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Measurement of radiation dose level in patients undergoing brain CT examinations

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Abstract
The recent increase in the applications of Computed Tomography (CT) for routine organ imaging has potential health implications of exposure to ionizing radiation. The present work assessed the dose patients were exposed during brain CT examinations using the direct method. Thermo-luminescent dosimeter (TLD) based chips were employed at the front and back of the patient's heads under examination. Twenty-four (24) patients drawn from both genders and all ages, ranging from 1 year to 70 years, participated in the brain computed tomography examinations. The background radiation was considered during the computation of the effective dose. The highest effective dose value was 0.22mSv while the minimum value was 0.01mSv. The mean effective dose (HETLD) was calculated as 0.1mSv. The study found that the radiation doses to the brain in this hospital and for the analyzed data are minimum relative to other studies in the literature and within the limit of no concern (absorb dose of 0.5Gy) set by the International Commission for Radiation Protection (ICRP). Periodic measurements are however necessary for ensuring optimal use of radiation on patients.

Keywords: X-ray Radiation, Effective Dose, Computed Tomography, Radiation dose, Thermo-luminescent Dosimeter (TLD)

1. Introduction

Radiation is the generic name given to any description of emission and propagation (waves or particles) in any material medium of propagation or space [1]. The energy can be broadly received either from the decay of unstable atoms undergoing radioactive decay or via machine production through medical and industrial applications.

In general, radiation can be classified into ionizing and non-ionizing type [2], depending on whether the energy (ionizing radiation) is enough to break chemical bonds in molecules, eject electrons, as well as the ability to ionizes body fluid or cells [3]. This petal type of radiation is also capable of leading to cell death, reproductive failure, causing sharp alteration of genes for cell growth, DNA degradation, deformation of nuclear structure and a major agent of carcinogenesis [4]. However, though ionizing radiation could completely temper or modify structure of gene, it is nevertheless essential in nuclear medicine for imaging of organs and treatments of ailment. Medical procedures practice involving ionizing radiation comprises of imaging of organs, interventional procedures, and therapeutic treatments. Most of these procedures are usually available in nuclear imaging, radio-oncology, radiology units or clinics [5]. It was estimated that, annually, nearly 3.6billion and 6million diagnostic procedures and therapeutic treatments are performed in the world, respectively [5]. The radiation exposure in medicine is primarily to the patients, although there may be accidental exposure of the personnel. The benefit attached to these deliberate and voluntary exposures overweighs the detrimental health concern, especially at the shortest period.

In recent years, statistics has shown that radiation exposures for diagnoses via nuclear medicine, radiology and all other routes contribute nearly one-fifth of the average annual dose to the world population from all sources [6]. Thus, we can classify associated effect of ionizing radiation into deterministic or stochastic.

Studies from epidemiological studies [6] suggest indisputable evidence of increase in cancer incidence and morbidity by high dose exposure to ionizing radiation. To evaluate the probability of producing any deterministic risk or corresponding genetic mutations and stochastic effects, an accurate knowledge of radiation induced doses to specific organs are highly necessary [7].

Due to its advantages such as the offering of 3D image quality over routing X-ray, suitability for complex bones, etc. application of computed tomography tool has been in massive increase over the past decades, resulting to unavoidable concurrent increase in associated radiation dose (exposure) of the ionizing radiation.

Furthermore, lack of optimized protocols and failures of many diagnostic units to follow the recommended guidelines are contributing to the overall dose increase, in addition to the fact that the CT examinations have the potential to deliver higher radiation dose to patients relative to conventional x-ray radiological procedure. It is therefore necessary to investigate the protocols and standard followed by our relevant local imaging or therapeutic centers for proper protection of patients.

Following large cases of traumas and medical conditions, head CT examinations have been reported as the most frequently carried out CT procedure in Europe, with a range of (30% - 40%) for more than a decade, significantly adding to the collective dose of the populace [8]. Similarly, CT of the head is very common procedure in many Nigerian CT-equipped hospitals. There is also a concern on the substantial dose received by organs sensitive to radiation like eye lens, irradiated unintentionally through imaging of head or brain. Despite the presence of non-ionizing imaging modalities such as magnetic resonance imaging that are available for head or brain scan, CT radiology procedures continue to be on the increase following its handiness and clinical advantages. Radiation exposure may be quantified using various methods, and therefore not only using machine parameters. A crucial method to estimate radiation risk in radiology is to evaluate the effective dose to individual organs and is one of the most measured quantities [9]. More so, this quantity gives the possibility of comparative analysis among the various CT examinations as well as other non-CT examinations undertaken by patients. The effective dose accounts for radiation to the exposed organs, and sensitivity of each organ to developing cancer from radiation exposure. The International Commission for Radiologic Protection (ICRP) has in 2011, recommended radiation enhancing optimization to avoid absorb dose reaching 0.5Gy to brain as it is likely to cause cerebrovascular disease [10]. Although CT impart high radiation dose to patient, its benefit may outweigh the risk, especially when proper guidelines for all equipment, personnel and technical know-how are adopted. Therefore, the current work assessed the amount of exposure due to X-rays radiation delivered to patients during head CT scans in General Amadi Rimi Orthopedic and Specialist Hospital. The literature survey has not shown significant data on this subject using TLD chips. In our preliminary study [11], we have evaluated the anticipated dose from machine parameters (CT machine settings) on same subject.

2. Materials and methods

2.1 Computer Tomography Scan Machine

The CT machine used for the study in Amadi Rimi orthopedics and Specialist hospital was the slice Soma tom 64, with specifications of 140 maximum kVp, 70kilowatt power capacity and a range of current of 28 to 580 maximum mAs. The Siemens product also has a voltage of 80, 100,120, and 140, as well as collimation of 0.5mm tube by 6.8mm. In addition, the product has a scan length of 157cm, storage capacity of 300GB as well as image storage capacity of 260,000. The machine can produce a maximum number of 64 slice image in 0.33 to 15s and can be operated at temperature of 15-28°C.

2.2 Thermo-Luminescent Dosimeter and TLD Reader

In the present work, the thermoluminescence lithium fluoride-based dosimeter in the form of TLD chips with a commercial name of TLD 100 were employed for radiation dose collection. The corresponding TLD reader used is the Model 4500 TLD reader available at Centre for Energy Research and Training (CERT) of the Ahmadu Bello University, Zaria, Nigeria, coupled with a computer program which was fully calibrated before use.

2.3 Procedure

In the present work, a clinically based prospective cross-sectional research method was applied, following the ethical approval of the work by the local ethics committee of the Amadi Rimi orthopedic and specialist hospital, Katsina, as well as consent of the patients that participated in the research. We collected radiation dose data for Twenty-four (24) patients by using the Lithium Fluoride Thermo-Luminescent Dosimeter (TLD-100) chips obtained from the Centre for Energy Research and Training (CERT) of the Ahmadu Bello University, Zaria, Nigeria. The TLD chips were first, as a preparation to the present work, annealed to 0.00Gy for elimination of any pre-existing data on them. Similarly, the diagnostic room background radiation (BAG) was carefully measured and noted using relevant survey meter.

Two chips of TLD (labeled BACK and FRONT) were used on each specimen (patient). With the patient in a proper position for the CT – radiation exposure and investigation (just prior to strapping the head to avoid movements), the two TLD chips were respectively glued using gummed tapes on the front of the patient's head for the beam entrance point (glabella) and at the back of the head for the beam exit point (external occipital protuberance). These chips recorded the entrance dose and exit dose respectively during the exposure. Each pair of exposed TLD chips were properly and carefully identified with the patient's hospital ID (identification number), age, sex, and the exposure parameters.

The exposed TLD chips were then read using Harshaw4500 Dual TLD Reader at the Health section of the Centre for Energy, Research and Training (CERT) of the Ahmadu Bello University, Zaria, Kaduna State.

$$\text{Dose, D} = \frac{\text{Q} \times \text{ECC}}{\text{RCF}} \quad (1)$$

From which Q represents charge (the glow curve peak value, in nano Coulomb), ECC is the Elemental correction coefficient and is equal to 3749 while RCF represents the Reader calibration factor and is equal to 0.0171.

Dose data was analyzed using mathematical excel spread sheet and relevant formulas. The equivalents dose, effective dose and mean effective dose were analyzed.

The absorbed dose was calculated by the relation used in [12]:

$$\text{Absorbed dose: DT} = \text{ENT} - (\text{EXT} + \text{BAG}) \quad (2)$$

From which ENT represents (TLD front reading) entrance dose, EXT (TLD back reading) is for exit dose while BAG is for background radiation of the room. effective dose for every organ was computed from the absorbed dose by the relation in [12]:

$$Equivalent\ dose: HT = DT \times WR \quad (3)$$

Where the effective dose:

$$E = \sum HT \times WT = \sum DT \times WR \times WT \quad (4)$$

In which HT represents equivalent dose for each organ (or tissue) T and is obtained by multiplying DT (absorbed dose) (mSv) by the WR (radiation weighting factor).

Noting that X-rays radiation weighting factor is 1, therefore the DT would be equal to HT (equivalent dose). Thus, E = Σ (absorbed dose × WT). The tissue weighting factor (WT) explains the sensitivity of tissue to radiation and therefore explain the associated risk of the radiation. During the computation of the effective dose in this work, absorbed dose to each patient was considered uniformly distributed over the head region.

3. Results and discussions

The assessed effective dose (H_E) from head computed tomography examination at radiology department of General Amadi Rimi Orthopedic and Specialist Hospital, Katsina, was determined directly ($H_{E,TLD}$) via the thermos-luminescent dosimeter (TLD-100). In Figure 3.1, a pictorial representation of the calculated effective dose has been presented for twenty-four (24) patients of both genders who undertook the brain CT examination. The mean absorbed dose was 7.525mSv range from (1.03 – 21.64) mSv and the mean effective dose (H_{ETLD}) was calculated as 0.1mSv.

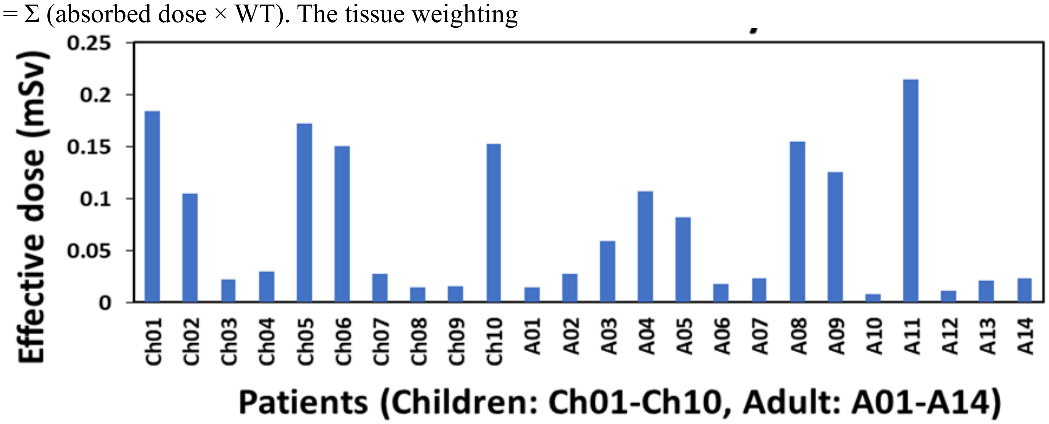

Figure 3.1: Effective dose for patients who undertook brain CT examination at Amadi Rimi Orthopedic and Specialist Hospital, Katsina

The illustrative representation in Figure 3.1 shows the effective radiation dose on brain via CT procedure for ages that range from 1year old baby to 70-year-old adults of both genders. The effective dose highest value was 0.22mSv while the minimum value was 0.01mSv. The effective dose $H_{E,TLD}$ (mSv) difference for various ages was found to be very minimal (between the children and adult), though the values for the adult appear to be slightly higher.

Table 3.1: Comparison of some reported works with the current study.

Study	Year	Location	$H_{E,TLD}$ (mSv)
Hyacienth *et al* [12]	2015	Nigeria	0.1
Islam [13]	2014	Bangladesh	1.9
Karim *et al.* [14]	2016	Malaysia	1.6
Hung Chinlin *et al.* [15]	2019	Taiwan	1.4
Present Study	2022	Nigeria	0.1

In Table 3.1, we have shown the comparison of the our calculated mean effective dose, $H_{E,TLD}$(mSv) with other studies around the globe, reported in [12 – 15]. The mean effective dose from this study was found to be among the lowest.

4. Conclusions

We have investigated radiation exposure to human brain via brain CT diagnosis with the help of TLD chips. The study found that the radiation doses to the brain are minimum and did not reach the limit of potential health concern for the analyzed data in the Amadi Rimi Orthopedic and Specialist Center, Katsina. The main concern is, however, the possibility of long-term effects, especially in cases of unnecessary repetitive CT examinations (except if justified), leading to probable concern induction by such low doses, especially in children who have higher life expectancy a head. Eye shielding (protection) during head CT scan may also help minimize exposure via eye (soft tissue). It is therefore recommended that periodic monitoring of radiation doses to patients in our local hospitals is enforced via the LTD chips analysis as well as careful monitoring of exposure parameters, to ascertain delivery of minimal radiation doses to subjects for optimal health.

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