بسم الله الرحمن الرحيم

# Sudan University of Science and Technology

# College of Graduate Studies

## *Evaluation of Computed Tomography Rooms Design in Khartoum State*

## تقويم تصميم غرف التصوير بالأشعه المقطعية في ولاية الخرطوم

*A thesis submitted in partial fulfillment for the requirements*

*of Master degree in Medical Physics*


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# الأية

**قال الله تعالى:**

**(أمَن هوَ قانِتٌ آناءَ اللّيل ساجِداً وقائماً يحذرُ الأخرة َويرجو رَحمة ربهِ قل هل يستوي الذين يعلمون والذين لا يعلمون إنما يتذكر أولو الالباب)**

**صدق الله العظيم**

**سورة الزمر الايه (9)**

# Dedication

To my Mother,,,,

To my Father,,,,

To my Brothers and Sisters,,,

To my Doctors,,,,

To all my friends,,,,

## Acknowledgment

My gratitude and thanks to:

Supervisor /Dr.Mohamed Elfadil Mohamed

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My gratitude and thanks to:

My friends /Abdallah, Fersan and Ibraheem.

My gratitude and thanks to:

All my Co-workers on Sudan University and kordfan university

## Abstract

This study was aimed to evaluate the design of computed tomography rooms in ten different hospitals and centers the Khartoum state; was conducted in October 2020 to march 2021 using dimensions' devices to measure the dimensions of the computed tomography rooms i.e. the control rooms and the device rooms in the sketch for each department. The result showed that seven rooms were designed based on the international recommendation of the international energy agency the dimension of the device room was 6 × 4 meters the dimension of the control room was 4 × 2 meters and the dimension of the waiting area was 18 meters square namely hospitals A, C, D, F, H, I and J; while hospital B the difference in the area was 2 meters as well the control room 2 meters, hospital E the difference was 1.75 meters for the waiting area as well the control room was 1.75 meters, hospitals G the difference was 1.85 meters for the waiting area as well as the control room. Also the study found that the best design of computed tomography scan rooms is found in the A and F hospitals as well as the lack of a complete separation between the control room and device room was in hospital B. therefore it is necessary to take the dimensions correctly in order to ensure the quality and integrity of the design of the computed tomography room in terms of the dimensions recognized by the atomic energy agency.

## ملخص البحث

هدفت هذه الدراسة لتصميم غرف التصويرالمقطعي في عشرة مستشفيات ومراكز مختلفة في ولاية الخرطوم . حيث اجريت هذه الدراسه في اكتوبر2020 الي مارس 2021 باستخدام عدادات متر لقياس ابعاد غرف التصويرالمقطعي المحوسب وتحدد ابعاد غرف التحكم وغرف الاجهزة في كل القسم. حيث اظهرت النتائج انه تم تصميم سبع غرف بناء علي التوصيات للوكاله الدولية للطاقة الزرية هي مطابقة للمواصفات والتي يبلغ ابعادها كما يلي: غرفه الجهاز 6 × 4 متر وابعاد غرفة التحكم 4 × 2 متر وابعاد منطقة الانتظار 18 متر مربع وهي مستشفي **أ ، ت ، ث ، ح ، د ، ذ ، ر** لنسبه لمستشفي **ب** وجد الاختلاف في منتطقه الانتظاروتبلغ 2 متر وكذلك غرفة التحكم تبلغ 2 متر والمستشفي **ج** وجد الاختلاف في منطقة الانتظار وتبلغ 1.75 متر وكذلك غرفة التحكم تبلغ 1.75 متر والمستشفي **خ** وجد الاختلاف في منطقة الانتظار1.85 متر وكذلك غرفه التحكم 1.85 متر. وجدت الدراسة ان افضل تصميم لغرف الاشعه المقطعية وجد في مستشفي **ج ، خ**. وعدم وجود فاصل كامل بين غرفة التحكم وغرف الجهاز بمشتشفي **ب**. يجب اخذ الابعاد بطريقة صحيحة وذلك لتاكد من جوده وسلامه تصميم غرف الاشعه المقطعية من ناحية الابعاد المتعرف بها من قبل وكالة الطاقة الذرية.

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**List of Abbreviation:**

CT: Computed Tomography

MDCT: Multi Detector Computed Tomography

USA: United States of America

MRI: Magnetic Resonance Image

ICRP: International Commission on Radiological Protection

ICRU: International Commission on Radiological units

ROV: Rontgen Veror Dnung

MDS: Mille Ampere Second

RPA: Radiation Protection Administrator

DXRAT: Dual energy X-Ray Absorption Try

CTDT: Computed Tomography Dose Index

MSAD: Multiple Scan Average Dose

DLP: Dose Length Product

NDT: Non-Destructive Testing

GE: General Electrict

# Chapter One
# Introduction

## 1.1. Medical Imaging:

Medical imaging has experienced significant changes in both the technologic and clinical arenas. Innovation has become common in radiology department and today the introduction of new ideas and method and refinements existing techniques are apparent. The goal of these developments is this acquisition of the optimal diagnostic information while the quality of care afforded to patient is improved. One such development that is revolutionary tool of medicine, particularly in medical imaging is computed tomography (CT) (Seeram, et al.,2001).

The word tomography is not new. It can trace back to early 1920, when a number of investigator were developing methods to image specific layer or section of body. At that time, terms such as (body section radiography). A conventional tomogram is an image of a section of the patient that is oriented parallel to the film. In 1937; Watson developed another topographic technique in which the section was transverse (cross section) this technique referred to as transverse axial tomography (Seeram *et al.*, 2001).

After preclinical research and development during the early 1970s, C T developed rapidly as an indispensable imaging modality in diagnostic radiology. It is impressive to realize that most of the modern C T technology that is being used in clinical practice now days had already been described by the end of 1983.

The development of multi detector eon C T (M D C T) and multisource C T had already been described in as patient from 1980. The patient describes what the authors call ‘ ‘ multiple purpose high speed topographic x-ray scanner ’ ’ . In the acquisition technique of helical CT, the patient states that ‘ ‘ the apparatus

enables helical scanning to be affected by the continuous transportation of the table couch.

The helix is the pathway of the continuously rotating x-ray source seen from the perspective of the patient. Volumetric CT with a scanner that was capable of imaging an entire volume within a fraction of a second was achieved with the installation of the dynamic spatial reconstruct in 1980 at the mayo clinic In the USA.

Currently, most scanners are helical MDCT scanners, but the technologies of dual source and volumetric CT scanning have been implemented on aside scale. (D.R.Dance *et al*., 2014)

**1-1-2 Design of CT Rooms:**

It is easy to adapt to a single corridor Approach by switching the staff entrance to the opposite wall. CT rooms are generally part of a suite with patient waiting, changing cubicles, and toilets.

As with interventional rooms, large numbers of staff are frequently involved and need access to the room, the patient and the console area.

The console area also often serves as image processing/reporting/teaching an consultation areas and again this must be borne in mind when selecting the dose constraints to be used It normally occupies the length of one wall with lead glass shielding providing a panoramic view. In addition, it may be expanded to serve two CT rooms, or a CT and MRI room, one each side of the operator area. An intercom must be used for communication with the patient as the door between the CT and console area must remain closed during exposures. Within the CT room, the oblique alignment of the scanner allows observation of the patient from the operator's area for the duration of the examination. It also facilitates easy movement of patients, wheelchairs, trolley s and staff in the room. Facilities suitable for storage of personal protective equipment (lead aprons, etc.) should be provided and easily accessed.

There are large variations in the shielding requirements for different CT systems. The increased patient throughput facilitated by modern multiline and spiral CT systems can result in very high levels of scattered radiation in the room and therefore greater levels of shielding are required.
(Jim F Malone *et al*., 2009)

### 1-1-3 Radiation protection:

Radiation protection, sometimes known as radiological protection is the science and practice protecting people and environment from the harmful effect of ionizing radiation. Ionizing radiation is widely used in industry and medicine, and can present a significant health hazard.

It causes microfiche damage to living tissue, which can result in skin burns and radiation sickness at high exposures known as {tissue effects} and statistically elevated risks of cancer at low exposures (stochastic effects).

Fundamental to radiation protection is the reduction of expected dose and the measurement of human dose uptake. For radiation protection dosimeter assessment, the international committee on radiation protection (ICRP) and international committee on radiation unit (ICRU) have published recommendations and data which is used to calculate the biological effects on the human body, set regulatory and guidance limits.

Radiation protection can be divided into occupational radiation protection which is the protection of workers, medical radiation protection which is the protection of patients, and public radiation protection which is the protection of individual members of public and of the population as a whole .The types of exposure as well as government regulations and legal exposure limits are different for each of these groups, so they must be considered separately (Maria Bletter, Heins Schmidberger and Hajo Zeeb *et al*.,2008).

radiation protection is almost as old as the invest- able rays discovered by Wilhelm Rontgen on 8 November 1895. The damaging effects of X-rays were discovered shortly afterwards. Physicians and patients who had been exposed to radiation for a protracted period often developed erythema. Although it follows that ionizing radiation can have adverse effects on health, radiological investigational procedures are now an accepted part of clinical practice, as the advantages for the patient far outweigh the risks of radiation exposure. To restrict the radiation exposure of individual persons and of the overall population, work and contact with ionizing radiation is regulated by recommendations, directives, ordinances, and laws. As a contract state of the European Atomic Community EURATOM, in the 1957 Rome agreements, Germany undertook to convert the EURATOM directives into national law.

The first of these directives dealt with protection of employees, not of patients The 1984 directive 84/466/EURATOM specified basic measures for radiation protection in medical investigations and treatments and was the first directive to deal with radiation protection of patients at the European level. This directive laid down for the first time that a justification must be given for each medical use of radiation. This was incorporated in 1987 in the X-ray Ordinance (Röntgenverordnung, RöV) and in 1987 in the Radiation Protection Ordinance (Strahlenschutzverordnung, StrlSchV).

Directive 97/43/EURATOM (5) – also known as the Patient Protection Directive (Patientenschutzrichtlinie, PatSRL) – was converted into national law in Germany through amendments in these two ordinances (3, 4) in 2001 and 2002. The Council of the European Community had already issued the PatSRL in 1997, with the aims of creating harmonized legislation in Europe, as this could stimulate and enhance the protection of patients from ionizing radiation throughout Europe. Recommendations of the International Commission on Radiological Protection (ICRP) were then adopted which greatly tightened the requirements for justification, optimization, training, as

well as for equipment and quality control of X-ray systems (6). The Radiological Protection Committee (Strahlen Schmutz kommission, SSK) was founded in 1974, with the aims of supporting and advising the federal ministries with responsibility for protection from ionizing.
(Maria Bletter, Heins Schmidberger and Hajo Zeeb *et al*. ,2008).

## 1-2 Problem of study:

Due to the different size of radiology departments in Sudan, which may come agree with international recommendations or not. CT rooms should be with specific dimensions for radiations scatter in control rooms or in waiting area we should check it to grantee if it suitable to be safety for the staff as well as for co patients in waiting area or around the departments.

## 1-3 Objectives of study:

### 1-3-1 General Objectives:

To evaluate the design of Computed Tomography rooms in Khartoum states**.**

### 1-3-2 Specific Objectives:

- To measure the dimensions of computed tomography rooms.
- To evaluation design of CT rooms and the positions of control area.
- To compare between the CT rooms, design in Sudan with international recommendations.
- To initiate local recommendations for how the design should be when build a room of computed tomography machines.

# Chapter Two
# Theoretical Background

## 2-1 Introduction

X-rays were discovered in 1895 by the German physicist Wilhelm Conrad Rontgen, who earned the Nobel Prize in Physics in 1901. Although their potential applications in medical imaging diagnosis were clear from the beginning, the implementation of the first X-ray computed tomography system was made in 1972 by Godfrey Newbolt Hounsfield (Nobel prize winner in 1979 for Physiology and Medicine), who constructed the prototype of the first medical CT scanner and is considered the father of computed tomography.

CT was introduced into clinical practice into 1971 with a scan of a cystic frontal lobe tumour on a patient at Atkinson Morley hospital in Wimbledon.

After this, CT was immediately welcomed by the medical community and has often been referred to as the most important invention in radiological diagnosis, since the discovery of X-rays.

(w. A. Kalender *et al*., (2006).

The first application of CT in an industrial context is traced back to the first 1980´s, in the field of non destructive testing, where small numbers of slices of the object were visually inspected. 3D quantitative industrial CT applications appeared in the later 1990s, withsimple volume and distance analysis (C. Reinhart, *et al*., (2004).

Today, thanks to relevant improvements in both hardware and software, CT has become a powerful and widely used tool among non-destructive techniques, capable of inspecting external and internal structures (without destroying them) in many industrial applications.

Development of more and more stable-ray sources and better detectors led to design of more complex CT system, providing accurate geometrical information with micrometer accuracy.

CT is widely used for geometrical characterization of test objects, material composition determination, and density variation inspection.

In a relative short time, CT is capable to produce a complete three-dimensional model and tolerances of the scanned machined parts can be verified. Because of the growing interest on precision in production engineering and an increasing demand for quality control and assurance, CT is leading the field of manufacturing and coordinates metrology.3

With respect to traditional techniques, CT systems have indisputable advantages: internal and external geometry can be acquired without destroying the part, with a density of information much higher than common tactile and optical coordinate measuring.

A key parameter for reliability of the measurement processes the establishment of measuring uncertainty. Since there are many influence parameters in CT, uncertainty contributors in CT and standards dealing with quantification of CT have not been completely established (Cantator, Angea ,*et al*.,2011).

## 2-2 CT principle:

A CT system consists of an X-ray source, a rotary table, an X-ray detector and a data processing unit for computation, visualization and data analysis of measurement results.

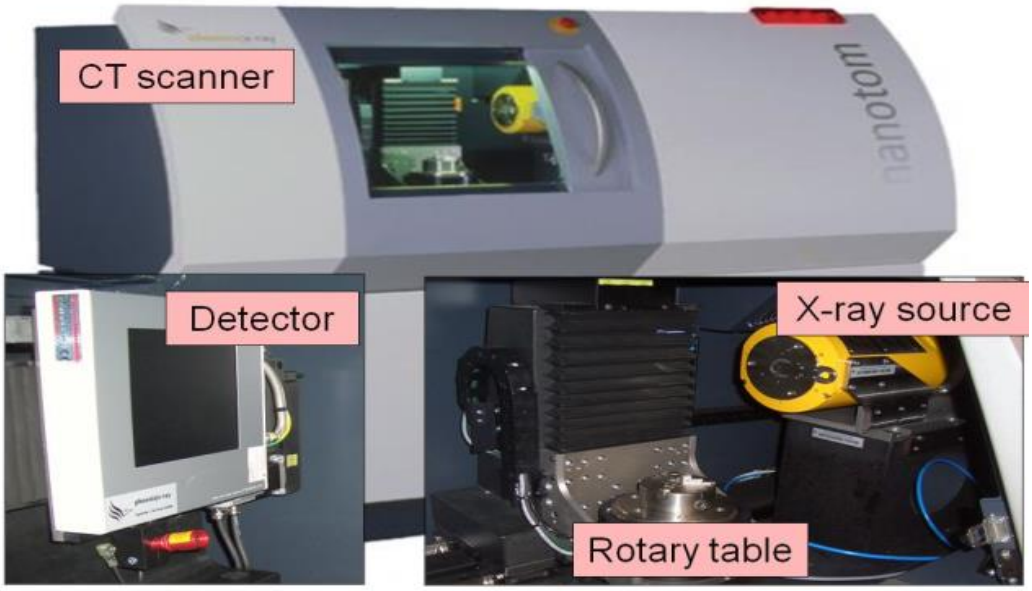


Figure (2-1) Computed tomography system consists

In principle, CT creates cross section images by projecting a beam of emitted photons through one plane of an object from defined angle positions performing one revolution. As the X-rays (emitted photons) pass through the object, some of them are absorbed, some are scattered, and some are transmitted.

The process of x-ray intensity reduction, involving just those X-rays which are scattered or absorbed, is called attenuation. Which are attenuated due to the interactions with the object does not reach the x- ray detector.

Photons transmitted through the object at each angle are collected on the detector and visualized by computer, creating a complete reconstruction of the scanned object.

The 3D gray value data structure gained in this way represents the electron density distribution in the measured object (Bartscher, U. Hilpert, J. Goebbels, G. Weideman, *et al.*,2007).

A process chain, that is the way a measurement result is obtained, including four different measuring tasks are described in a draft of a German guideline ((GMA), *et al*., (2010).

A general process is presented in and described as follows:

* Firstly, the acquisition (scanning) of an object is performed. Several parameters have to be set prior to scanning, e.g. magnification, orientation of the object, energy of the X-ray source, detector integration time etc.

* After scanning and obtaining a set of 2D projections, the volume is reconstructed the volume is modeled as a 3D matrix of vexes (abbreviation for volumetric pixels), where each vowels value represents the corresponding local attenuation coefficient of the scanned object. In other words, to each vowel a gray value is assigned representing a local X-ray absorption density. Here, some correction techniques can be applied on the 2D projections in order to minimize the effect of scattered radiation and beam hardening.

* Then, the threshold value has to be carefully determined as it is a critical parameter for accurate image segmentation and surface data determination thus has a great influence on the final geometry (S.Carmignato, et al., 2007).

* After a threshold value is determined, either the surface data or volume data are generated. Surface data are generated in the STL format, characterized by a polygonal mesh in the shape of triangles, on the surface.

* Then, direct dimensional measurement (e.g. fitting of geometrical primitives, wall thickness analysis, and nominal/actual comparison) can be performed on either of the earlier mentioned data sets (volume / surface).

* Finally, a measurement result is obtained. There are two main CT systems which can be found in industry.

These are 2D-CT systems have a fan beam source and a line detector which enable the acquisition of a slice of a 3D object by coupling translation and rotation movement of the object.

This sequence of rotation and translations repeated depending on number of slices which have to be reconstructed. The main drawback of these systems is the long scanning times; This problem is overcome by 3D-CT systems. The system consists of a flat area detector and a cone beam source, enabling the acquisition of a slide of the object just with one revolution of the rotary table. No linear translation of the rotary table is needed. This solution allows significant improvement in acquisition time but, on the other hand, other problems arise due to the cone beam source. Scattered radiations and reconstruction artefacts at the top and bottom of the geometry can affect the quality of the reconstructed geometry.

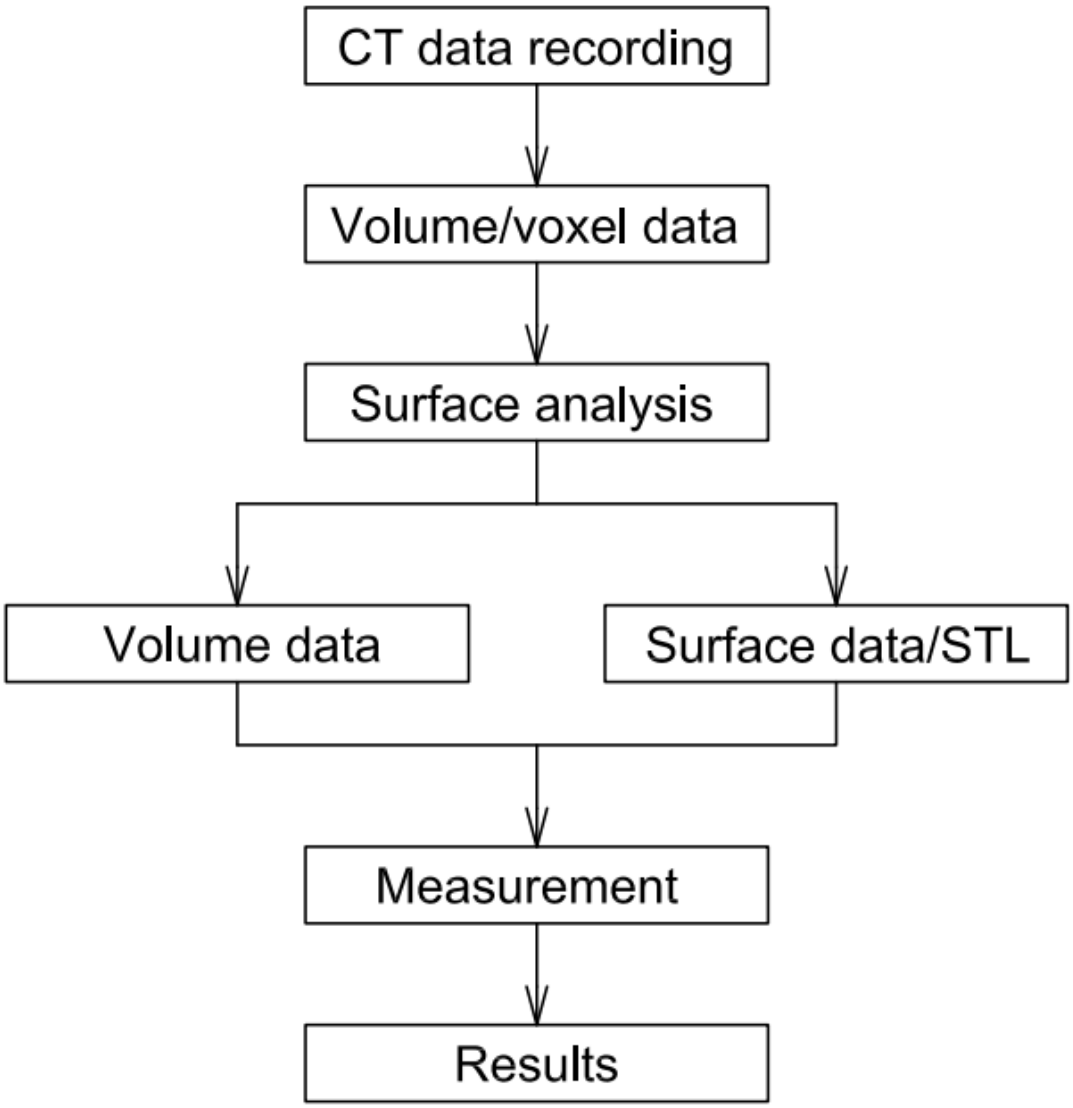


Figure (2-2*)* Process chain for CT measurement.

In particular, scanning quality deteriorates from the center to the borders of the detector, because of geometrical reasons (A.I.Te.M, *et al.*, (2007).

## 2-3 Generation of CT:

### 2-3-1 First generation: Rotate / Translate, pencil beam

The first generation of CT scanners employed a rotate / translate, pencil beam system. Only two x- ray detectors were used, and they measured the transmission of x-ray through the patient for two different slices The pencil beam allowed very efficient scatter reduction.

### 2-3-2 Second generation: Rotate / translate, narrow fan beam

The next incremental improvement to the CT scanner was the incorporation of a Linear A ray of 30 detectors. This increased the utilization of the x-ray beam by 30 times, compared with the single detector used per slice in first generation system. Relatively narrow fan angle of 10 degrees was used. In principle,

a reduction in scan time of about 30 – fold could be expected. However, this reduction time was not realized , because more data ( 600 rays ، x 540 views = 324 , 000 data points ) were acquired to improve image quality.

The shortest scan time with a second generation scanner was 18 seconds per slice 15 times faster than with the first generation system.

### 2-3-3 Third generation:

Rotate / Rotate, wide fan beam the translational motion of first – and second – generation CT scanners was a fundamental impediment to fast scanning.

At the end of each translation, the motion of the x-ray tube / detector system had to be stopped, the whole system rotated, and the translation motion restarted. The success of CT as a clinical modality in its infancy gave manufacturers reason to explore more efficient, but more costly, a approaches to the scanning geometry.

The number of detectors used in third – generation scanners was increased substantially to more than 800 detectors, and the angle of the fan beam was increased so that the detector array formed an are wide enough to allow the x-ray beam to interrogate the entire patient. Because detectors and the associated electronics are expensive, this led to more expensive CT scanners.

However, spanning the dimensions of the patient with an entire row of detectors eliminated the need for translation motion

**2-3-4 Fourth generation shift over time:**

The rotate / rotate geometry of third – generation scanners leads to a situation in which each detector is responsible for the data corresponding to airing in the image. Detectors toward the center of the detector array provide data in the reconstructed image in a ring that is small in diameter, and more peripheral detectors contribute to larger diameter rings.

**2-3-5 Fifth generation: stationary / stationary**

A novel CT scanner has been developed specifically for cardiac tomography imaging. This ‘ ‘ cine – CT ’ ’ scanner does not use a conventional x-ray tube; instead, a large are of tungsten encircles the patient and lies directly opposite to the detector ring.

**2-3-6 Sixth generation: Helical**

Helical CT scanners acquire data while the table is moving; as a result, the x-ray source moves in a helical pattern around the patient being scanned.

Helical CT scanners use either third –or fourth generation slip ring designs. By a voiding the time required to translate the patient table, the total scan time required to image the patient can be much shorter (30 seconds for the entire abdomen). Consequently, helical scanning allows the use of less contrast agent and increases patient throughput. In some instances, the entire scan can be preformed within a single hold of the patient, a voiding inconsistent levels of inspiration.

**2-3-7 Seventh generation: Multiple detectors a ray**

X-ray tubes designed for CT have impressive heat storage and cooling capabilities, although the instantaneous production of x – ray (x-rays per mille ampere –second (mAs) is constrained by the physics governing x-ray production an approach to overcoming x-ray tube output limitations is to make better use of the x-rays that are produced by the x-ray tube. When multiple

detectors a ray are used the collimator spacing is wider and therefore more of the x-rays that are produced by the x-ray tube are used in producing image data. With conventional, single detector an array scanner, opening up the collimator increases the slice thickness, which is good for improving the utilization of the x-ray beam but reduces spatial resolution in the slice thickness dimension.

With the introduction of multirole detector an arrays, the slice thickness is determined by the detector size and not by the collimator. This represents a major shift in CT technology (Bush berg, J., *et al*., (2002). Eur J Nucl Med Mol *et al*., (2003).

**2-3-8 Target: Rotate / stationary**

Third generation scanners suffered from the significant problem of ring artefacts, and in the late 1970s fourth – generation scanners were designed specifically to address these artefacts. it is never possible to have a large number of detectors in perfect balance with each other, and this was especially true 25 years ago each detector and its associated electronics has a certain a mount of drift, causing the signal levels from each detector.

((Bush berg, J., *et al*., 2003)

**2-4 Component of CT scanner:**

Are shown x-ray tube, collimator and detector array are mounted on a rotation gantry .by convention, the rotation axis is referred to as the z-axis. The x-ray beam is collimated as a wide fan beam sufficient to cover the patient cross-section at its widest it has a narrow width generally defines the imaged slice thickness (D.R.Dance, et al.,2014).

### 2-4-1 X-ray Tube:

The x-ray tube is mounted with its anode-cathode axis parallel to the axis of rotation of the scanner. this is so to minimize the influence of the anode heel effect because the size of the beam parallel to the axis of rotation is on more than a few centimetres even with amultislice scanner.

Tube for CT scan has to be capable of prolonged exposure times at high mille ampere age (AM). typically tubes have two focal spot sizes the smallest being about 0.6mm many are designed to run continuously for periods of as or greater at 120KVand 200MA to achieve this performance they have heat capacities of 4 major more in order to reach this standard they incorporate heat exchanger to cool oil and the within the gantry enclosure is main tainted at low temperature .typically scanner are operated at 120KV but a range of is usually available with three or four fixed setting between about 80KV and 120KV (D.R.Dance, et al.,2014).

### 2-4-2 Collimation and Filtration:

Ideally a monoenergetic photo beam would be used for ct, but this cannot be achieved with an x-ray source earlier scanner used additional capper filters to remove low-energy photon but because of improvements in reconstruction algorithms this is no longer necessary and generally scanner have a total tube filtration about 6MM aluminum.

The collimator is mounted on x-ray tube the beam is collimated to affixed width that is generally about 50cm at the axis of rotation, sufficient to cover the full cross-section of the patient. The cross-section of the patient is generally elliptical so that the edges of the patient the ray path from focus to detector passes through are natively low tissue thickness these serve to equalize the transmitted intensities emerging from the patient

They also even out the beam, because of their shape such filter are same times referred to be as beam tie filter generally different sizes of filter are used for head and body scanning (D.R.Dance, et al.,2014).

### 2-4-3 Detectors:

The requirement for scanner detector is as follow:

To be small in order to allow good spatial resolution for the single –slice scanner with 600-900 individual detector is no more than about 1.5mm.

To have a high detection efficiency.

To have a fast response with negligible afterglow as to keep up with fast scanning times and rapid changes in radiation intensity. To have a wide dynamic range the x-ray intensity many vary over a rang of 500 to 1between the salutation attenuation to which the beam passes by the side of the patient with no attenuation to that in which it passes through the lateral projection of heavy patient To have a stable noise-free response (D.R.Dance, et al.,2014).

## 2-5 Design and layout of radiology facilities

### 2-5-1 Radiology room types

The location, structural design and equipment layout of X-ray rooms must be carefully considered from a radiation protection perspective. This is easier when X-ray facilities are not designed as stand-alone rooms and are planned as part of an integrated radiology/imaging department with its supporting areas and services. Planning the room layouts should start as early as possible in the design process and be based on inputs from a team including architects, engineers, hospital management, radiologists, radiographers, therapy, other consultant medical staff such as cardiologists or vascular surgeons where relevant, and once identified, the equipment supplier(s).

The practical requirements for radiation protection depend on the clinical functions the room is designed for as well as the workload and adjacent occupancy.

For simplicity, at this point, rooms will be divided into four broad categories:

* Radiography (e.g. general, chest, dental, mammography, etc.).
* Fluoroscopy (e.g. general or interventional applications).

* Computed Tomography (CT).

* Shared function rooms (e.g. operating theatres or emergency departments where mobile or fixed x-ray equipment may be used). X-ray rooms should be of a size that allows unimpeded access and ease of movement around the equipment, the patient table and the operator's console. The size of the room will vary greatly depending on the modality and the cost of space. There are no absolute norms, but it may be helpful to bear in mind some examples from the UK National Health Service which recommends that general rooms, complex interventional suites and mammography rooms be 33, 50 and 15 m2 respectively (NHS, 2001). General X-ray rooms with ceiling mounted X-ray tubes must have a minimum height of 3.1 m between the door level and the underside of the ceiling support grid (normally concealed by a suspended ceiling). A conventional ceiling height of 2.4 m should be adequate for dental and dual energy X-ray absorptiometry (DXA) rooms (NHS, *et al.* 2001, NHS, *et al.* 2002).

**2-5-2 Radiographic equipment:**

Radiography equipment provides a single two-dimensional 'snap-shot' image, which is, essentially, a partially penetrated projected shadow. Staff are not normally required to be in the vicinity of the patient during the procedure. These rooms generally include a fixed screen to protect the operator console area. It is necessary to be able to see and communicate with the patient from this area. In addition, the rooms should be sufficiently large to reduce radiation intensity at the operator's screen and boundaries (Jim F Malone, *et al*., 2009).

**2-5-3 Design of Computer Tomography (CT) rooms:**

A CT room layout based on the two corridor model. It is easy to adapt to a single corridor approach by switching the staff entrance to the opposite wall. CT rooms are generally part of suite with patient waiting, changing cubicles, and toilets. As with interventional rooms, large numbers of staff are frequently involved and need access to the room, the patient and the console area. The

console area also often serves as image processing/reporting/teaching and consultation areas and again this must be borne in mind when selecting the dose constraints to be used. It normally occupies the length of one wall with lead glass shielding providing a panoramic view. In addition, it may be expanded to serve two CT rooms, or a CT and MRI room, one each side of the operator area. An intercom must be used for communication with the patient as the door between the CT and console area must remain closed during exposures. Within the CT room, the oblique alignment of the scanner allows observation of the patient from the operator's area for the duration of the examination. It also facilitates easy movement of patients, wheelchairs, trolleys and staff in the room.

Facilities suitable for storage of personal protective equipment (lead aprons, etc.) should be provided and easily accessed. The Design of Diagnostic Medical Facilities where Ionising Radiation is used There are large variations in the shielding requirements for different CT systems. The increased patient throughput facilitated by modern multiline and spiral CT systems can result in very high levels of scattered radiation in the room and therefore greater levels of shielding are required (Jim F Malone, *et al*., 2009).

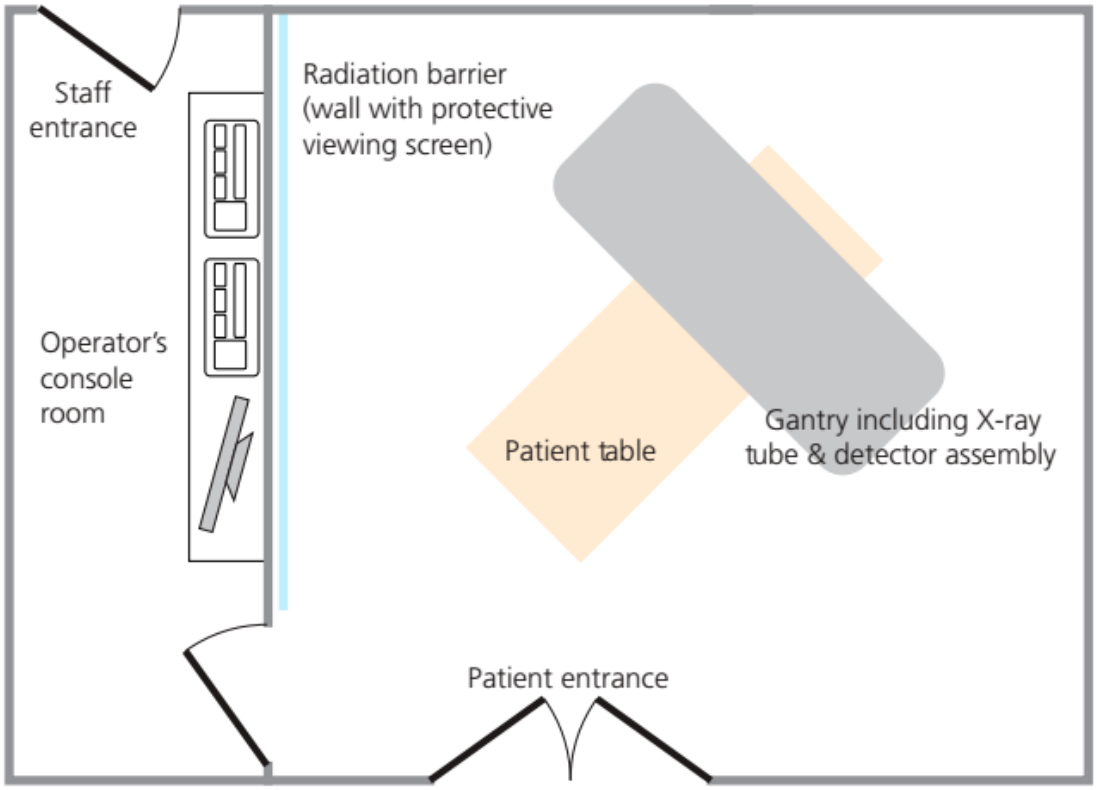


Figure (2-3) Tomography Computed (CT) room

Unlike interventional rooms the distribution of scattered radiation in the CT room is well defend and fixed as the position of the gantry is fixed and the X-ray tube follows the same rotation path for each exposure. Iodise curves for each scanner are normally available from the manufacturer and these should be used to determine shielding requirements taking due account of local technique. As a general guide, the shielding requirements for new multiline CT systems are between 3-4 mm lead (NHS, 2001). However, individual shielding assessments based on actual workloads, room dimensions and occupancy of adjoining areas are essential for these facilities and should be undertaken by the RPA.

**2-5-4 Shared function rooms:**

There are an increasing number of situations involving rooms with shared functions, one of which has a radiological component. At the extreme upper level of this range are operating theatres for vascular procedures which also have full permanent fixed radiological equipment installed. However, more commonly, these applications involve low dose fluoroscopy for short time

periods – e.g. during or following orthopaedic procedures. By comparison with conventional radiological practice, a large number of staff may be present in the room at the time. Because of the relatively low doses, radiation protection requirements are generally less demanding than in the other facilities described above. However, the large number of staff, not all of whom will be trained in radiation protection, presents special problems. In practice a combination of mobile shields, staff withdrawing from the immediate area and limited structural shielding can usually provide a good solution. However, the design of these areas is generally approached on a case by case basis. In addition, the number and type of these areas is increasing, and now routinely includes the Intensive Care, High Dependency, Theatre, and Emergency Medicine environments (Jim F Malone, *et al*., 2009).

## 2-6 Dissymmetric Quantities and unit:

### 2-6-1 Kerma and kerma rate:

Kerma is an acronym for kinetic energy released per unit mass. It is anon stochastic quantity applicable to in directly ionizing radiations such as photons and neutrons. It quantifies the average amount of energy transferred from in directly ionizing radiation to directly ionizing radiation without concern as to what happens after this transfer. In the discussion that follows we will limit ourselves to photons (podgorsak, E.B.*et al*., 2005).

The energy of photons is imparted to matter in a two stage process. In the first stage, the photon radiation transfers energy to the secondary charged particles (electrons) through various photon interactions (the photoelectric effect, the Compton effect, pair production, etc. In the second stage, the charged particle transfers energy to the medium through atomic excitation and ionization (podgorsak, E.B.*et al*., 2005).

In this context, the kerma is defined as the mean energy transferred from the in directly ionizing radiation to charged particles (electrons) in the medium $dE_{tr}$per unit mass dm .

$$K = dE_{tr} / dm$$

The unit of kerma is joule per kilogram ( J/ Kg ) . The name for the unit of kerma is the gray ( Gy ) ,Where 1 Gy = 1 J / Kg .

The kerma rate, $K^{\bullet}$ , is the quotient dk by dt , where dk is the increment of kerma in the time interval dt , Thus : $K^{\bullet} = dk / dt$ The unit is $J . kg^{-1} . s^{-1}$ . if the special name gray is used, the unit of kerma rate is gray per second ( Gy / S ) ( podgorsak , E.B.,*et al*., 2005).

**2-6-2 Cema:**

Is the acronym for converted energy per unit mass .it is non-stochastic quantity applicable to directly ionizing radiation such as electrons and protons? The cema C is the quotient of dE by dm, where dE is the energy lost by charged particle, except secondary electron in collisions in a mass of a material.

**C=dE/dm**

The unit of cema is joule per kilogram (J/kg). the name for the unit of cema is the gray (Gy) ( podgorsak , E.B.,*et al*., 2005).

**2-6-3 Absorbed Dose: D**

The absorbed dose, D, is the quotient $d\varepsilon^{-}$ by dm , where $d\varepsilon^{-}$ is the mean energy imparted to matter of mass dm , Thus :

$D = d\varepsilon^{-} / dm$ The unit is J / Kg.

Special name for the unit of absorbed dose is gray (Gy).

((pernicka , f,and I, Mclean.*et a*l.,2007)

## 2-7 Quantities for CT dosimeter

### 2-7-1 Computed Tomography Dose Index (CTDI)

The CTDI is the primary dose measurement concept in CT

$$CTDI = 1 / N \int D(Z)\, dZ$$

D (Z) = the radiation dose profile along the Z – axis,

N= The number of topographic sections imaged in a single axial scan.

This is equal to the number of data channels used in a particular scan. The value of N may be less than or equal to the maximum number of data channels available on the system, and T= the width of the topographic section along the Z – Axis imaged by one data channel.

In multiple – detector – row (multiline) CT scanners, several detector elements may be grouped together to form one data channel. In single – detector – row (single – slice) CT, the Z- axis collimation (T) is the nominal scan width. CTDI represents the average absorbed dose, along the Z- axis, from a series of contiguous irradiation. It is measured from one axial CT scan (one rotation of the x – ray tube), and is calculated by dividing the integrated absorbed dose by the nominal total beam collimation. The CTDI is always measured in the axial scan mode for a single rotation of the x –ray source, and theoretically estimates the average dose within the central region of scan volume consisting of multiple, contiguous CT scan [Multiple scan Average Dose (MSAD)] for the case where the scan length is sufficient for the central dose to approach its asymptotic upper limit. The MSAD represents the average dose over small interval ( -1/2, ½) about the center of the scan length (Z= 0) for as can interval I, but requires multiple exposures for its direct measurement.

The CTDI offered amore convenient yet nominally equivalent method of estimating this value, and required only a single – scan acquisition, which in the early days of CT, saved considerable amount of time (C.D.D.I.C.C.*et al*., 2008).

### 2-7-2 $CTDI_{FDA}$

Theoretically, the equivalence of the MSAD and the CTDI requires that all contributions from the tails of the radiation dose profile be included in the CTDI dose measurement.

The exact integration limits required to meet this criterion depend upon the width of the nominal radiation beam and the scattering medium.

To standardize CTDI measurement (infinity is not a likely measurement parameter), the FDA introduced the integration limits of + □ 7 T, where T represented the nominal slice width.

Interestingly, the original CT scanner, the EMI Mark I, was a dual detector – row system.

Hence, the nominal radiation beam width was equal to twice the nominal slice width (I. e., N X T mm). To account for this, the CTDI value must be normalized to 1 □ NT:

$CTDI_{FDA} = 1 / NT \int_{-7T}^{7T} D(Z)dz$

Unfortunately, the limits of integration were not similarly expressed in terms of NT, allowing for the potential underestimation of the MSAD by the CTDI.

For the technology available circa, 1984 the use of NT in the integration limits was deemed un necessary at the time. the scattering media for CTDI measurement were also standardized by the FDA.

These consist of two polymethylmethacrylate (PMMA, e. g., acrylic or Lucite TM) cylinder of 14 – cm length.

To estimate dose values for head examinations, admitter of 16 cm is tube used. These are typically referred to, respectively, as the head and body CTDI phantoms (C.D.D.I.C.C.*et al*., .2008).

### 2-7-3 $CTDI_{100}$ : -

$CTDI_{100}$ represents the accumulated multiple scan dose at the center of a 100 – mm scan and understimates the accumulated dose for longer scan lengths. It is thus smaller than the equilibrium dose or the MSAD.

The $CTDI_{100}$, like the $CTDI_{FDA}$ , requires integration of the radiation dose profile from a single axial scan over specific integration limits. In the case of $CTDI_{100}$ , the integration n limits are + □ 50mm, which corresponds to the 100 □ mm length of the commercially available " pencil " ionization chamber .

$$CTDI_{100} = 1/NT \int_{-50mm}^{50mm} D(z)dz$$

(C.D.D.I.C.C.*et al*., .2008).

### 2-7-4 Weighted $CTDI_W$ : -

To represent dose for a specific scan protocol, which almost always involves a series of scans, it is essential to take in to account any gaps or overlaps between the X – ray beams from consecutive rotations of the X- ray source.

This is accomplished with use of adose descriptor hnown as the volume $CTDI_W$ ( $CTDI_{VOL}$ ),

Where$CTDI_{VOL}$ = N * T / I $CTDI_W$ and

I = The table increment per axial scan (mm).

Since pitch is defined 19 as the ratio of the table travel per rotation (I) to the total nominal beam width (N x T)

Pitch = 1 / N * T

Thus, volume CTDI can be expressed as

$CTDI_{VOL}$ = 1 / pitch * $CTDI_W$

Where as $CTDI_W$ represents the average absorbed radiation dose over the X and Y directions at the center of the scan from a series of axial scans where the scatter tails are negligible beyond the 100 – mm integration limit, $CTDI_{VOL}$ represents the average absorbed radiation dose over the X, Y, and Z directions.

It is conceptually similar to the MSAD, but is standardized with respect to the integration limits (+ - 50 mm) and the F – Factor used to convert the exposure or air kerma measurement in to dose to air (C.D.D.I.C.C.*et al*.,2008).

**2-7-5 $CTDI_{VOL}$**

Is a measure of amount of energy deposited per unit mass, proportional to absorbed dose.

Unit is gray (GY), this is metric by the ACR for CT practice accreditation (ACR. *et al*., 2008)

**2-7-6 Dose length product (DLP):**

To better represent the overall energy delivered by agiven scan protocol, the absorbed dose can be integrated along the scan length to compute the dose – length product (DLP), where

DLP (mgy – cm) = $CTDI_{VOL}$ (mgy) * scan length (cm)

The DLP reflects the total energy absorbed (and thus the potential diological effect) attributable to the complete scan acquisition.

Thus, an abdomen – only CT exam might have the same CTDIVOL as an abdomen / pelvis CT exam, but the latter exam would have a greater DLP, proportional to the greater Z – extent of the scan volume.

In helical CT, data interpolation between two points must be preformed for all projection angles.

Thus, the images at the very beginning and end of a helical scan require data from Z axis projections beyond the defined ‘ ‘ scan” boundaries (i.e., The beginning and end of the anatomic range over which images are desired).

This increase in DLP due to the additional rotation (s) required for the helical interpolation algorithm is often referred to as ‘ ‘ over ranging”.

For MDCT scanners, the number of additional rotations is strongly pitch dependent, with atypical increase in irradiation length of 1.5 times the total nominal beam width.

The implications of over ranging with regard to the DLP depends on the length oh the imaged body region.

For helical scans that are short relative to the total beam width, the dose efficiency (with regard to over ranging) will decrease.

For the same anatomic coverage, it is generally more dose efficient to use a single helical scan than multiple helical scans (C.D.D.I.C.C.*et al*.,2008).

## 2-8 Quantities Related to Stochastic and Deterministic Effect:

### 2-8-1 Organ and Tissue Dose: $D_T$

The mean absorbed dose in a specified tissue or organ is given the symbol $D_T$ in ICRU 51 [ 3. 11]. It is equal to the ratio of the energy imparted, $\varepsilon_T$, to the tissue or organ to the mass, $M_T$, of the tissue or organ, Thus [ 3.1]:

$$D_T = \varepsilon / m_T$$

The mean absorbed dose in a specified tissue or organ is some time simply referred to as the organ dose. This simplification is a doped in this code of practice.

(Pernicka , F. and I. Mclean ,et al.,2007)

### 2-8-2 Equivalent Dose $H_T$

The equivalent dose, $H_T$, to an organ or tissue, T, is defined in ICRP 60 [ 3.13] and ICRU 51 [ 3.11].

For a single type of radiation, R, it is the product of radiation weighting factor, $W_R$, for radiation R and the organ dose, $D_T$

$$H_T = W_R D_T$$

The unit is J / Kg. The special name for the unit of equivalent dose is sever (sv)

The radiation weighting factor, $W_R$, allows for differences in the relative biological effectiveness of the incident radiation in producing stochastic effects at low doses in tissue or organ T.

For x ray energies used in diagnostic radiology, $W_R$ is taken to be unity.

((Pernicka, F. and I. Mclean. *et al*.,2007).

Table. (2.1):

Radiation weighting factors in publication ICRP 60 and Q in publication ICRP 60

| **Type and energy rang** | **$W_T$** | **Q** |
|---|---|---|
| Photons ( x ray and gamma ray ) all energies | 1 | 1 |
| Electron , muons all energies | 1 | 1 |
| Neutrons < 10 kev | 5 | _ |
| Neutrons 10 kev to 100 kev | 10 | _ |
| Neutrons > 100 kev to 2 Mev | 20 | _ |
| Neutrons > 2 Mev to 20 Mev | 10 | _ |
| Neutrons > 20 Mev | 5 | _ |
| Protons > 20 Mev | 5 | 1 |
| Alpha particles fission – fragment heavy nuclei | 20 | 20 |

**2-8-3 Effective dose: E**

The effective dose, E, is defined in ICRP 60 [ 3.13] and ICRU 51 [ 3.11]. It is the sum over all the organs and tissues of the body of the product of the equivalent dose, $H_T$, for that organ or tissue, thus:

$$E= \Sigma_T W_T H_T$$

Thetissue weighting factor, $W_T$, for organ or tissue T represents the relative contribution of that organ or tissue to the total detriment arising from stochastic effects for uniform irradiation of the whole body.

The unit is J/kg. The special name for the unit of effective dose is sievert (sv). The sum overall the organ and tissue of the body of the tissue weighting factors, $W_T$, is unity (Pernicka, F. and I. Mclean. *et al*.,2007).

The remainder is composed of the following additional tissue and organs adipose tisse, adrenals, connective tissue, extra thoracic airways, gallbladder,

heart wall, kidney, lymphatic nodes, muscle, pancreas, prostate, small intestine wall, spleen, thymus and uterus / cervix.

Table (2.2):

Tissue weighting factors for different organs.

| **Organs** | **Tissue weight factors** | | |
|---|---|---|---|
| | ICRP 30 ( 1979 ) | ICRP 60 ( 1990 ) | ICRP 103 ( 2007 ) |
| Gonads | 0.25 | 0.20 | 0.08 |
| Colon | _ | 0.12 | 0.12 |
| Lung | 0.12 | 0.12 | 0.12 |
| Red bone marrow | 0.12 | 0.12 | 0.12 |
| Stomach | _ | 0.12 | 0.12 |
| Bladder | _ | 0.05 | 0.04 |
| Breast | 0.15 | 0.05 | 0.12 |
| Liver | _ | 0.05 | 0.04 |
| Esophagus | _ | 0.05 | 0.04 |
| Thyroid | 0.03 | 0.05 | 0.04 |
| Bone surface | 0.03 | 0.01 | 0.01 |
| Skin | _ | 0.01 | 0.01 |
| Brain | _ | _ | 0.01 |
| Salivary | _ | _ | 0.01 |
| Remained | 0.03 | 0.05 | 0.01 |

**2-9 Previous studies:**

Nicholas Hashem march 2021, presents a literature review on techniques related to the computed tomography procedure that incorporate automation elements in their research investigations or industrial applications. Computed tomography (CT) is a non-destructive testing (NDT) technique in that the imaging and inspection are performed without damaging the sample, allowing for additional or repeated analysis if necessary. The reviewed literature is organized based on the steps associated withal general NDT task in order to define an end-to-end c imputed tomography automation architecture.

The process steps include activities prior to image collection, during the scan, and after the data are collected. It further reviews efforts related to repeating this process based on a previous scan result. By analyzing the multiple existing but disparate efforts found in the literature, we present framework for fully automating NDT procedures and discuss the remaining technical gaps in the

Developed framework.

HERBERT L. ABRAMS et al Because CT is unique, it has been accepted by physicians with unrestrained enthusiasm. However, the capital investment and cost of maintenance are high, and there has been no orderly program of dispersion despite the profound interest of the regulatory agencies in cost containment. Although the diagnostic accuracy of CT in both the head and body is high, its information gain over other competing imaging methods, particularly those in the abdomen (ultrasound, nuclear medicine), has not been fully documented.

In evaluating the cost effectiveness of CT, long-term outcome, while the most important criterion, requires carefully controlled studies over many years. Short-term value may be measured by assessing the degree to which CT furnishes new

diagnostic information, its accuracy, its effect on the morbidity and mortality of diagnostic and therapeutic procedures, its impact on treatment planning, and changes in cost and sayings incident to its use. Prospective studies must relate contribution of CT to that of competing methods and document the impact of additional diagnostic information.

# Chapter Three

# Material and Methods

## 3-1 Materials:

Table3-1: indicates the type of device used in the hospital

| Hospital | CT machine |
|---|---|
| Asia Hospital | GE/optima single |
| ALbageuh Hospital | GE/bright speed 16 |
| Alnaylin Diagnostic Center | Siemens 16 |
| Waead hospital | GE/DUO |
| Almahdawi Diagnostic Center | Hitachi |
| Ruyal Scan Center | Toshiba 64 |
| AlzaytunaHospita | Toshiba 64 |
| Ibnelhaithem Hospital | Siemens16 |
| Alfaysal Hospital | Siemens16 |
| Fadiel Hospital | Siemens16 |

## 3-2 Place and duration of study:

This study will be achieved in Khartoum state in different hospitals and centers (as shown above) in period from October 2020 till May 2021.

## 3-3 Method of data collection:

To by drawing CT scan rooms determining the areas of each room and determining neighbouring areas, using meters to measure dimensions.

The data were collected using meter for measure the rooms dimensions and check the rooms and around room and area the attached with the radiology

departments and compare the design with international recommendation from the international atomic energy agency and international organisation of physics and medical.

### 3-4 Data analysis:

The dimensions of CT rooms draw using AutoCAD software.

# Chapter four

# Results

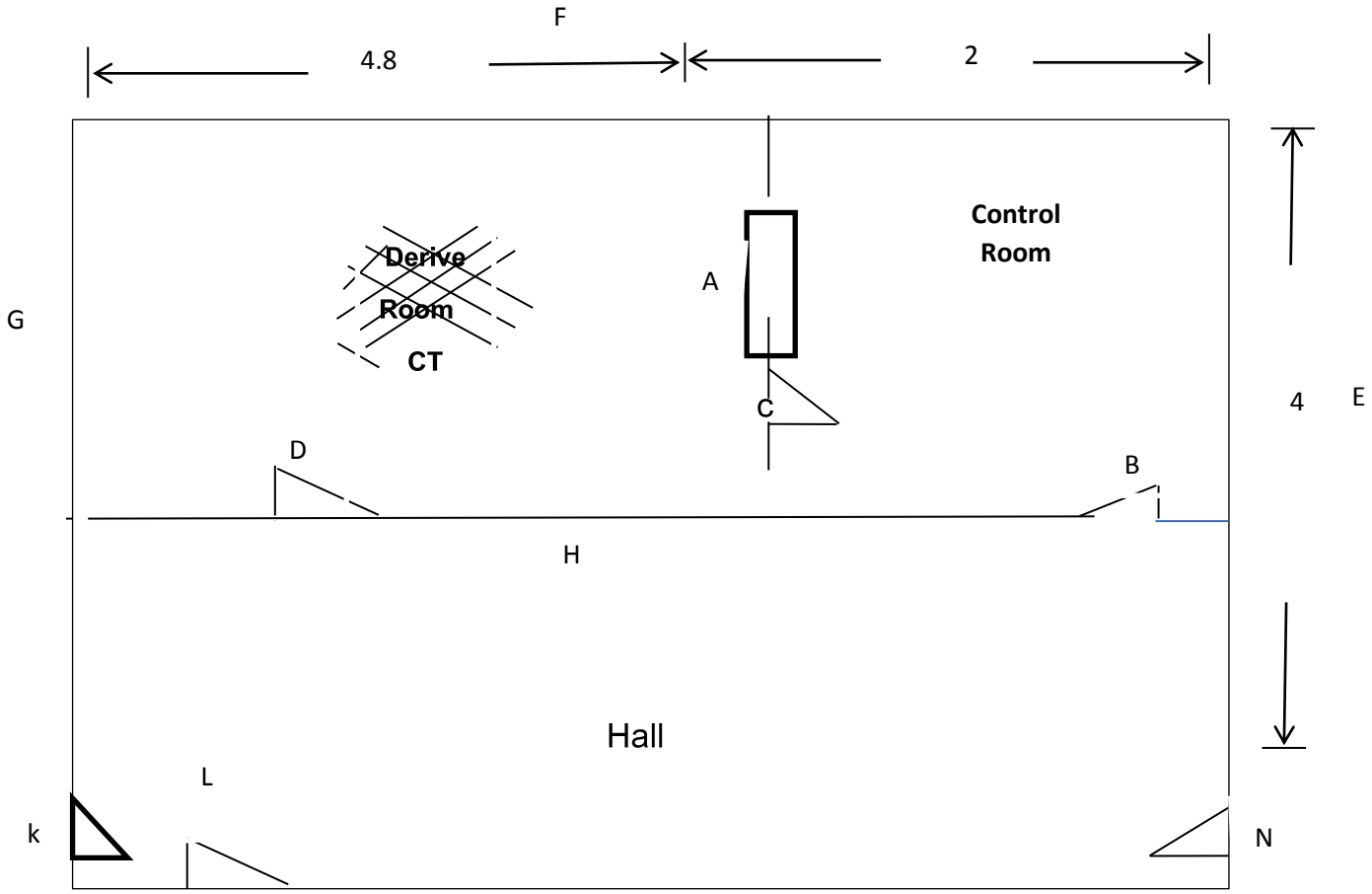


Figure 4-1 show design computed tomography dimension room at A Hospital

Table 4-1 show computed tomography dimension room at A Hospital

| *SAMPLE* | *Definition* |
|---|---|
| **A** | **LEAD OF GLASS** |
| **B** | **STAFF ENTRANCE** |
| **C** | **CONTROL ROODOO** |
| **D** | **PATIENT ENTRANCE** |
| **N** | **MAIN DOOR OF DEPARTMENT** |
| **L** | **OPERATING DEVICE** |
| **K** | **REPORT ROOM** |
| **H** | **AWAITING ARENA** |
| **E** | **PASSAGE** |

**Result: 4-1:**

| Room | Distance | Reference |
|---|---|---|
| Control | 4.25 | 3 |
| Waiting area | 2 | 2 |
| Door to control | 2 | 2 |

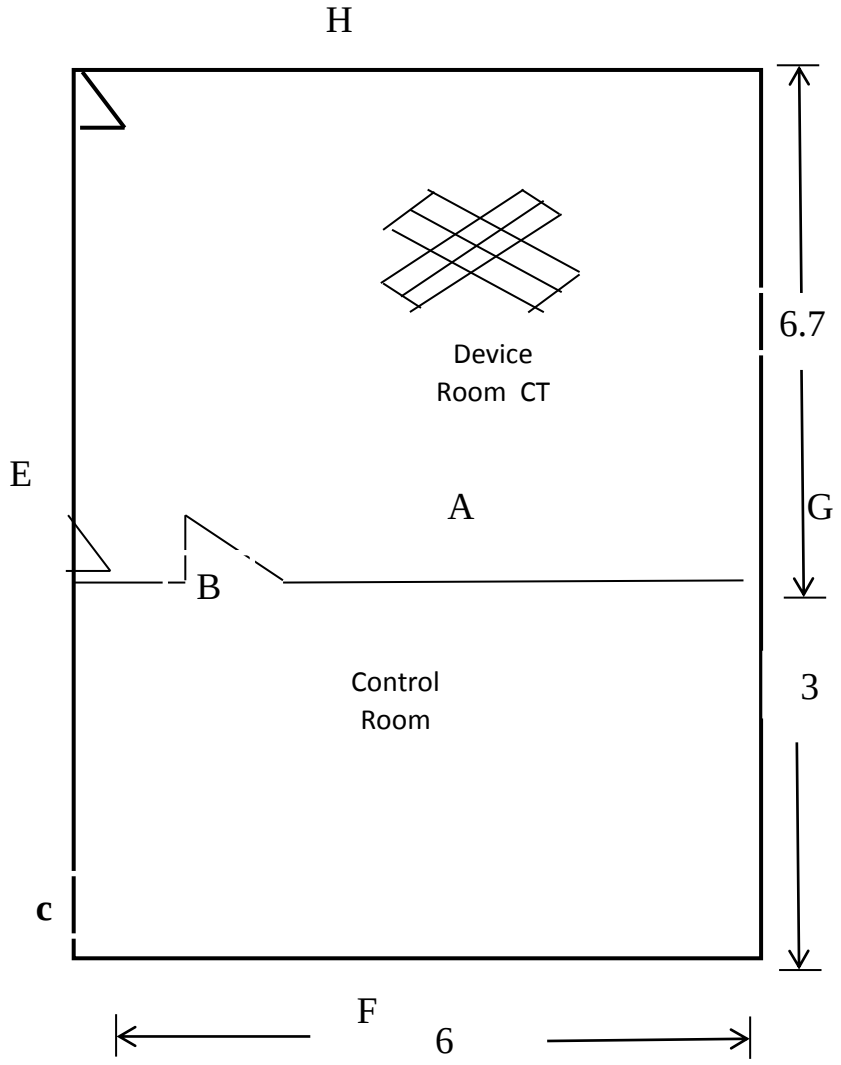


Figure 4-2 show design computed tomography dimension room at B hospital

Table 4-2 show computed tomography dimension room at B hospital

| *SAMPLE* | *Definition* |
|---|---|
| **A** | **Lead glass** |
| B | Control Room Door |
| **C** | **Staff entrance** |
| **D** | **Patient entrance** |
| **E** | **Passage** |
| **F** | **Lap** |
| **H** | **Officer** |

**Result 4-2:**

| Room | Distance | Reference |
|---|---|---|
| Control | 3 | 3 |
| Waiting area | 3 | 2 |
| Door to control | 3 | 2 |

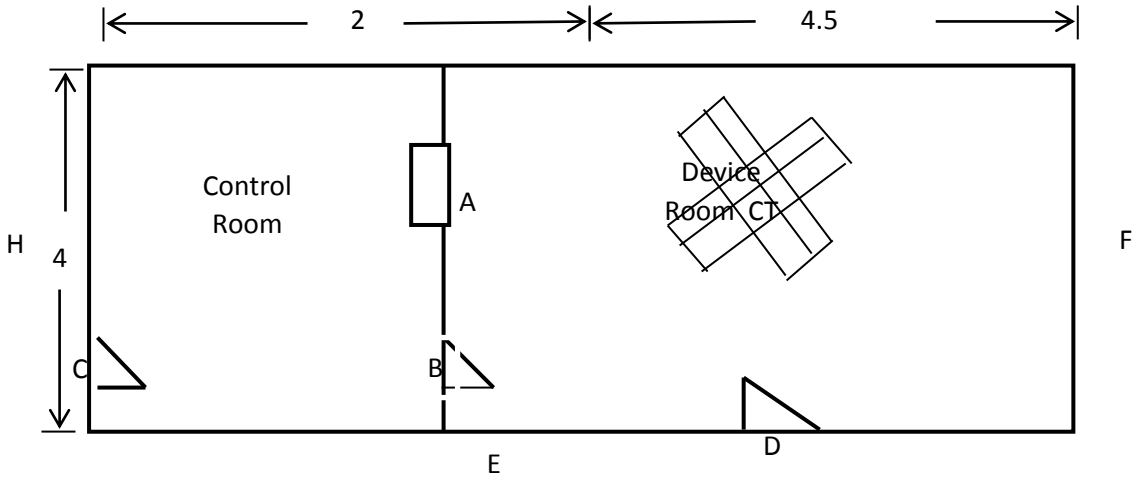


Figure 4-3 show design computed tomography dimension at C Diagnostic Center

Table 4-3 show computed tomography dimension at C Diagnostic Center

C

| *SAMPLE* | *Definition* |
|---|---|
| **A** | **Lead glass** |
| **B** | **Control Room Door** |
| **C** | **Staff entrance** |
| **D** | **Patient entrance** |
| **E** | **Passage** |
| **F** | **Awaiting arena** |
| **H** | **Passage** |

Result 4-3:

| Room | Distance | Reference |
|---|---|---|
| Control | 3 | 3 |
| Waiting area | 2 | 2 |
| Door to control | 2 | 2 |

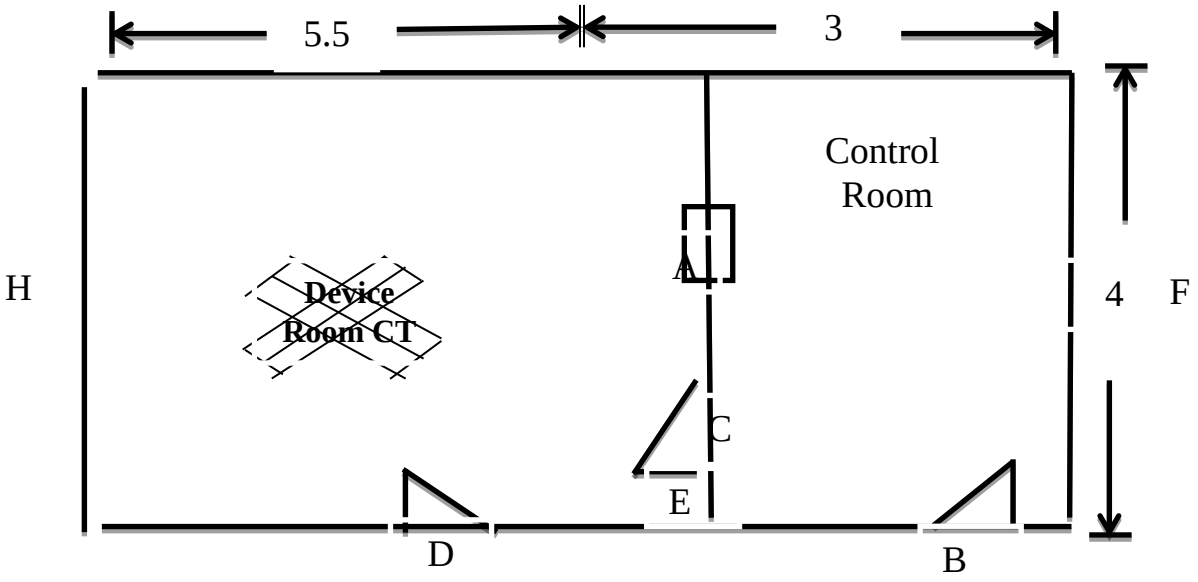


Figure 4-4 show design computed tomography dimension at D hospital

Table 4-4show computed tomography dimension

| ***SAMPLE*** | ***Definition*** |
|---|---|
| **A** | **Lead glass** |
| **B** | **Staff entrance** |
| **C** | **Control Room Door** |
| **D** | **Patient entrance** |
| **E** | **Awaiting Arena** |
| **H** | **Passage** |

Result 4-4:

| **Room** | **Distance** | **Reference** |
|---|---|---|
| Control | 3 | 3 |
| Waiting area | 2 | 2 |
| Door to control | 2 | 2 |

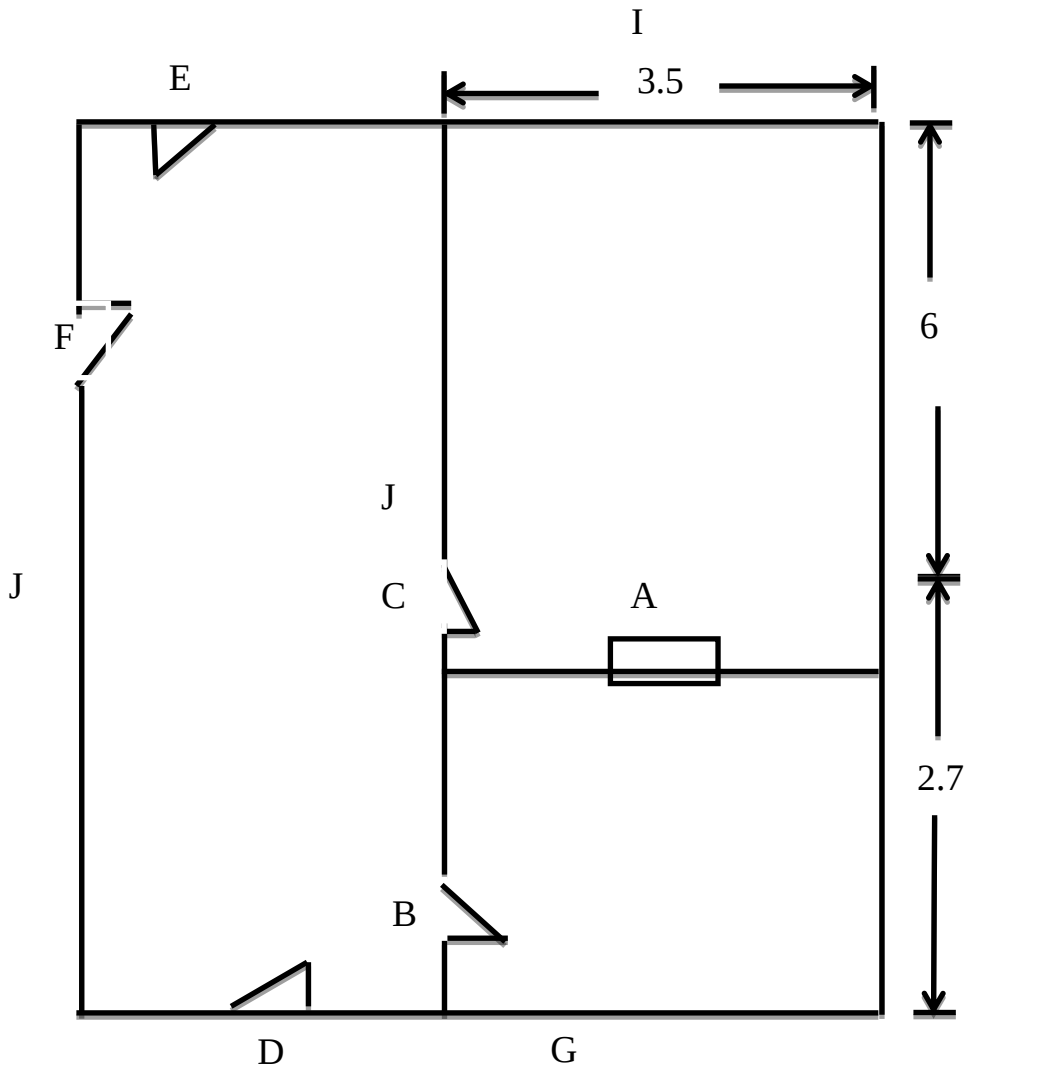


figure 4-5 show design computed tomography dimension at E

Table 4-5 show computed tomography dimension at E

| *SAMPLE* | *Definition* |
|---|---|
| **A** | **Lead glass** |
| **B** | **Staff entrance** |
| **C** | **Patient entrance** |
| **D** | **Main Door of Department** |
| **E** | **Report Room** |
| **F** | **Device Operating** |
| **G** | **Awaiting Arena** |

**Result 4-5:**

| Room | Distance | Reference |
|---|---|---|
| Control | 3 | 3 |
| Waiting area | 1.75 | 2 |
| Door to control | 1.75 | 2 |

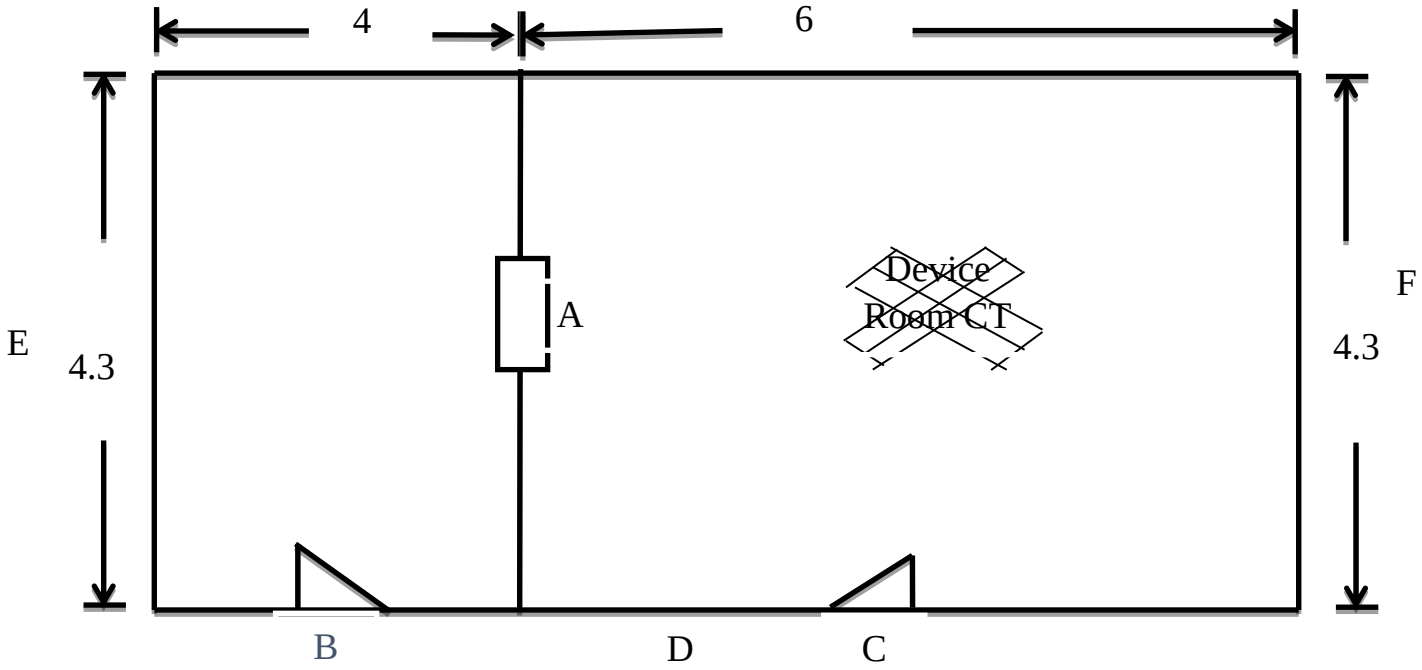


Figure 4-6 show design computed tomography dimension at F Center

Table 4-6 show computed tomography dimension at F Center

| *SAMPLE* | *Definition* |
|---|---|
| **A** | **Lead glass** |
| **B** | **Staff entrance** |
| **C** | **Patient entrance** |
| **D** | **Awaiting Arena** |
| **E** | **X-ray room** |
| **F** | **Officer** |

**Result 4-6:**

| Room | Distance | Reference |
|---|---|---|
| Control | 3 | 3 |
| Waiting area | 2 | 2 |
| Door to control | 2 | 2 |

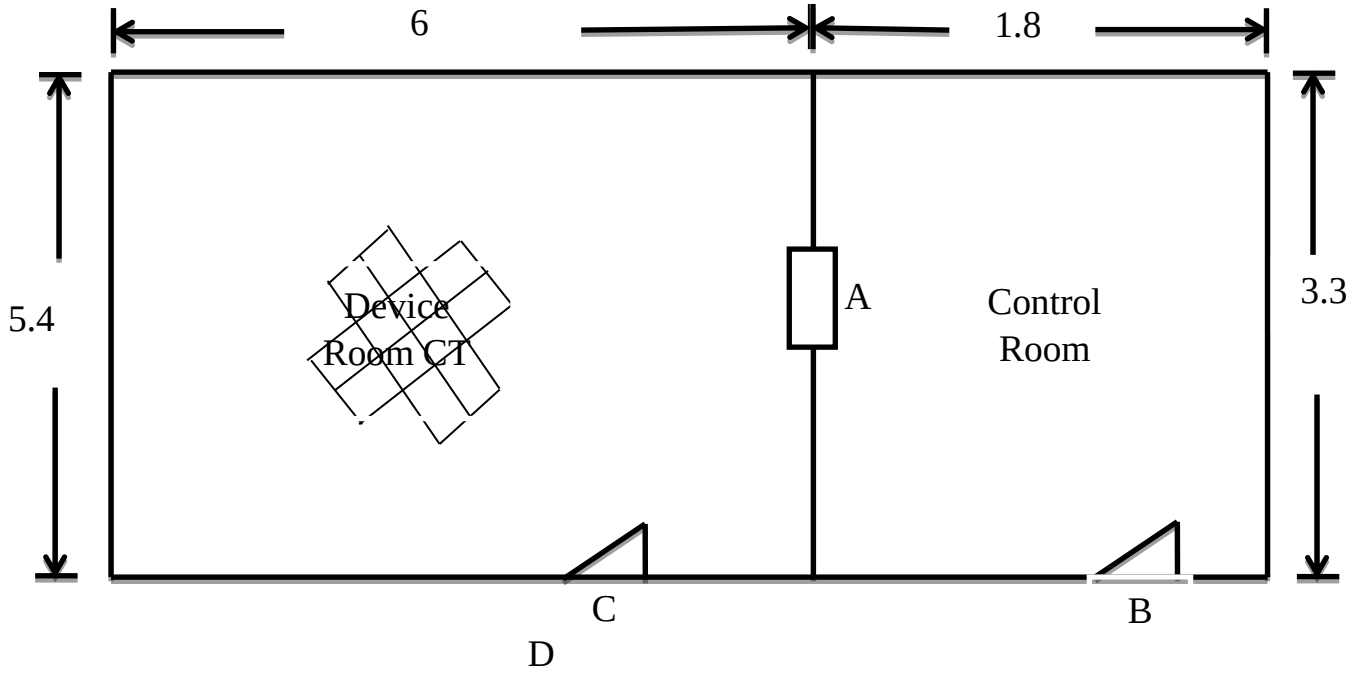


Figure 4-7 show design computed tomography dimension at G Hospital

Table 4-7 show computed tomography dimension at G Hospital

| *SAMPLE* | *Definition* |
|---|---|
| **A** | **Lead glass** |
| **B** | **Staff entrance** |
| **C** | **Patient entrance** |
| **D** | **Awaiting Arena** |

**Result 4-7:**

| Room | Distance | Reference |
|---|---|---|
| Control | 3 | 3 |
| Waiting area | 1.85 | 2 |
| Door to control | 1.85 | 2 |

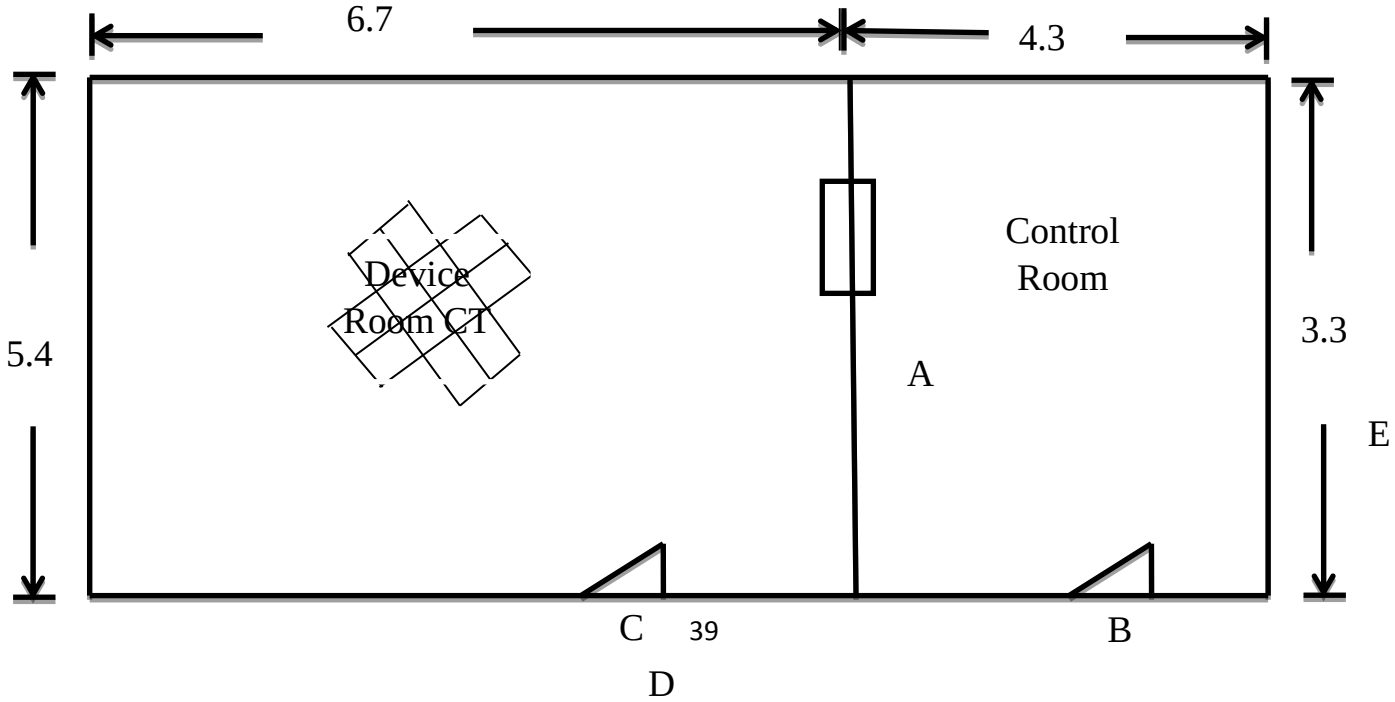

Figure 4-8 show design computed tomography dimension at H Hospital

Table 4-8 show computed tomography dimension at H Hospital

| *SAMPLE* | *Definition* |
|---|---|
| **A** | **Lead glass** |
| **B** | **Staff entrance** |
| **C** | **Patient entrance** |
| **D** | **Awaiting Arena** |
| **E** | **X-ray room** |

**Result 4-8:**

| **Room** | **Distance** | **Reference** |
|---|---|---|
| Control | 3 | 3 |
| Waiting area | 2 | 2 |
| Door to control | 2 | 2 |

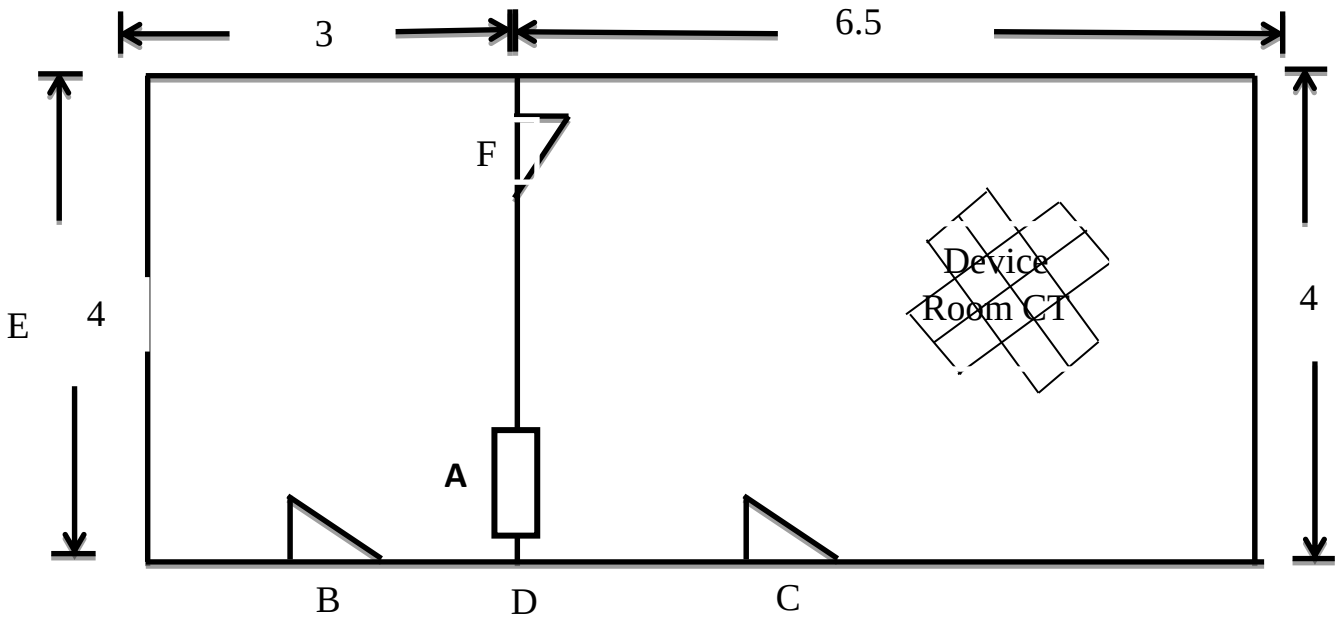

Figure 4-9 show design computed tomography dimension at I Hospital

Table 4-9 show computed tomography dimension at I Hospital

| ***SAMPLE*** | ***Definition*** |
|---|---|
| **A** | **Lead glass** |
| **B** | **Staff entrance** |
| **C** | **Patient entrance** |
| **D** | **Awaiting Arena** |
| **E** | **Passage** |
| **F** | **Control Room Door** |

**Result 4-9:**

| Room | Distance | Reference |
|---|---|---|
| Control | 3 | 3 |
| Waiting area | 2 | 2 |
| Door to control | 2 | 2 |

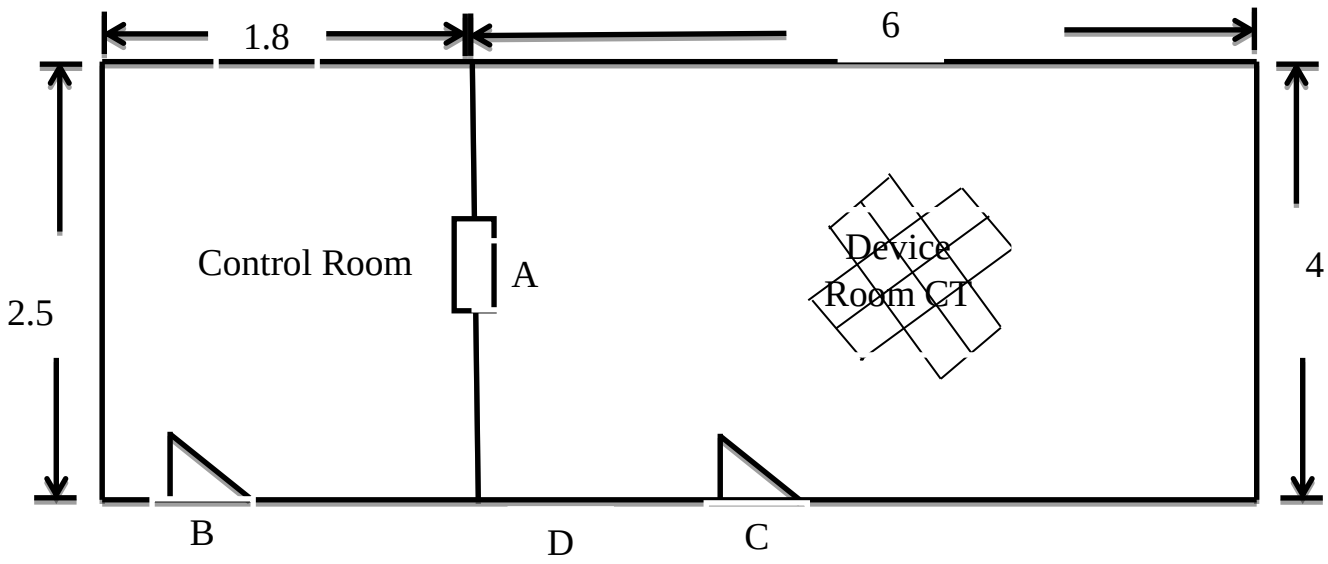

Figure 4-10 show design computed tomography dimension at J Hospital

Table 4-10 show computed tomography dimension at J Hospital

| ***SAMPLE*** | ***Definition*** |
|---|---|
| **A** | **Lead glass** |
| **B** | **Staff entrance** |
| **C** | **Patient entrance** |
| **D** | **Awaiting Arena** |

**Result 4-10:**

| Room | Distance | Reference |
|---|---|---|
| Control | 3 | 3 |
| Waiting area | 2 | 2 |
| Door to control | 2 | 2 |

## Chapter five

# Discussions, Conclusion and Recommendation

### 5-1 Discussion:

The study done in ten different department of diagnostic design CT rooms in Khartoum state from October 2020 to march 2021. The study was using ammeter to measure the dimensions of the CT scan rooms to compare them with the global system for the dimensions of the CT scan rooms and whether they were in conformity the international standards.

In A hospital, all the sizes of the control room and the device room were found in conformity with the specifications of the international design system, with awaiting room for patients and companions, a room for assistive devices and a room for writing reports as well as with the presence of the CT section away from the rest of the departments.

In B specialized hospital, found all dimensions of the control room and the device room are identical to the specifications of the international design system, but with an opening in the interval between the control room and the device room in upper area of lead glass and this opening violates the design, as well as with the presence of a laboratory adjacent to the CT room, and this exposes people to radiation.

In C diagnostic center all dimensions of the control room and the device room were found in accordance with the specification, with a waiting room for patients and companions, as well as with the presence of the department sit far from the rest of the department.

In D specialist hospital, the dimensions were found in compliance with the standards, with a waiting hall and a separate site for the department.

In E diagnostic center there is a shortage in the width of the control room, the device room and there is a room for writing reports, a room for assistive device,

a waiting room for patients and companions and the department is at the bottom of the building

In the F center is an integrated diagnostic radiology department that conforms to the specification an x-ray room and a CT room, and a common control room between them a waiting room and a report writing office, and this is the best design.

In G hospital, there is a shortage in the dimensions of specifications as well as presence of a waiting room and the location of the diagnostic radiology department separate from the rest of the sections at the bottom of building.

In H hospital, all dimensions were found identical and the presence of an integrated diagnostic radiology department includes room between them.

In I hospital, all dimensions of the control room and the device room were found identical with a waiting room for patents and companion.

In J hospital, there is a shortage in the dimensions of the control room and the device room in conformity with the specification, with awaiting room for patients and companions.

## Conclusion:

The design of the CT rooms is a relatively complex task, but it can be simplified by using some measurements and matching them with the international measurements of the CT rooms recognized in the global radiation protection organization. in order to reduce radiation damage to the technician the patient and the public.

This study was conducted in ten different hospitals in Khartoum state in the design of CT scan rooms, it has been found that there are seven hospitals that meet the international specifications for the design of CT rooms, and they are A, C, D, F, H, I, and J hospitals, also I found some differences in the design of the CT room B specialist hospital, there is an opening in the separation between the control room and the machine room in the upper area of the wall.

Also there is a difference in the design of the CT rooms in G and E hospital diagnostic center, represented by the lack of the scale dimensions of the control room and the device room (design room).

## 5-3 Recommendation:

In a futures study I recommend the:

- necessity of providing protection materials to protect the patient, the public and employees, and taking the following factors into account namely floors, walls, ceilings and doors on the basis of providing protection from radiation.
- The control room must be separated from the device room and has dimensions identical the design of the CT scan rooms.
- The study recommends the necessity to take the dimensions correctly in order to ensure the quality and integrity of the design of the CT room in terms of the dimensions recognized by the atomic energy agency.

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