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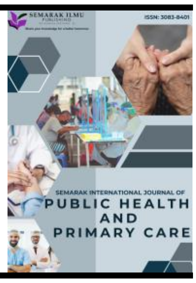

Radiation Doses from Computed Tomography of the Brain Based on Head Sizes in a Diagnostic Center in Northern Nigeria

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ABSTRACT

CT head imaging is an essential diagnostic method that gives high-resolution cross-sectional views of the brain, helping in detecting and evaluating neurological disorders and trauma. The study aims to evaluate and assess radiation dose and its relationship with the effective diameter of the head for CT brain examinations conducted using a 16 multi-slice CT scanning machine. Data from 30 patients who had CT brain examinations done at our facility was retrospectively collected in the month of May 2024. Data, including the volume Computed Tomography Dose Index (CTDIvol) value, dose-length product (DLP) value, scan range and the head diameter of the patient measured in the Antero-posterior (AP) and Lateral (LAT) orientations, were documented in a standardized format for analysis. The effective dosage E was then calculated. The mean ± S.D of E for brain CT was 2.5 ± 0.5 mSv. The mean ± S.D for the Effective Diameter DEFF was documented as 159.9 ± 8.7. The correlation (R2) between the E and DEFF showed 0.3315 as its values, indicating a positive correlation. The radiation increases according to the increase in head diameter. This study demonstrates that radiation exposures from CT brain scans may rely on the size of the head. Consequently, additional safety protocols should be implemented for the type of examination so as to reduce the potential risks linked to CT scans.

1. Introduction

Since the inception of Computed Tomography in the early 1970, it has transformed neuroimaging, establishing itself as a fundamental tool for identifying numerous neurological disorders, such as tumors, strokes, and traumatic injuries. Computed CT of the brain is an essential diagnostic instrument in contemporary medicine [1], it gives a swift and comprehensive image of the cranial anatomy[2]. CT imaging technique involves the use of X-ray technology to generate cross-sectional

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images of the body, enabling health care professionals to observe the structure of the brain and its pathology with a distinctive clarity.

The principal benefit of CT brain imaging is its rapidity and efficacy [3]. In emergency situations, where time is of the essence, CT scans can be conducted rapidly, facilitating prompt evaluation of acute disorders such as ischemic strokes and hemorrhages [4]. This speed facilitates prompt diagnosis and impacts treatment decisions, ultimately enhancing patient outcomes. The capacity to acquire images within minutes renders CT an indispensable asset in emergency care situations [5].

CT imaging is especially proficient in detecting alterations in brain density, which could signify the existence of disorders or abnormalities [6]. The modality is proficient in detecting acute hemorrhagic events, distinguishing between stroke types, and the identification of space-occupying lesions. These abilities are crucial for guiding subsequent management and interventions, including surgical treatments or medical therapy. Furthermore, developments in CT technology, which include multi-slice imaging and advanced algorithms, have improved the quality of images and precision in diagnosis [7].

Notwithstanding its various advantages, CT brain imaging has its own limitations. Ionizing radiation presents a risk, especially to susceptible groups like pediatrics and pregnant women [8,9]. Even though CT is proficient for acute cases, it may not consistently provide the same degree of detailed information for subtle brain lesions as other imaging techniques such as Magnetic Resonance Imaging (MRI) [2,10]. Health care professionals must put these factors into consideration when selecting the most suitable imaging technique for their patients.

Recent technological advancements in CT have concentrated more on minimizing radiation exposure while improving image quality. Innovations like iterative reconstruction techniques and low-dose protocols seek to reduce risks while maintaining diagnostic effectiveness [11,12]. As research advances, the amalgamation of artificial intelligence and sophisticated imaging algorithms may enhance the efficacy of CT brain imaging, perhaps leading to more precise and efficient diagnosis.

The rising exposure to low-dose radiation from diagnostic procedures has generated interest in assessing its carcinogenic risk; yet, calculating health risks associated with low-dose radiation exposure entails ambiguity [13,14]. The American Association of Physicists in Medicine (AAPM) states that the assessment of patient dose from any CT examination should put into consideration the size of the region to be examined [15]. This study emphasized the significance of effective diameter in the calculation of dose for CT head, as the effective dose alone is inadequate for evaluating patient-specific dose. The increased size may increase the dominance of the Compton scattering effect, hence influencing the distribution of dose and the diagnostic quality. The objective of this study is to evaluate patient radiation dose exposure and effective dose E for 16-slice CT brain exams, taking into account the effective diameter of the head.

2. Methodology

2.1 Scanner

Approval (SSREC/ID-0091-22) was granted by the research ethics committee of Sokoto State Advanced Medical Diagnostic Center (SSAMDC) to conduct this research. No consent was needed from patients. Data from 30 patients who had routine CT of the brain in May 2024 were collected retrospectively. The data was acquired from the Picture Archiving and Communication System (PACS) of 16 multi-slice CT scanners manufactured by GE Healthcare, USA. The scanner can rebuild 16 slices, each with a thickness of 0.63 mm or 1.25 mm, during rotation. The technology generates high-resolution 3D images that surpass the quality of those produced by current single-slice CT scans. The tube voltage is established at 120 kVp. The tube current is automatically modulated, varying from a minimum of 50 mA to a maximum of 250 mA. The gantry completes a rotation in 0.8 seconds. DLP and CTDIvol data were recorded from each CT dose report. The E were calculated by multiplying the DLP of each patient by conversion factor of the CT brain.

Table 1
Details of scanner

CT protocol	Parameter
Reference noise (mAs)	75
Tube voltage(kVp)	120
Pitch	1.75
Orientation	Caudalcranio
scanning mode	Helical
Slice thickness	3.0
Contrast media	No

2.2 Measurements of Diameter of the Head

The images were evaluated by utilizing a Picture Archiving and Communication System (PACS) in DICOM format. The diameter measurements were manually conducted using the electronic caliper located in the PACS system. Every study utilizes a uniform window level and configuration. The anteroposterior (AP) and lateral (LAT) diameters were quantified in millimeters (mm) on the localizer images. AP denotes the measurement of the skin-to-skin diameter from anterior to posterior in the lateral view picture at the central level, whereas LAT signifies the measurement of the skin-to-skin diameter from lateral to medial in the anteroposterior view image at the central level. The length of the AP of the brain was measured along the falx cerebri, whereas the length of LAT was measured from left to right of the external auditory meatus.

2.3 Computed Tomography Volume Weighted Index (CTDIvol)

$CTDI_{vol}$ represents the average dose delivered per unit length of the scan (measured in mGy/cm) and takes into account the axial length of the scan. CTDIvol is particularly useful for comparing doses between scans of different lengths and techniques.

$CTDI_{vol}$ is mathematically represented in Eq. (1) below:

$$CTDI_{vol} = \frac{CTDI_W}{pitch} \quad (1)$$

2.4 The Dose Length Product (DLP)

DLP is a metric used in CT to quantify the radiation dose received by a patient during a CT scan. It is expressed in milligray-centimeters (mGy·cm) and provides an estimate of the total radiation exposure for a specific scanned length of tissue. It is mathematically represented as Eq. (2):

$$DLP = CTDI_{vol} \times ScanLength \quad (2)$$

2.5 The Effective Diameter (DEFF)

DEFF refers to the diameter of the circle that is in the same area as the cross-sectional area of the brain at the midline level Figure 1.

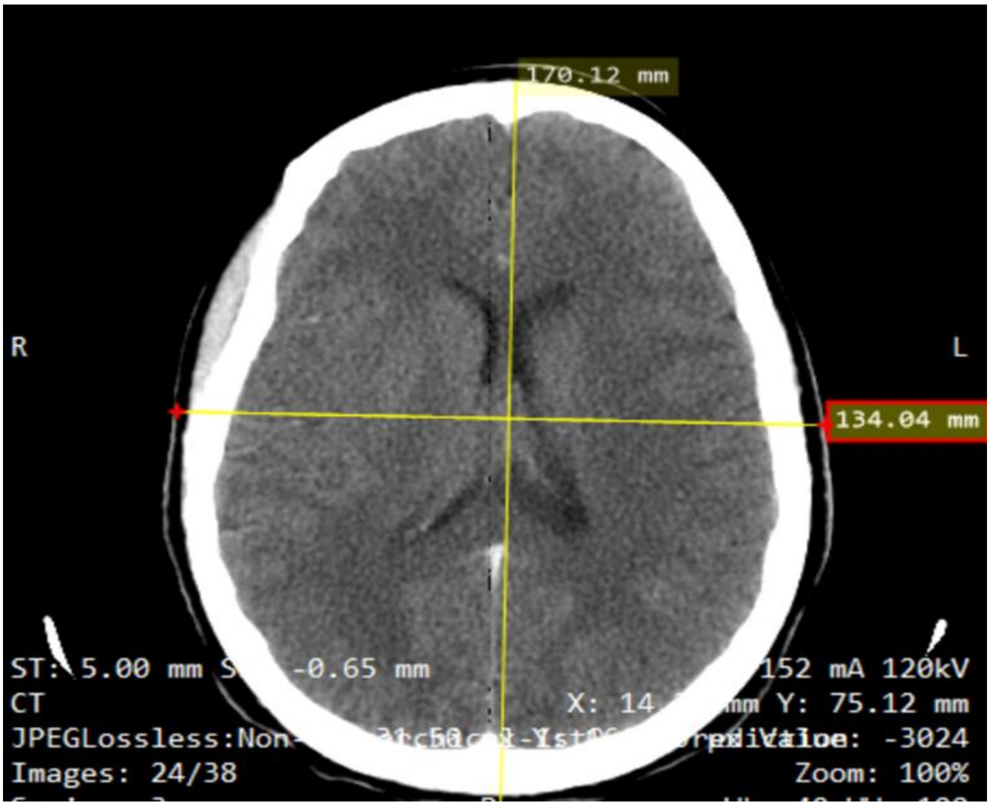

Fig. 1. Diameter measurement of LAT/AP along the falx cerebri as extracted from microDicom for the calculation of the effective diameter of the head

It can be derived by finding the geometric mean of the LAT and that of the AP, as shown in Eq. (3) below:

$$D_{EFF} = \sqrt{AP \times LAT} \tag{3}$$

2.6 Effective Dose (E)

The E was calculated by multiplying the DLP and the conversion coefficient factor k for the head and neck region. It is mathematically expressed as Eq. (4):

$$E = DLP \times k \tag{4}$$

Where the value of k for the head and neck region is 0.0026 Sv/mGy.cm, as documented by International Commission on Radiological Protection (ICRP) [16]. This technique of measurement has been proved to be practically robust and commonly used for determining the effective dose, notably for CT examination.

2.7 Statistical Analysis

The data were collected and recorded using Microsoft Excel 2010, and statistical analyses were conducted with the same Excel sheet. Descriptive statistics, including means and standard deviations, were calculated. The AP, LAT, and dose indices ($CTDI_{vol}$, DLP, and E) were recorded for each CT examination of the patients. The research examined the relationship between DEFF and E using a Pearson correlation analysis (r). The influence of dose metrics and size of the patient's head was assessed by linear regression models to ascertain the relationship between DEFF (independent variable) and E (dependent variable).

3. Results

Table 2 displays the dose metrics for CT head examinations for 30 patients, highlighting their mean values and standard deviations (SD). The $CTDI_{vol}$ is recorded as 43.9 ± 6.9, signifying a moderate variability in dose among the patients. The DLP is significantly higher at 975.1 ± 194.9, indicating the total radiation exposure over the duration of the scan. The E shows a mean of 2.5 ± 0.5, indicating a comparatively low risk of radiation exposure. The DEFF has a mean of 159.9 ± 8.7, reflecting the radiation risk linked to the imaging protocol. Overall, these metrics provide critical insights into the radiation exposure levels and potential risks linked with diagnostic imaging procedures.

Table 2
Mean values of CT dose metrics and DEFF

Dose metrics	Mean ± SD
$CTDI_{vol}$	43.9 ± 6.9
DLP	975.1 ± 194.9
E	2.5 ± 0.5
D_{EFF}	159.9 ± 8.7

The graph (Figure 2) shows the relationship between DEFF and E, revealing a positive correlation as seen in the trend line across the graph with an R^2 value of 0.3315. This implies that, as the effective diameter of the head increases, the effective dose tends to rise as well, although the correlation is moderate. This is evident in the research by Atlı *et al.,* [3] and Paolicchi *et al.,* [17] which is in line with this observation. in addition, a study by Kumsa *et al.,* [18] discusses how patients with larger head diameter sizes often require higher radiation doses to achieve adequate imaging quality, aligning with the trend shown in the graph. Similarly, a study carried out by Kanal *et al.,* [19] emphasizes the importance of adapting radiation dose based on the patient's head dimensions to minimize exposure while maintaining diagnostic efficacy. Furthermore, the findings in this study is in line with the research by Tan *et al.,* [20], where it was reported that patient-specific factors, including size of the head of a given patient, significantly influence the radiation dose required for imaging. This study is also related to the research by previous research, in which the implications of increased radiation exposure in patients with larger head diameter was highlighted, stressing the need for individualized dose management strategies [13]. Lastly, the correlation depicted in this graph reinforces findings from a study by Muhammad *et al.,* [21], which underscores the critical need for continuous assessment of dose metrics in relation to patient morphology to optimize safety in CT imaging. Overall, while the graph indicates a positive trend, the relatively low R^2 value suggests that other factors may also play significant roles in determining effective dose, warranting further investigation into the multifaceted nature of radiation exposure in diagnostic imaging.

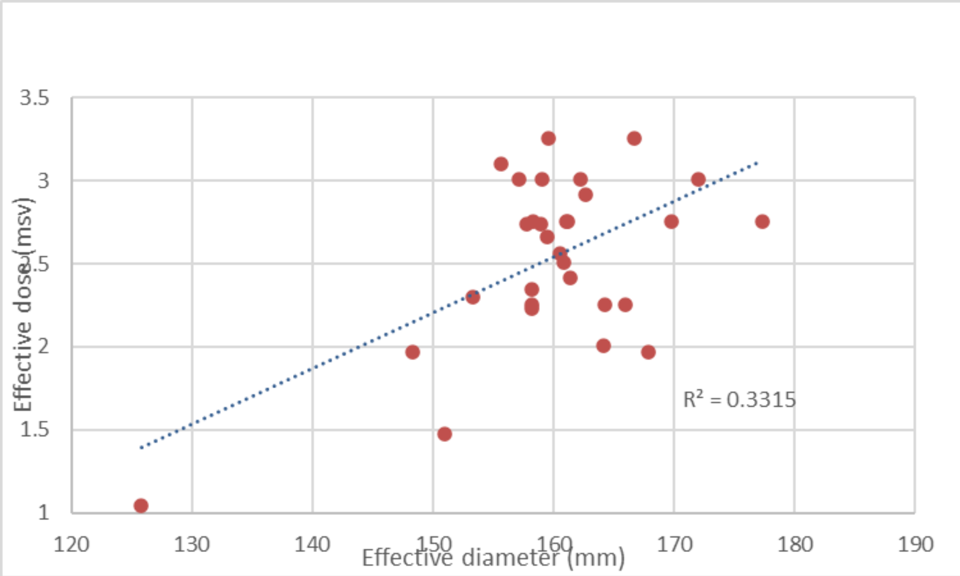

Fig. 2. Graph showing the positive correlation between the D_{EFF} and the E

4. Conclusions

This study concludes that there is moderate positive correlation between E and DEFF Patients with larger head diameter require more radiation to obtain a good image quality and accurate diagnosis. The dose exposure from a CT brain examination is moderately affected by the head size and by the type of protocol used during the scan. Therefore, additional safety protocols should be adopted for CT head scan so as to mitigate the potential risks associated with CT scans.

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