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Study of Scattered Radiation Dose From Computed Tomography In Adamawa German Medical Centre, Yola, Nigeria

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ABSTRACT: *In this work, we studied the relationship between the scattered radiation dose with stay time and distance, using computed tomography CT) in Adamawa German Medical centre, Yola. This is because distance and stay time are key figures of merit in radiography. Twenty thermo – luminescent dosimeters (TLD) were positioned at different places both inside and outside the CT scan room, to detect and measured the scattered radiation dose. The readings were taken to Energy and Research Center, ABU Zaria, where the scattered radiation dose were interpreted using Harsho 4500A. The results show an inverse correlation of* **-** *0.58 between the distance and the scattered radiation dose inside the CT room for both public and occupational exposure, and a strong inverse correlation of* **-** *0.96 between the distance and the scattered radiation dose outside the CT room for both public and occupational exposure. The results also show that if the scattered radiation dose is high, then, small stay time is required for one to be exposed to radiation hazard; and vice versa. The work has provided the time frame required for occupational workers in the center to go for periodic checkups against radiation risk.*

Keywords*: Computed tomography, thermo – luminescent dosimeter, radiation dose, stay time, distance.*

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I. INTRODUCTION

Radiation could be defined as the propagation or emission of energy by a radioactive source through space or a material medium. This form of energy can either be in the form of a particle or wave [1]. Radiation could be ionizing or non – ionizing. Radiations that do not cause ionization when they interact with matter are referred to as non – ionizing, while those that can cause ionization when they interact with matter are called ionized radiations. The use of ionizing radiation for diagnostic and treatment purposes has increased due to the development of new equipment and easier access to radiological exams [2].

Dose is defined as a carefully measured and administered quantity of a drug that is prescribed by a physician for a patient at any one time. It can also be defined as the actual quantity of a chemical administered, or, of radiation received by a person or an organism [3]. Radiation dose is the energy of ionizing radiation absorbed per unit mass of any material. When ionizing radiation penetrates the human body or an object, it deposits energy. Radiation dose quantities are described in three ways: absorbed, equivalent, and effective dose [4].

Computed tomography (CT) is a useful tool for diagnosis in medicine, though, as an ionizing radiation, if not properly utilized can cause cancer [5]. CT scanning is becoming a subject of concern because of its prevalence in pediatric patients [3]. It is one of the most important medical innovations in human history, because images display soft tissue contrasted with anatomic detail, facilitating unprecedented diagnostic accuracy [6].

In radiological departments and units, it is expected that appropriate radioprotection guidelines should be provided for workers, such as shielding materials, and, regular checkups to avoid possible harmful risk from escaped or scattered radiation dose. Most of technologist's occupational exposure comes from scattered radiation; therefore, using safety measures against scattered radiation will effectively lower a technologist's occupational exposure and possible risk [7].

Medical radiation is commonly used for clinical diagnosis and treatment [8]. In radiology, there are three guidelines for controlling exposure to radiation; time of exposure to be minimized; distance from the source should be maximized, and shielding should be adequate.

In this work, we studied the relationship between two of these three parameters; namely distance and stay time against radiation dose. Scattered radiation dose were detected using thermo – luminescent dosimeter (TLD) both inside and outside the CT scan room of Adamawa German Medical Centre, Yola. We were able to establish that there are scattered radiation dose both inside and outside the CT scan room, and, there is relationship between stay time, distance and radiation dose.

II. THEORETICAL BACKGROUND

The theoretical section of this study is divided into three; the working principles of CT scan; the TLD and the basic equations used in the research work.

Brief Working Principles of CT Scan

Computed tomography (CT) is an imaging procedure that uses special X – ray equipment to create detailed pictures, or scans, of areas inside the body taken in different directions, and combines data from several X – rays to produce these detailed images of structures inside the body [1]. A CT scanner emits a series of narrow beams through the human body as it moves through an arc. Unlike the X – ray machine that sends just one radiation beam, CT scans produce 2 – dimensional images of a "slice" or section of the body. The data can also be used to construct 3 – dimensional images, which could be displayed on the screen [9].

The CT scanner uses a motorized X – ray source that rotates around the circular opening of a donut – shaped structure called a gantry. During a CT scan, the patient lies on a bed that slowly moves through the gantry while the X – ray tube rotates around the patient, shooting narrow beams of X – rays through the body. Instead of film, CT scanners use special digital X – ray detectors located directly opposite the X – ray source [5].

The thermo – luminescent dosimeter (TLD)

The thermo – luminescent dosimeter (TLD) is a passive radiation detection device that is used for personal dose monitoring or to measure patient dose [10]. It is one of the dosimeters that are used in detecting scattered radiation dose. They are often used instead of the film badge. It is either powered with lithium fluoride or lithium borate crystals in compact Teflon coated casing, and could be placed in the collimated field to measure organ dose [4].

Basic Equations used

Three equations were used in this work as theoretical background equations; however, two were used in the computation process; the equation to compute the stay time, and the correlation equation that correlates the distance with radiation dose.

(i) The Stay time

The stay time is also known as time of exposure. It describes how long a person can stay in an area without exceeding a prescribe dose limit. The amount of radiation an individual accumulates will depend on how long the individual stays in the radiation field. The stay time is an important factor in radiography, since radioprotection requires periodic monitoring of radiation dose of operators. The stay time is given by equation (1).

$$\text{Stay time} = \frac{\text{dose limit}}{\text{dose rate}} \tag{1}$$

where dose limit is measured in mrem, and dose rate is in mrem/hr. The stay time is thus measured in Hr.

(i) Distance

Distance is a measure of how far an object has travelled from its starting point, or how far away it is. It is the same as length and is measured in meters. A greater distance from the radiation source can reduce radiation exposure. The amount of radiation exposure is inversely proportional to the square of the distance. The amount of radiation an individual receives depends on how close the person is to the source and this agrees with the inverse Square Law which states that " The intensity of the radiation (I) decreases in proportion to the inverse of the distance from the source (d) squared".

$$I \; \alpha \; \frac{1}{d^2} \tag{2}$$

Equation (2) can be written as

$$I = k \frac{1}{d^2} \tag{3}$$

where k is a constant.

(ii) Intensity of Radiation

The intensity of radiation as the rate of emitted energy from unit surface area through unit solid angle, expressed in W/m^2 [11]. It is expressed mathematically as.

$$I = \frac{\langle P \rangle}{A} \qquad (4)$$

where $\langle P \rangle$ is the time – averaged power, and A is the area which is propagating in a plane perpendicular to the direction of propagation.

(iii) Linear Correlation Coefficient

The correlation coefficient (r) is the measure of the strength of a linear relationship between two variables [4]. Part of this study was to determine the strength of the relationship between the distance where the TLD's are placed and the intensity of the scattered radiation from the CT scan. The correlation coefficient (r) is given as

$$r = \frac{N\Sigma XY - \Sigma X\Sigma Y}{\left\{\left(N\Sigma X^2 - (\Sigma X)^2\right)\left(N\Sigma Y^2 - (\Sigma Y)^2\right)\right\}^{1/2}} \qquad (5)$$

where X and Y are the two independent variables.

III. MATERIALS AND METHODS

This section is divided into five subsections; the brief history of the study area, the layout of the CT scan room; materials used in the study; how measurements were carried out, and, how the readings taken were analyzed.

Brief History of the Study Area

This research work was carried out in Yola, the capital of Adamawa state, located at longitude 9^o 20$'$ N and latitude 12^{o}50$'$ E [12]. The Adamawa German Medical centre (AGMC) is a hundred bed space capacity centre, established in the year 2009 by the administration of the governor, His Excellency, Vice Admiral Murtala H. Nyako (Rtd). It however came into full clinical operation and services in March, 2012, and, latter as a referral centre. It is located within the premises of the State's Specialist Hospital Yola, but clearly curved out and fenced from the Specialist Hospital.

The Layout of CT Scan Room

The layout of the CT radiological section of the Adamawa German Centre is shown in Fig1. The general description of the various rooms and points where the TDL's were placed is presented in Table 1.

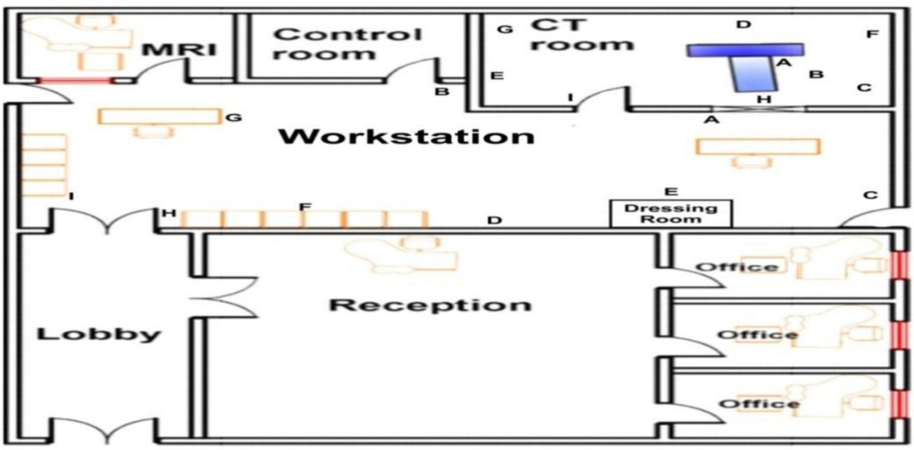

Figure 1: Layout of CT Radiological Section Adamawa German Medical Center Yola. (Source; [13])

Table 1. General description of positions of the CT room and points of measurement

S/N	Points of Measurement	Inside CT Room	Points of Measurement	Outside CT Room
1	A	Near the centre of gantry unit.	J	Radiographers console desk
2	B	Front, left of gantry unit.	K	Control room door

3	C	Front, far left of gantry unit	L	Kitchen door,
4	D	Directly behind the gantry unit.	M	Visitors and patient relatives 1
5	E	Front, right side of gantry unit.	N	Patients dressing room
6	F	Back, right side of gantry unit.	O	Visitors and patient Relatives 2
7	G	Back, left side of gantry unit	P	MRI Console desk
8	H	closed to the patient feet in front of the gantry unit	Q	Main door
9	I	CT room, main entrance	R	CT work station, main entrance

Materials
The materials used in the research work and their functions are presented in this sub – section
CT Scan: Syngo CT 2006A model was used for the diagnosis, it is placed inside the CT room
Measuring Tape: A measuring tape calibrated in meters was used to measure the distance where the TLD's were
positioned to the CT scan.
TLD: Twenty TLD's were used to detect the scattered radiation dose.
Harsho 4500A: Instrument used to interpret the scattered radiation dose detected by the TLD

IV. METHODOLOGY

The measuring tape was fixed at the referenced point being the base point of the gantry tube and then drawn, with calibration face up to the various points of interest in an increasing order of distance. Although, the radiographer decides where some of the points should be placed, so that busy areas were avoided. Twenty TLD's were used; nine inside the CT room, and nine outside. Each of the eighteen TLDs was placed at positions as indicated in Table 1, then, their respective distances were measured. The other two TLDs were used to measure the background radiation in each case, so that the background radiation is subtracted from the radiations detected from the eighteen TLDs. The background radiation is the radiation generated by the natural environment since the creation of the earth [14]. The TLDs detected the scattered radiation dose from the various positions both inside and outside the CT scan.

The TLDs were taken to Energy and Research Center, ABU Zaria, where the scattered radiation dose were interpreted using Harsho 4500A. The stay time was also calculated by first noting the standard dose limit given by the ICRP been 20 mSv (= 2000 mrem) absorption for a period of one year applicable to occupational exposure, and, 1mSv (= 100 mrem) dose absorption in a year for public exposure [15]. In each case, appropriate conversion from mSv to mrem was made according to [15].

Similarly, for each point, the calculated dose limit was used with the various corresponding measured radiation dose expressed in mrem to obtain the stay time in hours. The stay time was calculated using equation (1), while, the linear correlation coefficients were calculated using equation (5).

V. RESULTS AND DISCUSSION

In this section, the results obtained are presented and discussed

Results

The results are presented are based on the measurements taken from both inside and outside of the CT scan room. The correlation coefficients were calculated as well. The background radiation dose inside the CT scan room was 0.01 mSv, while the background radiation dose outside the CT scan room was 0.09 mSv.
Tables 2 and 3 present the values of the scattered radiation dose and the calculated stay time inside the CT scan room for occupational and public exposure respectively, while, Tables 4 and 5 present the values of the scattered radiation dose and the calculated stay time outside the CT scan room for occupational and public exposure respectively.

Table 2. Intensity of radiation dose and stay time inside CT examination room for occupational exposure

TLD Point of Measurement	Distance (m)	Intensity of Radiation Dose (mSv)	Intensity of Radiation Dose (mrem)	Stay Time for Occupational Exposure (Hr)
Point A	0.60	0.82	82	24.40
Point B	1.20	0.74	74	27.03
Point C	2.00	0.70	70	28.57
Point D	2.10	0.79	79	25.32
Point E	2.30	0.40	40	50.00
Point F	2.51	0.32	32	62.50
Point G	2.81	0.24	24	83.30
Point H	3.60	0.83	83	24.10
Point I	4.20	0.10	10	200.00

Table 3. Intensity of radiation dose and stay time inside CT examination room for public exposure

TLD Point of Measurement	Distance (m)	Intensities of Radiation Dose (mSv)	Intensity of Radiation Dose (mrem)	Stay Time for Public Exposure (Hr)
Point A	0.60	0.82	82	1.22
Point B	1.20	0.74	74	1.35
Point C	2.00	0.70	70	1.33
Point D	2.10	0.79	79	1.26
Point E	2.30	0.40	40	2.50
Point F	2.51	0.32	32	3.13
Point G	2.81	0.24	24	4.20
Point H	3.60	0.83	83	1.20
Point I	4.20	0.10	10	10.0

- The correlation coefficient between distance and radiation dose inside CT examination room for both occupational and public exposure = - 0. 58

Table 4. Intensity of radiation dose and stay time outside CT examination room for occupational exposure

TLD Point of Measurement	Distance (m)	Intensity of Radiation Dose (mSv)	Intensity of Radiation Dose (mrem)	Stay Time for Occupational Exposure (Hr)
Point J	4.00	0.08	8.0	250.00
Point K	5.90	0.07	7.0	285.00
Point L	7.80	0.06	6.0	333.30
Point M	8.30	0.05	5.0	400.00
Point N	8.70	0.04	4.0	500.00
Point O	9.40	0.03	3.0	666.70
Point P	10.00	0.02	2.0	1000.00
Point Q	10.80	0.01	1.0	2000.00
Point R	13.70	0.001	0.1	20,000.00

Table 5. Intensity of radiation dose and stay time outside CT examination room for public exposure

TLD Points of Measurement	Distance (m)	Intensity of Radiation Dose (mSv)	Intensity of Radiation Dose (mrem)	Stay Time for Public Exposure (Hr)
Point J	4.00	0.08	8.0	12.50
Point K	5.90	0.07	7.0	14.30
Point L	7.80	0.06	6.0	16.70

Point M	8.30	0.05	5.0	20.00
Point N	8.70	0.04	4.0	25.00
Point O	9.40	0.03	3.0	33.30
Point P	10.00	0.02	2.0	50.00
Point Q	10.80	0.01	1.0	100.00
Point R	13.70	0.001	0.1	1000.00

- The correlation coefficient between distance and radiation dose for both occupational and public exposure outside the CT examination room = **-** 0.96

VI. DISCUSSION

From Tables 2 and 3, the intensity of the scattered radiation dose for both the occupational and public exposure increases with increase in distance with the TLD's point of measurement, except at point H. This could be as a result of the position of the TLD to the gantry unit (See Table 1). This shows that the position of an operator from the CT scanner is also a risk factor. From Tables 2 and 3, there is an inverse correlation of **-** 0.58 between the distance and the scattered radiation dose inside the CT room for both public and occupational exposure. This is a good indication that the inverse square law is valid.

From Tables 4 and 5, there is a strong inverse correlation of **-** 0.96 between the distance and the scattered radiation dose outside the CT room for both public and occupational exposure. This is also in agreement with the inverse square law.

From Tables 2 – 5, it can be seen that the higher the radiation dose, the smaller the stay time, and vice versa. However, the stay time for occupational exposure is higher than that of the public exposure, this is in agreement with the [15]. It is expected that the operators should have protective cloths as against the public such as patient relatives that do not, and quite often ignorant of the risk involved in the process. Similarly, there is great difference in the values of the dose limit between the occupational and public exposure as given by[15} when calculating their respective stay times.

Since occupational exposure are at higher risk to the radiation hazard, from Tables 2 and 4, it is expected that an operator that works inside the CT room should go for periodic check up after every 50 Hrs of cumulative work time at an average distance of 2.3 m from the CT scan, while, those that stay outside should go for periodic check up after every 500 Hrs of cumulative work time at an average distance of 8.9 m from the CT.

VII. CONCLUSION

From the results obtained, one can conclude that:

Radiation dose: there are scattered radiations both inside and outside the CT examination room at Adamawa German Medical Center, Yola, when the machine is operational.

Distance and radiation dose: There is a strong inverse correlation between scattered radiation dose and distance both inside and outside the CT examination room, for both occupational and public exposure.

Stay time and radiation dose: One can also conclude that one requires only a small stay time to be at risk for higher radiation dose. The results also show that for higher distances, the scattered radiation dose is small, while the stay time is high, and, vice versa.

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