Rwanda Medical Journal RMJ

ORIGINAL ARTICLE Open Access

How well Nigerian radiographers adhere to pediatrics-specific protocols during computed tomography procedures

Authors: T. Adejoh[1,*]; E. E. Ezugwu[2]; F. O. Erondu[3]; M. C. Okeji[4]; A. W. Ijever[5]

Affiliations: *[1]Department of Radiography, Federal University of Technology, Owerri, Nigeria; [2]Department of Radiography & Radiological Sciences, Nnamdi Azikiwe University, Awka, (Nnewi Campus), Nigeria; [3]Department of Radiography & Radiation Sciences, Gregory University, Uturu, Abia State, Nigeria; [4]Department of Radiography & Radiological Sciences, University of Nigeria, Nsukka (Enugu Campus), Nigeria: [5]Radiology Department, Ahmadu Bello University Teaching Hospital (ABUTH), Zaria, Nigeria*

ABSTRACT

INTRODUCTION: Enormously high-dose procedures such as computed tomography requires pediatrics-specific protocols due to high tissue radio-sensitivity and higher lifetime attributable cancer risks. It's not known if radiographers in Nigeria consider this fact at all times.
This work aimed to survey head computed tomography dose in Nigeria for evidence of pediatric-specific practice.
METHODS: The census of CT scanners was undertaken prospectively across the country from June 2019 to September 2021, while the dose survey was undertaken retrospectively in 14 facilities distributed evenly across the geopolitical zones between February to September 2021. Data on computed tomography installations were supplied by radiographers spread across the country. A dose survey involving 490 and 700 pediatrics and adult patients emanated from fourteen of those facilities. Doses were extracted from on-screen volumetric CT dose index (CTDIvol) and dose-length product (DLP) in non-contrast investigations.
RESULTS: There were 209 CT scanners installed in Nigeria as of September 2021, with a triennial growth rate of 12.4% ($n = 26$). Monthly patient throughput for all CT requests was ≤ 41,412 with pediatric cases accounting for 10.4 % ($n = 4,311$). Mean head dose for pediatrics and adults with CTDIvol (41/58 mGy) and DLP (922/1198 mGy-cm) appeared different prima facie. However, a paired - sample t-test gave statistically significant difference in the CTDIvol ($p = 0.001$), but not with DLP ($p = 0.055$).
CONCLUSION: The installation of CT scanners is on the increase in Nigeria. Pediatric and adult CT dose had minimal differences. Given the higher lifetime attributable cancer risks for pediatrics, this should be worrisome. This calls for pediatric - specific protocol design and enforcement by relevant regulatory agencies, as well as meticulous optimization of protection from radiation by radiation practitioners.

Keywords: Computed Tomography, Dose, Radiation, Radiation risks, Optimization, Radiographer

***Corresponding author:** Thomas Adejoh, Department of Radiography, Federal University of Technology, Owerri, Nigeria; thomas.adejoh@futo.edu.ng; adtoms@yahoo.com, +2348133301005; **Potential Conflicts of Interest (CoI):** All authors: no potential conflicts of interest disclosed; **Funding:** All authors: All authors: no funding has been sought or gained for this project; **Academic Integrity.** All authors confirm that they have made substantial academic contributions to this manuscript as defined by the ICMJE; **Ethics of human subject participation:** The study was approved by the local Institutional Review Board. Informed consent was sought and gained where applicable; **Originality:** All authors: this manuscript is original has not been published elsewhere; **Review:** This manuscript was peer-reviewed by three reviewers in a double-blind review process; **Type-editor:** Cartledge (UK).

Received: 08th October 2021; **Initial decision given:** 15th February 2022; **Revised manuscript received:** 24th February 2020; **Accepted:** 27th April 2022.
 Publisher: Rwanda Biomedical Centre (RBC)/Rwanda Health Communication Center, P. O. Box 4586, Kigali. ISSN: 2079-097X (print); 2410-8626 (online)

Citation for this article: T. Adejoh; E. E. Ezugwu; F. O. Erondu et al. How well Nigerian radiographers adhere to pediatrics-specific protocols during computed tomography procedures. Rwanda Medical Journal, Vol. 79, no. 2, p. 27-36, 2022. https://dx.doi.org/10.4314/rmj.v79i2.4

INTRODUCTION

Computed tomography (CT) is a high-dose modality and the highest contributor to population irradiation from medical imaging [1,2]. Despite inherent risks from exposure to radiation, requests for pediatric imaging by clinicians has increased recently due primarily to advancement in CT technology and capabilities [3,4]. Risks from CT exposure have been shown to be directly proportional to radiation dose [5]. Evidence shows that it could be 10 times higher in pediatrics than in the adult population [6]. The absence of dose-specific legislations accentuates these risks, as well as non-implementation of diagnostic reference levels (DRLs), inadequate regulatory oversight, dearth of medical physicists, and unavailability of dosimetric equipment [7, 8]. Pediatric patients are worse off due to relatively smaller body surface area, greater tissue radiosensitivity, and higher lifetime attributable cancer risks [3,4].

Evidence of increased risk of malignancy amongst children subjected to CT examinations, and increasing demand for CT investigations is of serious concern to the scientific community [4, 9, 10]. Head requisitions are the most common due to trauma or space-occupying lesions [11,12]. These concerns have translated into hardware and software modifications by CT manufacturers, the widespread establishment of diagnostic reference levels (DRLs), and increasing attention to dose optimization by the imaging community. Nonetheless, there are still concerns about excessive CT doses [13]. Therefore, dose monitoring and reporting have been recommended as an additional layer of safeguard [14]. Whereas most developed countries have strong traditions in patient dosimetry, radiation protection and well-established medical physics support to radiology departments [11], this is not the case in many countries in Africa [9].

In Nigeria, whereas there are several surveys on adult head CT dose, pediatrics are often bypassed due primarily to paucity of data and perhaps, priority issues. Anecdotal evidence from our locality indicates that there were new CT installations after 2018, when a group of researchers undertook a nationwide census of the modality and survey of adult head dose [15]. In addition, CT protocols in some facilities were those set by vendors during installation. There was little or no attempt to adjust them by radiographers as long as images were of high diagnostic quality [9]. The increasing installations, fixed protocols, and challenges with dosimetry, medical physicists, legislation and weak regulatory oversight raises concern about safety

This work was undertaken to put the vulnerable pediatric population in the CT community's consciousness and enhance their radiation protection. A survey of existing and newer CT installations and radiographers' age-specific dose optimization bias may supply needful information to influence age-specific practice. Findings may also influence intervention in radiographers' retraining and scanner re-programming for dose-efficient protocols. It is also expected that relevant local regulatory agencies, as well as future researchers, will find the information useful. Nigeria is densely populated, with diverse religious groups, multiple ethnic groups and languages, and with a predominance of negroid race but with a significant number of others. These characteristics should make this work's findings validly extrapolated to other African countries.

METHODS

The census of CT scanners was undertaken prospectively across the country from June 2019 to September 2021, while the dose survey was undertaken retrospectively in 14 facilities distributed evenly across the geopolitical zones between February to September 2021.

Inclusion criteria: Scanners that were included were from facilities that granted unconditional access, had operated for ≥ one year to ensure that there were sufficient pediatrics data, and scanners that had on-screen dosimetrics such as volumetric CT dose index (CTDIvol) and dose-length product (DLP). Also included were scanners with a history of at least one quality control assessment within six months before data retrieval, and facilities with licensed radiographers and, or radiologists. Only non-contrast examinations showing skull outline free of distortions due to trauma, pathology or congenital anomaly were included. Although a minimum of 10 cases is considered admissible for dose assessment [10], much more was included by the researchers.

Data retrieval for CT scanners: Identification of existing and new CT installations was accomplished through radiographers spread across the country. This workforce's name and contact details were available and easily accessible from the Association of Radiographers of Nigeria (ARN) and Radiographers Registration Board of Nigeria (RRBN). Radiographers gave feedback on specific number of CT installations in their locality, functionality, other machine specifications, throughput, and cost of investigations. Feedback came through Whatsapp messages, phone calls, emails, and physical delivery.

Dose data retrieval: A dose survey of all functional scanners was contemplated ab initio but access to some facilities was unduly prolonged or outrightly denied. That difficulty led to sampling instead of total enumeration. The CT examination of the head was carried out by radiographers in each center according to standard protocol. Dose survey was carried out retrospectively in some of the facilities by the researchers who are radiographers themselves, while at some other facilities, radiographer colleagues previously coached on retrieval techniques helped to retrieve data from CT consoles. Dose was retrieved consecutively from ‘series 999’ on GE and Toshiba scanners, and the last series on other scanners. Data retrieved were recorded in datasheets. Age, gender, and investigation date were the only identifying parameters that accompanied the dose data. Images were also neither retrieved nor stored elsewhere. Technical and protocol information about the scanners were retrieved from displayed images on the screen.

Data analysis: Data were analyzed with statistical packages for social sciences, version 20.0 (SPSS Incorporated, Chicago, Illinois, USA). The mean, which is useful for inter-facility comparisons, and 75th percentile of median values, useful for benchmarking, were calculated for each population group. In addition, other descriptive statistical tools of frequency and mode were employed to summarize machine and subjects’ parameters and dose outputs. Inferential statistical tools were also employed for analysis. A paired-sample t-test was used to test for statistically significant differences in mean dose between pediatric and adult populations. In the t-test, differences found would indicate age-specific protocols by radiographers, which is a sign of good practice. The level of significance was set at $p \leq 0.05$.

Ethical approval was obtained from the Human and Animal Research Ethics Committee of Gregory University, Uturu, Nigeria (GUU/FHST/DRRS/EC/V.020/2019). Information was retrieved from records and not patients themselves, so, informed consent was not applicable.

RESULTS

There were 209 CT scanners installed in the country as of September 2021, with 64.1% (n = 134) and 24.4% (n = 51) in the southern and northern parts, respectively. The national capital, which is located in the northern part, had 11.5% (n = 24) (Fig I). Within a 3-year period (2018 – 2021), installations grew by 12.4% (n = 26). This is presented in Fig II. As shown in Table 1, monthly, a maximum of 41,412 requisitions for CT are made in the entire country, with pediatric cases accounting for approximately 10.4 % (n = 4,311). Summarized in

Table 1: Throughput of patients for CT in Nigeria as of September 2021

Zone	Population of CT scanners in zone	Range (monthly) Adults (a)	Pediatrics (b)	Total (a + b)	Total annual range
SW	60	2,280 – 15,780	120 – 1,620	2,400 – 17,400	28,800 – 208,800
SE	39	1,053 – 5,733	78- 858	1,131 – 6,591	13,572 – 79,092
SS	35	1,050 – 4,900	105- 420	1,155 – 5,320	13,860 – 63,840
NW	25	1,625 – 3,500	75- 626	1,700 – 4,126	20,400 – 49,512
NC	17	336 – 1,530	34- 119	370 – 1,649	4,440 – 19,788
NE	09	567- 855	18- 47	585- 902	7,020 – 10,824
Capital	24	912 – 4,800	72- 624	984 – 5,424	11,808 – 65,088
Total	209	7,823 – 37,098	502- 4,311	8,325 – 41,412	99,900 – 496,944

Table 2: Technical and demographic information about CT scanner

Zone	South-West		South-Est		South-South		North-West		North-Central		North-Est		FCT	
Ownership	Private	Private	Private	Private	Private	Private	Public	Public	Public	Public	Public	Public	Public	Public
Model	GE	Siem	Toshiba	Siem	GE	Neus	GE	GE	GE	GE	Philips	GE	Phil	Tosh
Slice	4	64	16	16	16	16	4	4	4	4	16	16	16	32
Manufactured	2007	NA	2013	2015	2013	2007	2007	2007	2007	2007	2008	2009	2009	NA
Installed	2016	2014	2014	2015	2013	2016	2010	2012	2011	2011	2008	2011	2009	2015
Protocol style	Auto	Auto	Auto	Auto	Auto	Auto	Auto	Adj	Adj	Adj	Auto	Auto	Auto	Auto
Range of head CT factors	120- 130kVp, 200- 300mA, 0.8- 1s GRT		100- 120kV, 220- 250mA, 0.5- 1s GRT		100- 120kVp, 200- 300mA, 0.8- 1s GRT		100- 120kVp, 230 - 250mA, 0.75- 1s GRT		100- 120kVp, 250- 300mA, 1s GRT		100- 120kVp, 250- 300mA, 1s GRT		100-120kVp, 200- 250mA, 1s GRT	
QC Period	Q2	Q2	Q1	Q2	Q2	Q2	Q1	Q1	Q1	Q1	Q1	Q1	Q2	Q2
Radiographers at centre	≥ 7	≥ 2	≥ 5	≥ 1	≥ 3	≥ 1	≥ 11	≥ 8	≥ 8	≥ 10	≥ 3	≥ 10	≥ 15	≥ 4
Cost of NC head CT (x N500)	$72	$60	$60	$80	$90	$60	$30	$60	$60	$70	$100	$50	$80	$80

NA = not available; Q1 – Q4 = 1st – 4th quarter; Siem = Siemens; Neus = Neusoft; Auto = automatic tube mA & kVp; adj = adjusted mA & kVp; paed = paediatrics; GRT = gantry rotation time; NC =Non-Contrast; N =Naira (Nigeria); FCT = Federal Capital Territory.

Table 3. Age and dose data for pediatric and adult head CT

	n		Age (pediatrics; years)		Age (adults; years)		CTDIvol (mGy)		DLP (mGy-cm)	
Zone	Paed	Adults	Range	Mean	Range	Mean	Ped	Adults	Ped	Adults
SW	70	100	2 – 17	12 ± 06	18 – 83	62 ± 12	58 – 76	65 – 76	551–1774	851–2007
SE	70	100	3 – 13	06 ± 02	18 – 91	51 ± 15	42 – 70	54- 72	422–1604	586–1988
SS	70	100	1 – 15	10 ± 04	18 – 92	54 ± 18	39- 62	45 – 62	502–1140	680–1378
NW	70	100	5 – 15	11 ± 07	23 – 84	52 ± 10	38- 82	38 – 82	650–1703	798–2110
NC	70	100	3 – 17	09 ± 07	19 – 85	55 ± 16	48- 74	56 – 88	545–1804	908–2162
NE	70	100	2 – 15	11 ± 03	22 – 83	48 ± 09	28- 62	37 – 68	458–1794	652–2053
NC	70	100	5 – 16	11 ± 05	18 – 82	53 ± 11	42- 63	50 – 66	601–1974	954–2035
Total	490	700	1- 17		18- 92		28- 82	37- 88	422- 1974	586- 2162
Mean				10 ± 05		53 ± 17	41	58	922	1198
75th PCTL*							60	62	1210	1288
T-test							p = 0.001		p = 0.055	

PCTL: Percentile; SW: South-West; NC: North-Central; SE: South-Est; SS: South-South; SW: South-West; NE: North-Est

Table 2 are information about the 14 CT scanners included in the dose assessment. Also given is the cost of a head CT scan in US dollars across facilities. Subject demographics and dose information are shown in Table 3. Patients whose digital folders were assessed were made up of 490 pediatrics aged 1–17 years (mean: 10 ± 05 years) and 700 adults aged 18 – 92 years (mean: 53 ± 17), all of

Figure 1: Map of CT scanner distribution according to geopolitical zones in Nigeria

both genders.

Dose values from different geopolitical zones ranged from 28 – 82 mGy (CTDIvol) for pediatrics and 37 – 88 mGy (CTDIvol) for adults. The pattern was replicated in pediatric DLP (422 – 1974 mGy-cm) and adult DLP (586 – 2162). The mean dose for pediatrics and adults in CTDIvol (41/58 mGy) and DLP (922/1198 mGy-cm) appeared different. The pattern repeated itself in the 75th percentile for CTDIvol (60/62 mGy) and DLP (1210/1288 mGy-cm). However, when an independent sample t-test was used to interrogate the means, there was a statistically significant difference in the CTDIvol (p = 0.001), an indication that different tube currents (mA/mAs) and tube potentials (kVp) were used –

Table 4. An overview of CT scanner installations in Africa

S/No	Country	Population	Number of CT scanners (≥)	Availability of CT scanner per 1,000000 population
		Western Africa		
1.	Nigeria (current study)	206,139,589	209	1
2.	Ghana [12]	31,072,940	35	1
3.	Liberia [16]	5,057,681	2	< 1
4.	Gambia [17]	2,416,668	2	1
		Total	248	
		Eastern Africa		
1.	Tanzania [18]	59,734,218	4	< 1
2.	Kenya [19]	53,771,296	30	< 1
3.	Uganda [20]	45,741,007	25	< 1
4.	Malawi [21]	19,129,952	2	< 1
5.	Zambia [22]	18,383,955	13	1
6.	Zimbabwe [23]	14,862,924	19	1
7.	Rwanda [24]	12,952,218	5	< 1
8.	Djibouti [25]	988,000	2	2
9.	Seychelles [26]	98,347	2	2
		Total	102	
		Northern Africa		
1.	Egypt [27]	102,334,404	450	4
2.	Libya [28]	6,871,292	41	6
		Total	491	
		South Africa		
1.	South Africa [29]	59,308,690	267	5
2.	Namibia [30]	2,540,905	2	1
		Total	269	
		Middle Africa		
1.	Cameroon [31]	26,545,863	24	1
		Total	24	
	Total number of CT scanners across Africa		≥ 1,134	

NB: Unlisted countries had no documented evidence of CT scanner availability

and rightly so- for both populations. The result of the t-test in DLP drew attention to the fact that the mean in both people was not significantly different (p = 0.055). That indicated similarity in tissue range used for both pediatrics and adult populations.
How many CT scanners are installed in Africa as of September 2021? An estimate is presented in Table 4. At least ≥ 1,134 scanners were identified, with the highest and least installations being in North Africa (n = 491) and Central Africa (n = 24), respectively. The installations in Africa appear so inadequate that the majority of countries had over 1,000,000 of the population sharing a single scanner. A few, including the country in focus, had a scanner or two to 1,000,000. The best equipped countries were Egypt (4:1,000,000), South Africa (5:1,000,000) and Libya (6:1,000,000).

DISCUSSION

Requisitions for pediatric computed tomography (CT) investigation have increased despite the enormously high-dose nature of the modality. Anecdotal evidence of CT protocols with wide dose latitude from practice in Nigeria spurred the authors to undertake the study. The quest was to ascertain the popularity of CT modality through a total enumeration. Furthermore, since pediatrics-specific protocol is standard practice, quality control of dose optimization practice was undertaken to investigate if that was the case.

Our census revealed that there were 209 CT scanners installed in Nigeria (Figure 1), with the majority in the Southern region (n = 134, 64.1 %) in comparison with the Northern region, which had 51 scanners (24.4%). The federal capital territory, located in the Northern region, had 24 scanners (11.5%), bringing the cumulative availability in Northern Nigeria to 35.9% (n = 75). As of 2018, there were 183 CT scanners in the country, with the lead being maintained by the South (n = 116, 63.4%) (15). Evidence of 26 newer installations (12.4%) from 2018 to September 2021, and still mainly in the Southern region, suggests that the modality is widespread and very popular in medical practice. The situation in the country is replicated in other African countries as there are currently a minimum of 1,132 CT scanners on the continent.

To assess the extent of optimization of pediatric dose, 14 facilities made up of 6 and 8 scanners from southern and northern regions were accessed and assessed. Radiographers' training curricula, practice standards, and oversight functions are centrally handled by a single regulatory agency, the Radiographers Registration Board of Nigeria (RRBN). Therefore, optimization practice in one region is not expected to be significantly different from the other [9]. Our findings, however, proved otherwise. The mean dose for pediatrics/adults was closely similar for CTDIvol (41/58 mGy) and DLP (922/1198 mGy-cm). The pattern repeated itself in the 75th percentile of median values for CTDIvol (60/62 mGy) and DLP (1210/1288 mGy-cm). The mean is useful for inter-facility peer review, while the 75th percentile is useful for benchmarking [10]. Further interrogation of the mean with a paired-sample t-test gave a statistically significant difference in the CTDIvol (p = 0.001). The CTDIvol is specifically a product of tube current (mA/mAs) and tube potentials (kVp) [15]. The statistically significant value indicates that the CT protocol had different mA/mAs and kVp rather than a uniform one for both populations, which is good practice.

However, effective dose, an indicator of risk from ionizing radiation, is generally calculated from DLP [10, 19]. So, good practice with CTDIvol does not necessarily translate to optimum radiation protection for the patient. Publications abound to show that radiographers do very well in setting optimum protocols for CTDIvol [2,3,8,10]. The major worry is the protocol for DLP. Whereas scan length is limited to the area of interest in other climes, this is seemingly difficult to achieve in our locality due to physicians' insistence on extensive coverage of anatomy in order to minimize cost and save patients a repeat visit to the hospital [15]. The scan length and CTDIvol make up the DLP, the major determinant of radiation risk. The result of the t-test with DLP indicated that the mean in both populations was not significantly different (p = 0.055). That suggests that although mA/mAs and kVp settings were different, the scan length/tissue range or scan field of view (SFOV) was similar rather than dissimilar.

Since pediatric patients have smaller body surface areas, a similar scan field of view (SFOV) with adults will tend to increase their dose as more tissues will be irradiated. Standard practice is to generate an image of the entire head for scanogram or scout. During the subsequent plan for axial scan, slices are then limited to the region of interest (ROI). But this will require a radiographer with an understanding of protocol settings. Scanogram is achieved in adults with SFOV setting of 140 mm superior and inferior from the centering point. The similarity noted in pediatric dose indicates that they too were subjected to this adult SFOV. A SFOV of 80 – 120, both superior and inferior, is generally adequate to address pediatric cases ≤ 15 years [8,10,15].

Doses from CT examinations depend on hardware, software and ‘humanware’ (radiographer). Although hardware and software provide the opportunity to decrease individual CT doses, variations in the patterns of use, and failure of dose reduction efforts by the humanware can lead to a reversal of the risk-benefit ratio associated with this imaging modality. Furthermore, a CT scanner should be used only when it has been programmed with protocols tailored to the anatomy of interest. In designing a suitable protocol, different adjustable parameters are manipulated. Some of these parameters include a size-specific SFOV/range, pitch greater than one to indicate tissue gap, shorter gantry rotation time, activation of automatic tube current and tube potential modulations, and gantry tilt less than 15 degrees caudad to reduce tissue range traveled by photons [15].

This study presents some limitations. The extensive landmass of the country and the huge number of CT installations was too daunting for the researchers to visit each facility to ascertain the information provided by third parties. Although the dose values are a fair representation of practice in the country, it would have been fulfilling to compare practices in both public and private settings to see if the optimization attitude is different. Despite this handicap, the authors are confident that the findings will be a useful launchpad for those who may wish to replicate the study.

In conclusion, there is increasing demand for CT scanners in the country. Troubling, however, is the evidence that adults and pediatric protocols have little difference. Although dose values were comparable or even lower than similar studies, radiation protection of the pediatric patient would be better enhanced if there were significant differences between them and adult patients. Regulatory agencies in the country are strongly urged to enforce radiographers' training and retraining on CT dose optimization. In addition, regulatory oversight to enforce compliance to diagnostic reference levels (DRLs), if available, is necessary. In addition, physicians and radiologists are urged to insist that a slide from series ’999’ be included in the printed CT image(s) by radiographers. This should make dose monitoring everybody’s affair, and specifically, place a moral obligation on radiographers to be dose-conscious.

REFERENCES

1. P. Graciano, J. Damilakis, V. Tsapaki, A. Schegerer, J. Repussard, W. Jaschke, et al. (2020). “Diagnostic reference levels based on clinical indications in computed tomography: a literature review.” Insights Imaging , vol 11. Available: https://doi.org/10.1186/s13244-020-00899-y.

2. D.Z. Joseph, T.Y. Haruna, M.S. Umar, et al. (2020). “Clinical indication-based diagnostic reference levels for paediatric head computed tomography examinations in Kano Metropolis, northwestern Nigeria.” Radiography. Available: https://doi.org/10.1016/j.radi.2020.11.021

3. M.K. Abdulkadir, N.A.Y.M. Rahim, N.S. Mazlan, N.M. Daud, I.L. Shuaib, N.D. Osmana. (2020). “Dose optimisation in paediatric CT examination: Assessment on current scanning protocols associated with radiation dose.” Radiation Physics and Chemistry, vol 171. Available: https://doi.org/10.1016/j.radphyschem.2020.108740

4. M.O. Bernier, H. Baysson, M.S. Pearce, M. Moissonnier.. “Cohort profile: the EPI-CT study: a European pooled epidemiological study to quantify the risk of radiation-induced cancer from paediatric CT.” Int J Epidemiol., vol. 48, no 2, pp.379–381g, 2019. Available: doi: 10.1093/ije/dyy231

5. J.P. Sheppard, T. Nguyen, Y. Alkhalid, J.S. Beckett, N. Salamon. and I. Yang. “Risk of brain tumor induction from pediatric head CT procedures: a systematic literature review.” Brain Tumor Res. Treat., vol. 5, no 1, pp. 1 – 7, 2018. Available: https://doi.org/10.14791/btrt.2018.6.e4

6. Y. Gao, B. Quinn, U. Mahmood, et al. (26 April,

2017). “A comparison of pediatric and adult CT organ dose estimation methods.” BMC Med. Imaging, vol. 17, no 1 Available: doi: 10.1186/s12880-017-0199-3

7. B.M. Idowu, T.A. Okedere. (2020). “Diagnostic radiology in Nigeria: A country report.” The Journal of Global Radiology, vol. 5, no 1. Available: DOI: 10.7191/jgr.2020.1072

8. A.D. Omojola, M.O. Akpochafor, S.O. Adeneye, I.O. Akala and A.A. Agboje. “Estimation of dose and cancer risk to newborn from chest X-ray in South-South Nigeria: a call for protocol optimization.” Egyptian Journal of Radiology and Nuclear Medicine, vol. 52, 2021. Available: https://doi.org/10.1186/s43055-021-00445-w

9. M.K. Abdulkadir, A.D. Piersson, G.M. Musa, S.A. Audu, A. Abubakar, B. Muftaudeen, and J.E. Umana. “Assessment of diagnostic reference levels awareness and knowledge amongst CT radiographers.” Egyptian Journal of Radiology and Nuclear Medicine, vol. 52, pp 67 – 73, 2021. Available: https://doi.org/10.1186/s43055-021-00444-x

10. E. Ekpo, T. Adejoh, E. Akwa. (2019). “Dose Benchmarks for Paediatric Head Computed Tomography (CT) Examinations in Nigeria.” Radiation Protection Dosimetry, vol. 185, no 4. Available: DOI: 10.1093/rpd/ncz036

11. J. Vassileva, M. Rehani, D. Kostova-Lefterova, H.M. Al-Naemi, J.S. Al Suwaidi, D. Arandjic, et. al. (2015). “A Study To Establish International Diagnostic Reference Levels For Paediatric Computed Tomography.” Radiation Protection Dosimetry, pp.1–11. Available: doi:10.1093/rpd/ncv116

12. B. Botwe, C. Schandorf , S. Inkoom , and A. Faanu. “An Investigation into the Infrastructure and Management of Computerized Tomography Units in Ghana.” Journal of Medical Imaging and Radiation Sciences, vol 51, pp. 165 – 172, 2020. Available: https://doi.org/10.1016/j.jmir.2019.11.140

13. M. Sidi and C.H. Elugwu. “Quantification of scattered radiation to adult female breasts during lumbosacral x-ray and head computed tomography in a Negroid population.” Pakistan Journal of Radiology, vol. 30, no 4, pp.252 – 256, 2020

14. A. B. Kharbanda, K. Ernest, L. Yi, B. Karen. “Analysis of radiation dose to pediatric patients during computed tomography examinations.” Acad. Emerg. Med., vol. 22, no 6, pp. 670–675, 2015. Available: www.aemj.org671

15. T. Adejoh, E.C. Onwujekwe, M. Abba, A.M. Ali, A.S. Imo, C.C. Nzotta, H.U. Chiegwu. “Computed Tomography Scanner Census and Adult Head Dose in Nigeria.” The Egyptian Journal of Radiology and Nuclear Medicine, vol. 49, pp. 66–70, 2018. Available: https://doi.org/10.1016/j.ejrnm.2017.09.001

16. RAD-AID. https://rad-aid.org/countries/africa/liberia/ [13-July-2021]

17. O. Omidiji. “Republic of the Gambia; General Country Profile.” https://rad-aid.org/wp-content/uploads/Gambia-CR.pdf , 2014 [13-July-2021]

18. P.S. Ngoya , W.E. Muhogora, R.D. Pitcher. (2016). “Defining the diagnostic divide: an analysis of registered radiological equipment resources in a low-income African country.” Pan African Medical Journal, vol. 25. Available: doi:10.11604/pamj.2016.25.99.9736

19. G.K. Korir , J.S. Wambani, I.K. Korir, M.A. Tries, and . “National diagnostic reference level initiative for computed tomography examinations in Kenya.” Radiation Protection Dosimetry, vol. 168, no 2, pp. 242–252, 19 March, 2016. Available: doi: 10.1093/rpd/ncv020

20. E. Kiguli-Malwadde, R. Byanyima, M.G. Kawooya, A.G. Mubuuke, R.C. Basiimwa, R. Pitcher. (2020). “An audit of registered radiology equipment resources in Uganda.” Pan-African Medical Journal, vol. 37, no 295. Available: 10.11604/pamj.2020.37.295.22046

21. K. Onjezani. “A brief history of CT scanners.” https://web.facebook.com/ 468869019814456/posts/a-brief-history-of-ct-scannersso-as-poor-malawians-suffer-with-a-ct-scanner-at-t/3747608788607113/?_rdc=1&_rdr [13-July-2021]

22. C. Mbewe, P. Chanda-Kapata, V. Sunkutu-

Sichizya, N. Lambwe, N. Yakovlyeva, M. Chirwa, B. Ayele, R.D. Pitcher. “An audit of licenced Zambian diagnostic imaging equipment and personnel.” Pan African Medical Journal, vol. 36, no 32, 2020. Available: 10.11604/pamj.2020.36.32.21043

23. T. Maboreke, J. Banhwa, and R.D. Pitcher. “An audit of licensed Zimbabwean radiology equipment resources as a measure of healthcare access and equity.” Pan Afr Med J., vol. 24, no 60, 2019. Available: doi: 10.11604/pamj.2019.34.60.18935

24. D.A. Rosman, J.J. Nshizirungu, E. Uwimana, E. Rudakemwa, L. Kalisa, C. Moshi, et al. “Imaging in the land of 1000 hills: Rwanda radiology country report.” J Glob Radiol., Vol. 1, no 1, Article 6, 2015. Available: https://core.ac.uk/download/pdf/56527013.pdf

25. J. Rullo. “Camp Lemonnier receives new CT scanner.” https://www.dvidshub.net/news/281525/camp-lemonnier-receives-new-ct-scanner, 2018 [15.July. 2021)

26. M.Z. Haque. “National Radiology Profile, 2017.” https://rad-aid.org/wp-content/uploads/Seychelles-CR.pdf [15.July. 2021)

27. P. Ward, T. El-Diasty. “Scanning the pharaohs: Ancient Egypt comes to Chicago.” https://www.auntminnie.com [07. July. 2021]

28. L. Bolton, P. Medway, A. Mahgoub, N. Al Gaseer. https://www.heart-resources.org/wp-content/uploads/2011/02/Libyan-Health-Service-Capacity-February-2011.pdf [17. July. 2021]

29. J.M. Kabongo, S. Nel, R.D. Pitcher. “Analysis of licensed South African diagnostic imaging equipment.” Pan-African Medical Journal., vol. 22, no 57, 2015. Available: doi:10.11604/pamj.2015.22.57.7016

30. K. Kambowe. “The struggle to bring imaging scanners to the North.” http://www.ewi.com.na/news/the-struggle-to-bring-imaging-scanners-to-the-north, 2016 [13. July. 2021]

31. W.E. Mankaa. “Cameroon Country Report, 2017.” https://rad-aid.org/wp-content/uploads/Cameroon-Country-Report.pdf [13. July. 2021]