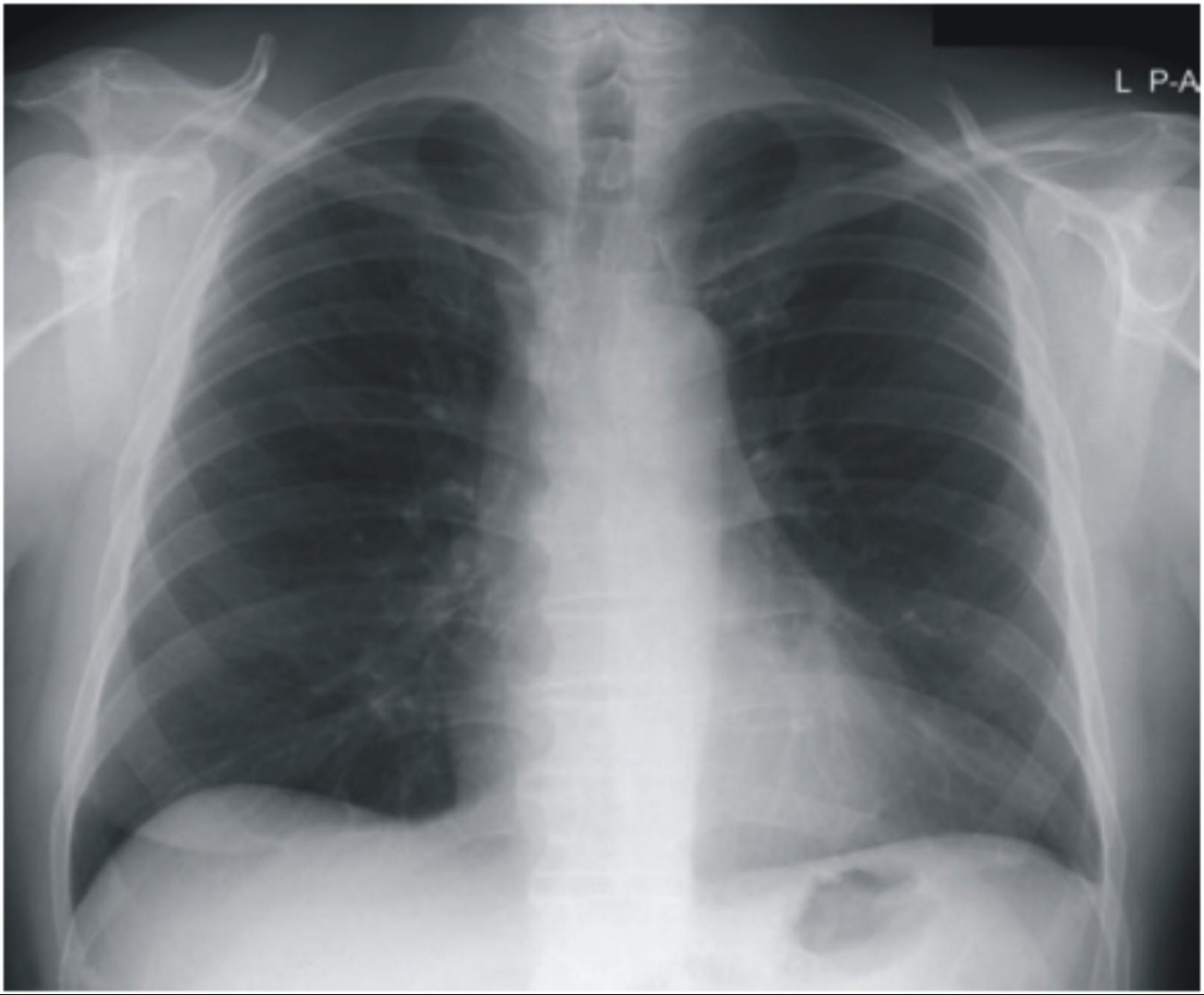
JOURNAL OF THE ASSOCIATION OF RADIOGRAPHERS OF NIGERIA

ISSN: 1115- 7976 Vol 30, Issue 1, December, 2016

The Official Journal of The Association of Radiographers of Nigeria

J A R N



Journal homepage: www.jarnxray.org

Computed tomography dose for adult head scan in Anambra State of Nigeria

Thomas Adejoh*, [1]Chukwuziem N. Anene, [1]Ubaka E. Akanegbu, Samuel A. Imo, [2]Hyacienth U. Chiegwu, [3]Emeka C. Onwujekwe

Radiology Department, Nnamdi Azikiwe University Teaching Hospital, Nnewi, Nigeria

[1]Department of Radiography & Radiological Sciences, Postgraduate School, Nnamdi Azikiwe University, Nnewi Campus, Nigeria
[2]Department of Radiography & Radiological Sciences, Nnamdi Azikiwe University, Nnewi Campus, Nigeria
[3]Department of Radiology, National Hospital, Abuja, Nigeria

*Corresponding author: Adejoh, T., adtoms@yahoo.com; +2348133301005

Received:11 June, 2016. Received in revised form: 30 June, 2016. Accepted:11 August, 2016

ABSTRACT

Background: Computed tomography is associated with relatively high radiation doses and could cause serious health risks. Globally, it is reported that many physicians do not to have adequate knowledge about CT dose. Furthermore, although dose records are available from developed countries, there is a paucity of literature in Nigeria. Dose outputs in our locality are also scarce in the literature.

Objective: To review adult head CT dose in the four largest centres in Anambra State.

Methodology: A 6-month retrospective retrieval of dose summary from the control console. Digital folders of subjects ≥ 18 years were sampled purposively and sequentially, out of the 2015 population of CT examinations. The $CTDI_{vol}$ and DLP for each case were recorded in a *pro forma*. The mean dose in each centre as well as the combined mean for all centres were calculated. The results were compared with the recommendations of the European Commission and similar studies from Nigeria.

Results: The digital folders of 200 subjects made up of 104 (52.0 %) males and 96 (48.0%) females with an age range of 18 – 93 years were involved in the study. Cranium (n = 164; 82 %) dominated the CT requests. The mean $CTDI_{vol}$ and DLP in the four centres was 58 mGy and 1112 mGy.cm. The mean $CTDI_{vol}$ (73 mGy) and DLP (1613 mGy-cm) in one of the centres was extreme. When excluded, the mean $CTDI_{vol}$ and DLP for the remaining three centres were 52 mGy and 945 mGy.cm, respectively.

Conclusion: Dose output in Anambra State was comparable to the recommendation of the European Commission but varied significantly from other local studies. The establishment of diagnostic reference levels for CT procedure in the locality is imperative.

Keywords: Dose, CTDI, DLP, optimization, justification, radiographer

Introduction

Computed tomography (CT) has become a popular and flexible imaging modality that has replaced many radiologic techniques [1]. It provides high-quality three dimensional data that enables faster and more accurate diagnosis, and the avoidance of interventional surgical techniques [2]. However, CT is associated with relatively high radiation doses, of up to 20 mSv [3], and radiation induced cancer risks of up to 1 in 1000/examination [4]. A strict adherence to medical justification of CT requests by clinicians, as well as conscientious radiation dose optimization by radiographers, are therefore, advocated to ensure that the risk to patients do not outweigh the benefits gained from the procedure [2].

Computed tomography dose investigation has become so imperative in view of its potential deleterious outcome, that the American College of Radiology (ACR), International Atomic Energy Agency (IAEA), and many other national regulatory agencies globally have not only begun recording dose, but have also advocated that CT facilities report dose [5, 6]. Dose records are displayed on the CT console after each scan [7], using the popular metrics of volume computed tomography dose index ($CTDI_{vol}$) and dose-length product (DLP) as recommended by the international electrotechnical commission, IEC [8]. The $CTDI_{vol}$ (mGy), is a standardized measure of the radiation output in a single slice of a CT scanner which allows users to compare different scanners and scan protocols [9]. Mathematically, it is calculated using the equation: $CTDI_{weight}$/pitch (pitch is the table incremental rate/per rotation divided by the beam collimation) [7]. Dose length product (in mGy.cm) on the other hand, combines the $CTDI_{vol}$ and the scan length/range (cm) to quantify the total radiation dose administered to the patient during a CT procedure [2].

Patient exposure are relatively higher in CT than for radiographic or fluoroscopic procedures, and these higher doses may eventually result in an increased incidence of stochastic and non-stochastic effects of radiation [10]. Therefore, competence in handling a CT scanner, and a strict adherence to the radiation protection principles of justification of requested investigations, and optimization of protection is necessary, to ensure that the risk of stochastic effect is kept minimal, and the severity of non-stochastic effects is non-existent, while generating CT images of high diagnostic quality.

Computed tomography requests are generated by physicians, many of whom are reported not to have adequate knowledge of radiation protection [11,12]. This therefore, has serious implication for justification of requests. Optimization of practice is however, in the purview of the CT Radiographer. At the core of optimization is the establishment of diagnostic reference levels (DRLs) which allow the identification of abnormally high dose levels by setting an upper threshold [2].

While published dose data are readily available in developed countries, this is not the case in Africa generally [13], and in Nigeria specifically [14, 15, 16], where the presumably available data are difficult to access. There are also no national CT diagnostic reference levels (DRLs) to guide CT professionals on the optimal $CTDI_{vol}$ and DLP range for the different CT procedures in the region. In the interim, the European Commission DRLs guidelines are applied to routine computed tomography (CT) examinations in Nigeria [14]. Since the CT modality is gaining more recognition in Nigeria, there is an urgent need for reference doses [17].

The absence of DRLs have presented the need for a review of CT practice in our locality, the outcome of which may place an obligation on physicians to justify CT requests, and on Radiographers, to optimize radiation dose administered to patients. The study might also be the precursor to the establishment of DRLs in the locality. The present survey was contemplated for head investigations which is the commonest procedure performed in CT scan [14].

Material and methods

The survey which was carried out from February to May 2016, involved the retrospective analyses of digital images generated in 2015 at four large CT centres in Anambra State. Ethical approval was obtained from the Nnamdi Azikiwe University Teaching Hospital, Nnewi, Nigeria as well as written approvals from all the centres. The identity of the subjects were masked by the activation of image anonymity features on the console.

Centre A was a government-owned tertiary hospital located in the urban town of Nnewi. It had a 4-slice, GE Brighspeed Excel, scanner which was manufactured in 2007, and installed in 2011. A large retinue of Radiologists and Radiographers were employed there. Centres B and C were private facilities owned by the Catholic and Anglican churches, respectively. Both had visiting Radiologists and atleast two on-site Radiographers each. They had a similar 16-slice, Toshiba Alexion scanners which was manufactured in 2013, and installed in 2014. The only centre owned by an individual is tagged ‘D’. It had a 16-slice Siemens Somaton-Perspective scanner manufactured and installed in 2015. Centres B and D are located in Onitsha, a city by the bank of the Niger, while centre C is located in Ogidi, a neighboring town to Onitsha.

Excluded were an uninstalled scanner at the state university teaching hospital, Awka; two new facilities in Awka and Onitsha, respectively, which were test-running their CT machines during the period of the study, as well as two others without inbuilt dosimetrics (CTDI and DLP). One of those was a public-private partnership (PPP) facility in Onitsha while the other was a private facility in Nnewi. Included facilities also had another level of exclusion involving digital images. On the console/workstation, digital folders which were not reported by the Radiologists as a result of digital noise or gross artefacts, were equally omitted. The records at the CT suite showed which images were rejected.

In line with the recommendation that quality control (QC) of equipment be carried out prior to dose study [18], the scanners were calibrated daily using inbuilt system software.

Folders of subjects ≥ 18 years were sampled purposively and sequentially, out of the 2015 population of CT examinations. Although, subjective determination of sample size (≥ 10) is acceptable in dose research [3, 17], formula was used to establish a sample size of 187. This was arbitrarily increased to 200 to improve statistical accuracy and to have an equal number of cases in the centres.

From the request cards the height (cm) and weight (kg) were retrieved and used to calculate the body mass index, BMI (kg/m^2). Technical parameters for exposure which were imprinted on images were also extracted from the console. They included tube current (mA), tube potential (kVp), duration of gantry rotation (s), scan length (cm), scan mode (axial, helical), azimuth (degrees), pitch and gantry tilt.

Dose charts for each scanned patient appear on scanners in both prospective and retrospective mode. The prospective chart appears during planning of the examination and could be adjusted to keep dose as low as reasonably achievable, while the retrospective mode is a permanent result which cannot be post-processed. Both give an idea of the total dose administered to the patient during the procedure. It was the retrospective chart that was used for the study. This chart is tagged as series '999' on the scanners used and, its result is written in white on black background. It appears as the last series for each patient and its output are displayed when an examination is terminated. It displays the CTDIvol for each series (except the scanogram) and the cumulative DLP for all series.

The mean $CTDI_{vol}$ and cumulative DLP were extracted from the monitor for each patient and recorded in a *pro forma*. The mean dose in each centre as well as the combined mean for all centres was then calculated. The results were compared with the recommendations of the European Commission [19], and similar studies from Nigeria. Data was analyzed with the aid of computer software, SPSS version 20.0 (SPSS Incorporated, Chicago, Illinois, USA.

Results

As shown in Table 1, the image records of two hundred subjects made up of one hundred and four male (52.0 %) and ninety-six female (48.0 %) were involved in the study. Their ages ranged from 18 to 93 years and had a mean of 48.0 ± 17.3 years. The mean BMI was 27.2 ± 2 kg/m^2. Cranium (n = 164; 82 %) dominated the CT requests while CT facial bones were the least (n = 6; 3%). The technical parameters for the investigations are shown in Table 2.

The mean $CTDI_{vol}$ and DLP in the four centres was 58 mGy and 1112 mGy.cm (Table 3). When centre B was excluded as an extreme outlier, the mean $CTDI_{vol}$ and DLP for the other three centres was 52 mGy and 945 mGy.cm, respectively. A comparison of the adjusted dose output from this work with others is shown in Table 4. Dose output in Anambra State was comparable with the recommendation of the European Commission in $CTDI_{vol}$ (13.3 %) and DLP (10.0 %), but varied significantly from other local studies in $CTDI_{vol}$ (27–32.5%) and DLP (4.1–50.2 %), respectively.

Discussion

Radiation from medical imaging seems excessive because researchers have observed wide variations for similar imaging procedures [20], thereby necessitating a renewed interest in dose recording and reporting [5, 6].

This study was designed to investigate and report the dose applied in adult head CT examinations in our locality, as a possible precursor to establishing DRLs.

Centre A alone recorded the biometric parameters of height and weight of subjects. Consequently, the BMI was calculated for that centre only. Age was however, recorded by all centres with a mean of 48.0 ± 17.3 years. The mean age for each centre had a narrow range of 41.0 – 52.2 years, an indication of a fair degree of similarity between patients (Table 1).This similarity in characteristics extended to technical parameters for examinations as well as slices of scanners, especially amongst centres B, C and D. Scanner types/models were however, only similar in B and C (Table 2). Each centre also had Radiographers while centre A had interns, in addition. This centre was also far away from the other three which were in close proximity to one another. With these similar characteristics in the locality in mind, the assumption of the researchers was that $CTDI_{vol}$ and DLP output would have minor variation.

The findings from this study revealed that the mean $CTDI_{vol}$ was 58 mGy with a centre-specific range of 44 – 73 mGy. For the DLP, the mean was 1112 mGy.cm with a range of 733–1613 mGy.cm. Centre B with 73 mGy ($CTDI_{vol}$) and 1613 mGy.cm (DLP) deviated significantly (21 % and 31 %, respectively) from the mean (Table 3). When it was excluded and the data re-analyzed, the mean values dropped to 52 mGy ($CTDI_{vol}$) and 945 mGy.cm (DLP), respectively (Table 4). This however, creates a moral dilemma as the centre cannot be excluded practically from CT procedures. It could however, benefit from a protocol remediation as it was observed that it had the highest radiation intensity (140 kVp, 250 mA, 2 seconds DGR), Table 2. The observed variations also justifies the clamour for the establishment of DRLs in the locality.

The $CTDI_{vol}$ from this work (52/58 mGy) and DLP (945/1112 mGy.cm) were compared with the 60 mGy ($CTDI_{vol}$) and 1050 mGy.cm (DLP) recommended by the European Commission [19]. With or without excluding any centre, the results were fairly comparable. Since the foreign values were however, set at the 75th percentile while the results from this study were mean values, further dose optimization is needful in this locality to bring outputs to a truly comparable level. Using the adjusted result from the three centres (Table 4) in comparison with two other works from northern Nigeria, it was observed that the $CTDI_{vol}$ of the present study was 27 % higher than the single-centre study [16], and 32.5 % lower than the multiple-centre survey [15].

However, the DLP from this study was 4.1 % and 36 % lower than both the multi-centre [15] and single centre [16] survey, respectively (Table 5). Similarly, the result of this work was much lower (52 mGy; 945 mGy.cm) than the values reported (74 mGy; 1898 mGy.cm) by some authors in Southwest Nigeria [14]. The wide variations in inter-centre and inter-locality studies, is a cause for concern. A logical inference could be that CT dose management in Anambra State specifically, and Nigeria in general, has no clear guidelines. The recommendation from some local works that diagnostic reference levels (DRLs) be established for CT practice in Nigeria buttresses this point [14, 20].

While the future DRLs are awaited, the CT community may wish to note that CT dose can be reduced in several ways. The tube potential (kVp) plays a significant part in dose reduction. It was reported that an increase in kVp from 80 to 140 will increase patient doses four- to fivefold [21]. This was confirmed in this study where it was observed that the centre with the highest radiation intensity (kVp & mAs) had a commensurately high dose compared to others (Tables 2 & 3).

Pitch is another parameter that should not be ignored because patient doses are inversely proportional to CT pitch and, decrease with increasing pitch [22]. From our study, only one centre (A) programmed their pitch appropriately, indicating that the function of this parameter may not be well understood in other centres.

In conclusion, the mean CT dose output in Anambra State is 52 mGy ($CTDI_{vol}$) and 945 mGy.cm (DLP), respectively. These are comparable to international recommendations but with wide variations from other local works. A national diagnostic reference level (nDRL) for standardization of practice is therefore, imperative in the country.

Table 1: Anthropometric characteristics of the digital population

Variable	Population			Age (years)		BMI	Frequency		
Centre	Male	Female	Total	Range	Mean ± SD	Mean ± SD	Cranium	Sinuses (%)	Facial bones (%)
A	24	26	50	19 - 73	50.4 ± 15.5	27.2 ± 5.4	38	9	3
B	25	25	50	20 - 82	47.0 ± 16.3	NA	40	9	1
C	30	20	50	18 - 75	52.3 ± 18.0	NA	41	7	2
D	25	25	50	18 - 93	41.0 ± 18.4	NA	45	5	0
Total	104	96	200	18 - 93	48.0 ± 17.3	27.2 ± 5.4	164 (82)	30 (15)	6 (3)

NA = not available

Table 2: Modal values of scan parameters used for head CT investigations

Variables	Range	A	B	C	D
kVp	80 - 140	120	140	120	120
mA	10 - 350	230	250	200	220
DGR (s)	0.48 - 4	1	2	1	1
Scan range (mm)	180 - 320	200	170	170	180
Pitch	0.75 – 1.5	1.5	0.7	0.7	0.7
Scan mode	Helical/axial	Axial	Helical	Helical	Helical
Azimuth (^{0})	0 - 360	90/180	0/90	0/90	90/180
Gantry tilt (^{0})	1 - 30	15	Nil	Nil	Nil

*DGR = duration of gantry rotation

Table 3: Actual dose output in Anambra State

Centre	$CTDI_{vol}$ (mGy)		DLP (mGy.cm)	
	Range	Mean	Range	Mean
A	30 - 94	57.0 ± 10.0	61 - 1599	925.0 ± 389.5
B	66 - 867	73.0 ± 8.2	921 - 1973	1613.0 ± 229.4
C	44 - 59	57.0 ± 4.4	664 - 1951	1177.0 ± 233.4
D	24 - 74	44.0 ± 6.1	350 - 1177	733.0 ± 122.4
Combined	24 - 94	58.0 ± 12.7	61 - 1973	1112.0 ± 420.0

Table 4: Ideal dose output (centre B excluded)

Centre	$CTDI_{vol}$ (mGy)		DLP (mGy.cm)	
	Range	Mean	Range	Mean
A	30 - 94	57.0 ± 10.0	61 - 1599	925.0 ± 389.5
C	44 - 59	57.0 ± 4.4	664 - 1951	1177.0 ± 233.4
D	24 - 74	44.0 ± 6.1	350 - 1177	733.0 ± 122.4
Combined	24 - 94	52.4 ± 9.2	61 - 1599	945.1 ± 325.1

Table 5: Comparison with accessible published local dose surveys and EC study

Parameters	Location	Year	Centres sampled	$CTDI_{vol}$ (mGy)	% variation from current ideal study	DLP (mGy.cm)	% variation from current ideal study
Present study (a)	Anambra	2016	*3	52		945	
Present study (b)	Anambra	2016	4	58	10.0	1112	15
Garba [15]	Northeast	2015	3	77	32.5	985	4.1
Abdullahi [16]	Abuja	2015	1	38	27.0	1477	36.0
Ogbole [14]	Ibadan	2014	1	74	30.0	1898	50.2
Eur Com[19]	Europe	2009	?	60	13.3	1050	10.0

* Adjusted dose output by removing extreme outlier

Further reduction in dose to the populace is possible if the request can be appropriately justified by clinicians. This justification can be consolidated by the Radiographers through regular optimization of all technical aspects of the examination, such that the required level of image quality can be obtained while keeping the doses as low as possible [8].

Recommendations: Requesting clinicians should demand for a dose report both on the printed image and in the report of the Radiologists to keep radiation personnel on their toes. Furthermore, the relevant regulatory authorities should establish, implement and monitor compliance with diagnostic reference levels in modalities that emit ionizing radiation, especially in computed tomography.

Acknowledgement: Radiographers, Radiologists, support staff and managements of the CT centres in Anambra State of Nigeria.

References

1. Kalra MK, Maher MM, Toth TL, Hamberg LM, Blake MA, Shepard JA, et al. Strategies for CT radiation dose optimization. Radiology, 2004;230:619–28

2. Foley SJ, McEntee MF and Rainford LA. Establishment of CT diagnostic reference levels in Ireland. *Br J Radiol*, 2012; 85:1390–1397

3. Wall BF, Shrimpton PC. The historical development of reference doses in diagnostic radiology. Radiat Prot Dosimetry, 1998;80:15–19

4. Hall EJ, Brenner DJ. Cancer risks from diagnostic radiology. Br J Radiol, 2008; 81: 362–78

5. Neumann RD, Bluemke DA. Tracking radiation exposure from diagnostic imaging devices at the NIH. J Am Coll Radiol, 2010;7:87–89

6. Rehani M, Frush D. Tracking radiation exposure of patients. Lancet, 2010; 376: 754–755

7. McNitt-Gray MF. AAPM/RSNA physics tutorial for residents: topics in CT—radiation dose in CT. RadioGraphics 2002;22:1541–1553

8. International Electrotechnical Commission Medical electrical equipment—part 2–44: particular requirements for the safety of X-ray equipment for computed tomography. Geneva, Switzerland: IEC; 2002

9. McCollough CH, Leng S, Yu L, Cody DD, Boone JM, and McNitt-Gray MF. CT Dose Index and Patient Dose: They Are *Not* the Same Thing. Radiology, 2011; 259: 311–316

10. Stephen AE. Jr, Priscilla FB, Kimberly EA, Steven BB, Libby FB, James MH, et al.. American College of Radiology White Paper on Radiation Dose in Medicine. *Journal of American College of Radiology*, 2007; 4:272-284

11. Lee WJ, Woo SH, Seol SH, Kim DH, Wee JH, Choi SP, Jeong WJ, Oh SH, Kyong YY, Kim SW. Physician and nurse knowledge about patient radiation exposure in the emergency department. Niger J Clin Pract, 2016;19:502-507

12. Famurewa OC, Ayoola OO, Ogunsemoyin AO, Onyade AA. Radiation protection and dose awareness among doctors in a Nigerian Teaching Hospital: A preliminary study. *West Afr J of Radiol*, 2013; 20:37 – 40

13. Muhogora WE and Rehani MM. Patient Doses in CT and Radiography in Africa. IFMBE Proceedings, 2009; 25:536-539

14. Ogbole G, Obed R. Radiation doses in computed tomography: Need for optimization and application of dose reference levels in Nigeria. *West Afr J Radiol*, 2014; 21:1-6

15. Garba I., Engel-Hills P., Davidson F. & Tabari A.M. Computed Tomography Dose Index For Head CT in Northern Nigeria. *Radiat Prot Dosimetry,2015; 165:98-101*

16. Abdullahi M, Shittu H, Joseph D, Aribisala A, Eshiett EP, Itopa R and Kpaku G. Diagnostic Reference Level for Adult Brain Computed Tomography Scans: A Case Study of a Tertiary Health Care Center in Nigeria. *IOSR Journal of Dental and Medical Sciences*, 2015;14:66-75

17. Olowookere, CJ; Babalola, IA; Jibiri, NN;Obed, RI; Bamidele L.; & Ajetumobi E.O.A Preliminary Radiation Dose Audit in some Nigerian Hospitals: Need for Determination of National Diagnostic Reference Levels (NDRLs). *The Pacific Journal of Science and Technology*,2012;13(1): 487-495

18. Saravanakumar A, Vaideki K, Govindarajan KN, and Jayakumar S. Establishment of diagnostic reference levels in computed tomography for select procedures in Pudhuchery, *India J Med Phys*, 2014;39: 50–55

19. European Commission. Council Directive 97/43/Euratom of June 30, 1997 on health protection of individuals against the dangers of ionising radiation in relation to medical exposure. Off J Eur Commun 1997;L180:22–27

20. Olarinoye, IO & Sharifat, I. A protocol for setting dose reference level for medical radiography in Nigeria: a review. Bayero Journal of Pure and Applied Sciences, 2010; 3:138–141

21. Elojeimy S, Tipnis S, Huda W. Relationship between radiographic techniques (kilovolt and milliampere-second) and CTDIvol . Radiat Prot Dosimetry 2010 ; 141 : 43 – 49

22. Huda W and Mettler FA. Volume CT Dose Index and Dose-Length Product Displayed during CT: What Good Are They? Radiology, 2011; 258:236-24

How to cite: Adejoh T, Anene CN, Akanegbu UE, Imo SA, Chiegwu HU, Onwujekwe EC. Computed tomography dose for adult head scan in Anambra State of Nigeria. J Assoc Rad Niger, 2016; 30 (1): 24 – 31.