Sudan University of Sciences and Technology

College of Graduate Studies

Optimization of Radiation Dose for Brain Computerized Tomography
امثلة الجرعة الاشعاعية لفحص الدماغ بالاشعة المقطعية

A Thesis Submitted in Partial Fulfillment for the Requirements of Master Degree of Science in diagnostic Radiological Technology

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• Abstract:

This study was conducted to evaluate the effective dose in adults during the examination of the brain computed tomography. The motivations for this study that frequency of the brain CT test is high and the radiation field of brain CT contain sensitive organ like eyes. By mathematical equation after it has been collecting the factors that affect the amount of radiation from producer ray tube in addition to the two factors CT radiation dose index (CTDI) and the dose length product (DLP) .the cancer risk was calculated by special program by used the factor dose length product. This study was done in three different centers on three different devices in the generations to collect 60 samples from (1-7-2014) to (10/03/2015) The study found that the effective dose in the first center (A1) may be worth (3.29 ± 0.55) This value is higher than the agreed value of the world while in second center (B2) has reached the value (0.545 ± 0.21) and this was set up by Ali that they value are also acceptable in third center (C3) amounted to value (2.0123 ± 0.24) which is also acceptable.

- الملخص:

أجريت هذه الدراسة لتقييم الجرعة المؤثرة والعوامل التي تؤثر عليها عند البالغين أثناء فحص المخ بواسطة الأشعة المقطعية كان الدافع لهذه الدراسة ان فحص المخ بالأشعة المقطعية هو الأكثر ترددا من بين الفحوصات الاخري علما بأن المساحة التي يغطيها الأشعاع بها اعضاء حساسة للأشعة كالعين. تم التقييم عن طريق معادلة حسابية بعد أن تم تحصيل العوامل التي تؤثر علي كمية الأشعة المنتجة من أنبوب الأشعة بالإضافة إلي عاملين هما مؤشر جرعة الإشعاع المقطعي (CTDI) وطول الجرعة المنتجة (DLP). كذلك تم حساب احتمالية حدوث مرض السرطان عن طريق برنامج حسابي متخصص وذلك عن طريق استخدام طول الجرعة المنتجة تم عمل هذه الدراسة في ثلاثة مراكز مختلفة وعلي ثلاثة أجهزة مختلفة في الأجيال بجمع 60 عينة في الفترة من (1-7-2014حتى (10-3-2015) وقد توصلت الدراسة إلي أن الجرعة المؤثرة في المركز الأول (A1) قد بلغت قيمتها (3.29±0.55) وتعتبر هذه القيمة اعلي من القيمة المتفق عليها عالميا أما في المركز الثاني (B2) قد بلغت القيمة (0.545±0.21) وهذه تم تقيمها علي أنها قيمة مقبولة. أيضا في المركز الثالث (C3) بلغت القيمة (2.0123±0.24) وهي مقبولة أيضا.

Dedication

This work is especially dedicated to my family beloved parents who support me always…

And to my wife

Give me what I need over all these years…

From my deep hearts I can't say thing except that may Allah save our mothers and father…

Acknowledgment:

Deep sincere thank to our spirituous father and teacher who believe on us to be what we are now

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2-D image	Two Dimensions Image
HU	Hounsfield Unit
CT	Computed Tomography
$CTDI_{vol}$	Computed Tomography Dose Index
RTA	Road Traffic accidents
CSF	Cerebrospinal Fluid
DLP	Dose Length Product.
ED	Effective Dose
msv	Millisevert
ICRP	Dose Length Product.
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
mA	Milliamperage
kVp	Kilo-voltage Peak
CAT	Computerized Axial Tomography
MSCT	Multi-Slice CT
kW	Kilowatts
MDCT	Multi-Detector CT
CPU	Central Processing Unit
RAM	Random Access Memory
ROM	Read-Only Memory

WORM	Write-Once Read-Many Times Memory
SAM	Serial Access Memory
HIPAA	Health Insurance Portability and Accountability Act
FOV	Field Of View
ALARA	As Low As Reasonably Achievable
TLD	Thermo-Luminescent Dosimeter
MSAD	Multiple Scan Average Doses
NCRP	National Council on Radiation Protection
AAPM	American Association of Physicists in Medicine.
ECG	Echocardiography

Chapter one

1.1: Introduction

Tomography refers to the cross-sectional imaging of an object from either transmission or reflection data collected by illuminating the object from many different directions. The impact of this technique in diagnostic medicine has been revolutionary, since it has enabled doctors to view internal organs with unprecedented precision and safety to the patient. The first medical application utilized x-rays for forming images of tissues based on their x-ray attenuation coefficient. More recently, however, medical imaging has also been successfully accomplished with radioisotopes, ultrasound, and magnetic resonance; the imaged parameter being different in each case. (Avinash C. Kak 1988)

There are numerous nonmedical imaging applications which lend themselves to the methods of computerized tomography. Researchers have already applied this methodology to the mapping of underground resources via cross borehole imaging, some specialized cases of cross-sectional imaging for nondestructive testing, the determination of the brightness distribution over a celestial sphere, and three-dimensional imaging with electron microscopy. Fundamentally, tomographic imaging deals with reconstructing an image from its projections. In the strict sense of the word, a projection at a given angle is the integral of the image in the direction specified by that angle. (Avinash C. Kak 1988)

A mathematical description of the method for reconstruction of a 2-D image from projections was given by Johann radon in 1917. Imaging instrumentation and computers evolved to a level in the 1960s enabling researchers to apply the theory to the reconstruction of cross-section images from projections acquired from physical objects. In 1972s x-ray computed tomography (CT) was introduces for clinical use and immediately followed by extensive technological refinements. (Avinash C. Kak 1988)

In 1979A.M.Cormack and godfrey Hounsfield were jointly awarded the Nobel prize for CT invention. Computed tomography is a medical imaging methods based on X-ray and is characterized by computerized tomography clearly very high image and shows details of the bone and soft tissue with high accuracy. Return call to the fact that this method is given pictures of X-ray in the form of sections of the body, being computed tomography by a special device, called a computed tomography or scanner, characterized by this method is accurate, give clear images, and can give images of parts may be difficult photographed, as well as scan be done quickly and accurately. CT scanning devices are classified into several generations by the development of mechanism scanning speed and the length of time it takes to compose your image. CT scans of the brain can provide more detailed information about brain tissue and brain structures than standard X-rays of the head, thus providing more information related to injuries or diseases of the brain. Dose in CT affected by many factors one of this factors is Volume Computed Tomography Dose Index ($CTDI_{vol}$) it is standardized parameter to measure Scanner Radiation Output. (Avinash C. Kak 1988)

1.2: Problem of the study:

CT for brain is the first choice of routine tests done at any CT medical radiology center. Brain contains a lot of structures that demand a CT brain scan for diagnoses many brain diseases also for patients who suffer from head injuries at RTA. For that reason frequency of CT brain is very high, it’s exceeds 40% of examination at Khartoum radiology scanning center. As known high dose at CT scan especially for brain, which has very sensitive organs (eye lens, thyroid, and sometimes breast) for radiation, the doses to tissues from CT can often approach or exceed the levels known to increase the probability of cancer. That mean a higher incidence of some diseases like eyes cataract, thyroid abnormal function, skin diseases In addition to many cancers affect this organs and its surrounded organs. Therefore the radiation dose measurement during the brain CT examination is considered a significant issue in order to match the accepted level of received dose for these organs.

1.3: Objectives of the study:

1.3.1: General objective:

To calculate and evaluate the dose during computed tomography of the brain by using different protocols in different center in order to compare its dose value with standard international acceptable level of brain CT doses.

1.3.2: Specific objectives:

- Evaluate the suitable amount of radiation dose for adult patients during brain scanning.
- Estimate the effective dose for the patient undergoing CT exam.
- To correlate between the doses and the technical parameters of the scan.
- Rule out the responsibility of technologist, physicians, radiologist for reduces of radiation dose and image quality.

1.4: Significant of this study:

The prominence of this study is to optimize the radiation dose, estimate the effective dose and radiation risk during adult computed tomography (CT) for brain, when the exam performed at different centers by different machine generations.

1.5: Overview of this study:

This study was consist of five chapters, chapter one will be an introduction introduce briefly this thesis and it was contain, general introduction about the CT dose measurement and radiation risk, problem of the study, general and specific objectives, significant of the study in addition to the overview of the study. Chapters two was the literature review which contain the general theoretical background and previous study about evaluation of dose and calculate of doses during computed tomography scan for brain also effective dose and risk of radiation. Chapter three will describe the methodology (materials, methods) was used in this study. Chapter four was including result of presentation of final finding of study. Chapter five was including discussion, conclusion and recommendation for future scope in addition to references and appendices.

Chapter Two

2.1: Theoretical Background

2.1.1: Anatomy of the Brain:

The nervous system is one of the regulating systems electrochemical impulses of the nervous system make it possible to obtain information about the external or internal environment and do whatever is necessary to maintain homeostasis. Some of this activity is conscious, but much of it happens without our awareness.

The nervous system Have two divisions the central Nervous system consists of the brain ,Spinal cord and the peripheral nervous system.the peripheral nervous system consists of cranial nerves and spinal nerves. The basic function of the central nervous system is processing of information, coordination of voluntary involuntary behaviors and higher-order cognition. (m.f.reiser 2009)

The brain of a man weighs on average 1375 g, that of a woman about 1245 g. The lesser weight in the woman is ascribed to the weaker Development of her loco-motor system and its consequently reduced representation in the CNS. However, when the actual brain weight is compared to body weight (brain/body weight ratio), women show on an average 22 g of brain weight per kg of body weight, while in men the figure is 20 g. The connective tissue membranes that cover the brain and spinal cord are called meninges; the three layers are illustrated. The thick outermost layer, made of fibrous connective tissue, is the dura-mater, which lines the skull and vertebral canal. The middle arachnoid membrane is made of web-like strands of connective tissue. The innermost pia mater is a very thin membrane on the surface of the spinal cord and brain. Between the arachnoid and the pia mater is the subarachnoid space, which contains cerebrospinal fluid (CSF), the tissue fluid of the central nervous system. The brain consists of many parts that function as an Integrated whole. The major parts are the medulla, Pons, midbrain, the cerebellum, the hypothalamus, the thalamus and the cerebrum. (m.f.reiser 2009)

2.1.2: Ventricles:

The ventricles are four cavities within the brain: two lateral ventricles, the third ventricle, and the fourth ventricle. Each ventricle contains a capillary network called a choroid plexus, which forms cerebrospinal fluid (CSF) from blood plasma. Cerebrospinal fluid is the tissue fluid of the central nervous system; its circulation and functions will be discussed in the section on meninges. (m.f.reiser 2009)

2.1.3: Medulla:

The medulla extends from the spinal cord to the pons and is anterior to the cerebellum. Its functions are those we think of as vital (as in “vital signs”). The medulla contains cardiac centers that regulate heart rate, vasomotor centers that regulate the diameter of blood vessels and, thereby, blood pressure, and respiratory centers that regulate breathing. You can see why a crushing injury to the occipital bone may be rapidly fatal we cannot survive without the medulla. Also in the medulla are reflex centers for coughing, sneezing, swallowing, and vomiting.

2.1.4: Pons:

The pons bulges anteriorly from the upper part of the medulla. Within the pons are two respiratory centers that work with those in the medulla to produce a normal breathing rhythm. The many other neurons in the pons connect the medulla with other parts of the brain. (m.f.reiser 2009)

2.1.5: Midbrain:

The midbrain extends from the pons to the hypothalamus and encloses the cerebral aqueduct, a tunnel that connects the third and fourth ventricles. Several different kinds of reflexes are integrated in the midbrain, including visual and auditory reflexes. (m.f.reiser 2009)

2.1.6: Cerebellum:

The cerebellum is separated from the medulla and pons by the fourth ventricle and is inferior to the occipital lobes of the cerebrum. Many functions of the cerebellum are concerned with movement. These include coordination, regulation of muscle tone, the appropriate trajectory and endpoint of movements, and the maintenance of posture and equilibrium. Notice that these are all involuntary; that is, the cerebellum functions below the level of conscious thought. This is important to permit the conscious brain to work without being overburdened. (m.f.reiser 2009)

2.1.7: Hypothalamus:

Located superior to the pituitary gland and inferior to the thalamus, the hypothalamus is a small area of the brain with many diverse functions as Production of antidiuretic hormone and Oxytocin, Production of releasing hormones that stimulate the secretion of hormones by the anterior pituitary gland, Regulation of body temperature by promoting responses such as sweating in a warm environment or shivering in a cold environment, Regulation of food intake the hypothalamus is believed to respond to changes in blood nutrient levels, to chemicals secreted by fat cells, and to hormones secreted by the gastrointestinal tract, Integration of the functioning of the autonomic nervous system, which in turn regulates the activity of organs such as the heart, blood vessels, and intestines, Stimulation of visceral responses during emotional Situations, Regulation of body rhythms such as secretion of hormones, sleep cycles, changes in mood, or mental alertness. (m.f.reiser 2009)

2.1.8: Thalamus:

The thalamus is superior to the hypothalamus and inferior to the cerebrum. The third ventricle is a narrow cavity that passes through both the thalamus and hypothalamus. Many of the functions of the thalamus are concerned with sensation. Sensory impulses to the brain except those for the sense of smell follow neuron pathways that first enter the thalamus, which groups the impulses before relaying them to the cerebrum, where sensations are felt. Some sensations, especially unpleasant ones such as pain, are believed to be felt by the thalamus. However, the thalamus cannot localize the sensation; that is; it does not know where the painful sensation is. The sensory areas of the cerebrum are required for localization and precise awareness. The thalamus may also suppress unimportant sensations. Parts of the thalamus are also involved in alertness and awareness and others contribute to memory. For these functions, as for others, the thalamus works very closely with the cerebrum. (m.f.reiser 2009)

2.1.9: Cerebrum:

The largest part of the human brain is the cerebrum, which consists of two hemispheres separated by the longitudinal fissure. At the base of this deep groove is the corpus callosum, a band of 200 million neurons that connects the right and left hemispheres. Within each hemisphere is a lateral ventricle. The surface of the cerebrum is gray matter called the cerebral cortex. Gray matter consists of cell bodies of neurons, which carry out the many functions of the cerebrum. Internal to the gray matter is white matter, made of myelinated axons and dendrites that connect the lobes of the cerebrum to one another and to all other parts of the brain. In the human brain the cerebral cortex is folded extensively. The folds are called convolutions or gyri and the grooves between them are fissures or sulci. This folding permits the presence of millions more neurons in the cerebral cortex. The cerebral cortex is divided into lobes that have the same names as the cranial bones external to them. Therefore, each hemisphere has a frontal lobe, parietal lobe, temporal lobe, and occipital lobe. These lobes have been mapped; that is, certain areas are known to be associated with specific functions. We will discuss the functions of the cerebrum according to these mapped areas. (m.f.reiser 2009)

2.1.10: Frontal lobes:

Within the frontal lobes are the motor areas that generate the impulses for voluntary movement. The largest portions are for movement of the hands and face, those areas with many muscles capable of very fine or precise movements. It is the large size of the motor area devoted to them that gives these muscles their precision. (m.f.reiser 2009)

2.1.1: Parietal lobes:

The general sensory areas in the parietal lobes receive impulses from receptors in the skin and feel and interpret the cutaneous sensations. The left area is for the right side of the body and vice versa. These areas also receive impulses from stretch receptors in muscles for conscious muscle sense. (m.f.reiser 2009)

2.1.12: Temporal lobes:

The olfactory areas in the temporal lobes receive impulses from receptors in the nasal cavities for the Sense of smell. (m.f.reiser 2009)

2.1.13: Occipital lobes:

Impulses from the retinas of the eyes travel along the optic nerves to the visual areas in the occipital lobes. The visual association areas interpret what is seen, and enable the thinking cerebrum to use the information. (m.f.reiser 2009)

2.1.14: Association areas:-

2.1.14.1: Basal ganglia:

Are paired masses of gray matter within the white matter of the cerebral hemispheres their functions are certain subconscious aspects of voluntary movement, and they work with the cerebellum. (m.f.reiser 2009)

2.1.14.2: Corpus callosum:

As mentioned previously, the corpus callosumis a band of nerve fibers that connects the left and right cerebral hemispheres. This enables each hemisphere to know of the activity of the other. (m.f.reiser 2009)

2.1.15: Brain tumors:

2.1.15.1: Gliomas:

The most common type of primary brain tumor is the glioma accounting for approximately 45% of all intracranial tumors. Although derived from glial (supporting) cells, their precise classification is still being debated. However, several growth factors and their receptors have been identified and are associated with the development of gliomas. These tumors may contain different types of cells in the same tumor, but one commonality is loss of genetic information from chromosome 17p. Gliomas commonly occur in the cerebral hemispheres and the posterior fossa, with nearly half of all gliomas classified as the malignant glioblastoma variety .Other types of gliomas include benign astrocytoma, oligodendrogliomas, and ependymomas. (jiang hsieh 1999)

2.1.15.2: Medulloblastoma:

Like astrocytic tumors, medulloblastomas are soft, infiltrating tumors of neuroepithelial tissue. These rapidly growing tumors are highly malignant and most often occur in the cerebellum of children and young adults and usually extend from the roof of the fourth ventricle. They are more common in boys and rarely seen in adults besides of Craniopharyngioma. A Craniopharyngioma is a cystic, benign tumor growing from remnants of the development of the pituitary gland. . (jiang hsieh 1999)

2.1.15.3: Meningioma:

A meningioma is a slow-growing, generally benign tumor that originates in the arachnoid tissue. It is the most common nonglial tumor, accounting for about 15% of all intracranial tumors. Meningiomas are more frequent in women than in men, and although Meningiomas may affect individuals at any age, they usually arise in adults between the ages of 40 and 60 years. Furthermore, a loss of chromosome 22 has been isolated as a possible genetic etiology of this tumor type. Meningiomas are most often found adhering to the dura in relation to the intracranial venous sinuses. These tumors do not invade the brain but compress it with their growth. . (jiang hsieh 1999)

2.1.15.4: Pituitary Adenoma:

A pituitary adenoma is usually a benign tumor of the pituitary gland, and these tumors comprise about 15% of all intracranial tumors. Anatomically, these tumors are classified according to size, based on radiologic findings, as either microadenomas (less than <10 mm) or macroadenomas (≥10 mm). Hormones produced by the pituitary are affected, with one type of adenoma of the anterior pituitary resulting in gigantism if it develops before puberty and acromegaly if it occurs in adults because of excessive production of growth hormone (GH). Prolactin-secreting adenomas cause amenorrhea–galactorrhea syndrome, in which the breasts spontaneously secrete milk and menstrual periods cease. Pituitary adenomas may grow out of the sellaturcica. As they grow, they compress structures such as the optic chiasm, resulting in vision problems. (jiang hsieh 1999)

2.1.15.5: Tumors of Central Nerve Sheath Cells:

Two tumors of the peripheral nerve sheath are the acoustic neuroma, and schwannoma. They account for up to 10% of all intracranial tumors and are most common in middle-aged and older adults. The most common site is the eighth cranial nerve. At this location, the tumor compresses the adjacent brain tissue and erodes the temporal bone. . (jiang hsieh 1999)

2.1.16: Physics of radiation dose

Effective Dose (E) and dose length product (DLP) are CT specific dose descriptors that do not allow for comparisons with radiation exposures from other source. The only common denominator to achieve this goal is the "effective dose" effective dose (E) units (Millisevert) (msv) according to International Commission on Radiological Protection ICRP 60 (ICRP 1991) is defined as the weighted emerge of organ dose values H/1 for a number of specific organs:

$E = \sum_i W_1$ E≡ effective dose W≡ weighting factor

$E = DLP. F$ DLP≡ dose length product F≡ conversion factor

2.1.17: Radiation risk:

The individual risk from the radiation associated with a CT scan is quite small compared to the benefits that accurate diagnosis and treatment can provide. Still, unnecessary radiation may be delivered when CT scanner parameters are not appropriately adjusted for patient size. In conventional x-ray procedures medical personnel can tell if the patient has been overexposed because the resulting film is overexposed, producing a dark image. However with CT there is no obvious evidence that the patient has been overexposed because the quality of the image may not be compromised. (D.tack 2007)

Several recent articles stress that it is importance to use the lowest radiation dose necessary to provide an image from which an accurate diagnosis can be made, and that significant dose reduction can be achieved without compromising clinical efficacy. The United Nations scientific committee on the effects of atomic radiation (UNSCEAR) has highlighted that worldwide there about 93 million CT examinations performed annually at a rate of about 57 examinations per 1000 persons. UNSCEAR also estimated that CT constitutes about 5% of all x-ray examination worldwide while accounting for about 34% of the resultant collective dose. In the countries that were identified as having the highest levels of healthcare, the corresponding figures were 6% and 41% respectively.(D.tack 2007)

2.1.18: The X-ray Tube and parameters:

2.1.18.1: Exposure Time:

Exposure time is a measure of how long the exposure will continue and is measured in units of seconds, fractions of seconds, or milliseconds or thousandths of seconds. Electronic timers provide a wide range of possible settings, allowing the operator to precisely control the length of exposure. Together with milliamperage, exposure time determines the total quantity of radiation that will be product. (D karthikeyan 2005)

2.1.18.2: Milliamperage (mA):

mA Is a measure of the current flow rate in the x-ray tube circuit. It determines the number of electrons available to cross the tube and thus the rate at which x-rays are produced. You can think of mA as an indication of the number of x-ray photons that will be produced per second. Thus, the rnA setting will determine how much time is required to produce a given amount of x-ray exposure.(D karthikeyan 2005)

2.1.18.3: Kilovoltage:

The Kilovoltage or Kilovoltage peak (kVp) is a measure of the potential difference across the x-ray tube and determines the speed of the electrons in the electron stream. This determines the amount of kinetic energy each electron has when it collides with the target and therefore determines the amount of energy in the resulting x-ray beam. This energy is expressed by the wavelength of the photons. X-ray photons with shorter wavelengths have more energy and are more penetrating than those with longer wavelengths. For this reason, an increase in Kvp results in a more penetrating x-ray beam. (D karthikeyan 2005)

2.1.19: Generations of the computed tomography:

The first generation scanners, which produced a fine, pencil-thin x-ray beam with only one or two detectors, required up to 4.5 minutes to gather enough information for one slice from a 180^0 rotation of the tube and detector. The second generation scanners were greatly improved and provided a fan-shaped x-ray beam with up to 30 or more detectors. Scanning time was much shorter, at about 15 seconds per slice or 10 minute for a 40-slice exam. (M.J.booker 2012)

Third-generation scanner includes a bank of up to 960 detectors opposite the x-ray tube that together rotate around the patient in a complete 360^{0} cycle to create one slice of tissue data. The patient and table are then moved one increment through the gantry aperture, and the tube and detectors rotate a full 360^{0} cycle in the opposite direction to create a second slice of tissue data. Scanning times were again reduced significantly. In addition, 1-second scanning is used for most modern third-generation scanners. A larger aperture allows full-body scanning, which was not possible with early scanners. (M.J.booker 2012)

Fourth generation scanners developed during the 1980s and possess a fixed ring of as many as 4800 detectors, completely surrounding the patient in a full circle within the gantry. A single x-ray tube rotates through a 360^{0} arc during data collection. Throughout the continuous rotates motion, short bursts of radiation are provided by a pulsed, rotating-anode x-ray tube providing shorter scan times of down to 1 minuet for a multiple-slice exam. (M.J. BOOKER 2012)

Volume (helical/spiral) CT, with this system the patient continuously moves slowly through the aperture during the 360^{0} circling of the x-ray tube and detectors, creating a helical or “coiled spring” type of data acquisition. In this way a volume of tissue is examined, and data are collected, rather than individual slice as with other system. Volume CT systems utilize either third or fourth generation type detector arrangement, depending on the specific manufacture. The development of slip ring to replace the high tension x-ray tube cables allow for continual tube rotation, such as is necessary for helical type scanning. Formerly the x-ray tube movement was restricted by attached high-tension cables and limited to one 360^0 rotation in one direction comprising one slice, followed by another 360^0 rotation in the opposite direction, creating a second slice with the patient moved one increment between slice. The development of slip ring engineering technology allows for continuing tube rotations, which when combined with patient movement create a helical-type scan data with total scan times that are one half or less that of other third or fourth generation scanners. (M.J. BOOKER 2012)

Slip ring technology allows the x-ray tube to rotate around the patient on a ring, which transfers current to the tube by contact with the ring rather than through high tension cables. Modern volume-type scanners are capable of full volume multi planer or CT angiography three dimensional scanning. Multislice CT scanners, by late 1998 four CT manufacturers announced new multislice scanners all capable of imaging four slices simultaneously. Advantage imaging speed is a potential of multi-slice CT imaging, especially when patient motion is a limiting factor. Second advantage related to imaging speed is the ability to acquire a large number of thin slices rapidly. (M.J. BOOKER 2012)

2.1.20:X-ray radiation and Dose-Reduction Techniques:

Computed tomography (CT) has evolved into an indispensable imaging method in clinical routine. It was the first method to non-invasively acquire images of the Inside of the human body that were not biased by superposition of distinct anatomical Structures. This is due to the projection of all the information into a two dimensional imaging plane, as typically seen in planar X-ray fluoroscopy. Therefore, CT yields images of much higher contrast compared with conventional radiography. During the 1970s, this was an enormous step toward the advance of diagnostic Possibilities in medicine. GN Hounsfield, a senior research scientist in Middlesex, England announced the invention of a revolutionary imaging technique. In the year 1972, that he called computed axial transverse scanning (tomos meaning section, graphy picture in Greek). He presented a cross-sectional image of the head that revealed the internal structures of the brain in a manner previously only seen at surgery or autopsy and for the first time pathologic processes such as blood clots, tumors, and strokes could be easily seen noninvasively. (Thorsten M. Buzug.2008)

There are many different or common names for Computed/computerized tomography computerized axial transverse scanning, Computerized axial tomography (CAT), X-ray computed tomography (X-ray CT), and computed tomography (CT) is currently the preferred name.

The general idea for computed tomography is X-ray source on one side of subject and film on another, diagonally opposed then Source and detector move at constant rates in opposite directions. Source and detector distances from the imaging plane and rate of motion determined such that objects in the imaging plane always project to the same relative locations on the film. The Objects out of the plane project to several locations and are thus blurred. (Thorsten M. Buzug.2008)

The basic goals of computed tomography were based to rectify the pitfalls of conventional tomography; they are to overcome superimposition of structures, to improve the contrast of the image and to measure small differences in tissue contrast. The goals were accomplished by transmitting a collimated X-ray beam through a specific cross-section of the body, Detectors that can measure small differences in tissue contrast by computer that allows data to be manipulated and enhanced. (Thorsten M. Buzug.2008)

2.1.21: Multislice CT:

Based on the introduction of slip ring technology to get power to and data off the rotating gantry, continuous rotation of the X-ray tube and the detector became possible. The ability of continuous rotation led to the development of spiral CT scanners in the early 1990s (Crawford and King 1990; Kalender et al. 1990), a method proposed already several years before (Mori 1986; Nishimura and Miyazaki 1988). Volume data could be acquired without the danger of mis- or double-registration of anatomical details. Images could be reconstructed at any position along the patient axis (longitudinal axis, z-axis), and overlapping image reconstruction could be used to improve longitudinal resolution.

Larger volume coverage in shorter scan times and improved longitudinal resolution became feasible after the broad introduction of four-slice CT systems by all major CT manufacturers in 1998 (Klingenbeck-Regn et al. 1999; McCollough and Zink 1999; Hu et al. 2000). The increased performance allowed for the optimization of a variety of clinical protocols. Examination times for standard protocols could be significantly reduced; alternatively, scan ranges could be significantly extended. Furthermore, a given anatomic volume could be scanned within a given scan time with substantially reduced slice width. This way, for many clinical applications the goal of isotropic resolution was within reach with four-slice. (Thorsten M. Buzug.2008)

The introduction of an eight-slice CT system in 2000 enabled shorter scan times, but did not yet provide improved longitudinal resolution (thinnest collimation 8×1.25 mm). The latter was achieved with the introduction of 16-slice CT (Flohr et al. 2002a, 2002b), which made it possible to routinely acquire substantial anatomic volumes with isotropic sub-millimeter spatial resolution. ECG-gated cardiac scanning was enhanced by both improved temporal resolution achieved by gantry rotation time down to 0.375 s and improved spatial resolution (Nieman et al. 2002; Ropers et al. 2003).

The generation of 64-slice CT systems introduced in 2004 is currently the established standard in the high-end segment of the market. Two different scanner concepts were introduced by the different vendors: the “volume concept” was pursued by GE, while Philips and Toshiba aimed at a further increase in volume coverage speed by using 64 detector rows instead of 16 without changing the physical parameters of the scanner compared to the respective 16-slice version. The “resolution concept” pursued by Siemens uses 32 physical detector rows in combination with double z-sampling, a refined z-sampling technique enabled by a periodic motion of the focal spot in the z-direction, to simultaneously acquire 64 overlapping slices with the goal of pitch-independent increase of longitudinal resolution and reduction of spiral artifacts. (m.f.reiser 2009)

Today, high end single-source scanners offer rotation times of down to 0.30 s and can acquire up to 128 slices with an isotropic resolution of down to 0.3 mm (Siemens SOMATOM Definition AS+). In late 2007, two manufacturers, Philips and Toshiba, introduced single-source scanners that can acquire 256 and 320 slices during one rotation, respectively, keeping “Moore’s law of multislice CT (MSCT)” intact. When looking at the number of slices of multi-slice CT systems versus the year of their market introduction, the number of slices has increased exponentially as a function of time, roughly doubling every 2 years. This is an interesting parallel to Moore’s law in the microelectronics sector. It remains to be seen how the recent enhancements in the number of slices translate into clinical benefits of these systems as only clinical performance will be able to justify the additional costs of such large detectors. (m.f.reiser 2009)

2.1.23: Major Components of the CT scanner:

By breaking down the main CT system into subsystems with a step by step analysis, CT scanning can be readily understood. Basically, a CT scanner comprises five main units the gantry, X-ray production, computers, consoles and image storage and production. These five main units can be further divided into subdivisions or peripherals. The gantry houses the X-ray tube and detectors. The data, transmitted in the form of X-ray photons, pass into the detector where they are converted into a digital form, and then passed into the computer where analysis and reconstruction takes place. The reconstructed images are viewed on the console and may be permanently archived on magnetic tape or imaged on to hardcopy film. (M.J. BOOKER 2012)

2.1.23.1: GANTRY:

The gantry is the backbone of a CT system, so the amount of mechanical design effort placed on the gantry cannot be taken lightly. The rotating side of the gantry typically contains the x-ray tube, detector, high-voltage device, tube-cooling tank, slip ring, and other supporting devices, these components weigh well over 1000 pounds. With such a large load, the gantry still needs to maintain angular and position accuracy. Angular accuracy requires the gantry to rotate at highly constant speeds. Position accuracy requires the gantry to be free of significant vibrations in all directions (both in-plane and cross-plane). Consider, for example, clinical applications in which sub millimeter slice thickness is required. Since the width of the x-ray beam is less than a millimeter, the position of the x-ray beam should not vary more than a small fraction of the beam width during gantry rotation to ensure true sub millimeter imaging (the slice thickness of the reconstructed image is the weighted sum of the x-ray beams at different locations). Consequently, the gantry must be stable within a fraction of a millimeter for all projection angles. At a 500-mm radius (for typical CT scanners), this is not an easy task.(jiang hsieh 1999)

With increasingly demanding scan speeds, the requirements of gantry performance have also increased significantly. These requirements place large design constraints on the components that are mounted on the gantry. Since the centrifugal force increases with the square of the rotation speed, these components must endure a high G-force while conducting routine operations. Another key component of the CT system is the slip ring. Its function is to supply power to the rotating side of the gantry, transmit command signals both ways, and send the CT projection data to the stationary side. Although the slip ring was introduced to CT in the early 1980s to facilitate continuous gantry rotation, it became the de facto standard only after the invention of the helical scan mode. The data signals and the power to the x-ray tube both flow between the continuously rotating gantry and the stationary CT components through the electrical, optical, or RF connections on the slip ring. The amount of data that must be transmitted is large. For a typical multislice scanner, there are roughly 1000 channels per detector row, and each rotation contains nearly 1000 projections or views. (jiang hsieh 1999)

To avoid excessive storage on the rotating side of the scanner, the data transfer rate needs to be in sync with the data generation rate. The data transfer rate R for a 0.35-secper- revolution 64-slice scanner is:

R=Number of samples per rotation/ Time per rotation

2.1.23.2: Slip Rings:

Early CT scanners used recoiling system cables to rotate the gantry frame. This design limited the scan method to the step-and-shoot mode and considerably limited the gantry rotation times. Current systems use electromechanical devices called slip rings. Slip rings use a brush like apparatus to provide continuous electrical power and electronic communication across a rotating surface. They permit the gantry frame to rotate continuously, eliminating the need to straighten twisted system cables. (jiang hsieh 1999)

2.1.23.3: Generator

High-frequency generators are currently used in CT. They are small enough so that they can be located within the gantry. Highly stable three-phase generators have also been used, but because these are stand-alone units located near the gantry and require cables, they have become obsolete. Generators produce high voltage and transmit it to the x-ray tube. The power capacity of the generator is listed in kilowatts (kW). The power capacity of the generator determines the range of exposure techniques kV and mA settings available on a particular system. CT generators produce high kV generally (120–140 kV) to increase the intensity of the beam, which will increase the penetrating ability of the x-ray beam and thereby reduce patient dose. In addition, a higher kV setting will help to reduce the heat load on the x-ray tube by allowing a lower mA setting. Reducing the heat load on the x-ray tube will extend the life of the tube. (lois E.romans 2010)

2.1.23.4:X-ray tube:

The x-ray tube is one of the most important components of a CT system. Indeed x-ray tubes supply the necessary x-ray photons to perform the scan. In the early days of CT, pulsed x-ray tubes were generally used.1 In the pulsed mode, x-ray tubes produced x-ray photons in short-duration pulses. The pulse time varied between 1 and 4 ms. the nonoperating period was typically 12 to 15 ms during which no x-ray photons were emitted because x-ray detectors could not take measurements while the signals were sampled. Some benefits of the pulsed x-ray

tube include the elimination of a large number of signal integrators, the ability to reset the electronics between pulses, the ability to adjust pulse length and therefore photon flux based on patient size, and the potential reduction of azimuthal blurring. With the advances in electronics and tube technology, the advantages of the pulsed x-ray tube have diminished although its use in micro-CT continues. In fact, for high-speed CT scanning, pulsed x-ray tubes are disadvantageous since the duty cycle of the tube is less than 100%. The duty cycle is defined as the fraction of the x-ray emitting time over the total operating time. For high-speed scanning, it is necessary to have x-ray tubes constantly producing x-rays to provide sufficient
x-ray flux. Although the size and appearance of the x-ray tube have changed significantly since its invention by Roentgen in 1895, the fundamental principles of x-ray generation have not changed. The basic components of an x-ray tube are a cathode and an anode. The cathode supplies electrons and the anode provides the target. (jiang hsieh 1999)

X-ray photons are produced when a target is bombarded with high-speed electrons. The intensity of the produced x rays is proportional to the atomic number of the target material and to the number of electrons bombarding the target. The energy of the generated x-ray photons depends on the electric potential difference between the cathode and the anode. Most of the x-ray tubes used in CT scanners today employ the heated cathode design. The glass frame provides the housing and support to the anode and cathode assemblies and sustains a vacuum of 5×10^{-7}Torr (the vacuum level in the early operating life tends to be in the range of 10^{-6} to 10^{-7}Torr, and the internal pressure decreases over the tube life). The glass frame is a composite of several types of glass. The main section is a borosilicate glass with good thermal and electrical insulation properties. The thickness of the glass is typically between 0.18 and 0.30 mm. The glass seals at both ends of the tube are made with splice rings of various grades of glass to match the thermal expansion coefficients between the metal and the borosilicate glass. In more advanced tube designs, the glass frames are replaced with metal frames. The metal frame has the advantage of being able to operate at or near ground potential to improve the efficiency of the motor that drives the anode assembly. (jiang hsieh 1999)

Another advantage of the metal frame is the reduced spacing between the frame and anode, which accommodates a larger sized anode without significantly increasing the size of the tube envelope. The metal case can also collect off-target backscattered electrons. Since the intensity of x-ray radiation is proportional to the number of impacting electrons, it is critical to precisely control the tube current. This is accomplished by operating the cathode filament in the thermionic emission mode. In this mode, the tube current becomes strongly dependent on the cathode temperature and independent of the voltage between the cathode and the anode. (jiang hsieh 1999)

2.1.23.5: Cooling Systems:

Cooling mechanisms are included in the gantry. They can take different forms, such as blowers, filters, or devices that perform oil-to-air heat exchange. Cooling mechanisms are important because many imaging components can be affected by temperature fluctuation. (lois E.romans 2010)

2.1.23.6: Collimation and Filtration

Collimation in CT serves two purposes: to reduce unnecessary dose to the patient and to ensure good image quality. Generally speaking, there are two types of collimation: prepatient collimation and postpatient collimation. As its name implies, prepatient collimation is positioned between the x-ray source and the patient. Since x-ray photons emitted from the x-ray tube cover a very wide range in z, prepatient collimation restricts the x-ray flux to the patient to a narrow region, It's not only reduces dose to the patient, but also defines the slice thickness of the imaging plane. However, for multislice CT the slice thickness is defined by the detector aperture instead of the collimator. Because over 90% of the x-ray photons emitted from the x-ray tube are blocked by prepatient collimation, x-ray tube utilization for CT is poor. (Jiang hsieh 1999)

Due to geometric limitations, the x-ray beam, after passing prepatient collimation, has two regions (in z): umbra and penumbra. The umbra is a region in which the x-ray flux is homogeneous. If one were to look at the x-ray source at any point inside this region, one would see no blockage by the collimation. In other words, the entire x-ray focal spot can be seen at any point inside the region. The second type of collimation is postpatient collimation. Typically, two kinds of collimators are used, one for in-plane collimation and one for crossplane collimation. In-plane collimation (a grid) is used by third-generation CT scanners to reject scattered x-ray photons (this technique cannot be employed effectively by fourth generation scanners due to their wide acceptance angle. The in-plane collimator is made of many thin and highly attenuating plates that are placed in front of the detector to focus on the x-ray source. Since the path of the scattered radiation generally deviates from the original x-ray photon (the primary photon) path, the plates block these photons from entering the detector. (Jiang hsieh 1999)

2.1.23.7: Detectors:

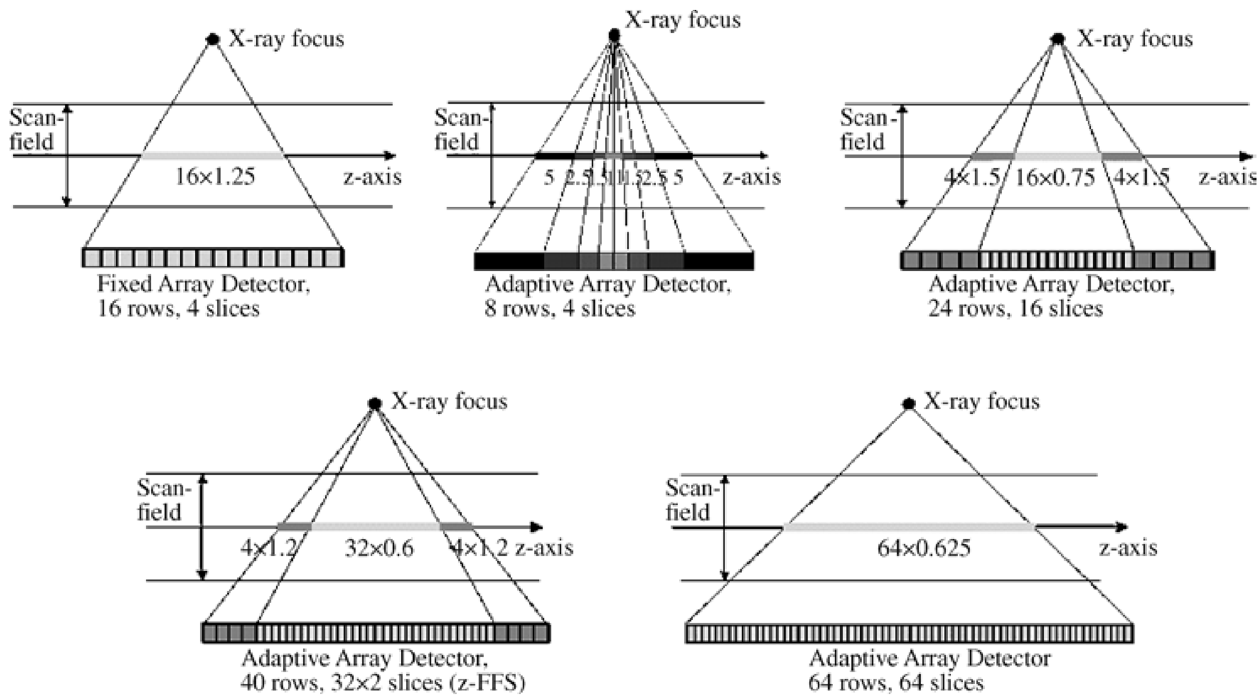
As the x-ray beam passes through the patient it is attenuated to some degree. To create an x-ray image we must collect information regarding the degree to which each anatomic structure attenuated the beam. In conventional radiography we used a film-screen system to record the attenuation information. In CT, detectors used to collect the information. The term detector refers to a single element or a single type of detector used in a CT system. The term detector array is used to describe the entire collection of detectors included in a CT system. Specifically, the detector array comprises detector elements situated in an arc or a ring, each of which measures the intensity of transmitted x-ray radiation along a beam projected from the x-ray source to that particular detector element. Also included in the array are elements referred to as reference detectors that help to calibrate data and reduce artifacts. (m.f.reiser 2009)

Detectors can be made from different substances, each with their own advantages and disadvantages. The optimal characteristics of a detector are as high detector efficiency, defined as the ability of the detector to capture transmitted photons and change them to electronic signals. Low, or no, afterglow, defined as a brief, persistent flash of scintillation that must be taken into account and subtracted before image reconstruction. High scatter suppression high stability which allows

a system to be used without the interruption of frequent calibration. Overall detector efficiency is the product of a number of factors as stopping power of the detector material. Scintillator efficiency in solid-state types Charge collection efficiency in xenon types Geometric efficiency, defined as the amount of space occupied by the detector collimator plates relative to the surface area of the detector and scatter rejection. (m.f.reiser 2009)

Other terms are sometimes used to describe aspects of a detector's efficiency. Capture efficiency refers to the ability with which the detector obtains photons that have passed through the patient. Absorption efficiency refers to the number of photons absorbed by the detector and is dependent on the physical properties of the detector. Response time is the time required for the signal from the detector to return to zero after stimulation of the detector by x-ray radiation so that it is ready to detect another x-ray event. The detector response is generally a function of the detector design. Dynamic range is the ratio of the maximum signal measured to the minimum signal the detectors can measure. All new scanners possess detectors of the solid-state crystal variety. Detectors made from xenon gas have been manufactured but have largely become obsolete as their design prevents them from use in MDCT systems. (m.f.reiser 2009)

CT detectors must provide different slice widths to adjust the optimum scan speed, longitudinal resolution and image noise for each application. With a singleslice CT detector, different collimated slice widths are obtained by pre-patient collimation of the X-ray beam. For a very elementary model of a two-slice CT detector consisting of M=2 detector rows, different slice widths can be obtained by pre-patient collimation if the detector is separated midway along the z-extent of the X-ray beam. For M>2, this simple design principle must be replaced by more flexible concepts requiring more than M detector rows to simultaneously acquire M slices. Different manufacturers of MDCT scanners have introduced different detector designs. In order to be able to select different slice widths, all scanners combine several detector rows electronically to a smaller number of slices according to the selected beam collimation and the desired slice width. (m.f.reiser 2009)



2.1.23.8: PATIENT TABLE:

The patient lies on the table or couch, as it is referred to by some manufacturers and is moved within the gantry for scanning. The process of moving the table by a specified measure is most commonly called incrimination, but is also referred to as feed, step, or index. Helical CT table incrimination is quantified in millimeters per second because the table continues to move throughout the scan. The degree to which a table can move horizontally is called the scan able range, and will determine the extent a patient can be scanned without repositioning.

(lois E.romans 2010)

2.1.24: Equipment Components Used For Image Reconstruction:

2.1.24.1: Hardware and Software:

A computer consists of both hardware and software. The hardware is the portion of the computer that can be physically touched. Software is instructions that tell the computer what to do and when to do it. Each time the x-ray tube is activated; information is gathered and fed into the system computer. The computer processes thousands of bits of data from each scan acquired to create the CT image. These data must be saved to a computer file so that the information will be available for use in the formation of an image. These stored data can later be retrieved and manipulated. The hard disk is the device within the computer that saves this information. (loise.romans 2010)

2.1.24.2: Hard Disk:

The hard disk (or hard drive) is an essential component of all CT systems. The number of images that the hard disk can store varies according to the make and model of the scanner. It is important to remember than an enormous amount of information is collected for each image. (loise.romans 2010)

2.1.24.3: Computer:

A computer consists of both hardware and software. The hardware is the portion of the computer that can be physically touched. Software is instructions that tell the computer what to do and when to do it. Each time the x-ray tube is activated; information is gathered and fed into the system computer. The computer processes thousands of bits of data from each scan acquired to create the CT image. These data must be saved to a computer file so that the information will be available for use in the formation of an image. These stored data can later be retrieved and manipulated. The hard disk is the device within the computer that saves this information. The principal components in a computer are an input device, an output device, a central processing unit (CPU), and memory. Input and output devices are ancillary pieces of computer hardware designed to feed data into the computer or accept processed data from the computer. Examples of input devices are keyboard, mouse, touch-sensitive plasma screen, and CT detector mechanisms. Output devices include monitor, laser camera, printer, and archiving equipment such as optical disks or magnetic tape. (loise.romans 2010)

2.1.24.4: Central Processing Unit

The CPU is the component that interprets computer program instructions and sequences tasks. It contains the microprocessor, the control unit, and the primary memory. In the past the CPU design frequently used for CT image reconstruction was the array processor. Also called a vector processor, this design was able to run mathematical operations on multiple data elements simultaneously. (loise.romans 2010)

2.1.24.5: Computer Memory

The three principal types of solid-state memory are read-only memory (ROM), random access memory (RAM), and write-once read-many times (WORM) memory. Both ROM and RAM are part of the system's primary memory. Primary storage refers to the computer's internal memory. It is accessible to the CPU without the use of the computer's input/output channels. Primary memory is used to store data that are likely to be in active use. Primary storage is typically very fast. ROM is imprinted at the factory and is used to store frequently used instructions such as those required for starting the system. RAM includes instructions that are frequently changed, such as the data used to reconstruct images. RAM is so named because all parts of it can be reached easily at random. RAM is very fast, but is also volatile, losing the stored data in the case of a power loss. (loise.romans 2010)

The opposite of RAM is serial access memory (SAM), which stores data that can only be accessed sequentially (like a cassette tape). WORM refers to computer storage devices that can be written to once, but read from many times. These can be subdivided into two types: those that can be physically written to only once, such as CD-R (compact disk-recordable) and DVD-R (digital video disk-recordable), and those that have rewriting capabilities but use devices that prevent data already written on a tape from being rewritten, reformatted, or erased. The rationale for disabling rewrite functionality is to comply with regulatory standards, such as the Health Insurance Portability and Accountability Act (HIPAA). (loise.romans 2010)

2.1.25: DATA TYPES:

2.1.25.1: Raw Data

All of the thousands of bits of data acquired by the system with each scan are called raw data. The terms scan data and raw data are used interchangeably to refer to the data sitting in the computer waiting to be made into an image. The process of using raw data to create an image is called image reconstruction. The reconstruction that is automatically produced during scanning is often called prospective reconstruction. The same raw data may be used later to generate a new image. This process is referred to as retrospective reconstruction. Because raw data include all measurements obtained from the detector array, a variety of images can be created from the same data. Because raw data requires a vast amount of hard disk space the CT systems offer limited disk space for the storage of raw data. (loise.romans 2010)

2.1.25.2: Image Data

To form an image, the computer assigns one value (Hounsfield unit) to each pixel. This value, or density number, is the average of all attenuation measurements for that pixel. The two-dimensional pixel represents a three-dimensional portion of patient tissue. The pixel value represents the proportional amount of x-ray energy that passes through anatomy and strikes the detector. Once the data are averaged so that each pixel has one associated number, an image can be formed. The data included in this image are appropriately called image data. Image data require approximately one-fifth of the computer space needed for raw data. For this reason it is common for CT systems to accommodate many more image data files than they do raw data files. If only image data are available, data manipulation is limited. Image data allow measurements such as Hounsfield units, standard deviation, and distance, but anything not seen on the image is unavailable for analysis. (loise.romans 2010)

2.1.26: Technical Parameters:

The quality of the image relates to the fidelity of the CT numbers and to the accurate reproduction of small differences in attenuation (low contrast resolution) and fine detail (spatial resolution). Good imaging performance demands that image quality should be sufficient to meet the clinical requirement for the examination, whilst maintaining the dose to the patient at the lowest level that is reasonably practicable. In order to achieve this, there must be careful selection of technical parameters that control exposure of the patient and the display of the images, and also regular checking of scanner performance with measurement of physical image parameters as part of a program of quality assurance. (D.Karthikeyan 2005)

2.1.26: Display and Exposure Parameters with an Influence on Image Quality and Dose:

2.1.26.1: Slice Thickness:

The slice thickness in CT is a value selected by the operator according to the clinical requirement and generally lies in the range between 1 and 10 mm.

In general, the larger the slice thickness, greater the low contrast resolution in the image; the smaller the slice thickness, the greater the spatial resolution. If the slice thickness is large, the images can be affected by artifact, due to partial volume effects; if the slice thickness is small (e.g. 1-2 mm), the images may be significantly affected by noise. (D.Karthikeyan 2005)

2.1.26.2:Inter-slice Distance/Pitch Factor:

Inter-slice distance is defined as the couch increment (distance) between two slices. In helical CT the pitch factor is the ratio of the couch increment per rotation to the slice thickness at the axis of rotation. In clinical practice the inter-slice distance generally lies in the range between 2 and 10 mm, and the pitch factor between 1 and 2. In general, for a constant volume of investigation, the smaller the inter-slice distance or pitch factor, the higher both the local dose and the integral dose to the patient. The increase in the local dose is due to superimposition of the dose profiles of the adjacent slices. (D.Karthikeyan 2005)

The increase in the integral dose is due to an increase in the volume of tissue undergoing direct irradiation as indicated by a packing factor. In those cases where 3D reconstruction or reformatting of the images in coronal, sagittal or oblique planes is required, it is necessary to reduce the inter-slice distance to zero or perform a helical scan. In screening or examinations performed with regard to control of disease it can be diagnostically justifiable to have an inter-slice distance corresponding to half the slice thickness or a pitch factor of 1.5 to 2.0. (D.TACK 2007)

2.1.26.3: Volume of Investigation:

Volume of investigation, or imaging volume, is the whole volume of the region under examination. It is defined by the outermost margins of the first and last examined slices or helical exposure. The extent of the volume of investigation depends on the clinical needs; in general the greater its value the higher the integral dose to the patient, unless an increased inter-slice distance or pitch factor is used. (D.TACK 2007)

2.1.26.4: Field of View:

Field of view (FOV) is defined as the maximum diameter of the reconstructed image. Its value can be selected by the operator and generally lies in the range between 12 and 50 cm. The choice of a small FOV allows increased spatial resolution in the image, because the whole reconstruction matrix is used for a smaller region than is the case with a larger FOV; this results in reduction of the pixel size. In any case, the selection of the FOV must take into account not only the opportunity for increasing the spatial resolution but also the need for examining all the areas of possible disease. If the FOV is too small, relevant areas may be excluded from the visible image. If raw data are available the FOV can be changed by post-processing. (D.TACK 2007)

2.1.26.5: Gantry Tilt:

Gantry tilt is defined as the angle between the vertical plane and the plane containing the X-ray tube, the X-ray beam and the detector array. Its value normally lies in the range between -25° and +25°. The degree of gantry tilt is chosen in each case according to the clinical objective. It may also be used to reduce the radiation dose to sensitive organs or tissues and/or to reduce or eliminate artifacts. (D.TACK 2007)

2.1.26.6: Reconstruction Matrix:

Reconstruction matrix is the array of rows and columns of pixels in the reconstructed image, typically 512×512.

2.1.26.7: Reconstruction Algorithm:

Reconstruction algorithm (filter or kernel) is defined as the mathematical procedure used for the convolution of the attenuation profiles and the consequent reconstruction of the CT image. In most CT scanners, several reconstruction algorithms are available. The appearance and the characteristics of the CT image depend strongly on the algorithm selected. Most CT scanners have special soft tissue or standard algorithms for examination of the head, abdomen, etc. Depending on clinical requirements, it may be necessary to select a high resolution algorithm which provides greater spatial resolution, for detailed representation of bone and other regions of high natural contrast such as pulmonary parenchyma. (D.TACK 2007)

2.1.26.8: Window Width:

Window width is defined as the range of CT numbers converted into grey levels and displayed on the image monitor. It is expressed in HU. The window width can be selected by the operator according to the clinical requirements, in order to produce an image from which the clinical information may be easily extracted. In general, a large window (for instance 400 HU) represents a good choice for acceptable representation of a wide range of tissues. Narrower window widths adjusted to diagnostic requirements are necessary to display details of specific tissues with acceptable accuracy. (D.TACK 2007)

2.1.26.9: Window Level:

Window level is expressed in HU and is defined as the central value of the window used for the display of the reconstructed CT image. It should be selected by the viewer according to the attenuation characteristics of the structure under examination. (D.TACK 2007)

2.1.27: The ALARA Principle:

The ALARA principle states that all medicinal exposure for diagnostic purposes shall be kept as low as reasonably achievable. It is based on the radiation assurance recommendations of various international expert committees and organizations and forms the cornerstone of radiation protection. Based on the assumption that there is no lower threshold for carcinogenesis, the reduction of radiation exposure to 'ALARA' remains an ongoing challenge.

2.1.28: Radiation dose in computed tomography:

Always concerned with the radiation dose to patients from various imaging studies as known CT is a high dose examination. Dose in CT is measured by the effective dose (dose received by critical organs). The majority of dose in CT scanning is delivered to the thin volume of tissue (1-10 mm) exposed to the primary beam. Tissues outside this will also receive some dose from scatter radiation. Radiation dose from CT procedures varies from 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. (m.f.reiser 2009)

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 actual dose from a procedure could be two or three times larger or smaller than the estimates. Facilities performing "screening" procedures may adjust the radiation dose used to levels less (by factors such as 1/2 to 1/5 for so called "low doses CT scans) than those typically used for diagnostic CT procedures. The quantity most relevant for assessing the risk of cancer detriment from CT procedures is the effective dose. Effective dose is evaluated in units of millisieverts (abbreviated mSv; 1 mSv = 1 mGv in the case of X-rays). Using the concept of effective dose allows comparison of the risk estimates associated with partial or whole-body radiation exposures. This quantity also incorporates the different radiation sensitivities of the various organs in the body. Estimates of the effective dose from a diagnostic CT procedure can vary by a factor of 10 or more depending on the type of CT procedure patient size and the CT system and its operating technique. The primary dose comes from the acquisition of data for slice recon. Scout scans have a lower radiation dose than their conventional counterparts. (m.f.reiser 2009)

2.1.29: Computed Tomography Dose Index:

The terms most commonly employed for expressing radiation dose exposure in daily practice are computed tomography dose index in a predefined volume ($CTDI_{vol}$) denoting dose in Gray (Gy), dose length-product (DLP), which is computed by multiplying CTDI with scan length, and effective dose, which is measured in Sievert (Sv). The former two parameters are commonly displayed on the scanner console. The $CTDI_{vol}$ value is useful for comparing different scanning protocols. The effective dose is the sum of the dose of the exposed organs, weighted by radiation sensitivity. This is not routinely done for every scan, but is the only way to compare the dose of different modalities. Effective dose in computed tomography is always an estimated Value and cannot be assigned to an individual patient. (m.f.reiser 2009)

$$CTDI = \frac{1}{N.h_{col-x}} .D(z).dz$$

* Dz = 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.

2.1.30: Dose-length product (DLP):

Dose descriptor used as an indicator of overall exposure for a complete CT examination in order to allow comparison of performance against a reference dose value set for the purpose of promoting optimization of patient protection.

$$DLP = \sum_i CTDI_w - T - N$$ (mGy.cm)

Where i represent each scan sequence forming part of an examination, and CTDIw is the weighted CTDI for each of the N slices of thickness T (cm) in the sequence. (D.Karthikeyan 2005)

2.1.31: Effective dose:

Risk-related quantity used as indicator of overall patient dose. It is defined by the International Commission on Radiological Protection (ICRP) CTDI and DLP are CT specific dose descriptors that do not allow for comparison with radiation exposure from other source. The only common denominator to achieve this goul is the effective dose (E) unites (Millisevert) (msv) according to ICRP 60 is defined as the weighted emerge of organ dose values H/1 for a number of specific organs.For adults of standard size, the following generic mean conversion factors fmean apply:

- ❖ 0.025 (mSv/mGy.cm) for the head region
- ❖ 0.060 (mSv/mGy.cm) for the neck region, scanned in head mode
- ❖ 0.100 (mSv/mGy.cm) for the neck region, scanned in body mode
- ❖ 0.175 (mSv/mGy.cm) for the trunk region. (D.TACK 2007)

$$E = DLP.f$$

(f) For Head = 0.0021 mSv/(mGy.cm) *Conversion factor f

2.1.32: Factors Affecting Radiation Dose:

There are many factors affecting of the dose on CT during exams. Scanner generation, Rotation angle 360° produce more dose, Filtration decreases the patient dose from removal of low energy X-rays, Detector efficiency, Tube current direct linear relationship between mAs and radiation dose, Slice thickness thin slice more radiation, Patient thickness, Focal spot size directly proportional. Two main variables used to describe doses received from CT scanning includes CTDI (computed tomography dose index): Measures the radiation dose within the slice width, measured using a ionization chamber, or TLD chips and MSAD (multiple scan average dose): Represents dose to a specific section location resulting from the scan at that location as well as from adjacent location. MSAD equals the CTDI from seven contiguous sections above and below the section of interests if the interval between sections is equal to the section thickness. (D.TACK 2007)

2.1.33: Factors Affecting the Dose in Conventional CT:

Beam energy and filtration is Higher at the beam energy for an otherwise constant exposure higher the dose. Use of most appropriate peak dose for a given patient keeps the dose reasonable. The type of filter used by the manufacturer also plays a major role in beam modulation. Collimation is both pre- and post-patient collimation plays a significant role in modulating patient dose. Number and spacing of adjacent sections is more sections are scanned more total volume of tissue is irradiated. Image quality and noise is Statistical noise and loss of image contrast as a result of scattered radiation, to maintain acceptable level of noise the peak kilovoltage and tube current used to acquire the image may need to be increased. (D.TACK 2007)

2.1.34: National council on radiation protection (NCRP) and measurements:

Occupational Dose Limits are 50 mSv (5 rem) annual effective dose limit, 10 mSv (1 rem) × age (y) cumulative effective dose limit, 150 mSv (15 rem)annual equivalent dose limit to lens of eye and 500 mSv (50 rem) annual equivalent dose limit to skin, hands, and feet. They are Public Dose Limits 1 mSv (0.1 rem) annual effective dose limit for continuous exposure, 5 mSv (0.5 rem) annual effective dose limit for infrequent exposure, 50 mSv (5 rem) annual effective dose limit to lens of eye, skin, and extremities. (D.Karthikeyan 2005)

2.1.35: Standard protocol for brain CT:

- ❖ Indication: Trauma, cerebrovascular accidents, seizures, congenital lesions, meningitis.
- ❖ Patient preparation: Information about the procedure; restraint from food, but not fluid, is recommended, if intravenous contrast media are to be given.
- ❖ Scanogram: Lateral scano from vertex to maxilla.
- ❖ Image criteria: Visualization of all brain structures, skull base and sinus if needed.
- ❖ FOV: Head dimension (about 24 cm). Gantry tilt: 0 to –10° from OM for axial scanning.
- ❖ X-ray tube voltage (kV): Standard
- ❖ Tube current and exposure time product (mAs): Should be as low as consistent with required image quality
- ❖ Reconstruction algorithm: Standard
- ❖ Window width: 1500-3000 HU (bones) 140-1000 HU (soft tissue)
- ❖ Window level: 200-400 HU (bones) 30-100 HU (soft tissue).

(D.Karthikeyan 2005)

2.2 Previous studies:

S. Suzuki et.al 2010 aims to measure the lens dose during brain CT scans with multi-detector row CT and to assess methods for estimating the lens dose. Some recent studies on radiation lens injuries have indicated much lower dose thresholds than specified by the current radiation protection guidelines. The material and methods were with 8 types of multi-detector row CT scanners, both axial and helical scans were obtained for the head part of a human-shaped phantom by using normal clinical settings with the orbitomeatal line as the baseline. We measured the doses on both eyelids by using a radiophoto-luminescent glass dosimeter during whole-brain scans including the orbit with the starting point at the level of the inferior orbital rim To assess the effect of the starting points on the lens doses, thy measured the lens doses by using 2 other starting points for scanning. The results were the $CTDI_{vol}$ and the lens doses during whole-brain CT including the orbit were 50.9–113.3 mGy and 42.6–103.5 mGy, respectively. The ratios of lens dose to $CTDI_{vol}$ were 80.6%–103.4%. The lens doses decreased as the starting points were set more superiorly. The lens doses during scans from the superior orbital rim were 11.8%–20.9% of the doses during the scans from the inferior orbital rim. The conclusion was $CTDI_{vol}$ can be used to estimate the lens dose during whole-brain CT when the orbit is included in the scanning range.

Niu Yet.al 2010 stated that the Temporal bone CT is performed frequently in clinical practice. At the same time, the eye lens is exposed to ionizing radiation without any useful diagnostic information delivered. Our aim was to investigate the radiation dose to the lens of the eye by using temporal bone CT scanning with different protocols. The materials and methods was direct axial and coronal CT by using a conventional sequential scanning mode (140 KV, 220 MAs/section, 1.25-mm thickness, 1.25-mm increment, 16 x 0.625mm collimation, the glabellomeatal line as a scanning baseline), a routine helical scanning mode (140 KV, 220 MAs/section, 0.315 pitch, 0.67-mm thickness, 0.33-mm increment, 16 x 0.625 collimation, the orbitomeatal line as a scanning baseline), and a modified helical scanning mode (a canthiomeatal line as a scanning baseline; other parameters, same as above) was performed on an exsomatized cadaveric head.

$CTDI_{(vol)}$ and DLP were recorded for each scanning mode, and effective doses were calculated. Organ doses for the lens were measured with TLDs. The results when the sequential scanning mode was used the gross effective dose was 1.21 msv and the organ dose to the lens was 50.96 and 1.73 mGy, respectively, for direct axial and coronal imaging. The effective dose was 0.803 msv in routine helical scanning, while the lens dose was 40.17 mGy. With the modified helical scanning mode, the effective dose was as same as that for the routine helical scanning, but the lens dose was reduced significantly to 10.33 mGy.

The conclusions of this study were effective doses resulting from sequential axial and coronal scanning was 1.51 times higher than the dose from helical scanning, and the lens dose was 1.31 times higher. With the modified helical scanning mode, thinner section images could be used to reformat axial, coronal, and sagittal images with a further 74.3% reduction in lens dose beyond that achieved with the conventional helical protocol.

Cohnenet.al 1998 stated that, In view of the increasing frequency of computed tomographic examinations the organ doses of the thyroid gland and the eye lenses in spiral CT examinations of the head and neck should be determined. The material and methods was standard CT-examinations of the neck, the paranasal sinuses in axial and coronal sections, and the mandibula were simulated by help of an alderson-rando phantom. Dose measurements were performed as well in 28 patients. The examinations were carried out in spiral mode ("Somatom AR.SP", "Picker PQ 2000", and "Toshiba Xpress SX") and conventional single slice technique ("Somatom Plus"). Three LiF-TLD were placed on each eyelid and three on the thyroid. The results with direct exposure to the x-ray-beam the organ doses did not exceed 64 mGy. When exposed by scatter radiation only, doses may be reduced by a factor of up to 10. The measurements in 28 patients showed similar results. Conclusions were the organ doses in spiral CT correspond with data known from conventional CT.

Hamacher et.al 2000 stated that CT is a frequent examination that is performed using ionizing radiation. We sought to assess image-quality changes on CT scans of the head when the radiation dose is reduced by changing tube current and kilovoltage. Methods were a formalin-fixed cadaver was examined in conventional and helical mode by use of two CT-scanners. Surface dose was measured with standard scanning parameters, and after reduction of tube current and kilovoltage. Five experienced examiners independently evaluated subjective image quality. The result was in the conventional mode, the highest surface dose was 83.2 mGy (scanner 1: helical mode, 55.6 mGy), and 66.0 mGy (scanner 2: helical mode, 55.9 mGy). By changing kVp and mAs, a dose reduction of up to 75% (scanner 1), and 60% (scanner 2) was achieved. No observable differences in image quality between scans obtained with doses from 100% to 60% of standard settings were noted. Ten of 20 images obtained with the highest dose and 13 of 20 images obtained with lowest dose (19-29.4 mGy) were reliably identified by subjective quality assessment. Scans produced with a surface dose of less than 30 mGy were judged uninterpretable. He conclude that it was standard parameters used in cranial ct are oriented toward best image quality. A dose reduction up to 40% may be possible without loss of diagnostic image quality.

Chapter three

Materials and Methods

3.1: Materials:

The study was use three computed tomography machines. MDCT scan machine, at Khartoum state. The data was collect from four centers (Al- Amal diagnostic center, Al-Nelain diagnostic center and AL-Faysal specialized Hospital. The study sample was consisting of 60 patients with CT brain after each successful examination the data was collected.

3.1.1: The Machine used at this study:

- 64-slice machine (Toshiba) made in Japan, detector array, and fan beam shape.
- Dual-slice helical (Siemens) made in German.
- 4-slice (GE) made in America.

3.2: Methods:

All the centers used same technique for brain CT of patient position which is supine but there are many different at selection of exposure parameters This study was aimed to measure the dose of radiation which is control by many parameters (Kvp, MAs, $CTDI_{vol}$, DLP, beam and gantry rotation time) this parameter was calculated using console of the machine after completion exam done. Then apply special mathematical equations to get the result of radiation output and effective dose after these calculations these received doses was computed and analyzed in order to manage the difference and the association between the parameters of the exams.

3.3: Inclusion criteria:

The study sample was including all patients with CT brain at age above to 20 years, female or male.

3.4: Exclusion criteria:

Patients age down to 20 years, female or male.

3.5: Variables of this study:

Patient age, weight, gender and clinical, KVP, MAS, pitch, collimation, rotation time, DLP data in addition to $CTDI_{vol}$.

Example of master data sheet used in data collection:

effective dose	PITCH	DLP	CTDIV	Mas	kv	scan time	gender	wt	age	cancer risk
3.2424	1.5	1544	80	225	120	15.79	2	69	42	0.03

3.6: Method of data collection analysis

The data was collected using standard master data sheet used to collect the scan parameters and patient data which contain all parameters used for calculation, the data was analyzed using Microsoft excel program and IBM SPSS statistics 21.

3.7: Ethical issues

- The data was collected with written permission from the hospitals and kept in personal computer with secret password.
- Also no patient data was published.

Example of equations used in calculation:

$$E = DLP.\ F$$

E=Effective dose.

DLP= Dose Length Products.

F=Conversion factor.

Chapter four

4.1: Result presentation

This study was conducted to measure, evaluate and to compare the CT brain doses in three different diagnostic center which was Alamal, Alfaisal and Alnelain diagnostic medical center. More than 60 patients underwent CT dose measurement and the result presented as follow:

Variable	*ED*	*Pitch*	*DLP*	*$CTDI_{vol}$*	*mAs*	*Kvp*	*Scan time*
Center A1	*3.29±0.55*	*1.26±0.257*	*1565.2±261.2*	*78.8±1.57*	*225*	*120*	*22.2±17.04*
Center B2	*0.545±0.121*	*1.1±0.21*	*259.5±57.4*	*27.36±000*	*120*	*130*	*25.09±5.7*
Center C3	*2.0123±0.24*	*1.15±0.24*	*958.3±114.08*	*51.8±5.67*	*172.5±34*	*120*	*19.53±3.079*

Table 4:1 showing the mean ± STD of scan and dose parameters of these three different centers which compare its value.

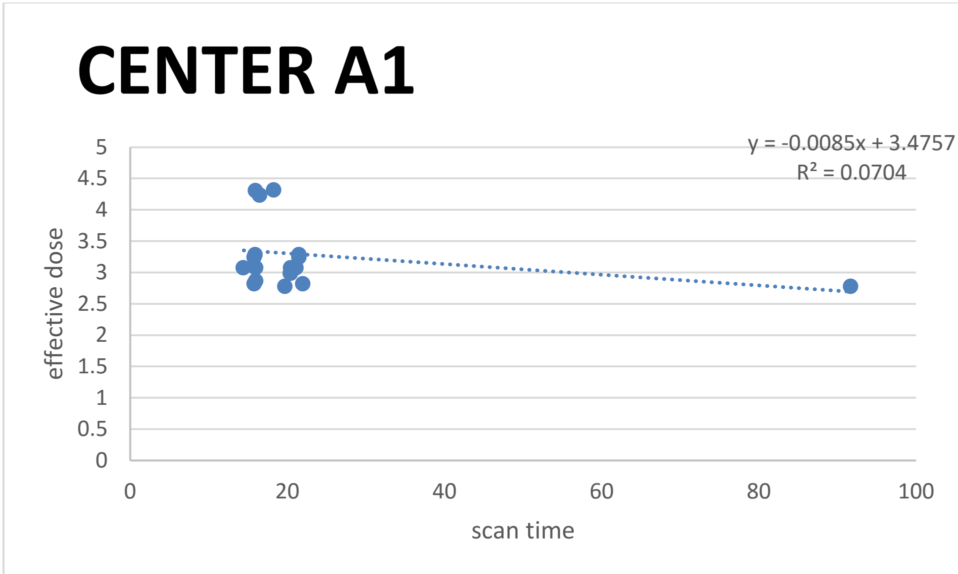


Fig 4:1 showed the relation between scan time and the effective dose

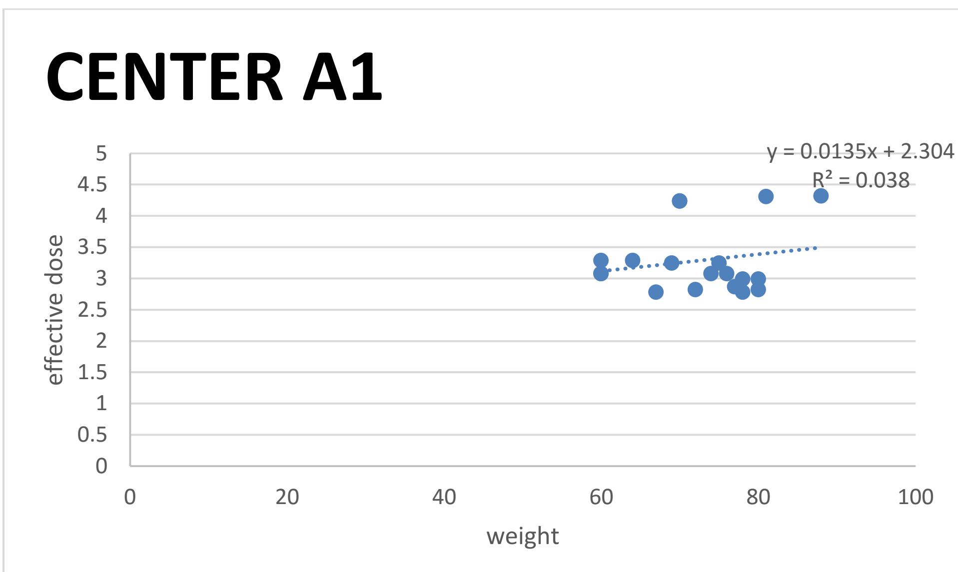


Fig 4:2 showed the relation between patient and the effective dose

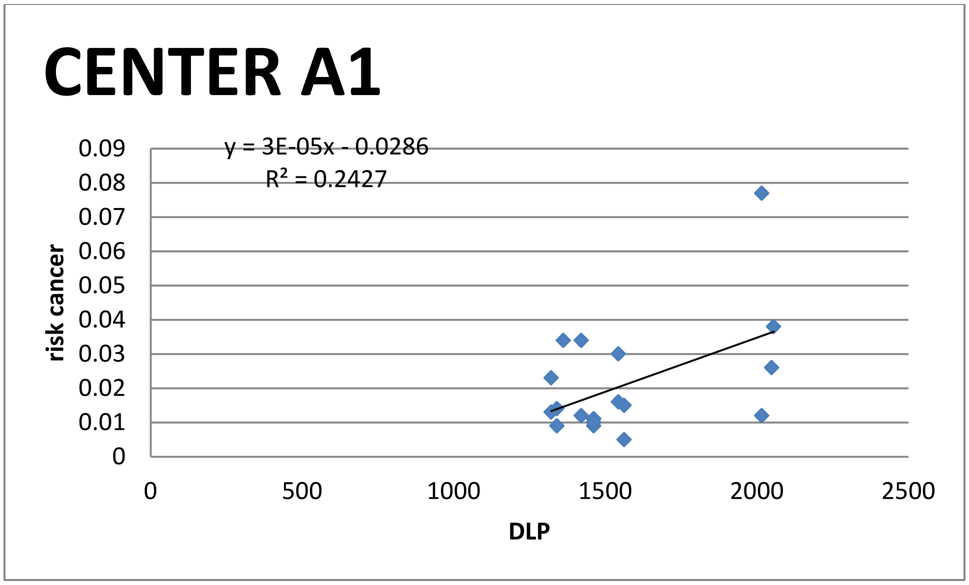


Fig 4:3 showed the relation between cancer risk factor and the dose length product

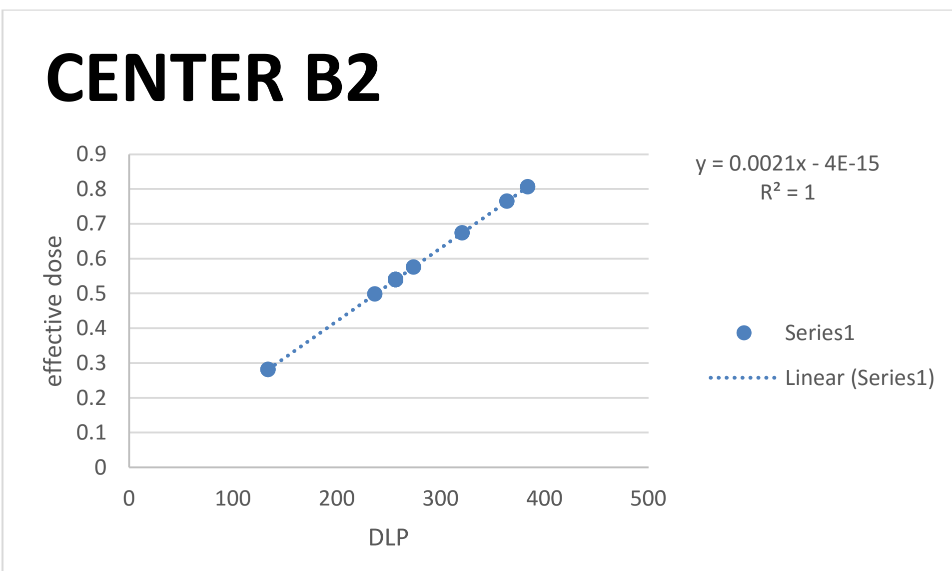


Fig 4:4 showed the relation between effective dose and the patient DLP

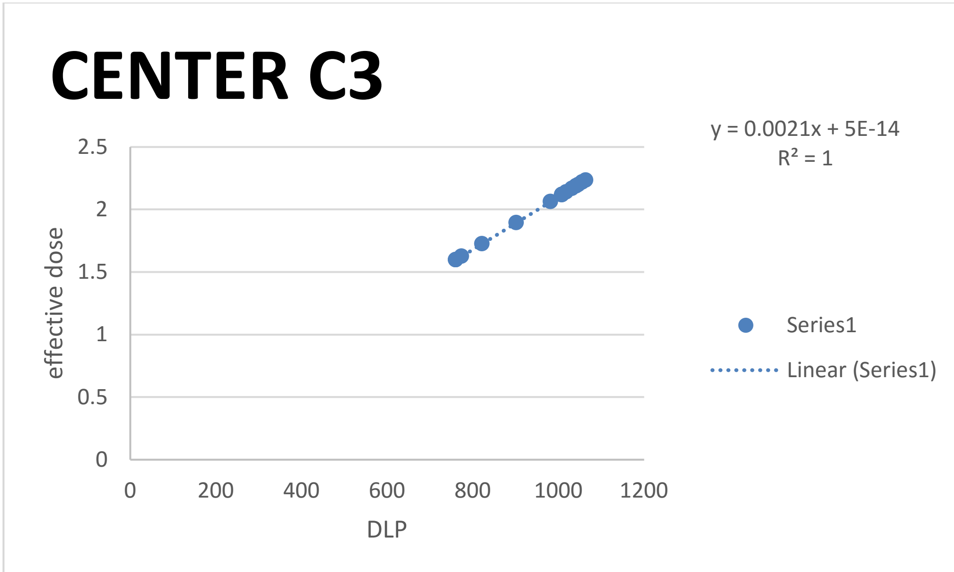


Fig 4:5 showed the relation between effective dose and the patient DLP

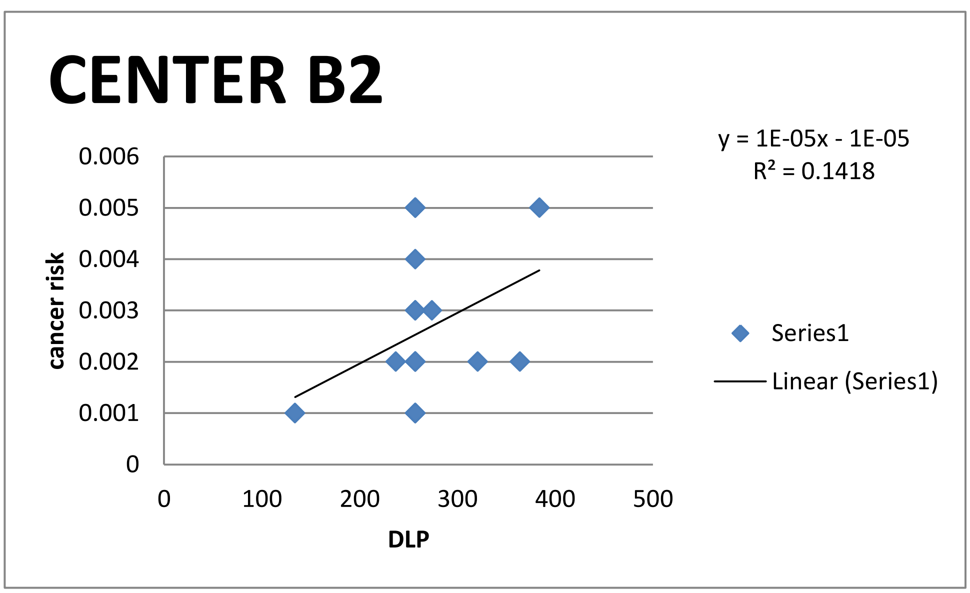


Fig 4:6Showed the relation between cancer risk and the patient DLP

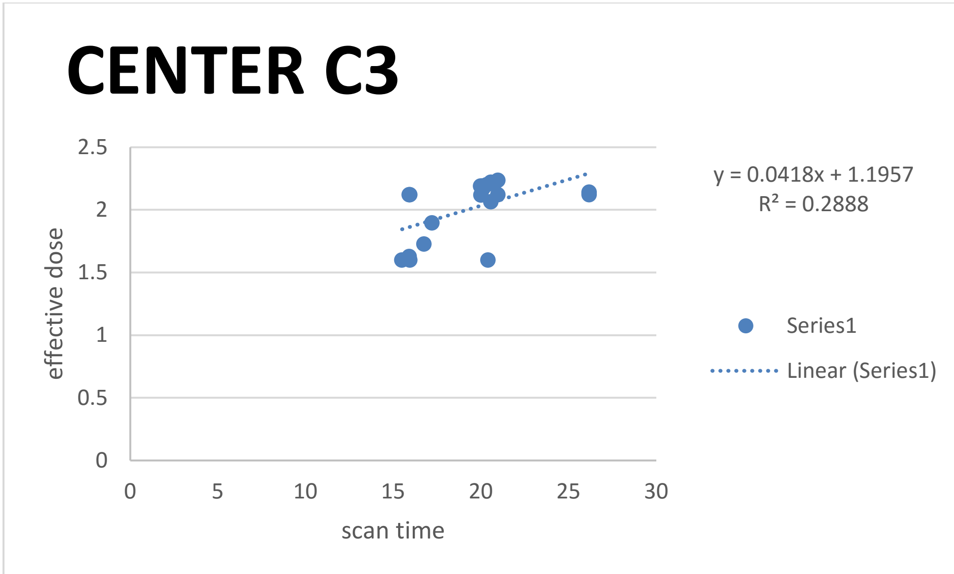


Fig 4:7 showed the relation between effective dose and the scan time

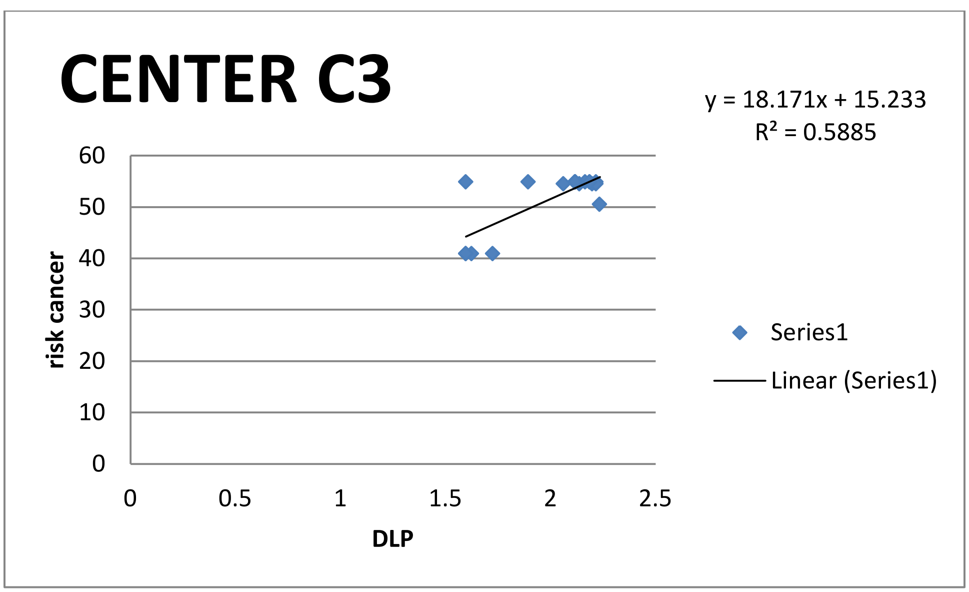


Fig 4:8 showed the relation between cancer risk and the patient DLP

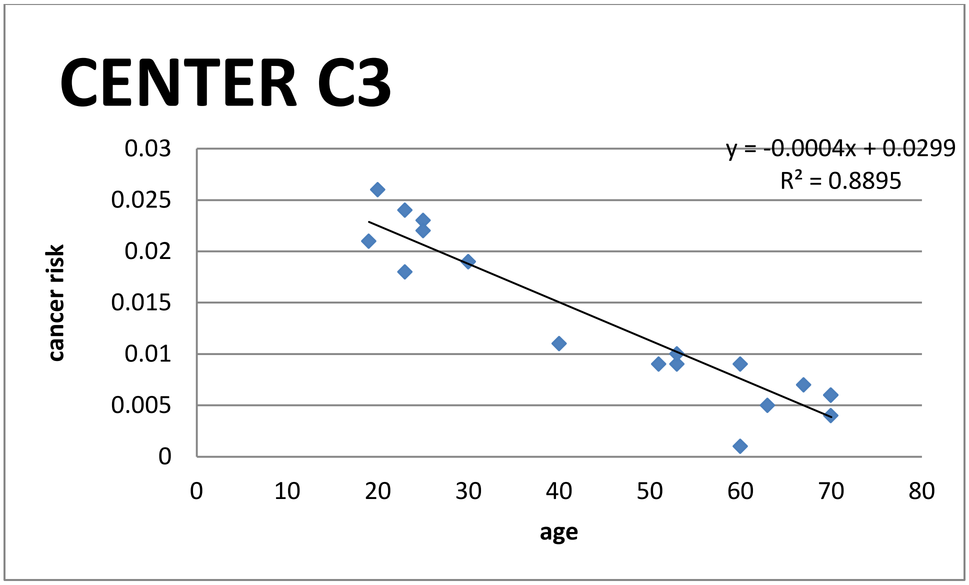


Fig 4:9 showed the relation between cancer risk and the patient age

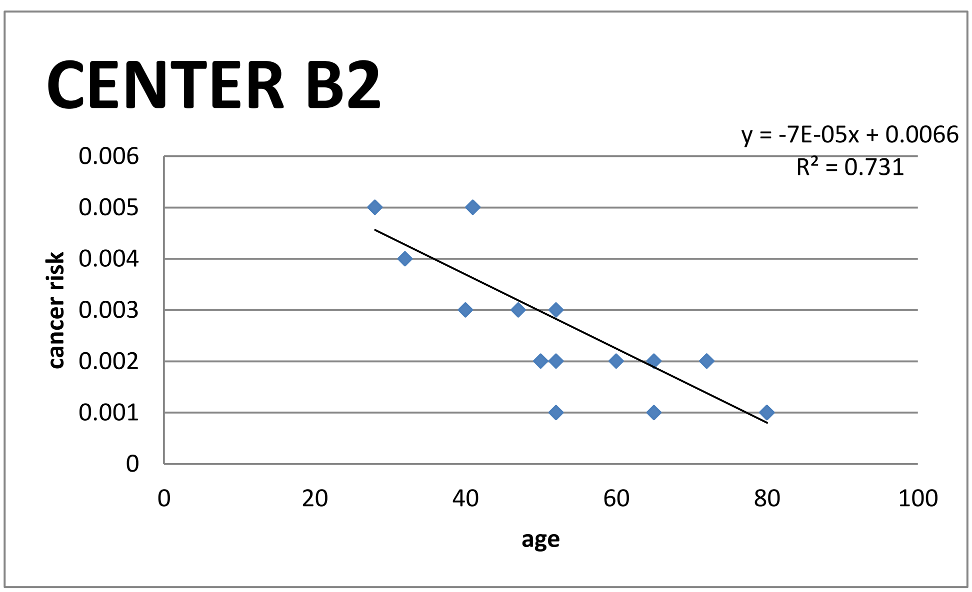


Fig 4:10 showed the relation between cancer risk and the patient age

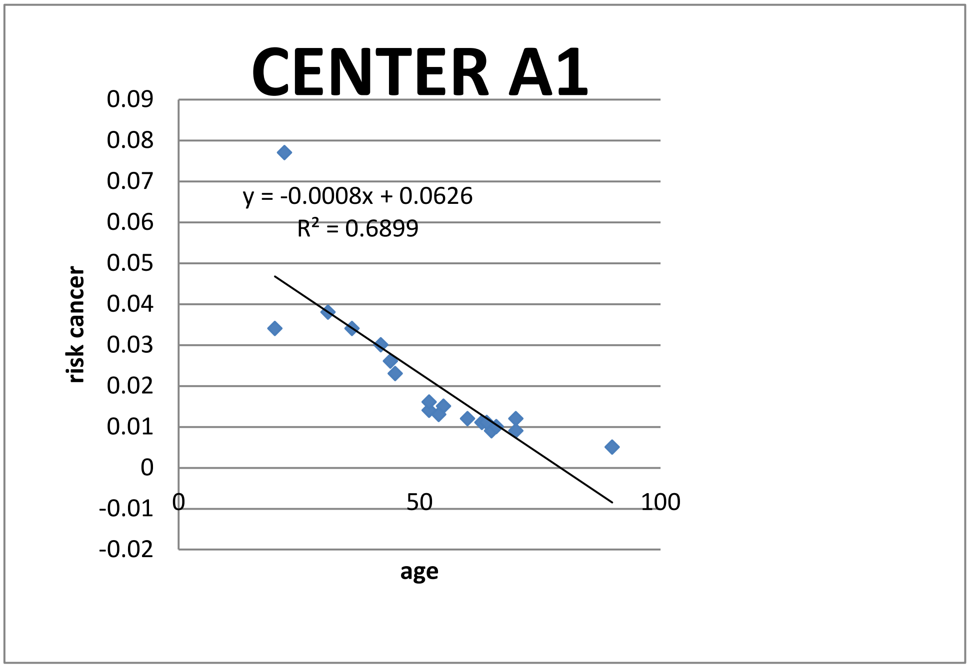


Fig 4:11 Showed the relation between cancer risk and the patient age

Chapter five

Discussion, conclusion and recommendation

5.1Discussion

There was many factor that can effects on dose in computed tomography scanning such as; X-ray tube filtration, X-ray beam shaping, Collimator design (in scan plane and along z-axis) and Focus to axis distance.

Also there was factor that can effects on dose efficiency such as; Detector material, filters Number, width and spacing of detectors, more over this study was investigate the effect of the pitch, DLP, CTDI vol, MAS , KVP and scan time which having mean ±stander deviation of 1.26±0.257, 1565.2±261.2, 78.8±1.57, 225, 120, 22.2±17.04 for canter A1. 1.1±0.21, 259.5±57.4, 27.36±000, 120, 130, 25.09±5.7 for center B2, 1.15±0.24, 958.3±114.08, 51.8±5.67, 172.5±34, 120, 19.53±3.079 for center C3 respectively.

Also the value of effective dose was measure and compared with these three center according to this values 3.29±0.55, 0.545±0.121 and 2.0123±0.24 for center A1, center B2 and center C3 respectively.

table (4:1), as we mention her a higher value noted at center A1 and this may related to higher MAS used in this center that because the MAS affect the amount of radiation coming from the cathode to target the anode in x-ray tube rather than the Kvp which responsible for the amount of penetration and x-ray quality. the pitch also affect the received dose according to this study effective dose decreased by increased the pitch and the table above describe this result This was stated by Maria Lewis 2005 stated that the absorbed radiation dose is inversely proportional to pitch if the tube current time product (mAs) and tube potential (kV) are kept constant i.e. the dose will be halved if the pitch is doubled.

Due to the nature of the reconstruction method used, on single slice scanners the imaged slice width increases as the pitch increases. In these circumstances the noise will increase as the pitch increases. Some multi-slice scanner manufacturers automatically adjust the tube current to compensate for changes in pitch. This maintains a constant noise and dose with changing pitch.

All time in all radiographic examinations it was a direct relationship between exposure time and the amount of dose received but in this study there was an inverse correlation between the effective dose and total scan time recorded by the machine after each examination which decreased by 0.0085mSv for ever one second increment in scan time and the R2= 0.07 showed a weak and significant correlation possibly due to use of high mAs, high Kvp and long scan time for center A1.

At figure (4:1) relation between scan time and the effective dose is inverse relationship that because of the value of the factors Kvp and MAs is constant and high that made the value of the DLP is high. For all this values result is high value of effective dose, but at figure (4:7) the relation is direct proportion between scan time and the effective dose and this is perfect this relations was substantiation by Paula Brill et.al at study of a guide to CT radiation dose management developed in conjunction with Weill Cornell Imaging at New York–Presbyterian.

Mannudeep K.Kalara and Pierre Alain Gerenios substantiation that at their book title by radiation dose from multi-detector CT.

A correlation was done between the effective dose and the scan time as given by the operating system of CT scanner of center A1 which showed that there was an inverse relationship between ED and the scan time of the machine and examination the dose decreased by (0.0085) as given by this equation ($y = -0.0085x + 3.4757$)

($R^2 = 0.0704$), this result compared with AAPM report no. 96 which stated that typical values of effective dose for several common imaging exams (CT and non-CT), as well as the annual level of naturally occurring background radiation in the United States (3.0mSv). For this center having value of (3.29±0.55) which was relatively more than this by (0.29mSv).But this result was not noted at center C3 which was a direct relation between both of it according to this linear association ($y= 0.0418x + 1.1957$), ($R^2 = 0.2888$) but also there is significantly weak correlation, in center B2 that due to constantly of Kvp, mAs and $CTDI_{vol}$ at figure (4:6)

The patient weight in center A1 is relatively in direct correlation with the dose and the effective dose was increased by (0.0135mSv) ($y = 0.0135x + 2.304$) ($R^2 = 0.038$) for every one kg of weight increment, this relatively significant association may be due to that the patient thickness can affected more at the site of the head when the weight increased.

The risk of cancer estimation as calculated using x-ray cancer risk calculation program as was calculated and correlated with the dose length product in order to test the effect of increment in this dose value in cancer risk, a strong correlation was noted in direct relationship; when the DLP increased by one unit the risk of cancer increased by this equation ($y = 3E\text{-}05x - 0.0286$), ($R^2 = 0.2427$). The risk of cancer caused by radiation is random as in linear non-threshold dose response curve meaning that a small amount of radiation may cause cancer but we can’t defiantly say who and when that happen, and for center B2 ($y = 0.0021x - 4E\ 15$)

($R^2 = 1$) that very strong association also noted that for center C3 at the figure (4:6 and 4:8) when compare with other centers.

The cancer risk that calculated to estimate risk originating from these received dose for patient undergoing computed tomographic examination for brain so it can affected by the age according to the correlation made with it which we found strong association between both of it according to R2=0.88 and the cancer risk decreased by 0.0004% For every one year increment in the age this for age group between 19 to 85 years In center C3 and $y = -7E\text{-}05x + 0.0066$, $R^2 = 0.731$ for canter B2, $y = -0.0008x + 0.0626$, $R^2 = 0.6899$ for center A1 this inverse relationship can be explained by that the cancer random effect decrease with age till late teen and begin to increase after age of 40 according to the bergonae and trebin doae low.

the absorbed radiation dose is inversely proportional to pitch if the tube current – time product (mAs) and tube potential (kV) are kept constant i.e. the dose will be halved if the pitch is doubled. Due to the nature of the reconstruction method used, on single slice scanners the imaged slice width increases as the pitch increases.

At figures (4:9), (4:10), (4:11) the relation between the cancer risk and age is Inverse relationship that mean when the human age increase the possibility of Incidence by cancer is increase. Vincent T.Devita confirms this relation at Cancer Principles and Practice.

5.2: Conclusion

The current study concluded that: the optimization of CT brain protocol can be obtained by applying suitable amount of KV and MAs.

Concept of dose calculation and evaluation al times considered as crucial issue in all radiation studies in order to achieve the best performance, optimization, and justification of radiographic studies at CT (computed tomography) more radiation used to achieve best image quality although there is a minimum scan time used. the calculation done for more than 60 patient underwent tomographic examination of brain, the machine used to perform this examination was MDCT scan machine, with 64-slice machine (Toshiba) (Al-Amal), detector array, and fan beam shape, dual-slice helical (Siemens) (Al-Nelain),and four slice at AL-Faysal specialized Hospital the data was collected from three center at Khartoum state diagnostic centers which was center A1, center B2 and center C3 which are Al-Amal hospital, Al Nelain diagnostic medical center And alfaisal specialized hospital. Study was investigate the effect of the pitch, DLP, $CTDI_{vol}$, MAS, KVP and scan time which having mean ±stander deviation of 1.26±0.257, 1565.2±261.2, 78.8±1.57, 225, 120, 22.2±17.04 for canter A1. 1.1±0.21, 259.5±57.4, 27.36±000, 120, 130, 25.09±5.7 for center B2, 1.15±0.24, 958.3±114.08, 51.8±5.67, 172.5±34, 120, 19.53±3.079 for center C3 respectively, also the value of effective dose was measure and compared with these three center according to this values 3.29±0.55, 0.545±0.121 and 2.0123±0.24 for center A1, center B2 and center C3 respectively.

The higher effective dose value was noted at center A1 which where *3.29±0.55mv* Compare with the standardized value considered relatively higher because of higher mAs, Kvp used during the brain scan also higher scan time and DLP.

5.3 Recommendation:

- Radiologic technologist must take into account the weigh, size and age of the patient and choose the suitable exposure factors to decrease the output of radiation.
- Use of technical advances that aim to decrease radiation dose like X-ray Beam Utilization, X-ray Filtration, Automatic Modulation of Tube Current, Computer-simulated Dose-Reduction Software and Filters.

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5:5: Appendices:

(A) standard master data sheet used in data collection:

age	wt	gender	scan time	kv	mAs	CTDIV	DLP	PITCH	effective dose	CA risk
Alamal data										
42	69	2	15.79	120	225	80	1544	1.5	3.2424	0.03
36	80	1	20.43	120	225	80.8	1422	1	2.9862	0.034
45	78	2	19.71	120	225	77	1322	1	2.7762	0.023
22	70	1	16.5	120	225	77	2017	1.5	4.2357	0.077
63	74	2	21.14	120	225	80	1463	1	3.0723	0.011
20	77	1	16	120	225	77	1363	1.5	2.8623	0.034
55	64	2	15.91	120	225	80	1563	1.5	3.2823	0.015
31	88	1	18.29	120	225	80	2056	1	4.3176	0.038
52	80	2	22	120	225	77	1341	1	2.8161	0.014
52	75	1	21.5	120	225	80	1544	1	3.2424	0.016
60	78	2	20.42	120	225	77	1422	1	2.9862	0.012
54	67	2	19.71	120	225	80	1322	1	2.7762	0.013
70	70	1	16.5	120	225	77	2017	1.5	4.2357	0.012
65	72	2	15.79	120	225	80	1341	1.5	2.8161	0.009
64	60	1	14.42	120	225	80	1463	1.5	3.0723	0.011
44	81	1	15.97	120	225	77	2050	1.5	4.305	0.026
70	76	1	20.43	120	225	80	1463	1	3.0723	0.009
90	60	1	21.5	120	225	77	1563	1.5	3.2823	0.005
66	60	1	16	120	225	80	1463	1.5	3.0723	0.01
Alnelain										
28	65	1	16.33	130	120	27.36	257	1.5	0.5397	0.005
80	80	2	30.38	130	120	27.36	257	1	0.5397	0.001
65	70	1	26.44	130	120	27.36	257	1	0.5397	0.001
52	60	1	27.95	130	120	27.36	257	1	0.5397	0.002
80	60	1	16.03	130	120	27.36	134	1.5	0.2814	0.001
41	75	1	23.09	130	120	27.36	384	1	0.8064	0.005
32	89	1	28.65	130	120	27.36	257	1	0.5397	0.004
40	70	2	27.65	130	120	27.36	257	1	0.5397	0.003
50	70	2	30.53	130	120	27.36	257	1	0.5397	0.002
47	80	1	30.53	130	120	27.36	274	1	0.5754	0.003
72	70	1	26.44	130	120	27.36	321	1	0.6741	0.002
72	70	1	28.71	130	120	27.36	257	1	0.5397	0.002
60	80	1	16.3	130	120	27.36	237	1.5	0.4977	0.002

28	70	1	31.74	130	120	27.36	257	1	0.5397	0.005
80	65	1	16.33	130	120	27.36	134	1	0.2814	0.001
65	65	1	30.83	130	120	27.36	364	1	0.7644	0.002
52	70	1	26.44	130	120	27.36	257	1	0.5397	0.003
52	65	1	27.95	130	120	27.36	257	1	0.5397	0.001
80	80	1	16.3	130	120	27.36	257	1.5	0.5397	0.001
41	70	1	23.09	130	120	27.36	257	1	0.5397	0.005
Alfaisal										
23	82	1	15.93	120	150	40.9	774.2	1.5	1.62582	0.018
25	70	1	20.99	120	200	50.5	1064.5	1	2.23545	0.023
30	79	2	26.19	120	200	54.5	1018.7	1	2.13927	0.019
63	64	2	15.96	120	150	40.9	760.8	1.5	1.59768	0.005
60	74	1	20.35	120	200	54.5	1047.4	1	2.19954	0.009
19	79	1	16.76	120	150	40.9	822.1	1.5	1.72641	0.021
70	69	1	20.84	120	150	54.9	1056.3	1	2.21823	0.006
53	59	2	17.22	120	200	54.9	902.2	1	1.89462	0.009
70	69	1	15.5	120	200	40.9	760.8	1.5	1.59768	0.004
53	86	2	20.59	120	200	54.5	1056.3	1	2.21823	0.01
70	62	1	20.59	120	200	54.5	982.2	1	2.06262	0.006
40	76	2	20.42	120	200	54.9	760.8	1	1.59768	0.011
70	78	1	20.11	120	100	54.9	1041.6	1	2.18736	0.006
20	80	1	20.13	120	100	54.9	1031.8	1	2.16678	0.026
60	60	1	20.01	120	150	54.9	1041.6	1	2.18736	0.001
51	82	2	20.02	120	200	54.9	1008.36	1	2.117556	0.009
67	70	1	15.93	120	150	54.9	1008.9	1.5	2.11869	0.007
23	70	2	20.99	120	200	54.9	1008.9	1	2.11869	0.024
25	80	2	2619	120	200	54.9	1008.9	1	2.11869	0.022
30	82	1	15.96	120	150	54.9	1008.9	1.5	2.11869	0.019