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Estimation of Radiation Dose to the Eye Lens in Cranial Computed Tomography Examinations in Federal Neuro-Psychiatric Hospital Maiduguri, Borno State, Nigeria

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Abstract: In this study, the amount of dose to the eye lens of patients undergoing cranial CT examination at Federal Neuro-Psychiatric Hospital Maiduguri was assessed. Sixty patients were recruited randomly based on patients' consent. Thermo luminescence Dosimeter chips were placed directly above the eye lens for dose measurement and evaluation. The TLDs were retrieved after exposure and were taken to the Centre for Energy Research and Training (CERT) Zaria for dose estimation using a TLD reader. The tube voltage and tube current ranged from 80 kVp to 140 kVp and 110 mAs to 140 mAs respectively. The result indicates that the cumulative doses to the eye lens for pediatric, young adults and adults ranged from (0.61 to 1.76) mGy, (1.34 to 7.52) mGy, and (1.81 to 8.69) mGy respectively. The entrance surface dose (ESD) to the eye lens of patients who underwent cranial CT radiography in Federal Neuro-Psychiatric Hospital Maiduguri is within the threshold level of 500 mGy as prescribed by the International Standards Organization on Radiation Protection. Therefore, this study concludes that the procedure of cranial CT examination at Federal Neuro-Psychiatric Hospital Maiduguri is clinically safe and the ALARA principle is being practiced.

Keywords: Cranial computed tomography, entrance surface dose, lens of the eyes, Federal neuro-psychiatric hospital Maiduguri.

1 Introduction

Computed Tomography (CT) has become the most outstanding tool either for diagnostic or therapeutic purposes in medicine which brings about detailed anatomical information. Exposure to high doses of radiation to the eye lens can cause visual impairment, cataracts, cancer, and even total blindness [1, 2].

Computed tomography (CT) scan has evolved in recent years in a very wide range and has become the most outstanding tool either for diagnostic or therapeutic purposes in medicine as a result of imaging selection and high resolution that brings about details anatomical information [1, 3]. 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. Tissues are not superimposed on the image as they are in conventional projections [4, 5]. The CT provides improved low-contrast resolution for better visualization of soft tissue but with a relatively high radiation dose [6].

A cranial CT scan is a diagnostic tool used to create detailed pictures of features inside our head, such as the skull, brain, paranasal sinuses, ventricles, and eye sockets [3, 7, 8]. A cranial CT scan is known by a variety of names as well, including brain scan, head scan, skull scan, and sinus scan. This procedure is noninvasive, meaning it doesn't require surgery. It's usually suggested to investigate various symptoms involving the nervous system before turning to invasive procedures. CT of the head uses special X-ray equipment to help assess head injuries, severe headaches, dizziness, and other symptoms of aneurysm, bleeding, stroke, and brain tumors. It also helps your doctor to evaluate your face, sinuses, and skull or to plan radiation therapy for brain cancer [1, 9, 10]. In emergency cases, it can reveal internal injuries and bleeding quickly enough to help save lives. The Cranial (CT) procedure involves consideration of the risk of ionizing radiation to the eye lens, the lens is composed of transparent, flexible tissue and is located directly behind the iris and the pupil. It is the second part of the eyes, after the cornea, that helps to focus light and images on your retina [6, 11, 12].

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In 2007, the International Commission on Radiological Protection (ICRP) report 103 was released, in which a detailed review of the epidemiological and (limited) mechanistic literature suggested that the lens of the eye may be more radiosensitive than previously thought [6, 13, 14]. However, at the time, insufficient information was available from which to draw a firm conclusion on eye sensitivity. This has since been followed by the ICRP statement on tissue reactions and report 118 which suggest an assumed absorbed dose threshold of 0.5 Gy for the lens of the eye and conclude with the recommendation to reduce the occupational equivalent dose limit for the lens from 150 mSv year21 to 20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv. The revised dose limits have now been incorporated into the current European basic safety standard (BSS), which must be implemented by the European Union (EU) member states by February 2018 [6, 14].

In humans, the lens of an eye is very radiosensitive, to as little as 0.5 - 2 Gy, which can cause detectable opacities while exposures of over 4 Gy may cause visual impairment secondary to cataract induction. The eyes of children are especially radiosensitive, with less than half of this exposure causing cataracts [1, 5, 15]. 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 the eyes of the patients and this is a cause for concern. The concern about ocular exposure during the CT scan could lead to possible induction of cancer and cataracts. In Nigeria, there is a paucity of data on CT scans, especially cranial CT scans. The situation in Nigeria contrasts with what is obtainable in countries like the US, UK, and Japan [3, 16, 17]. The present research project aims to measure and analyze radiation dose to the lens of the eye in cranial computed tomography examinations at Federal Neuro-psychiatric Hospital Maiduguri, Borno state. Nigeria.

2 Materials and Methods

This study is prospective research conducted on sixty patients undergoing cranial (CT) examination at Federal Neuro-Psychiatric Hospital Maiduguri. The patients are grouped based on age consisting of pediatric (1-17yrs), young adult (18-49yrs), and adults (50yrs above). The study was conducted between November 2020 and April 2021. Sixty patients (thirty-five males and twenty-five females) planned for cranial CT scans for various ailments were recruited. The dose was measured using pre-annealed TLD chips obtained from the Centre for Energy Research and Training (CERT) Ahmadu Bello University (ABU), Zaria. The Pre-annealing was carried out at 400^{o}C for 1 hour and allowed to cool for 20-24 hours before use. After the initial annealing, the chips were calibrated and coded for easy identification during exposure and reading. The TLD chips of dimension 3.2 mm square and thickness 0.15 mm were placed above the eyebrow of the patient before exposure. Due to the size and composition of the TLD chip, no artifact was seen on the radiograph produced. The consent of the patients was obtained from the family members or guardians. Patients were divided into two groups: patients with contrast and without contrast. Exposed TLD (chips) were returned to CERT, Zaria for reading and recording using TLD reader model 3500 with Winrem.

3 Results and Discussion

The gender distribution of the research work consists of 58% males and 42% females in the study group as shown in Table 1. Data generated are presented in four sections which include the medical conditions of the cranial CT patients, contrast medium of the patients, Entrance Surface Dose (ESD) dose of the patients, the comparison of dose obtained from TLDs to the threshold dose prescribed by organizations concerned with radiation protection. Results obtained from the TLD reading are then compared to the dose prescribed by organizations concerned with radiation protection, on the threshold limit of ionizing radiation to the lens of the eye of a patient undergoing cranial (CT) Examination.

Table 1 presents **the** Gender distribution of the patients either male or female and their respective percentages. Tables 2, 3, and 4 present data on Pediatric Patients, Young Adult Patients, and Adult Patients medical conditions respectively.

Table 1: Gender distribution of the patients

Sex	**Frequency**	**Percentage**
Male	35	58%
Female	25	42%
Total	**60**	**100%**

Tables 5, 6, and 7 present the results of entrance surface dose to the lens of eyes of pediatric, young adult, and adult patients respectively. The results indicate that the ESD doses to the patients undergoing cranial (CT) examination ranged between 0.61 mGy and 8.69 mGy within the period of the study. The TLD chip doses are in mSv, which were converted to mGy while the result of each age distribution is presented as their mean and standard deviation (Mean $\pm$ SD).

Table 2 The data of Pediatric Patients and their Medical Conditions.

Patients Label	**Age (yrs)**	**Sex**	**Medical conditions**
F/1/1	03	Male	Head Injury
F/1/2	11	Male	Road Traffic Accident
F/1/3	02	Female	Recurrent seizure necessary
F/1/4	14	Female	Headache
F/1/5	08	Male	Head injury due to fall
F/1/6	04	Female	Facial swelling gradually from birth
F/1/7	12	Male	Sudden weakness of lower limb
F/1/8	14	Female	Severe Headache
F/1/9	05	Male	Microcephaly seizure
F/1/10	07	Male	2^0 Scoliosis
F/1/11	17	Female	Nasal blockage
F/1/12	2	Male	Multiple convulsion
F/1/13	4	Female	Seizure
F/1/14	12	Male	Post infective Hydrocephalous
F/1/15	05	Female	Sudden inability to speak
F/1/16	07	Male	Dizziness after a Road Traffic Accident
F/1/17	1	Male	Frontal lobe syndrome
F/1/18	3	Male	Frontal Bossing at 1yr with speaking difficulties
F/1/19	7	Male	Hemispaneous of 1month
F/1/20	9	Female	Convulsion, loss of consciousness, and stiff neck

Table 3 The data of Young Adult Patients and their Medical Conditions.

Patients Label	Age (yrs)	Sex	Medical conditions
F/2/1	38	Male	Seizure disorder
F/2/2	32	Female	Facial Nerve palsy
F/2/3	38	Female	Stroke
F/2/4	30	Male	Nasal blockage
F/2/5	33	Male	Trauma to the head 12 years
F/2/6	40	Male	Gunshot injury
F/2/7	18	Female	Head trauma headache
F/2/8	29	Male	Recurrent Nasal Blockage
F/2/9	23	Female	Headache Blur vision
F/2/10	41	Male	Road Traffic Accident
F/2/11	35	Female	Head Injury due to Road Traffic Accident
F/2/12	35	Female	Stroke
F/2/13	48	Female	Palatal Mass
F/2/14	48	Female	Cervical spondylosis
F/2/15	27	Male	Nasal polyps
F/2/16	39	Male	Chronic Nuno sinusitis
F/2/17	35	Male	2^0 hemiparesis
F/2/18	32	Male	Headache & Poor Concentration
F/2/19	32	Female	Headache before loss of vision
F/2/20	40	Male	Headache

Table 4: The data of Adult Patients and their Medical Conditions.

Patients Label	Age (yrs)	Sex	Medical Conditions
F/3/1	76	Female	Stroke
F/3/2	67	Male	Sudden weakness of the right side
F/3/3	50	Male	Persistent headache
F/3/4	55	Male	Weakness of both lower limb
F/3/5	55	Female	Stroke
F/3/6	59	Male	Right weakness sided by welder
F/3/7	56	Male	Sudden weakness of left side of L body
F/3/8	55	Male	Front temporal dementia
F/3/9	60	Female	Sudden loss of speech
F/3/10	55	Male	Left maxillary swelling
F/3/11	53	Female	Stroke
F/3/12	70	Male	Transient Ischemic attack
F/3/13	70	Female	Headache due to fall
F/3/14	55	Male	Severe Headache
F/3/15	77	Male	Sudden inability to use LF upper limb
F/3/16	85	Female	Recurrent falls & dizziness
F/3/17	90	Female	Stroke
F/3/18	56	Female	Swelling on the nasal plate
F/3/19	55	Male	Cardiovascular disease
F/3/20	67	Male	5years headache/blindness for 6years

Table 5: The Entrance surface dose to the lens of the eyes of the Pediatric Patients.

Patients Label	**Sex**	**Contrasting Medium**	**Dose to the lens of the patients (mGy)**
F/1/1	Male	YES	1.45
F/1/2	Male	YES	1.60
F/1/3	Female	YES	1.34
F/1/4	Female	NO	0.61
F/1/5	Male	YES	1.63
F/1/6	Female	NO	1.00
F/1/7	Male	YES	1.15
F/1/8	Female	NO	0.83
F/1/9	Male	YES	1.55
F/1/10	Male	NO	1.05
F/1/11	Female	NO	1.06
F/1/12	Male	NO	0.79
F/1/13	Female	YES	1.51
F/1/14	Male	NO	0.86
F/1/15	Female	YES	1.45
F/1/16	Male	YES	1.76
F/1/17	Male	YES	1.66
F/1/18	Male	Yes	1.25
F/1/19	Male	NO	0.97
F/1/20	Female	YES	1.60
		Mean dose (STD)	**1.26 ± 0.34**
		Max dose	**1.76**
		Min dose	**0.61**

Table 6: The Entrance surface dose to the lens of eyes of the Young Adult Patients.

Patients Label	Sex	Contrasting Medium	Dose to the lens of the patients (mGy)
F/2/1	Male	YES	4.33
F/2/2	Female	YES	4.78
F/2/3	Female	YES	3.26
F/2/4	Male	NO	2.90
F/2/5	Male	YES	4.86
F/2/6	Male	YES	3.70
F/2/7	Female	NO	1.34
F/2/8	Male	NO	1.39
F/2/9	Female	YES	6.37
F/2/10	Male	YES	5.06
F/2/11	Female	YES	5.93
F/2/12	Female	YES	6.10
F/2/13	Female	NO	1.64
F/2/14	Female	YES	3.59
F/2/15	Male	NO	1.86
F/2/16	Male	YES	7.47
F/2/17	Male	YES	7.52
F/2/18	Male	YES	4.33
F/2/19	Female	YES	4.78
F/2/20	Male	YES	3.26
		Mean dose (STD)	**4.24 ± 1.88**
		Max dose	**7.52**
		Min dose	**1.34**

Table 7: The Entrance surface dose to the lens of eyes of the Adult Patients.

Patients Label	Sex	Contrasting Medium	Dose to the lens of the patients (mGy)
F/3/1	Female	YES	6.49
F/3/2	Male	YES	7.96
F/3/3	Male	YES	8.69
F/3/4	Male	YES	6.07
F/3/5	Female	YES	4.16
F/3/6	Male	YES	7.87
F/3/7	Male	YES	5.56
F/3/8	Male	NO	2.82
F/3/9	Female	YES	4.48
F/3/10	Male	NO	3.02
F/3/11	Female	YES	5.91
F/3/12	Male	YES	4.35
F/3/13	Female	YES	5.89
F/3/14	Male	YES	6.02
F/3/15	Male	NO	1.48
F/3/16	Female	NO	1.81
F/3/17	Female	YES	2.23
F/3/18	Female	YES	5.62
F/3/19	Male	YES	6.49
F/3/20	Male	YES	7.96
		Mean dose (STD)	**5.24 ± 2.14**
		Max dose	**8.69**
		Min dose	**1.81**

Table 8: Entrance surface dose to patients with contrast.

Patients	Age range (years)	Number of Patients (n)	Entrance dose (mGy)	Mean dose (mGy)
Pediatrics	1-17	12	1.25 – 1.76	1.5 ± 0.18
Young adults	18-49	15	3.26 – 7.52	5.02 ± 1.39
Adults	50 and above	16	2.23 – 8.69	5.98 ± 1.67

Table 9: Entrance surface dose to patients without contrast.

Patients	Age range (years)	Number of patients (n)	Entrance dose (mGy)	Mean dose (mGy)
Pediatrics	1-17	08	0.61 – 1.06	0.90 ± 0.15
Young adults	18-49	05	1.34 – 2.90	1.83 ± 0.64
Adults	50 and above	04	1.48 – 3.02	2.28 ± 0.75

Table 10: Entrance surface Dose to all patients considered in this study with their labels.

Patients	Age range (years)	Number of Patients (n)	Entrance dose (mGy)	Mean dose (mGy)
Pediatrics (F/1/1-20)	1-17	20	1.76 – 0.61	1.26 ± 0.34
Young adults (F/2/1-20)	18-49	20	7.52 – 1.34	4.24 ± 1.88
Adults (F/3/1-20)	50 and above	20	8.69 – 1.81	5.24 ± 2.14

Table 11: A Comparison of International Standards for eye lens exposure threshold dose to TLD Readings obtained from patients of all age groups.

Patients Categories	Present Study (Gy)	(ICRP) Standard Threshold Level (Gy)	(IAEA) Standard Threshold Level (Gy)
Pediatrics TLD Mean Readings (Gy)	0.00126	0.5	0.5
Young Adult TLD Mean Readings (Gy))	0.00424	0.5	0.5
Adult TLD Mean Readings (Gy)	0.00524	0.5	0.5

The average doses obtained for the pediatric patients (F/1/1-20) (1-17 yrs), young adults (F/2/1-20) (18-49 yrs), and adults (F/3/1-20) (≥50 yrs) were 1.26 ± 0.34 mGy, 4.24 ± 1.88 mGy and 5.24 ± 2.14 mGy respectively. The mean dose obtained in this study was much lower than the threshold of (0.5Gy) for causing vision impairment, cataracts, or even lens damage, therefore the dose recorded in this study is very much clinically safe.

For each patient, the medical conditions were noted down to enable one to understand how necessary administering contrast is. If the medical condition requires contrast, (Iodine-based) intravenous (IV) contrast agents have been developed that are highly visible in CT scans and are safe

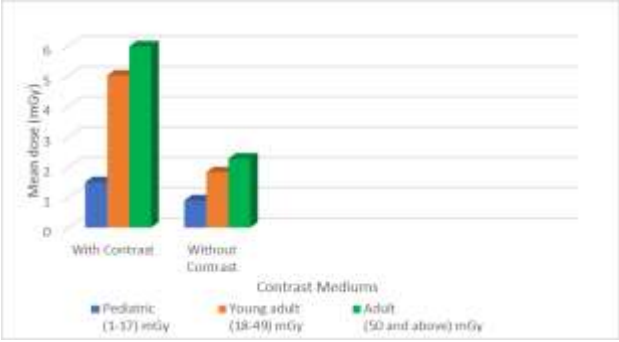

Fig.3: A Comparison chart of patients with and without contrast during their cranial CT scan.

to use on patients. The contrast agents contain substances that are better at stopping X-rays and, thus, are more visible on the CT image slice. Table 8 and Table 9 show the entrance surface dose to patients with and without contrast respectively while Figure 3 shows clearly how patients with contrast are in number than those without contrast which indicates that cranial CT patients have more severe medical conditions.

Table 10 shows the Entrance surface Dose for all patients considered in this research study which are all labeled according to their age groups, for pediatric age (1-17) label (F/1/1-20), Young adult age (18-49) label (F/2/1-2-) while adult age (50 above) label (F/3/1-20) while their ESD is (1.76 – 0.61) mGy, (7.52 – 1.34) mGy, (8.69 - 1.81) mGy respectively.

Table 11 shows a Comparison of International Standards for eye lens exposure threshold dose to TLD Readings obtained from patients of all age groups in the research work, the results presented show that the entrance surface dose (ESD) to the eye lens of patients undergoing cranial (CT) radiography in Federal Neuro-Psychiatric Hospital Maiduguri is within the threshold of 500mGy prescribed by the ICRP Standards and other organizations concerned with Radiation Protection [6, 18, 19].

The entrance surface dose (ESD) to the eye lens of patients undergoing cranial (CT) examination using a TLD chip placed right above the eye as shown in Fig. 2 Data obtained were analyzed on a software, Microsoft Excel 2019 application using the formula in equations 1 and 2. The mean doses obtained for all the sixty (60) patient is (4.00 $\pm$ 2.40) mGy while for age group, pediatric (1.26 $\pm$ 0.34) mGy, young adult (4.24 $\pm$ 1.88) mGy and adult (5.24 $\pm$ 2.14) mGy respectively.

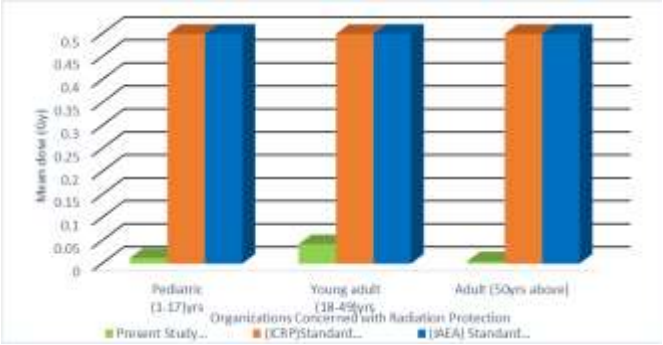

Fig.4: A Comparison of International Standards for eye lens exposure threshold dose to TLD Readings obtained from patients of all age groups.

The findings of this study have revealed that the entrance Surface dose (ESD) to the eye lens of pediatric patients is (1.26 $\pm$ 0.34) mGy which is very much below the international standard threshold of (500 mGy). Also, the entrance Surface dose (ESD) to the eye lens of young adult patients is (4.24 $\pm$ 1.88) mGy which is also very much below the international standard threshold of (500 mGy). Finally, the findings of this study have indicated that the entrance Surface dose (ESD) to the eye lens of adult patients is (5.24 $\pm$ 2.14) mGy which is also below the international standard threshold of (500 mGy) for causing vision impairment, cataract or even lens damage [14, 15].
Therefore, the Findings of my research work indicate that the entrance surface dose (ESD) to the eye lens of patients undergoing cranial (CT) examination in Federal Neuro-Psychiatric Hospital Maiduguri, Borno State. Nigeria. Are very much below the threshold value of (500 mGy) dose prescribed by the ICRP Standards and other organizations concerned with radiation protection [20-21]. Hence, the cranial (CT) examinations being conducted are clinically safe.

3 Conclusions

In this study, the amount of dose to the eye lens of patients undergoing cranial CT examination at Federal Neuro-Psychiatric Hospital Maiduguri was evaluated. It can be stated that the entrance surface dose (ESD) to the eye lens of patients undergoing cranial (CT) examination in Federal Neuro-Psychiatric Hospital Maiduguri is within the threshold level of 500 mGy as prescribed by the International Organizations concerned with Radiation Protection. Therefore, the procedure of cranial CT examination at Federal Neuro-Psychiatric Hospital Maiduguri is clinically safe and the ALARA principle is also achieved.

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Conflict of interest

The authors declare that they have no conflict of interest.

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