a consequence, dedicated dose quantities that account for these peculiarities are needed. The 'Computed Tomography Dose Index (CTDI)', which is a measure of the local dose, and the Dose Length Product (DLP), representing the integral radiation exposure associated with a CT examination. Fortunately, a bridge exists that enables to compare CT with radiation exposure from the other modalities and sources; this can be achieved by the effective dose (E). So there are three dose descriptors in all, which everyone dealing with CT should be familiar with (Nagel 2007).

2.5.2.1 Computed tomography dose index (CTDI)

The 'Computed Tomography Dose Index (CTDI)' is the fundamental CT dose descriptor. By making use of this quantity, the first two peculiarities of CT scanning are taken into account: The CTDI (unit: Milligray (mGy)) is derived from the dose distribution a long a line which is parallel to the axis of rotation for the scanner (=z axis) and which is recorded for a single rotation of X-ray source. illustrates the meaning of the term: CTDI is the equivalent of the dose value inside the irradiated slice (beam), that would result if the absorbed radiation dose profile were entirely concentrated to a rectangular of width equal to the nominal beam width with N being the number of independent (i.e. non-overlapping) slices that are acquired simultaneously. Accordingly, all dose contributions from outside the nominal beam width, i.e. the areas under the tails of the dose profile, are added to the area inside the slice (Nagel 2007).

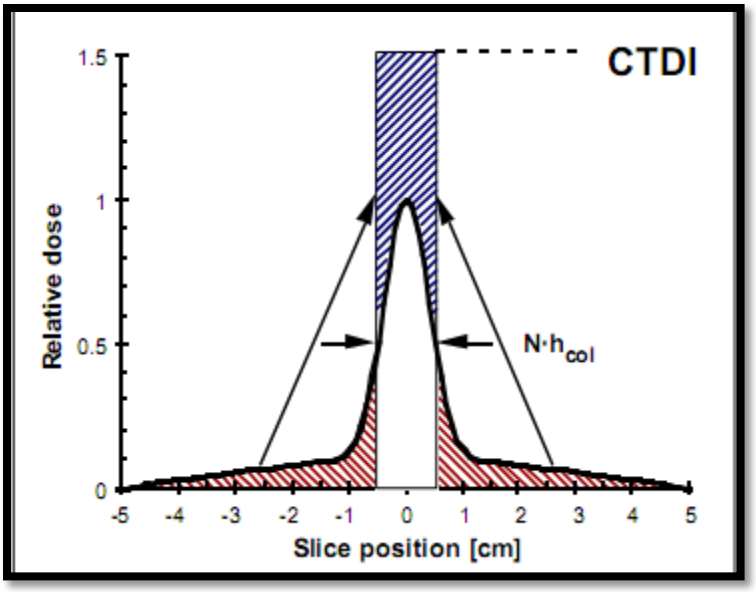


Figure: 2.5: Illustration of term 'Computed Tomography Dose Index (CTDI)': is the equivalent of the dose value inside the irradiated slice (beam) that would result if the absorbed radiation dose profile were entirely concentrated to a rectangular of width equal to the nominal beam width N.hcol, with N being the number of independent (i.e. non-overlapping) slices that are acquired simultaneously (Nagel 2007).

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

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

Where D(z) is the value of the dose at a given location, z, and N.hcol is the nominal value of the total collimation (beam width) that is used for data acquisition. CTDI is therefore equal to the area of the dose profile (the 'dose-profile integral') divided by the nominal beam width. In practice, the dose profile is accumulated in a range of -50 mm to +50 mm relative to the centre of the beam, i.e. over a distance of 100mm.

The relevancy of CTDI becomes obvious from the total dose profile of a scan series with e.g. n=15 subsequent rotations (Fig.2.15).The average level of the total dose profile, which

is called 'Multiple Scans Average Dose (MSAD)' (Shope 1981), is higher than the peak value of each single dose profile. This increase results from the tails of the single dose profiles. Obviously MSAD and CTDI are exactly equal of the table feed (TF) is equal to the nominal beam width N.hcol, i.e. if the pitch factor

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

is equal to 1. In general (i.e. if the pitch factor is not equal to 1, Fig.2.16), the relationship between CTDI and MSAD is given by:

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

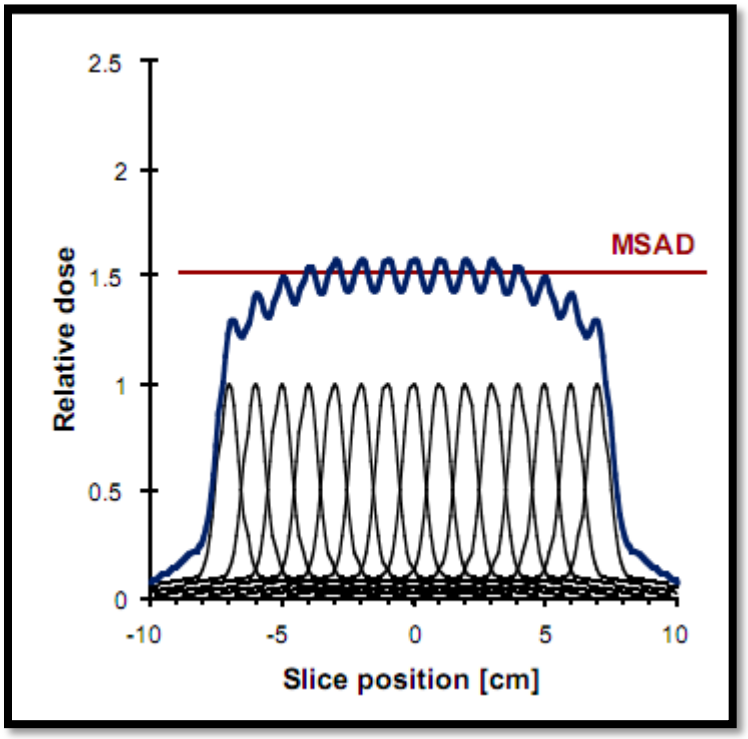


Figure: 2.6: The average level of the total dose profile, which is called 'Multiple Scans Average Dose (MSAD)'- (Shope 1981), is higher than the peak value of each single dose profile. This increase results from the tails of the single dose profiles (Nagel 2007).

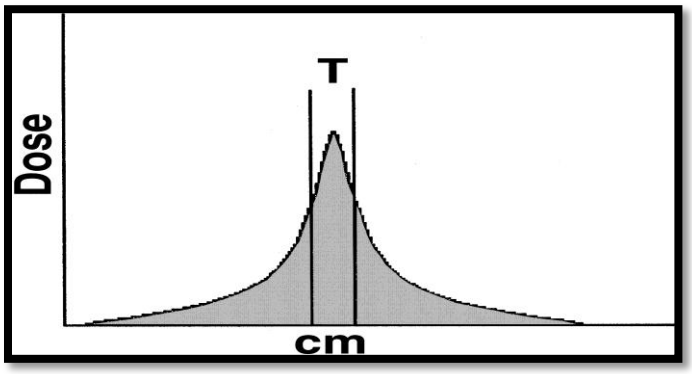
Each pair of CTDI (central and peripheral) can be combined into a single are named weighted CTDI (CTDIw):

$$CTDI_W = \frac{1}{3}CTDI_{100_c} + \frac{2}{3}CTDI_{100_P} \quad (2.5)$$

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

$$CTDIvol = CTDIw/P \quad (2.6)$$

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



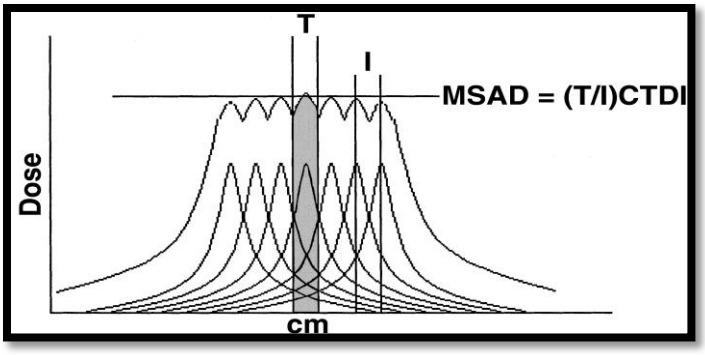


Figure: 2.7: (1) Schematic illustrates the profile of radiation dose delivered during a single CT scan. The CTDI equals the shaded area under the curve divided by the section thickness (*T*). (**2)** Schematic illustrates the profile of radiation dose delivered during multiple CT scans. *T* represents section thickness, and *I* represent the interval between sections. The MSAD includes the contributions of neighboring sections to the dose of the section of interest (D.Tack 2007).

2.5.2.2 Dose length product (DLP) unit (mGy)

DLP = CTDIw**.**L (mGy-cm). DLP takes both the 'intensity') represented by CTDIvol) and the extension (represented by scan length L) of an irradiation into account:

$$DLP = CTDI_{vol} \cdot scan\ length \quad (2.7)$$

So DLP increases with number of slices (correctly: with length of irradiated body section), while the dose (i.e. CTDIvol) remains the same regardless of the number of slices or length, respectively. The area of the total dose profile of the scan series represents the DLP. DLP is the equivalent of the dose-area product (DAP) in projection radiography, a quantity that also combines both aspects (intensity and extension) of patient exposure. In sequential scanning, the scan length is determined by the beam width N.hcol and number of the table feed (TF):

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

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

$$L = n \cdot TF = \frac{T}{t_{rot}} \cdot p \cdot N \cdot h_{col} \quad (2.9)$$

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

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

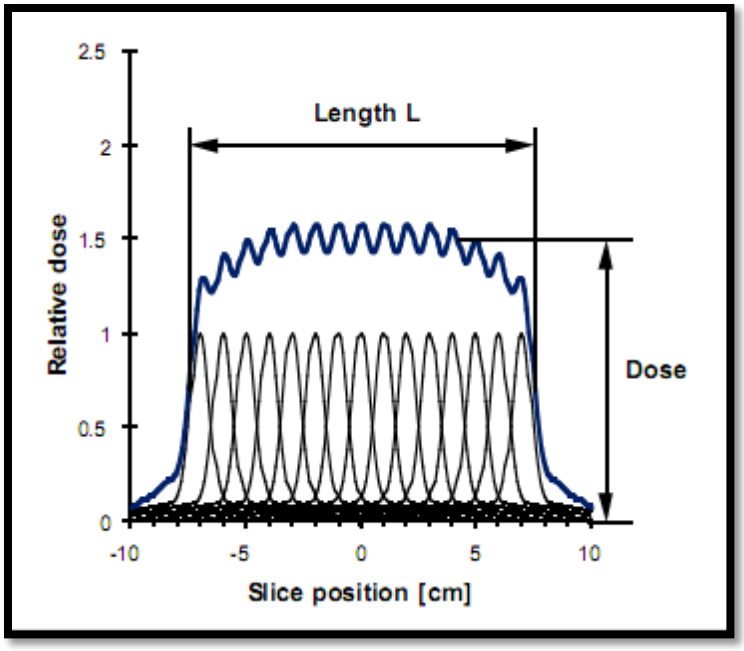


Figure 2.8: Dose length product (DLP) in CT (Total dose profile of a scan series with n=15 sub-sequent rotations. The dose-length product (DLP) is the product of the height (dose, i.e. CTDIvol) and the width (scan length L) of the total dose profile and is equal to the area under the curve (Nagel 2007).

2.5.2.3 DLP and Effective Dose

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

$$E = \sum i \; Wi* \qquad (2.11)$$

2.6 Performance of electromechanical components

Proper operation of electromechanical components cans affect patient safety and the accuracy of CT-simulation process. This portion of the document describes testing of these components (SasaMutic, et al, 2003).

2.6.1 Patient marking, positioning lasers

As previously described, scanners used for CT-simulation are typically equipped with external lasers. These lasers are used to position the patient in the treatment position assuring that patients are straight and properly rotated. These lasers are also used to place positioning marks on patient skin (SasaMutic, et al, 2003).

Just as the treatment room lasers possess a well-defined and precise spatial relationship to the treatment machine iso center, the CT-simulation patient marking lasers must possess a similar relationship to the CT-scanner image center (SasaMutic, et al, 2003).

Thus, the accuracy of the lasers directly affects the ability to localize treatment volumes relative to patient skin marks and the reproducibly of patient positioning from the CT-scanner to the treatment machine (SasaMutic, et al, 2003).

Accuracy and spatial orientation of lasers therefore must be comparable to treatment machine laser accuracy (SasaMutic, et al, 2003).

Laser accuracy tolerances depend on the goals of radiation therapy and required accuracy of treatment procedures. Tolerances recommended in Table II need to be evaluated by individual institutions (SasaMutic, et al, 2003).

The following are performance requirements for CT- scanner lasers(gantry lasers should accurately identify scan plane within the gantry opening;gantry lasers should be parallel and orthogonal with the scan plane and should intersect in the center of scan plane;vertical side-wall lasers should be accurately spaced from imaging plane;wall lasers should be parallel and orthogonal with the scan plane, and should intersect at a point which is coincident with the center of the scan plane; the over head sagittal laser should be orthogonal to the imaging

planethe overhead sagittal laser movement should be accurate, linear, and reproducible (SasaMutic, et al, 2003).

2.6.2 Couch and tabletop

Diagnostic CT-scanners are usually equipped with only a cradle-shaped couch top

Of the tabletop is cup shaped to con- form to the circular opening of the CT-scanner gantry, scanners used for CT-simulation require a flat tabletop similar to the treatment machine's tabletop geometry. The flat tabletop can be an insert that fits inside the cradle of the existing table or an overlay which is mounted on the top of the cradle (SasaMutic, et al, 2003).

2.6.3 QA goals:

The following are performance requirements for the CT-scanner couch and tabletop:

Flat tabletop should be level and orthogonal with respect to the imaging plane; table vertical and longitudinal motion according to digital indicators should be accurate and reproducible; table indexing and position under scanner control should be accurate;flat tabletop should not contain any objectionable artifact producing objects collimation (SasaMutic, et al, 2003).

The majority of CT-scanners collimates the radiation beam in the longitudinal direction distal to the x-ray source pre patient collimation and also immediately prior to the detector array post-patient collimation the accuracy of both, the pre- and post-patient collimation can significantly influence the scan image quality (SasaMutic, et al, 2003).

Additionally, the pre-patient collimation has direct influence on patient dose from a CT-scan. The accuracy of the pre-patient collimation is evaluated by measuring the radiation Profile Width emerging from the scanner ,the actual width of the imaged slice, which is affected by the post-patient collimation, is assed by measuring the Sensitivity Profile Width, if the radiation profile width is wider than indicated, unnecessary radiation will be delivered to the patient, thus increasing the total dose from the scan (SasaMutic, et al, 2003).

An excessively narrow radiation profile or sensitivity profile width may cause increased quantum noise due to reduced photon count (SasaMutic, et al, 2003).

Excessive sensitivity profile width can result in some lose of resolution in the longitudinal direction (SasaMutic, et al, 2003).

2.7 Imaging technique Computer Assisted Tomography (CT) uses special x-ray equipment to obtain three-dimensional anatomical images of bone, soft tissues and air

An x-ray emitter rotated around the head measures the rays' intensities from different angles. Sensors measure the amount of radiation absorbed by different tissues; a computer uses the differences in X-ray absorption to form cross-sectional images or "slices" of brain called "tomograms." CT can be done quickly, and so is used extensively in the ER to identify evidence of brain trauma, such as swelling or bleeding (as from hemorrhagic stroke or a ruptured brain aneurysm) (Carolyn Asbury, 2011).

2.8 Previous studies

RT , Sodickson A , 2009 , evaluated the cumulative radiation exposure and cancer risk estimate in emergency department patients undergoing repeat or multiple CT in order to define a conservative estimate of the number of patients undergoing repeat or multiple emergency department CT studies and to quantify their cumulative CT radiation doses and lifetime attributable risk of developing cancer. They found in conclusion a small proportion (1.9%) of emergency department patients undergoing CT of the neck, chest, abdomen, or pelvis have high cumulative rates of multiple or repeat imaging. Collectively, this patient subgroup may have a heightened risk of developing cancer from cumulative CT radiation exposure.

Numerous studies have suggested that, although CT is not the most commonly performed radiologic examination, it is the largest source of radiation dose. (Nagel et al. 1989) found

that, although CT represents only about 4% of all radiologic examinations, it is responsible for up to 35% of collective radiation dose to the population from radiologic examinations. In related National Cancer Institute report, data suggested that the use of CT in adults and children has increased approximately 7 folds in the past 10 years. In large U.S hospitals, CT represents 10% of diagnostic procedures and accounts for approximately65% of the for all medical effective radiation dose examinations.

(Aldrich et al. 2007) conducted a study to compare the dose length product (DLP) and effective radiation dose to the patients from CT examinations. They compared data from 1070 CT examinations and concluded that considerable variation existed in the dose length product and patients radiation dose for specific examination. This study called attention to the need to optimize the effective dose to the patient and conduct more research to determine which additional efforts are needed to minimize patient exposure. Optimizing technical factors for examinations can help reduce patient radiation dose, thereby reducing risks. A pivotal study by (Lee 2001) assessed awareness levels among patients, emergency department physicians and the radiologists concerning radiation dose and the risks involved with CT scans. Lee and colleagues concluded that patients were not given information about the risks, benefits and radiation dose from a CT scan. Regardless of their experience levels, few of the participants in the study (including the emergency department physicians and the radiologists) were able to provide accurate estimates of CT radiation doses. This study underscores the prevalent lack of attention to the issue lifetime cumulative radiation

doses. This must be become a central issue so that risk can be studied and monitored. One disadvantage to communicating instinct of cumulative radiation dose would be the natural instinct of some patients to defer or cancel the examination. Professionals should highlight the benefits of the examination when discussing risks with the patient. Physicians improve their understanding of radiation risks from medical imaging examinations.

(Alice B, et al. 2009) quantified retrospectively the effect of systematic use of tube current modulation for neuroradiology CT protocols on patient dose and image quality. The authors evaluated effect of dose modulation on four types of neuroradiologic CT studies: brain CT performed without contrast, material (unenhanced CT) in adult patients, unenhanced brain CT in pediatric patients, adult cervical spine CT, and adult cervical and intracranial CT angiography. For each type of CT study, three of 100 consecutive studies were reviewed: 100 studies performed without dose modulation, 100 studies performed with z-axis dose modulation, and 100 studies performed with x-y-z-axis dose modulation. For each examination, the weighted volume CT dose index (CTDIvol) and dose length product (DLP) were recorded and noise was measured. Each study was also reviewed for image quality. Continuous variables (CTDIvol, DLP, noise) were compared by using t test and categorical variables (image quality) were compared by using Wilcoxon rank-sum test. For unenhanced CT of adult brains, the CTDIvol and DLP, respectively, were reduced by 60.9% and 60.3%, respectively, by using z-axis dose modulation and by 50.4% and 22.4% by using x-y-z-axis dose modulation. Significant dose reductions ($P < 0.001$) were also

observed for pediatric unenhanced brain CT, cervical spine CT, and adult cervical and intracranial CT angiography performed with each dose modulation technique. Image quality and noise were unaffected by use of either dose modulation technique ($P < 0.05$). Use of dose modulation techniques for neuroradiology CT examinations affords significant dose reduction while image quality is maintained.

For unenhanced CT of adult brains, the CTDIvol and DLP, respectively, were reduced by 60.9% and 60.3%, respectively, by using z-axis dose modulation and by 50.4% and 22.4% by using x-y-z–axis dose modulation. Significant dose reductions ($P < .001$) were also observed for pediatric unenhanced brain CT, cervical spine CT, and adult cervical and intracranial CT angiography performed with each dose modulation technique. Image quality and noise were unaffected by the use of either dose modulation technique ($P > .05$).

Finally, a unique study conducted in Sudan regarding patient dose in CT (M A Aziz 2007). The study assessed the radiation doses for patients undergoing routine CT examinations in four centers in Khartoum state for various CT examinations of head, neck, abdomen, pelvis and chest. CTDIvol, DLP and effective dose were calculated using CT-exposure software. The mean CTDIw, CTDIvol DLP and effective dose were found to be 32.6 mGy, 26.5 mGy, 454 mGy and 3.3 mSv respectively.

Chapter three:

Material and Method

3.1 Introduction

The data used in this study were collected from Department of Radiology, Sultan Gabues University hospital in Oman National Nizwa Governmental Hospital and by 128 slices and 64 slice scanner in respect for CT abdomen. Data of the technical parameters used in CT Procedures were taken during October, 2013 to May, 2014. An informed consent was obtained from all patients prior to the procedure.

3.2 Patient data

Table 3.1 The CT Abdomen patient's population of the study in Sultan Qabues University hospital and National Nizwa Governmental Hospital

Hospital	No of CT Abdomen patients
Sultan Qabues University hospital (SQUH)	43
National Nizwa Governmental Hospital (NNGH)	29
Total	72

3.3 CT machines

CT machines were used to collect data during this study. These machines are installed in radiological departments, the annual quality control tests were performed to these machines before the data collection, and all this tests are revealing that all scanning parameters were within acceptable range.

Table 3.2 CT machine

Hospital	manufacture	model	installation	No of Detectors
Sultan Qabues University hospital (SGUH)	Philips	Ingenuity	2013	128 slice
National Nizwa Governmental Hospital (NNGH)	Siemens	Light speed	2009	64 slice

3.4 Data collection

Data were collected using a sheet for all patients in order to maintain consistency of the information from display .A data collection sheet was designed to evaluate the patient doses and the radiation related factor.

The collected data included , age; tube voltage and tube current–time product settings; pitch; section thickness; and number of sections, In addition, we also recorded all scanning parameters, as well as the CT dose descriptors CT weighted dose index (in millisievert) and dose-length product (in millisievert-centimeters).All these factors have a direct influence on radiation dose. The entire hospital was passed successfully the extensive quality control tests performed by annually by atomic energy commission.

3.5 Analysis of data

All dose parameters were registered in the raw data in CT scan protocol and they use in calculation for the effective dose using conversion factor of abdomen, then analysis this data by statistical software (SPSS) and Microsoft excel.

3.6Patient Data

A total of 72 patients were referred to Sultan Qabues University hospital (SGUH) Nizwa Hospitalin the period of study with abdominal disturbances, patient-related parameters (e.g., age, gender, diagnostic purpose of an examined body region, and use of contrast media)and patient dose were collected in addition, Exposure-related parameters(gantry tilt, kilo voltage (kV), tube current (mA), exposure time, slicethickness, table increment, number of slices, and start and end positions of scans)on patient dose.

3.6.1 Patient Preparation:

The patient should be fasting at least 8 hours before the exam and should be well hydrated and full bladder just before exam.

3.6.2 Patient positioning:

The patient is optimally positioned on the CT scanner table. As the patient is advanced into the scanner, he or she is coached by the technologists, who have direct visualization and bidirectional auditory communication with the patient as the study is performed. Typically, the patient is warned to anticipate the effects of contrast injection are informed about breath-holding requirements during the scan. The technologists select the correct protocol for the prescribed examination and select exposure parameters, taking into consideration factors such as the patient’s body habitus, in order to optimize image quality while limiting radiation exposure.

3.6.3 The protocol used in abdominal CT:

Oral Prep: Water, injection rate: 4cc/sec, Post processing/reformatting/sending:

to PACS:1.25mm axial recons-both phases ,5mm axial recons-both phases,3mm coronal and sag recons-both phases.

3.6.3.1 CT dose measurements:

The patient dose estimation from CT examination using the Monte Carlo technique requires measurements of CTDI and conversion coefficient data packages (1-1). In theory, the CTDI, which is a measure of the dose from single-slice irradiation, is defined as the integral along a line parallel to the axis of rotation (z) of the dose profile, D(z), divided by the nominal slice thickness, t.(1,1–5,41) In this study, CTDI was obtained from a measurement of dose, D(z), along the z-axis made in air using a special pencil-shaped ionization chamber (didoes, type M30009, PTW-Freiburg) connected to an electrometer (Diodes, type 11003, PTW-Freiburg). The calibration of the ion chamber is traceable to the standards of the German National Laboratory and was calibrated according to the International Electrical Commission standards. The overall accuracy of ionization chamber measurements was estimated to be ±5%. Measurements of CTDI in air (CTDI100, air) were made as recommended by the EUR 16262EN based on each combination of typical scanning parameters obtained from the machine (Ware DE, 1999).

Chapter Four:

Results

4.1 introductions

The following chapter will highlight the results deal with the CT abdominal cases together with their relevant CTDI and DLP and affective mAs.

Figure 4.1 shows the age group correlated with the frequency of abdominal pathologies. It

Examination	National Nizwa Governmental Hospital (NNGH)	Sultan Qabues University hospital (SQUH)	Total

reveals that the vast majority of patients undergoing abdominal CT scan in the age group between 20 to 80 years old.

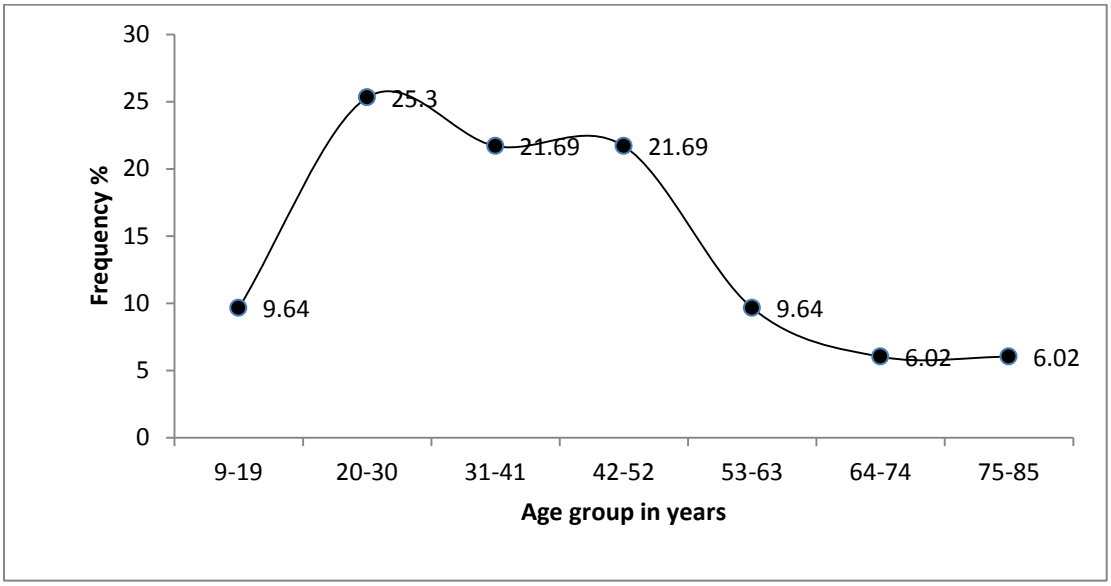


Figure 4.1 shows the age group correlated with the frequency of abdominal pathologies

abdomen	6	15	21
KUB	12	15	27
CTU	11	13	24
Total	29	43	72

Table 4.1 Represent CT abdomen patient by specific classification per hospital.

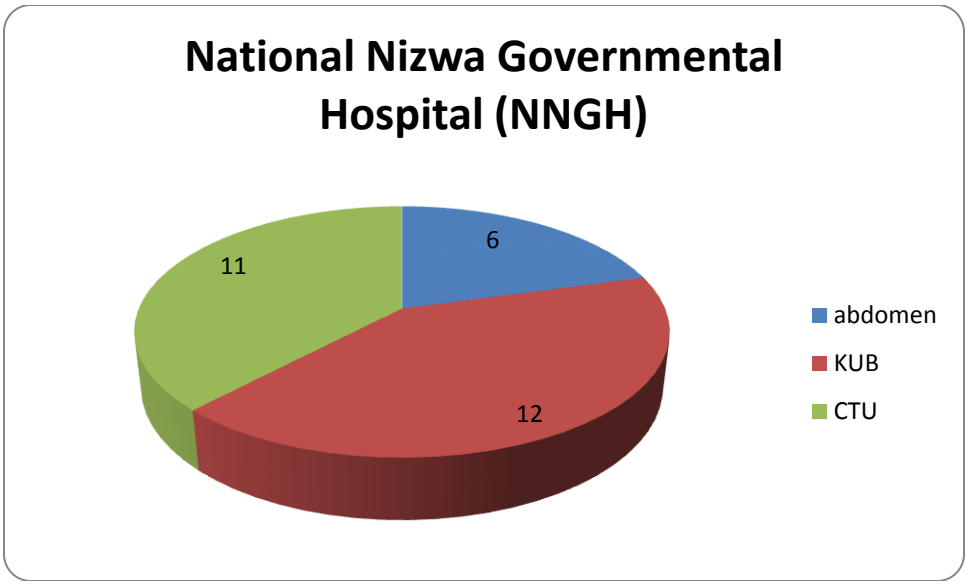


Figure 4.2 Show a Pie chart represent specific classification of ct abdominal frequency in (NNGH).

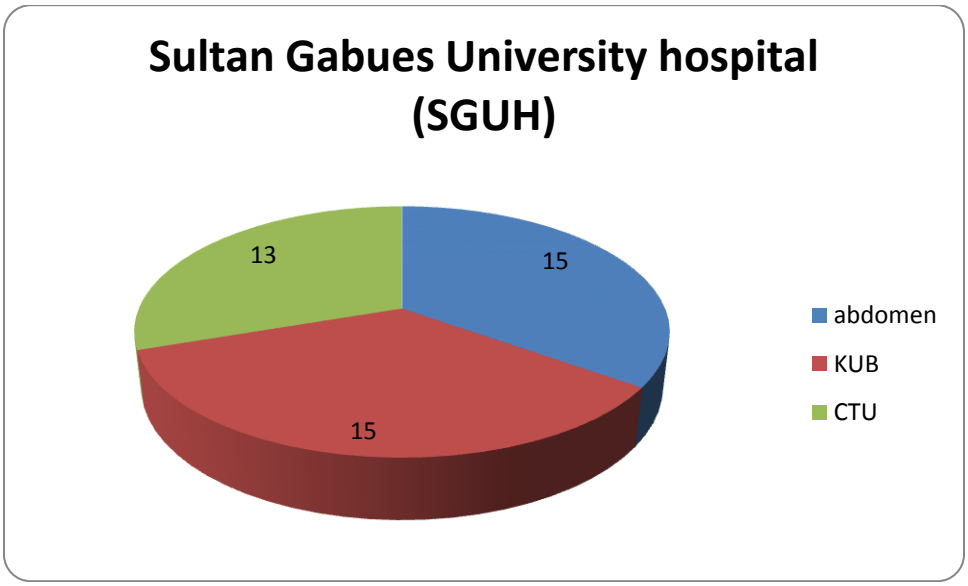


Figure 4.3 Show a Pie chart represent specific classification of ct abdominal frequency in (SGUH).

Table 4.2 Patient exposure parameters during CT abdomen procedures: Mean±sd deviation and the range in the parenthesis at constant kVp =120.
In Sultan Qabues University hospital (SGUH)

Examination	CTDI vol	DLP	mAs
Abdomen	214.1±109.5 (56.0-382.0)	3113.2±527.1 (2333-4165)	150±0
KUB	16.3±6.0 (12.00-26.30)	855.7±299.8 (508-1362)	158±13.7 (150-180)
CTU	127.1±127.3 (61-481)	3550.4±1054.0 (2435-5877)	154.6±11.2 (150-180)

Table 4.3 Patient exposure parameters during CT procedures: Mean±sddeviation and the range in the parenthesis

In National Nizwa Governmental Hospital (NNGH)

Examination	CTDI vol	DLP	mAs

Abdomen	52.0±34.7 (19.0-119.3)	1573.3±844.1 (299.0-2567.8)	147.6±52.1 (76-208)
KUB	14.0±5.9 (5.2-23.2)	591.7±276.6 (208.04-1009.6)	273.3±140.3 (58-440)
CTU	40.0±22.4 (15.3-94.7)	1692.6±955.2 (646.7-3977.2)	192.9±119.8 (71-435)

Table 4.4 show DLP and Effective dose for CT abdomen patients in the two hospitals

Hospital	DLP mGy.cm	Effective Dose mSv
National Nizwa Governmental Hospital(NNGH)	1212.4±875.7	18.2±13.1
Sultan Qabues University hospital (SQUH)	2457.9±1370.9	36.9±20.6

Chapter Five:

Discussion conclusion Recommendations

5.1 Discussion

Table: 5.1: Comparison of patient dose during CT ABD with previous studies**:**

Author	No. of pts	Exam	Machine model	Pitch	kVp	mAs	Slice th	Dose mSv		
								CTDIvol	DLP	Effective dose
Ali Abdelrazig	31	Chest, Abd, Brain & s	Toshiba Sensation aquilion 64	1.5	120	242.8	5.5	178.3	2344.4	20.05
A.M Nour	83	Abd	Siemens Somatom emotion	0.75-1	80-120	42-243	24	18.87 mGy	865.3 mGy.cm	13.5
Entisar Omer	51	CTU	Siemens Somatom emotion duo		110-130	37-111		25.1-10.95	85-425	1.29-6.37
European Commission1999		Routine Abd, Pelvis & Liver							780	11.7
I.I.Suliman	445	Head, chest, abd& pelvis	Toshiba Somatom sensation 16	NA	120	41±17	5.8±1	65	507.3	11.3
In this study	72	abdomen	PhilipsIngenuity128 Siemens	N.A	120		N.A	115.9	1608.24	17.38

			Ingenuity 64							

5.2 Conclusion

The radiation dose was measured in tow hospitals using different CT modalities. The radiation doses higher in Sultan Qabues University hospital (SGUH) while the radiation dose in National Nizwa Governmental Hospital(NNGH) the lowest. MSCT scanners 128 slice exposed patients to a higher dose than 64 slice scanners.Radiation dose from CT procedures varies from patient to patient. A particular radiation dose will depend on the size of the body part examined, the type of procedure, and the type of CT equipment and its operation. Typical values cited for radiation dose should be considered as estimates that cannot be precisely associated with any individual patient, examination, or type of CT system. The main dose variations in the same Ct unit could be attributed to the different techniques, which justify the important of use radiation dose optimization technique and technologists training.Dose reduction strategies must be well understood and properly used.

5.3 Recommendations

Using the best strategies available for reducing radiation doseto allow for mAs reduction in relation to the patient's size and weight, adapted tube current based on patient sizesuch as (weight with fixed tube current scanning)

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

(ii) Further studies are highly encouraged in this field with larger samples and different CT modalities.

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

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.