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Estimation of radiation dose to the lens of eyes of patients undergoing cranial computed tomography in a teaching Hospital in Osun state, Nigeria

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▸ ***Original article***

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ABSTRACT

Background: One of the means of assessing dose to patients from Computed tomography (CT) procedure is through the determination of the skin entrance dose (ESD) with the appreciation of the concern that ocular exposure effects from CT scan includes possible induction of cancer and cataract. Due to the relatively more recent introduction of CT scans, little work has been done in this area in the country including exposure dose on the lens of the eyes of patients undergoing Cranial Computed Tomography (C-CT). ***Materials and Methods***: The Entrance Surface Dose (ESD) to the lens of eyes of 26 patients who had cranial CT procedures at a University Teaching Hospital in Ile-Ife, Nigeria has been determined in order to assess the level of radiation protection compliance and optimization of radiation safety at the hospital. ***Results***: Results indicate that the doses to the patients ranged between 17.13 mGy and 51.98 mGy within the period under study. The average doses obtained for the pediatric patients (1.5-18 yrs), young adults (19-49 yrs) and adults (≥50 yrs) were 31.14 ±11.02 mGy, 41.81±12.60 mGy and 31.97 ± 11.31 mGy respectively. The mean dose obtained in this study was lower than threshold for lens damage, therefore the dose recorded in this study is clinically safe. ***Conclusion***: This study represents a requisite pedestal on the need for a nation-wide evaluation and investigation of optimization of procedures in radiological examinations with a view to establishing a national dosimetry protocol and reference dose level or guidance level in the country.

Keywords: *Patients, cranial computed tomography, entrance surface dose, lens of the eyes, University teaching hospital.*

INTRODUCTION

Radiological examination utilizing X-rays remains the most frequently used ionizing radiation in Medicine, constituting the most significant manmade source of radiation exposure to the world population [1,2]. In diagnostic radiology, periodic dose assessments are carried out to encourage the optimization of the radiation protection of patients [3]. Dose measurements are required in every hospital to ensure compliance with acceptable dose limit. During the past two decades, several radiation dose surveys have been undertaken in many countries around the world. One of the outcomes of these efforts was the recognition of significant variations in patient doses between different radiological departments for the same type of examination [4]. These variations in dose within and among hospitals justify dose assessment in order to optimize the diagnostic radiological practice [5]. During recent years, dose to patient has become a major issue because of the increasing awareness and greater realization of the effects of ionizing radiation.

Moreover, X-ray users are also interested in dose information and demand for dose reduction. [6].

The use of computed tomography has shown a tremendous increase following technical advances in equipment that have enabled much faster image acquisition and greater processing capability [7]. Computed tomography (CT) is an invaluable diagnostic tool for many clinical applications. These applications range from cancer diagnosis to trauma and to osteoporosis screening. A cranial Computed Tomography (C-CT) scan is defined as an imaging method that uses X-rays to create cross-section pictures of the head, including the skull, brain, eyes sockets and sinuses. A computed tomography (CT) can reduce the need for invasive procedure to diagnose problem in the skull. This computed tomography (CT) is also known with various names according to the part of the body involved such as: Brain CT, Head CT, CT Scan-Skull, CT Scan- head. A cranial CT scan is recommended to help diagnose or monitor the following conditions: abnormal development of the head or neck; bleeding in the brain; brain tumor; craniosynotosis; injury to the head and face; hydrocephalus. In addition, a cranial CT may also be performed to look for the causes of: changes in thinking or behavior; fainting or multiple convulsion; headache, when certain other signs or symptoms are present; symptoms of damage to part of the brain, such as vision problems, muscle weakness, numbness and tingling hearing loss, speaking difficulties or swallowing problems. CT was the first imaging modality that made it possible to probe into the inner depths of the body slice-by-slice. Computed Tomography (CT) was introduced into clinical practice in 1972 and revolutionized X-ray imaging by providing high quality images which reproduced transverse cross sections of the body. Since 1972, CT imaging techniques has advanced greatly and gained technological sophistication. Tissues are therefore not superimposed on the image as they are in conventional projections. The technique offers in particular improved low contrast resolution for better visualization of soft tissue, but with relatively high absorbed radiation dose.

Because of the long acquisition times required for the early scanners and the constraint of cardiac respiratory motion, it was originally thought that CT would be practical only for head scans. Recent advances in acquisition geometry, detector technology, multiple detector arrays and X- ray tube design have reduced scan times to fractions of a second [8]. Computed tomography scanner technology today is used not only in medicine but in many other industrial applications, such as non-destructive testing and soil core analysis [9]. Modern CT scanners are so fast that they can scan through large sections of the body in just a few seconds. Such speed is beneficial to patients; especially children, the elderly and critically ill. For children, the CT scanner technique is usually adjusted to reduce the radiation dose because of the radiosensitive criticality of their organs[10-12]. Chodick *et al.* [13] reported that pediatric CT procedures might result in a small but non-negligible increased lifetime risk for cancer mortality.

The advent of CT has resulted in improved spatial resolution and faster scans acquisitions; consequently, CT has become a more widely used diagnostic tool, responsible for a greater proportion of medical radiation exposure to patients. Although, CT represents 11% of all radiographic examinations, it accounts for 67% of medically induced radiation exposure. Ten percent of all CT examinations are performed in children (age range: newborn – 15 years) to assess, disorders such as trauma, congenital abnormalities, metabolic diseases, inflammatory lesions, and tumors. During CT of the brain, the eye receives approximately 50mGy of radiation dose, depending on the instrument and protocol. The as low as reasonably achievable [ALARA] principle dictates that the radiation dose be limited to optimize the dose. The lens of the eye is particularly radiosensitive, as little as 0.5-2 Gy can cause detectable opacities while exposures of over 4 Gy may cause visual impairment secondary to cataracts induction. The eyes of children are especially radiosensitive, with less than half of this exposure causing cataracts [14]. Controlling radiation exposure to the eyes is important in patients with visual impairment, cataracts, young or sensitive eyes, and in patients who require multiple scans. Other than positioning the eyes outside the scan, no other radiation protection measure has been in place to protect eyes of the patients and this is a cause for concern. One of the dose descriptors for assessing level of exposure to radiation is skin entrance dose of patients undergoing the CT procedure, knowing fully well the concern about ocular exposure during the CT scan could lead to possible induction of cancer and cataract. In Nigeria there is paucity of data on CT scan, especially cranial CT scans. The situation in Nigeria is in contrast to what is obtainable in countries like the US, UK and Japan. In the UK for instance, X-ray computed tomography scans accounted for 46% of the medical radiation dose while nuclear medicine procedures accounted for a further 23% [8,14].

The present research project was initiated with the aim of evaluating the radiation doses to the eyes of patients undergoing some cranial diagnostic examinations in one of the major teaching hospitals in Nigeria. It was also anticipated that the study will help to understand the radiation optimization procedures operational at the center for the patients undergoing cranial CT. Specifically the objectives of this work were as follows:

(i) To estimate the ocular exposure from cranial CT in patients at the hospital.
(ii) To determine the maximum exposure to the lens of the eyes during cranial CT at the hospital.
(iii) To evaluate the compliance level of the practice at the hospital with respect to international guidelines pertaining to optimization of the radiological technique.

MATERIALS AND METHODS

This study was carried out on 26 patients (11 males and 15 females) consisting of pediatrics patients (1/2 -18 yrs), young adults (19- 49 yrs) and adults (≥ 49 years) who visited or referred to Radiology Department of Obafemi Awolowo University Teaching Hospital (OAUTH), Ile Ife, Nigeria. The patients undergone through cranial CT scan for various ailments. The dose was measured using pre-annealed TLD (100) chips obtained from the Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile Ife. The Pre-annealing was carried out using the external oven at the TLD laboratory of CERD, Ile - Ife. Annealing was carried out at a temperature of 400°C for 1 hour and allowed to cool for 24 hours before used. After the initial annealing the chips were calibrated and coded for easy identification during exposure and reading. After preparing the TLD chips of dimension 3.2 mm square and thickness 0.15 mm they were placed on the eyebrow of the patient as shown in figure 1 where the team enters into the patient. Due to the size and composition of the TLD chip, it does not affect the radiograph produced. The consent of the patients were obtained from the family members or guardians. Patients were divided into two groups: patient with contrast and some without contrast. Exposed TLD (chips) were returned to CERD for reading and recording using TLD reader model 3500 with Winrem.

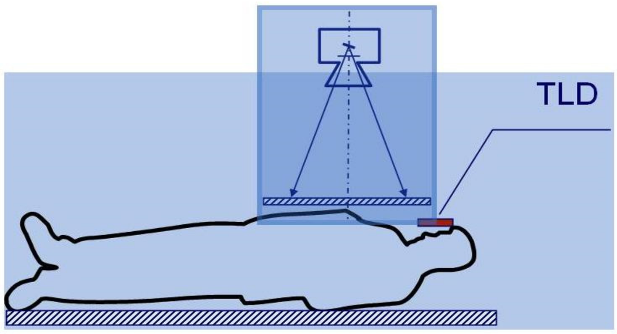

Figure 1. Typical placement of the TLDs on patients on central field axis of X-ray beam in the ESD measurements.

RESULTS

Table 1 shows patient identification number, age, sex and the medical condition of the patient during the CT scan. The table shows that the age of the patient range between 3 and 70 years and the number of pediatric patient scanned were five. Other patients include ten young adult and eleven adults.

The result of the entrance dose surface dose in mGy (ESD) delivered to the eyes of the patient undergoing cranial CT at the hospital (OAUTH) is presented in table 2.

The dose range between 17.13 mGy and 51.98 mGy. The mean dose for this study is 35.60 ± 12.37 mGy. The ESD for different age groups are presented in table 3. The mean ESD for pediatric, young adult and adult are 31.14 ± 11.02 mGy, 41.81 ± 12. 60 mGy and 31.97 ± 11.31 mGy respectively. Tables 4 and 5 show the entrance surface dose of patients (with and without contrast). For the patients scanned without contrast, the dose range between 19.58 and 25.08 (with mean of 22.27 mGy) and those with contrast have their dose ranging between 18.02 and 50.84 mGy (mean of 40.50 mGy).

DISCUSSION

Presently, the dose information on CT techniques are very few in Nigeria and the use of the CT technology is increasing steadily, therefore, the uses and the risks have not been well characterized [15]. The result of the investigation in table 1 shows that patients in this study undergone through cranial Computed Tomography (C-CT) because of different medical condition that range from head injury (due to accident) through paranasal sinuses to convulsion and loss of consciousness in the patient. Head injury due to road accident is part of the common examinations conducted during the course of this investigation. This medical condition is seen to be common among the young adult and adults. Sinusitis is one of the most common health care problems worldwide and there is evidence that it is increasing in prevalence and incidence. In patient suspected to have acute sinusitis, this stage is usually treated medically and radiological investigation is rarely required [16]. While plain radiographs have often been used as part of the initial workup of patients with suspected chronic

Table 1. The data of Patients and their medical conditions.

Patients	Age (Yr)	Sex	Medical conditions
P1	3	Male	Frontal Bossing at 1yr with speaking difficulties
P2	7	Male	Left Hemispaneous of 1month
P3	9	Female	Multiple Convulsion, loss of consciousness and stiff-neck
P4	11	Female	Head Injury following Road Traffic Accident, loss of Consciousness
P5	14	Female	Recurrent right ear discharge with polyploidy mass in right ear
P6	19	Male	Intra Cellebrallession probably neoplastic
P7	23	Female	Paranasal Sinuses (Recurrent Nasal discharge)
P8	23	Male	Right lower Jaw swelling of 6yrs
P9	23	Male	Loss of Consciousness 20hrs from Road Traffic Accident, Severe open Head Injury
P10	23	Female	Road Traffic Accident
P11	24	Female	Right Hemi Facial hypertrophy since Birth being prepared for reconstruction
P12	24	Male	Paranasal Sinuses (Nasal Tumor)
P13	40	Female	Multiple Cranial Nerve, Intracranial Space occupying lesion
P14	40	Male	Moderate Head injury following Road Traffic Accident
P15	49	Female	Headache, Sleeplessness associated with blurring of vision
P16	50	Male	Moderate Head injury following Road Traffic Accident
P17	51	Male	Paranasal Sinuses
P18	58	Female	Headache
P19	59	Male	Hemispheric Stroke probably hemorrlegic
P20	60	Female	Sudden loss of Consciousness while working in the Farm, Haemorrhage CVD
P21	67	Male	Hemispheric CVD
P22	70	Female	Headache, Neck Pain and loss of Consciousness
P23	72	Female	Brain-stem stroke with cross hemiparesis
P24	73	Female	Left Hemispheric
P25	75	Female	Recurrent Falls in a known hypertensive with sub-optimal B.P control
P26	75	Female	Convulsion, loss of Consciousness

sinusitis, it is well known that the sensitivity of plain radiography in diagnosing this condition is much lower than Computed Tomography as interpretation is fraught with difficulty due to the great variation in normal appearance of the paranasal sinuses the presence of many complex overlapping structures. Plain radiographs also have specificity and sensitivity when compared with clinical and surgical findings [17]. Earlier study carried out by the working party of the Royal College of Radiologist [18] showed that plain radiographs have no place in the routine management of rhino sinusitis, hence the need for CT.

Computed Tomography has become the method of choice for confirming and determining the extent of the disease (16). High-quality CT has become a well-established mandatory pre-operative diagnostic tool. It provides detailed information of the highly variable anatomy of the nasal cavities and paranasal sinuses in addition to the relationship

Table 2. The Entrance surface dose to the lens of eyes of the patients.

Patients	Sex	Contrasting Medium	Dose to the lens of the patients (m Gy)
P1	Male	YES	18.02
P2	Male	YES	39.48
P3	Female	YES	40.68
P4	Female	NO	20.35
P5	Female	YES	37.17
P6	Male	YES	50.79
P7	Female	YES	48.56
P8	Male	YES	49.96
P9	Male	NO	23.96
P10	Female	NO	22.20
P11	Female	YES	47.78
P12	Male	YES	51.98
P13	Female	YES	51.81
P14	Male	NO	25.08
P15	Female	YES	45.95
P16	Male	NO	22.12
P17	Male	YES	35.66
P18	Female	Yes	17.13
P19	Male	YES	24.76
P20	Female	NO	22.57
P21	Male	YES	42.75
P22	Female	NO	19.58
P23	Female	YES	33.42
P24	Female	YES	50.84
P25	Female	YES	40.61
P26	Female	YES	42.23
		Mean dose (STD)	35.60 ± 12.37
		Max dose	51.98
		Min dose	17.13

STD- Standard deviation

Table 3. Entrance surface Dose to all patients considered in study.

Patients	Age range (years)	Number of Patients (n)	Entrance dose (mGy)	Mean dose (mGy)
Pediatrics	1.5-18	5	18.02- 40.68	31.14±11.02
Young adults	19-49	10	22.20- 51.98	41.81± 12.60
Adults	50 and above	11	17.13- 50.84	31.97 ±11.31

of the diseased areas to vital structure. It provides a roadmap for endoscopic surgery [19-21].

In spite of the advantages of CT over plain radiography in paranasal sinusis diagnosis, it offers some disadvantages. CT imaging is a source of radiation exposure to some radiosensitive organs within the scanning field such as thyroid gland and the lens of the eyes. The eyes lens is prone to radiation-induced cataract [22]. To avoid the inherent detriment due to the eye lens during cranial Computed Tomography examinations.

It is evident from table 2 that patients who are injected with contrast medium received relatively higher doses of radiation with only exceptions of patients P1, P18 and P19. The contrast medium was applied to ensure visible image for radiologist to report accurately any observed abnormalities. Patients who had the procedure performed without contrast were especially victims of road accident and patients with hemorrhage conditions. The contrast was not applied to reduce dose during the CT scan and to ensure dose reduction at the first examination, since they might return to the hospital post screening evaluation.

The average dose of all patients received is given as 35.60 ±12.37 mGy recorded in the study is less than the dose recorded in Tanzania by Ngaile and Mesaki (2006) [23], that is 63.9 mGy. However, the dose obtained in this study is greater than those of Germany and Japan (24.8 mGy and 22.4 mGy respectively). The variation in the dose could be attributed to the difference in the number of slices in each study [24,25]. The usage of contrast and non-usage could also affect the dose measured.

Moreover, Table 3 shows the range of doses and mean doses delivered to different categories of patients. The range of the dose received by the adult is higher than the paediatric patient, only that the average dose received by the adult is greater than that of the pediatric by 0.83mGy. However the young adult received a mean dose of 41.81± 12.60 mGy. The upper bound of the dose of patients with contrast (51.98 mGy) in Table 5 is greater than those without contrast in Table 4. This is an indication that higher doses are being delivered to patients with contrast. This higher dose could be attributed to the longer time of exposure of the patient in order to obtain good image and for better diagnosis of deformities and abnormalities. The short period of examination of patients without contrast was to ensure dose reduction at the first examination since they might return for follow-up examinations.

The doses to young adults and adults are generally higher than those of the pediatric patients. This trend is an indication of dose optimization in pediatric patients. This is in agreement with international best practice. Although some individual doses (P6, P12, P13, P24- about 15% of the patients scanned) as indicated in Table 2 are relatively higher by a factor of 1.02 than the reference dose. However, the mean dose (35.60 mGy) recorded in this study is relatively lower than the reference dose of 50 mGy (multiple scan average dose-MSAD) [26]. This is an indication that to some extent, doses to the patient have been optimized. The results of this study shows that patient scanned here are at lower health risk. Moreover, our measured doses are still much lower than the 500 mGy threshold for lens damage and thus appear to be clinically safe, especially as patients are unlikely to need more than 1or 2 such fine scans in a lifetime. Additionally, a dose between 6 and 14 Gy is required for cataract formation [27]. This is at least about 120 CT scans based on our present result. This is far more than any patient is likely to receive.

With the advancement of CT scanning, accuracy of diagnosis and the attached benefits are clear, however, there are potential detriments attached to its use [8]. As children are at greater health risk of incurring stochastic effects, pediatric examinations should require special consideration in the justification process, thus the benefits of some high dose examinations in CT should be carefully weighed against the increased risk.

This study being a preliminary study especially in South Western, Nigeria requires that more exposure study to be undertaken in order to determine local reference dose of CT examination in SW Nigeria. In addition, it is essential to record the technical factors used during the examination in the future studies.

Table 4. Entrance surface dose to patients without contrast.

Patients	Age range (years)	Number of patients (n)	Entrance dose (mGy)
Pediatrics	1.5-18	1	20.35
Young adults	19-49	2	22.20- 23.96
Adults	50 an above	4	19.58- 25.08

Table 5. Entrance surface dose to patients with contrast.

Patients	Age range (years)	Number of Patients (n)	Entrance dose (mGy)
Pediatrics	1.5-18	4	18.02- 39.48
Young adults	19-49	7	45.95- 51.98
Adults	50 and above	8	24.76- 50.84

CONCLUSION

In this study, entrance surface doses to the lens of the eyes of patients who undergone through cranial CT scan at the Radiology Department of Obafemi Awolowo University Teaching Hospital, Ile Ife Nigeria have been measured to ascertain the level of radiation dose received by the patients during CT examinations. The mean dose obtained in the study is 35.60 ± 12.37 mGy and the entrance surface dose range between 17.13 mGy and 51.98 mGy. The average dose is relatively lower than the 50 mGy recommended by ICRP. The upper bound of dose (51.98 mGy) in this study is much lower than the 500 mGy threshold for lens damage and thus appears to be clinically safe.

This study forms a preliminary CT dose measurement in Nigeria and it would serve as baseline on which future dose measurement is based. However, more extensive dose measurement is required.

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