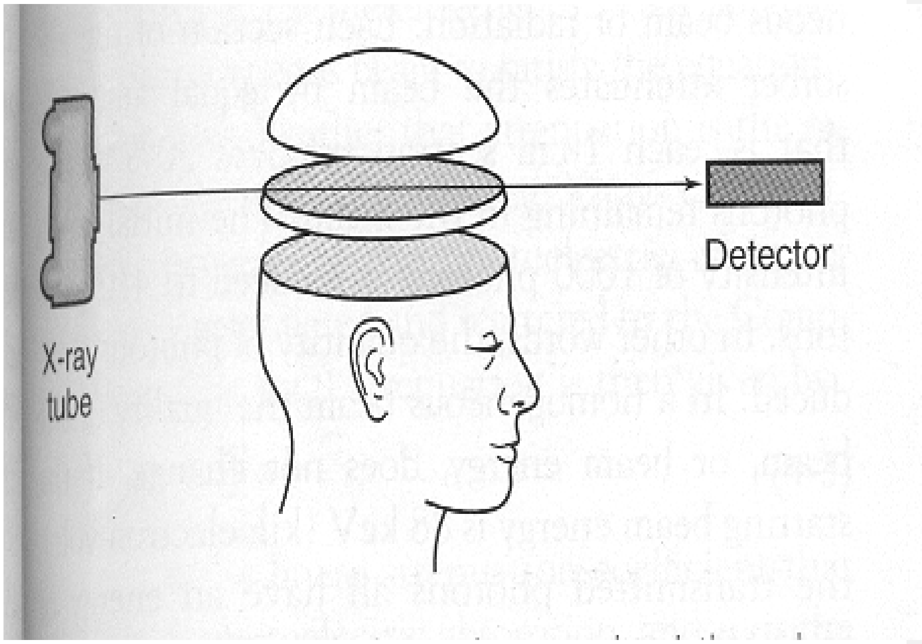
Chapter 3

3.1.: computed tomography:

Computed tomography (CT) is the science that creates two-dimensional cross-sectional images from three-dimensional body structures. Computed tomography utilizes a mathematical technique called reconstruction to accomplish this task. It is important for any individual studying the CT science to recognize that CT is a mathematical process. Practically we can say- Computerized Tomography is the process of scanning a patient to gather x-ray absorption coefficients taken from thin sections through the body, obtaining multiple measurements from these coefficients and reconstructing these measurements into an image that displays that section’s anatomy.

generate a three-dimensional image of the inside of an object from a large series of two-dimensional radiographic images taken around a single axis of rotation.

Ct utilizes mathematical technique called reconstruction to accomplish this task,a CT image is a result of "breaking part" a three dimensional structure and mathematically putting it back together again and displaying it as a two-dimensional image on a television screen.this goal is accomplished by computed tomography's superior ability to overcome superimposition of structures and demonstrates slight differences in tissue contrast .



Figure(3.1) show simple description to Computer Tomography

Formatted: Font: Bold, Complex Script Font: Bold

3.2: basic principles of CT:

Fundmentally, a CT scanner makes many measurements of attenuation through the plane of a finite-thickness cross section of the body .the system uses these data to reconstruct a digital image of a cross section , with each pixel in the image representing a measurement of mean attenuation of a box like element (a voxel) that extends through the thickness of the section (Mahesh,2002)

An attenuation measurement quantifies the fraction of radiation removed in passing through a given amount of a specific material of thickness. Attenuation is expressed as follows : where I_t is the x-ray intensity measured with the material in x-ray beam path,I_0 is the x-ray intensity measured without the material in the x-ray beam path, and μ is the linear attenuation coefficient of the ~~speciefic~~ material ,Δx thicknes of the material , the transmitted intensity is given by the following formula :

$$I_t = I_o e^{-\mu \Delta x} \quad \text{.......................................(3-1)}$$

Formatted: Font: 16 pt, Complex Script Font: 16 pt this formula is expressed as the natural logarithm :

$$\ln\left(\frac{I_0}{I_t}\right) = \sum_{i=1}^{k} \mu_i \Delta x \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3\text{-}2)$$

the specific attenuation of a voxel (μ) increase with the density and the atomic number of tissue averaged through the volume of the voxel and declines with increasing x-ray energy.

the individual voxel attenuation values are scaled to more cnvient integers and normalized to voxel values containing water (μ_w) . ct numbers are computed as follows :

$$ct\# = k\left(\frac{\mu_m - \mu_w}{\mu_w}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3\text{-}3)$$

Where μ_m is measured attenuation of the material in the voxel and k (1,000) is the scaling factor .the attenuation coefficient of water is obtained during calibration of the CT machine. voxel containing materials that attenuate more than water (eg, ~~muscle~~ tissue, liver, and bone) have positive CT numbers, whereas materials with less attenuation than water (eg. lung or adipose tissues) have negative CT numbers .

3.3: historical development :

In1917 Austrian professor in mathematics at the University of Vienna johaan radon, working with gravitational theory. He proved that three dimensional object could be produced from a large number of projections or views of that object.

In 1956 Australian researching astronomy and a professor of electrical engineering at Stanford University Ronald barcewell. Used Radon’s technique to reconstruct a solar microwave emission map by measuring the total radiation from a ribbon-like strip and then repeating the process in many different directions.

In 1963 American neurologist at University of California William oldendorf was First researcher to apply these construction techniques to the medical field. Used a collimated source of gamma rays to scan a three dimensional object and reconstruct an image from that scan The object was a small concentric ring of nails and one scan took one hour.

Formatted: Font: Bold, Complex Script Font: Bold

Formatted: Font: 16 pt, Complex Script Font: 16 pt

Formatted: Font: 16 pt, Complex Script Font: 16 pt

The first experiments on medical applications of this type of reconstructive tomography were carried out by the physicist a m Cormack, he developed a method of calculating radiation absorption distributions in the human body based on transistion measurements .however he never had the chance of putting his theory into practice . Conceived the idea of producing images of the human body from a set of transmission measurements taken in a slice of an object.

The first successful practical implementation of the heory was achieved in 1972 by English engineer Hounsfield engineer with Central Research Laboratories at EMI (Electric and Musical Industries) he Worked on digital pattern reconstruction techniques,and Conceived the idea of producing images of the human body from a set of transmission measurements taken in a slice of an object. the first ct scan on a patient took place on 1st

October 1971 at atkinson's morley hospital,in London,England.the patient , a lady with a suspected frontal lobe tumor , was scanned with a prototype scanner ,developed by godfery Hounsfield and his team at emi central research labrotariies in hayes west London. The first scanner used a gamma source with exposure times up to 9 days and reconstruction times of 2.5 hours per slice.

3.4: CT generations :

3.4.1: first –generation CT scanners:

Started at 1970.x-ray source and detector fixed relative position(translate and rotate),rotate 1 degree ,the scan time for single image take 5 minutes (128x128 image)

3.4.2:second-generations CT scanners:

At 1974 still translate and rotate,rotation increased from1 degree to 3 degree,scan time for single image take3.5 minute

3.4.3: third- generations CT scanners :

1977 rotation only with array of detector,the rotation (21-45)degree .the scan time for single image take 4.5 seconds

3.4.4: fourth-generation ct scanners:

In 1980 rotation only ,the rotation between(48-120)degree with full ring of detectors,scan time for single image take 5 seconds

3.5:Principles of Helical(spiral) CT scanners:

The development of helical or spiral ct around1990 was a truly revolutionary advancement in ct scanning that allowed true 3d image acquisition within a single breath hold. The technique involves the continous acquisition of projection data through a 3d volume of tissue by continous rotation of x-ray tube and detectors and simultaneous translation of the patient through the gantry opening .three technological developments were required:slip-ring gantry designs ,very high power x-ray tubes and interpolation algorithms to handle the non-coplanar projection data(beck,1996).

3.6: Slip-ring technology:

That transmit electrical energy across a moving interface .all power and control signals from the stationary parts of the scanner system are communicated to rotating frame through the slip ring through the slip ring >the slip-rings designs consists of sets of pararllel conductive rings concentric to the gantry axis that connect to the tube,detectors,and control circuits by sliding contactors .these sliding contactors allow the scan frame to rotate continuously with no need to stop between rotations to rewind system cables .this engineering advancement resulted initially from a desire to reduce interscan delay and improve throughput.

3.7: Scan parameters:

3.7.1: Tube potential(KVp):

The relationship between the dose and the tube potential is not straight and linear one tube potential is usually modified only through the (KVp) setting. These KVp values differ from one manufacture to on other , as well from one CT scanner to another , and vary from 80 KVp to 140 KVp as the effect of increasing tube potential has a huge influence on radiation does .

3.7.2: Tube current-time product (mAs):

As in convential radiography , a straight linear relationship exists between the mAs and the does. The setting for mAs should be adapted to the characteristics of the scanner unit , the patent's size ,and the dose requirements for the each type of examination .

Appropriate use of mAs also depends on the patient's size , which is an important parameter to consider in does optimization . in order to avoid unnecessary over exposure , mAs should be intentionally adapted by the operator unless automatic exposure control(AEC) devices , or similar , are available .

3.8: the ct scanner components :

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

1. The Data Acquisition and transfer system , which encompasses the gantry , the patient's table , the power distribution unit and the data transfer unit .
   The gantry which is a central opening gantry is a movable frame that contains the x-ray tube including collimators and filters, detectors, data acquisition system and all associated (DAS), rotational components including slip ring systems and all associated electronics such as gantry angulations motors and position laser light .a ct gantry can be angled up to 30 degree toward a forward or backward position .

   The table is where the patient is positioned (lie down) and it moves through the gantry ,the patients table and the gantry constitute ct scanner itself .

   The power distribution unit supplys power to the gantry , the patients table and the computers of the computing systems ,which is localized in separate room as will be explained next .

2. The computing system (or operator's console) is installed in separate room , making it possible for the operator (technician) to control the acquisition process , introducing patient data and selecting several acquisition parameters such as the K Vp , mA values the protocol is going to use .

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

3.9:Ct gantry:

The first major component of a CT system is referred to as the scan or imaging system. The imaging system primarily includes the gantry and patient table or couch. The gantry is a moveable frame that contains the x-ray tube including collimators and filters, detectors, data acquisition system (DAS), rotational components including slip ring systems and all associated electronics such as gantry angulation motors and positioning laser lights. In older CT systems a small generator supplied power to the x-ray tube and the rotational components via cables for operation. This type of generator was mounted on the rotational component of the CT system and rotated with the x-ray tube. Some generators remain mounted inside the gantry wall. Some newer scanner designs utilize a generator that is located outside the gantry. Slip ring technology eliminated the need for cables and allows continuous rotation of the gantry components. The inclusion of slip ring technology into a CT system allows for continuous scanning without interference of cables. A CT gantry can be angled up to 30 degrees toward a forward or backward position. Gantry angulation is determined by the manufacturer and varies among CT systems. Gantry angulation allows the operator to align pertinent anatomy with the scanning plane. The opening through which a patient passes is referred to as the gantry aperture. Gantry aperture diameters generally range from 50-85 cm. Generally, larger gantry aperture diameters, 70-85 cm, are necessary for CT departments that do a large volume of biopsy procedures. The larger gantry aperture allows for easier manipulation of biopsy equipment and reduces the risk of injury

when scanning the patient and the placement of the biopsy needle simultaneously. The diameter of the gantry aperture is different for the diameter of the scanning circle or scan field of view. If a CT system has a gantry aperture of 70 cm diameter it does not mean that you can acquire patient data utilizing a 70 cm diameter. Generally, the scanning diameter in which patient or projection data is acquired is less than the size of the gantry aperture. Lasers or high intensity lights are included within or mounted on the gantry. The lasers or high intensity lights serve as anatomical positioning guides that reference the center of the axial, coronal, and sagittal planes.

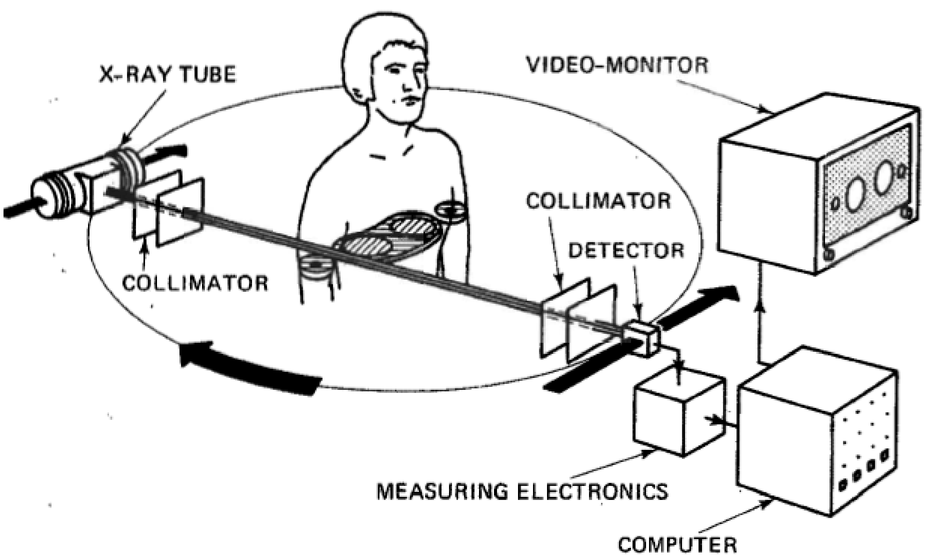


Figure (3.1) show components of the gantry

Formatted: Font: Bold, Complex Script Font: Bold

3.10: detectors:

When the x-ray beam travels through the patient, it is attenuated by the anatomical structures it passes through. In conventional radiography we utilize a film-screen system as the primary image receptor to collect the attenuated information. The image receptors that are utilized in CT are referred to as detectors. The CT process essentially relies on collecting attenuated photon energy and converting it to an electrical signal, which will then be converted to a digital signal for computer reconstruction. A detector is a crystal or ionizing gas that when struck by an x-ray photon produces light or electrical energy. The two types of detectors utilized in

CT systems are scintillation or solid state and xenon gas detectors. Scintillation detectors utilize a crystal that fluoresces when struck by an x-ray photon which produces light energy. A photodiode is attached to the scintillation portion of the detector. The photodiode transforms the light energy into electrical or analog energy. The strength of the detector signal is proportional to the number of attenuated photons that are successfully converted to light energy and then to an electrical or analog signal. The most frequently used scintillation crystals are made of Bismuth Germinate (Bi4Ge3012) and Cadmium Tungstate (CdWO4). Earlier designs utilized Sodium and Cesium Iodide as the light producing agent. One of the problems associated with these element was that at times it would fluoresce more than necessary. The after glow problems associated with Sodium and Cesium Iodide altered the strength of the detector signal which could cause inaccuracies

during computer reconstruction.