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Evaluation of Absorbed Dose and Protocols During Brain Computed Tomography Scans in a Nigerian Tertiary Hospital

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Abstract: Computed tomography (CT) scan of the brain is the commonest CT examination performed and had been recognized to deliver very high radiation dose to the patients. This study was aimed at evaluating the radiation dose from routine brain CT scan and to compare the dose from the protocols for brain CT. The *ex-post-facto* design was adopted. All the records of brain CT scan from September 2011 to August 2015, acquired with a 16 slice CT machine (Phillips Brilliance Medical System, MX8000) in the Radiology Department of University of Maiduguri Teaching Hospital (UMTH) were evaluated. Ethical approval was obtained from the Ethical Committee of UMTH. The weighted CT dose index ($CTDI_w$), volume CT dose index ($CTDI_{vol}$) and dose length product (DLP) values were recorded for each of the examination. Results showed that the two main protocols used were axial and helical scan modes. The mean $CTDI_{vol}$ and DLP values were 76.6 mGy and 1285.8 mGy*cm for axial and 103 mGy and 1903 mGy*cm for helical scan modes respectively. There was a significant difference ($p < 0.05$) between the $CTDI_{vol}$ and DLP values of axial and helical scan modes. Conclusion: the study found higher radiation dose in helical than axial scan modes. This study therefore recommends the use of axial scan mode for routine brain CT scan, to reduce radiation dose, except where speed is desirable such as in unconscious patients, uncooperative patients and when automatic injector pump is to be used.

Key words: Brain CT · Absorbed Dose · Dose Length Product · Volume CT Dose Index.

INTRODUCTION

Computed tomography (CT) scan is a non-invasive method of images acquisition of the inside of human body without superimposition of different anatomical structures. It utilizes mathematical reconstruction of x-ray beam attenuation measurement made through a thin axial slice of the patient [1, 2]. It allows a quicker and more accurate diagnosis of injuries and diseases of the brain than other alternative invasive and less sensitive imaging techniques like conventional angiography and ultrasound scan [3]. Computed tomography imaging also plays a major role in the staging, treatment planning and follow up of cancer.

Since its introduction into clinical use, CT has been recognized to impact high radiation dose to the patients when compared to other diagnostic imaging modalities and this has become a matter of concern [4]. With the amount of radiation dissipated in a single scan, there is a potential risk of radiation induced malignancy [5]. Computed tomography alone almost contributes one half of the total radiation exposure from medical use and one quarter of the average radiation exposure per region in the United State of America [6].

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Computed tomography examination account for an ever-increasing fraction of radiological radiation dose and contributes up to 60-80% of patient's radiation dose in some centres [7, 8].

In United Kingdom, CT account for only 3-5% of all examination performed using X-rays, but accounts for approximately 40-47% of the collective radiation dose arising from medical exposure [1, 9].

The CT scan of the head is the most common CT examination performed in Europe and had been reported to contribute significantly to total collective effective dose of the population [10, 11].

McCollough *et al*. [12] reported in their study that CT dose could be reduced by justification of every CT request and also optimizing all the technical aspects of the examination such that the required level of image quality can be obtained while keeping the dose as low as reasonably achievable.

The computed tomography scanner in our centre operates two protocols, helical and axial. In the helical scan mode, the entire volume is scanned while the couch and the x-ray tube are in continuous motion. In the axial scan mode the x-ray tube and couch are in step and shoot motion resulting in less number of slices. Computed tomography scanners with patient size-specific scanning protocols select lower volume CT dose index ($CTDI_{vol}$) values for paediatric patient but higher values for oversized or adult patients. The total amount of radiation delivered to a patient at a given examination is also dependent on the CT scan length [13].

The product of $CTDI_{vol}$ and scan length is the dose length product (DLP), which can be used to quantify the total amount of radiation received by a patient during a given scan [14]. The Dose Length Product is therefore an indirect measure of the absorbed dose. The aim of the study was to assess the absorbed dose from CT protocols in the study centre and to compare the doses from the protocols for the purposes of optimization.

MATERIALS AND METHODS

The study adopted *ex-post- facto* design. All the records of brain CT scan from September 2011 to August 2015, acquired with a 16 slice CT machine (Phillips Brilliance Medical System, MX8000) in the Radiology Department of University of Maiduguri Teaching Hospital were evaluated. Confidentiality of the patient's data was maintained. The characteristics and estimated dose was derived from $CTDI_{vol}$ and DLP values displayed on the monitor, the estimated effective dose was calculated using software developed by IMPACT scanner group with the National Radiological Protection Board-S250 conversion coefficients and also by multiplying the DLP values with the tissue weighting factor of the brain 0.0021 to determined the effective dose. Data on exposure factors, weighted CT dose index ($CTDI_w$), volume CT dose index ($CTDI_{vol}$) and dose length product (DLP) values were recorded for each patient on a data capture sheet. Data were subjected to descriptive statistics and analyzed using paired sample T-test. Probability value ($P < 0.05$) was considered statistically significant.

RESULTS

A total of 251 brain CT examinations of patients were reviewed. There were 179 (71%) males and 72 (29%) females.

From Table 1 below the patients' age ranged from 5 to 85 years. The age group 40-49 years had the highest frequency of 44 (17.5%) of which 33 (75%) were male and 11 (25%) were female.

Majority of the patients 197 (78.5%) were scanned using helical scan mode while 54 (21.5%) were scanned using axial scan mode (Fig.1).

Table 1: Distribution of patients' age and sex

	F	M	Total
<10	5	4	9
10-19	7	11	18
20-29	12	18	30
30-39	4	16	20
40-49	11	33	44
50-59	8	30	38
60-69	7	25	32
70-79	11	24	35
> 80	7	11	18
Total	72	179	251

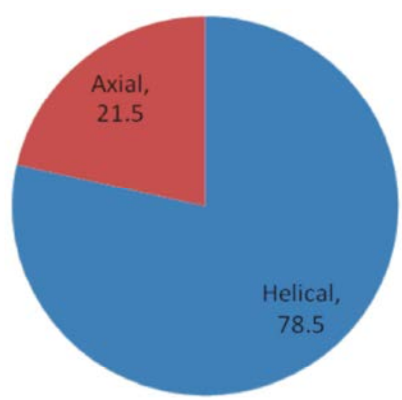

Fig. 1: Distribution of patients based on the scan mode used.

Table 2: Mean scan parameters for Philips Brilliance 16 slice CT scanner

Scan Parameters	Kv	mAs	Scan time (sec)	Number of Slices	ST (mm)	FOV(cm)	Pitch
Helical Mode	120(±20)	550(±49)	1.5	104(±14.)	3.0 (±0)		0.69(±0.01)
Axial Mode	120(±0)	350(±75)	1.75	52(±8.)	3.0(±0.0)	220(±14)	0.75(±0.01)

Keys
ST: Slice thickness,
FOV: Field of View,
mAs: milliampere per second,
kV: kilovoltage

Table 3: Absorbed dose for the different protocols used

Protocol		CTDI (mGy)	TDLP (mGy*cm) (E) mSv
AXIAL	Mean absorbed dose	76.63±21.43	1285.76±458.73 2.7
	No of patients	59	58
HELICAL	Mean absorbed dose	103.78±39.10	1903.57±813.81 3.99
	No of patients	192	192
Total	Mean absorbed dose for both	97.40±37.52	1760.24±790.23 3.69
	No of patients	251	250

Keys:
CTDI: Dose Index Computed Tomography,
TDLP: Total Dose Length Product and
E: Effective dose.

The parameters used in the study center for different scan modes were shown in table 2. The mAs and the number of slices varied significantly.

The mean CTDI (mGy) and DLP (mGy*cm) for axial scan mode were 76.63 ± 21.43 mGy and 1285.76 ±458.73 mGy*cm with the effective dose (E) of 2.7mSv while that for helical scan mode was 103.78±39.10 mGy and 1903.6 ±813.8 mGy*cm with an effective dose (E) of 3.99 mSv respectively. The total mean CTDI and DLP for both scan modes were 97.4±37.5mGy and 1760.2±790.2mGy*cm with an effective dose (E) of 3.69 mSv respectively.

DISCUSSION

Out of 251 patients that underwent brain CT examination during the period of study, 197(78.5%) of the patients were scanned using helical scan mode and 54 (21.5%) were scanned using axial scan mode.

The mean $CTDI_{vol}$ and DLP values for axial scan mode were 76.60 ± 21.43 mGy and 1285.76 ± 458.73 mGy*cm respectively with an effective dose of 2.70 mSv. The mean $CTDI_{vol}$ and DLP values for helical scan mode were 103.78 ± 39.10 mGy and 1903.57 ± 813.81 mGy*cm respectively with an effective dose of 3.99 mSv. There was statistically significant difference ($p< 0.05$) in the value of $CTDI_{vol}$ and DLP of helical scan mode when compared to axial scan mode. The preference for helical scan mode was attributed to its faster image acquisition and allowing thinner slices to be obtained without reconstruction. It also eliminates the interslice lose of data or information as the entire volume is scanned while the couch and the x-ray tube are in continuous motion. However in helical mode more slices were acquired and this resulted in the increased radiation dose to the patients.

This study therefore recommends the use of axial scan mode for routine brain CT scan, to reduce radiation dose, except where speed is desirable such as in unconscious patients, uncooperative patients and when automatic injector pump is to be used.

The lower radiation dose during the axial mode is predicated on less number of slices and the gantry angulation which could reduce radiation dose to the eyes. The axial scan mode however, has a drawback due to its acquisition of images in large volumes which may result in stir and step artifact but this can be eliminated by reconstruction into thinner slices after image acquisition.

This study found the mean absorbed dose of $CTDI_{vol}$ and DLP values for the axial scan mode and helical scan mode, for the 251patients, to be 97.40 ± 37.52 mGy and 1760.24 ± 790.23 mGy*cm respectively with an effective dose of 3.69 mSv. These values are higher than the European Commission [15] committee on radiation protection recommended dose values of 60 mGy and 1050 mGy*cm for $CTDI_{vol}$ and DLP respectively. It is also higher than 76.94 mGy and 985.48 mGy*cm respectively for a study by Garba and Tabari [16]. These variations may be due to the selection of standardized patient weight category of 70 ± 3 kg for the European Commission and in that of Garba and Tabari [16] which was not applied in our study.

CONCLUSIONS

This study revealed two main protocols used for brain CT scan in the study center; axial and helical scan modes. The absorbed dose in helical scan mode was found to be higher than that of axial scan mode. Scan parameters like mAs, kVp, slice thickness and pitch among others have been shown to be the major contributors to the patient dose. Numbers of slices determine the scan length and scan length has linear relationship with DLP [10]. Therefore axial scan mode is recommended for routine brain CT scan where speed of image acquisition is not of essence. There is need for optimization by radiographers to reduce radiation exposure to the patients. Also awareness seminars for referring physicians is recommended as they often view CT examination in the same light as other radiological procedures, even when radiation doses are much higher with CT.

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