Head Computed Tomography: Dose Output and Relationship with Anthropotechnical Parameters

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ABSTRACT

Background: The number of computed tomography (CT) centers and examinations in Nigeria has shown a steady increase. This will increase the collective dose and may potentially result in an increased incidence of cancer, hereditary diseases, and the possibility of mild deterministic effects. **Objective:** To determine radiation dose output and its relationship with anthropotechnical parameters. **Methodology:** A retrospective analyses of digital CT files. Effective dose was derived from the dose-length product and factor for examination of head CT (0.0023 mSv/mGy-cm). SPSS version 20.0 (SPSS Inc., Chicago, IL, USA) was used to analyze the data. **Results:** Files of 43 male and 42 female (n = 85) adult patients were analyzed. The mean (and 75th percentile) of the CT dose index (CTDI), dose-length product (DLP), and effective dose in noncontrast examinations were 48 (59) mGy, 874 (1301) mGy-cm, and 1.8 (2.7) mSv, respectively. Contrast examinations yielded 54 (61) mGy, 1476 (2044) mGy-cm, and 3.1 (4.3) mSv, respectively. DLP showed a weak relationship with BPD (r = −0.220), age (r = 0.211), cephalic index (r = −0.186), height (r = 0.158), and gantry tilt (r = 0.154). There was no relationship with weight (r = 0.076), range (r = −0.073), occipitofrontal diameter (r = 0.037), and body mass index (r = −0.018). The correlations were neither statistically nor clinically significant. **Conclusion:** The CTDI is comparable with local values while the DLP is lower by a range of 5–31% but higher than foreign values by a range of 19–35%. Further optimization of CT radiation dose should be explored to eliminate the gulf between local and foreign dose outputs.

Key words: Computed tomography; computed tomography dose index; dose; dose length product; effective dose; parameters

Introduction

Computed tomography (CT) is considered in medical imaging as the most important contributor to patients' radiation exposures.[1] Moreover, this high-dose procedure has multiplied in number and increasing frequency in recent times.[2] Patients' exposures are more critical in CT because, aside using ionizing radiation, the doses are typically much higher than for radiographic or fluoroscopic procedures.[3]

At present, about 1–14 mSv is the radiation dose associated with a typical CT scan, and this is comparable to the annual dose received from natural sources of radiation, such as radon and cosmic radiation (1–10 mSv), depending on location.[4] One study suggested that as much as 0.4% of all current cancers in the United States may be attributable to the radiation from CT studies based on data from 1991 to 1996. When organ-specific cancer risk was adjusted for current levels of CT usage, it was determined that 1.5–2% of cancers may eventually be caused by the ionizing radiation used in CT.[5] This situation places an obligation on the CT community to review the amount of radiation prescribed for CT scans and to improve the usefulness of the data for daily clinical practice.[1] This obligation has ultimately resulted in an aggressive effort to minimize CT doses and optimize image quality.[6]

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A survey of CT doses in four continents and covering forty countries indicated that CT of the head is the most common examination.[7] Current works on CT doses in Nigeria focuses specifically on the head, which is also adjudged as the most common procedure.[8-10]

In Nigeria, the number of CT scanners and the frequency of CT examinations have been on a steady increase.[10] Current dose assessment in the country are few, sporadic, and have shown a wide variation (>30%) between them.[8-11] These observed variations have presented the need for the establishment of standards in Nigeria through a dose survey.[12] The variations in dose between CT departments as well as between identical scanners also suggests a large potential for optimization of examinations.[13]

A prerequisite for a national standard is the determination of center-specific dose output. Our facility is a foremost teaching hospital and the only government-owned CT scanner in the province. However, there are five other private-owned CT scanners. These serve a population of approximately four million people. Since the first installation of a CT scanner in the province in 2012, no dose survey or center-specific study has been carried out. The present effort is, therefore, aimed at establishing typical dose output in our facility. It is hoped that the outcome of the study will spur a deliberate dose survey in all CT facilities in the country, and set the tone for a local, provincial, and national diagnostic reference level (DRL).

Methodology

The work was a retrospective study carried out throughout the month of October 2015 and it involved CT examinations done between January 2014 and September 2015. Written permission was obtained to carry out the work (NAUTH/RAD/EZ/004 of 08/10/15). A General Electric Brightspeed scanner, manufactured in 2007 and installed in 2012, with 4-slice per rotation capacity was available at the center.

All head CT cases in the digital archive were considered. Cases scanned supine and at an azimuth of 180°, with no evidence of bandages, scalp edema, and distortion of bony skull tables or facial bones were included. Digital files with a missing posteroanterior scanogram as well as incomplete data on age, gender, height, and weight were excluded. A total of 85/324 digital head CT files eventually met the inclusion criteria. The bulk of the cases excluded lacked information on height and weight.

Each digital file was analyzed at the console by the researchers in the CT suite to establish the technical parameters used for each examination. These parameters are imprinted on each image if full anonymity features are not activated. They can also be investigated through "protocol management" icon. Confidentiality was maintained by omitting the names of the patients during data collection. Volume CT dose index (CTDI) and dose length product (DLP) which are metrics for dose output, appear by default, as the last series of each examination.

The dose-length product was subsequently multiplied by the factor for the examination of head CT (0.0023 mSv/mGy-cm).[14] For appropriate comparison of effective dose, the dose-length products from this study and similar works were multiplied by a uniform weighting factor (0.0023 mSv/mGy-cm). This normalized all values and neutralized variations in methodology. Body mass index (BMI) (kg/m^2) was calculated from weight and height records in the digital archive of the monitor. Cephalic index (%), was calculated using biparietal and occipitofrontal diameters from nonrotated scanograms. The Statistical package for the social sciences, version 20.0 (SPSS Incorporated, Chicago, Illinois, USA) was used to analyze the data.

Results

Files of 43 male and 42 female (n = 85) patients aged 22–73 years were analyzed. Modal values of the scan range (15 cm), gantry rotation time (1 s), gantry tilt (17.5°), tube current (230 mA), and tube voltage (120 kVp) were lesser than the maximum used in the center [Table 1]. The mean (and 75th percentile) of the CTDI, DLP, and effective dose in noncontrast examinations were 48 (59) mGy, 874 (1301) mGy-cm, and 1.8 (2.7) mSv, respectively. Contrast examinations yielded 54 (61) mGy, 1476 (2044) mGy-cm, and 3.1 (4.3) mSv, respectively [Table 2]. Dose-length product showed a weak relationship with biparietal diameter (r = –0.220), age (r = 0.211), cephalic index (r = –0.186), height (r = 0.158), and gantry tilt (r = 0.154). There was no relationship with weight (r = 0.076), range (r = –0.073), occipito-diameter (r = 0.037), and BMI (r = –0.018).

Table 1: Anthropotechnical characteristics

Parameter	Anthropometric		
	Range		Mean
	Male (n=43)	Female (n=42)	Both gender (n=85)
Age (years)	24-68	22-73	50.0±2.0
Weight (kg)	52-92	44-98	74.5±15.0
Height (cm)	157-186	144-180	165.7±11.4
BMI (kg/m^2)	19.70-30.70	24.8-43.2	27.2±5.7
OFD (cm)	174-203	174-191	185.5±7.2
BPD (cm)	128-150	120-154	137.4±7.3
CI (%)	69-85	65-85	74.0±5.0
	Technical		
	Range		Mode
Scan range (cm)	11-26	10-20	15
mA	150-230	150-230	230
Tilt (°)	12.5-24	8-28	17.5
Rotation (s)	0.7-2		1
kVp	100-140		120

BMI – Body mass index; OFD – Occipitofrontal diameter; BPD – Bipareital diameter; CI – Cephalic index

The correlations were neither statistically nor clinically significant [Table 3]. A lower effective dose was noted in this study (2.7 mSv) compared to similar studies in Nigeria (3.10 and 4.0 mSv) but higher than other works outside Africa (2.0–2.3 mSv). This is summarized in Table 4.

Discussion

The expanding use of multidetector CT may result in an increase in levels of patient exposure.[15] Our study was planned in order to have an overview of the intensity of radiation applied for head CT in a busy and foremost university teaching hospital in Nigeria.

Table 2: Dose characteristics

Variables	*n*	Mean CTDI (75th percentile)	Mean DLP (75th percentile)	Mean effective dose (75th percentile)
Contrast				
Noncontrast exams	43	48 (59)	874 (1301)	2.0 (3.0)
Contrast exams	42	54 (61)	1476 (2044)	3.4 (4.7)
Gender				
Male	43	49 (59)	1163 (1836)	2.7 (4.2)
Female	42	52 (60)	1169 (1689)	2.7 (3.9)
Both gender	85	51 (60)	1166 (1746)	2.7 (4.0)
Obesity				
Obese population	19	49 (65)	1124 (1754)	2.6 (4.0)
Nonobese population	66	51 (59)	1178 (1746)	2.7 (4.0)
Age groups				
21-30	7	60 (63)	1500 (1780)	3.5 (4.1)
31-40	22	42 (60)	798 (1110)	1.8 (2.6)
41-50	12	45 (59)	1079 (1804)	2.5 (4.1)
51-60	22	61 (64)	1352 (1672)	3.1 (3.9)
61-70	17	46 (58)	1333 (1982)	3.1 (4.6)
71-80	5	61 (62)	1078 (1819)	2.5 (4.2)

CTDI – Computed tomography dose index; DLP – Dose-length product

Table 3: Pearson correlation of dose length product with anthropotechnical parameters

Variable	*n*=85				
	r	*P*	Relationship	Statistical significance	Clinical significance
BPD	−0.220	0.204	Weak	None	None
Age	0.211	0.225	Weak	None	None
CI	−0.186	0.286	Poor	None	None
Height	0.158	0.364	Poor	None	None
Gantry tilt	0.154	0.378	Poor	None	None
Weight	0.076	0.664	None	None	None
Scan length	−0.073	0.675	None	None	None
OFD	0.037	0.835	None	None	None
BMI	−0.018	0.918	None	None	None

BMI – Body mass index; OFD – Occipitofrontal diameter; BPD – Bipareital diameter; CI – Cephalic index

The 75th percentile (1301 mGy-cm) of the DLP from noncontrast investigations in our work was <2 similar works from our locality by a variation of 12–31%[9,10] and comparable to a Kenyan study with 5% variation, respectively.[16] However, it differed from the European Commission values and another study in Germany by 19 and 22%, respectively.[15,17] The highest variation (35%) was found in a work from Taiwan which had a lower value (850 mGy-cm) than ours [Table 2].[18]

While our values were lower than every work from the shores of Africa, it was higher than all those from Europe and Asia. When subjectivity in the manipulation of exposure parameters is reduced through strict regulation by professional bodies, the tendency for a more efficient dose optimization is high.[19] This appears to be the situation from non-African countries where strict regulation may be the norm. It is also reported in literature that there are strict guidelines regarding radiation protection in the European Commission and their member countries.[15] This oversight function may be the missing ingredient between them and other centers where dose variation is high.

From our work [Table 4], the CTDI, which is a metric of radiation output from a single slice, was marginally lesser (59 mGy) than the values from the European Commission (60 mGy)[17] and Germany (61 mGy).[15] This lower CTDI arose from the manual tube current selection done at the center with tube currents as low as 150 mA and gantry rotation time of 0.7 s [Table 1].

Manual tube current selection always fluctuates with pitch and has the tendency to increase the radiation dose per slice if pitch is <1. The radiographer, therefore, needs to be vigilant to consistently use tube currents as low as reasonably achievable. This is, however, not realistic in a center with multiple radiographers with different attitudes to radiation optimization. In the center in question, it was noticed from the protocol that deliberate efforts were made to use tube currents lower than what was obtainable in the review of the literature. This actually paid off in grossly reducing the CTDI (59 mGy) and the mean DLP to 874 mGy-cm [Table 2] which is comparable to the work from Taiwan (850 mGy-cm).[18]

In most of the centers surveyed from outside Africa, automatic tube current modulation (mA) was activated on the scanners. This practice is noted to maintain constant image quality regardless of patient attenuation characteristics, thus allowing radiation dose to patients to be reduced.[15,20] The marginal difference in CTDI values between our work (59 mGy) and the European studies (60 mGy and 60 mGy)[15,17] may be because of our very small sample size (85) and single modality. A larger sample size with multimodality survey on manual tube current selection may have increased our values. The DLP from this study was, however, higher (1301 mGy-cm) than the two European studies (1016 and 1050 mGy-cm) [Table 4].

Table 4: Comparison of the present work with others

Variables	Present work	Abdullahi *et al.*[9]	Ogbole and Obed[10]	Wambani *et al.*[16]	Tsai *et al.*[18]	Brix *et al.*[15]	European commission[17]
Location	Nnewi, Nigeria	Abuja, Nigeria	Ibadan, Nigeria	Kenya	Taiwan	Germany	Europe
Year	2015	2015	2014	2010	2007	2003	1999
$CTDI_{vol}$	59	38	74	51	72	61	60
DLP	1301	1477	1898	1364	850	1016	1050
D_{eff} (EC)	2.7	3.10	4.0	3.1	2.0	2.3	2.2

DLP – Dose length product; EC – European Commission; $CTDI_{vol}$ – Volume computed tomography dose index

Since the DLP is the product of CTDI and scan range, it was assumed that at similar scan range, the DLP from our work should be lower, which was, however, not so. The higher DLP from our work arising from a range of 15 cm may be an indication of unnecessary extension of the borders of the area of interest. Reducing scan range, therefore, may be a useful technique in dose optimization. However, statistical analysis of this assumption yielded no relationship between DLP and scan range ($r = -0.073$). This stalemate was clarified by another work where it was suggested that a reduction in tube potential and tube current are better influences on dose rather than scan range.[2,21] In addition, scan range becomes a better influence on radiation dose when other technical parameters are kept constant, a fact that was not keenly kept in view at the centre.

The higher CTDI (61 mGy) and DLP (2044 mGy-cm) noted in contrast exams suggest an increment in tube potential and/or current in the contrast phase. From the perspective of dose optimization, there is no justification for tampering with the precontrast protocol. A similar intensity of radiation should be applied in both noncontrast and contrast phase. It has even been advocated that the possibility of reducing tube potential and current should be explored when necessary.[22]

It has been suggested that CT doses need to take into account patient age, head size, as well as the selected technique factors.[21] In line with this, the researchers investigated the relationship between some anthropotechnical parameters and DLP. Our findings are not in agreement with the suggestion as we found little or no relationship between age, head size, and some exposure parameters [Table 3]. However, we found that dose was reduced in younger age group (21–30 years) compared to older persons aged 71–80 years [Table 2]. Although this is in agreement with the findings of Huda *et al.*,[21] a change in protocol influenced by age may have been responsible for this rather than any physiological process.

Conclusion

The CTDI is comparable with values seen in our locality and in the review of the literature while the DLP is lower than local values by a range of 5–31% but higher than foreign values by a range of 19–35%. Furthermore, the relationship between DLP and anthropotechnical factors was poor. The potential for further optimization of radiation dose using lower technical parameters should be explored. Radiologists and other clinicians who manage CT patients should request for dose chart to be included in the printed CT films. In the absence of a national DRL, a CTDI of 48–61 mGy and DLP between 874 and 1301 mGy-cm should be considered adequate.

Recommendation

For head CT scan in adults, tube current and tube potential rather than age and weight should be put into consideration. The radiologists and radiographers should also have image quality and justifiable patient dose as a dual goal at all times.

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Conflicts of interest

There are no conflicts of interest.

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