FAMPO
FEDERATION OF AFRICAN MEDICAL PHYSICS ORGANIZATIONS

African Journal of Medical Physics
2019; 2(1): 10-14. doi: 10.

Research Paper

Radiation Doses and Risks in Computed Tomography Examinations at three Hospitals in South-Western Nigeria

Mary-Ann E. Ekpo✉ and Rachel I. Obed

Department of Physics, University of Ibadan, Ibadan, Oyo State, Nigeria.

✉ Corresponding author: Mary-Ann E. Ekpo, Department of Physics, University of Ibadan, Ibadan, Oyo State, Nigeria. Tel: +234(0)7034611140; E-mail: maryannekpo2013@gmail.com

ISSN 2643-5977

Received: 2019.03.06; Accepted: 2019.08.09; Published: 2019.09.01

Abstract

This study is aimed at estimating the radiation doses and associated risks in computed tomography examinations at three hospitals in South-western, Nigeria. A total of 238 adult patients' data were retrieved from three different scanners (Toshiba Aquillion 64-slice, Philips Brilliance 16-slice and GE 8-slice) representing three hospital facilities in Lagos, South-Western Nigeria. Data retrieved were: demographic data and exposure-related parameters. Measurements of CT dose indexes (CTDI) were performed on the scanners and CT-ExPO dosimetry software was used to estimate absorbed dose to the organs. Risk of cancer was also estimated using the mean effective doses and the ICRP 103 conversion factors. Mean organ doses for the brain, eye lens, thyroid, breasts, stomach, ovaries/testicles for head, chest and abdomen CT procedures were (58.1, 74.9, 12.6, 19.5, 25.4, 25.3/3.8) mGy respectively. Mean CTDIvol and DLP values for the head, chest and abdomen procedures from the three hospitals were 43.2±13.9, 14.4±4.86, 14.0±5.31 and 973.1±421.5, 433.2±162.3, 699.1±322.4 respectively. The overall risk of cancer per procedure ranged from (8-30) x 10 -5/Sv, (40-52) x 10 -5/Sv, (9-18) x 10 -5/Sv for head, chest and abdomen CT scans respectively. These values were comparable to other values obtained in literature. Large variations in mean organ doses were observed among same CT procedures in the different hospitals. These variations depended largely on the variations in CT protocols used in the different hospitals and scanner type. Protocols tailored to clinical indication, patient size and scan region will contribute largely to protocol optimization. It is important that facilities optimize exposure parameters so as to stay within acceptable limits of radiation dose.

Keywords: Computed Tomography Dose Index; Dose Length Product; CT scanners; Radiosensitivity; DICOM

Introduction

Computed tomography (CT) examinations uses x-rays to make detailed pictures of structures inside the body and constitutes the largest contribution to radiation exposure of the population thereby making diagnostic medical x-rays the largest man-made source of ionizing radiation exposure [1]. Estimation of dose from a CT procedure has been made possible with the use of dose descriptors: Computed Tomography Dose Index (CTDI) and the Dose Length Product (DLP). The CTDI is a commonly used radiation exposure index and has its unit as the gray (Gy) and can be used together with patient size to determine the absorbed dose [2]. The CTDI is estimated by integrating over the dose profile for a single axial rotation, then dividing by the nominal beam width.

$$\boldsymbol{CTDI = 1/nT \int_{-z}^{+z} D(z)dz} \quad (1)$$

where n is the number of slices acquired per single axial rotation, T is the width of a single acquired slice and nT is the nominal beam width and D(z) is the radiation dose measured at position z along the scanner's main axis – the dose profile. This measurement is often made using a 100-mm standard pencil-ion dose chamber representative of the integration length which is the scan length [3].

$$CTDI_{100} = 1/nT \int_{-50mm}^{+50mm} D(z)dz \qquad (2)$$

The weighted CTDI was introduced to account for homogenous dose distribution imparted by a CT scan which is much more than that imparted by radiography, but somewhat larger near the skin that at the centre of the body [4].

$$CTDI_W = {}^{1}/_{3}\, CTDI_{100central} + {}^{2}/_{3}\, CTDI_{100periphery} \qquad (3)$$

In CT, the total amount of radiation incident on the patient is known as the DLP and it is the product of the CTDIvol and scan length (in cm) measured in mmGy.cm. The DLP indicates the total amount of radiation (ie intensity ^{x} scan length) used to perform the CT examination and is quantified in a cylindrical phantom of a specified size (that is, 16 or 32cm in diameter). The CTDIvol and DLP are related by the expression [5].

$$DLP = CTDI_{vol} \cdot nT \qquad (4)$$

where nT is the total scan length. The effective dose (ED) takes into account the equivalent doses to all exposed organs as well as the organ radiosensitivity [6]. It is the uniform whole body dose that has the same nominal radiation risk of carcinogenesis and induction of genetic effects as any given non-uniform exposure. A major benefit of the effective dose is that different types of exposure to ionizing radiation, such as chest CT radiography (~0.05mSv) and chest CT (~5mSv) can be intercompared on a common scale [2]. The DLP is directly proportional to the patient's effective dose. Dividing the effective dose by the DLP yields an ED/DLP ratio. This ratio is a conversion factor that can be used to convert "DLP" data into a corresponding estimate of effective dose [7].

There is a small theoretical risk of carcinogenesis attributable to low doses of ionizing radiation based on epidemiological evidence at higher doses and dose rates. Several studies such as life span study of atomic bomb survivors, medical studies and experimental animal research have investigated the correlation between radiation exposure and cancer risk [6]. Radiation doses delivered during diagnostic procedures should not cause deterministic effects. This study is aimed at estimating the radiation doses and associated risks in computed tomography examinations at three hospitals in South-West Nigeria for the purpose of identifying facilities with unusually high doses and hence suggests possible parameters for protocol optimization.

Materials and Methods

A total of 238 adult patients' data were retrieved from three different CT scanners (Toshiba Aqullion 64-slice, Philps Brilliance 16-slice and GE Bright speed 8-slice) representing three hospital facilities A, B and C in Lagos, South-Western Nigeria. Patient demographic data (age and sex) were collected as well as exposure-related parameters. Patients' data collected consisted of 100(42%) head examinations, 56(24%) chest examinations and 82(34%) abdomen examinations respectively. Ethical clearance was obtained from hospital management following due process for individual hospitals. Data was manually retrieved via questionnaire sheets from the DICOM. CT dose index measurements were performed free-in-air on all scanners using a 100 mm pencil-shaped ionization chamber (Raysafe X2 CT sensor) along with an electrometer (Raysafe X2 Base unit). The calibration of the ion chambers was traceable to the Secondary Standards Dosimetry Laboratory of the National Institute of Radiation Protection and Research (NIRPR), University of Ibadan, Ibadan and was calibrated according to the International Electrical Commission (IEC) standards and a calibration factor of 1.00 was obtained. $CTDI_{100}$ measurements were normalized to the mAs values used per procedure. Organ and effective doses were estimated using the CT-ExPO dosimetry software and the estimated risk of cancer per procedure was determined by multiplying the mean effective dose per procedure by the ICRP 103 conversion coefficients. The measurements used in this study were the routine CT examinations of the head, chest and abdomen which are the commonest CT procedures. These examinations represent about 90% of the overall CT examinations performed in Nigeria.

Results and Data Analysis

The mean values of scan parameters conducted in each hospital for CT examinations (head, chest and abdomen) were analyzed and the results given in table 1.

The results of $CTDI_{air}$ normalized values are displayed in table 2 below for each scanner model to assess the influence of the CTDI values from the scanner and the applied potential on the dose delivery accuracy of the scanners.

Table 1. Mean scan parameters per hospital

CT Exam	Hospital	mA	Scan Length(cm)	kVp	Slice thickness	Pitch
HEAD	A	149.4	25.4	112.7	0.5	0.7
	B	225.0	24.3	120.0	2.0	0.2
	C	90.0	16.3	120.0	1.3	1.0
CHEST	A	222.8	45.4	104.0	0.5	1.5
	B	200.0	30.3	120.0	2.0	0.2
	C	288.7	28.6	120.0	1.3	1.4
ABD	A	161.7	57.1	104.5	0.5	0.9
	B	200.0	93.6	120.0	5.0	0.2
	C	267.5	43.5	120.0	1.3	1.4

Table 2. Normalized $CTDI_{100air}$ values

Scanner model	Tube Potential	Mas	Exposure time	$CTDI_{100}$	${}_{n}CTDI_{air}$ (mGy/mAs)
Toshiba Aqullion (A)	120	258	2.7	58.5	22.7
Philips Brilliance (B)	120	450	4.2	68.6	15.2
GE Bright speed (C)	120	280	1.0	13.5	2.3

Table 3. Mean exposure parameters

CT Examination	Hospital	$CTDI_{vol}$ (mGy)	DLP(mGy.cm)
HEAD	A	40.9 ± 14.9	1043.0 ± 451.4
	B	56.9 ± 15.8	1275.2 ± 373.2
	C	43.7 ± 10.4	717.2 ± 196.3
CHEST	A	11.6 ± 0.8	529.2 ± 109.2
	B	14.7 ± 8.8	333.2 ± 287.1
	C	15.1 ± 3.5	437.2 ± 96.1
ABDOMEN	A	16.3 ± 4.7	899.9 ± 316.9
	B	11.2 ± 6.3	583.0 ± 348.7
	C	13.3 ± 4.7	574.5 ± 215.1

Table 4. Mean Organ doses per hospital

Hospital	Brain	Eye lens	Thyroid	Breast	Stomach	Ovaries/Testicles
A	51.0	65.4	25.2	18.9	35.1	13.3/0.3
B	121.1	158.6	13.4	15.7	24.9	9.6/0.1
C	46.4	59.9	8.8	20.9	16.8	13.8/6.7

Table 5. Mean Effective Doses per hospital

CT Examination	Hospital	Effective dose (mSv)
HEAD	A	2.7
	B	5.3
	C	1.6
CHEST	A	9.4
	B	7.5
	C	8.1
ABDOMEN	A	17.5
	B	11.9

	C	9.4

Table 6. Overall Cancer risk per procedure

CT Examination	Hospital	Cancer risk (x 10^{-5}/Sv)
	A	14.9
HEAD	B	29.2
	C	8.8
	A	51.7
CHEST	B	41.3
	C	44.6
	A	17.5
ABDOMEN	B	11.9
	C	9.4

Table 7. Risk of cancer development for specific organs (x 10^{-2})

Hospital	Thyroid	Breasts	Stomach	Ovaries
A	0.6	0.1	23.7	1.3
B	0.7	0.1	16.8	0.9
C	0.2	0.2	11.4	1.3

Table 8. Comparison of mean CTDIvol and DLP of this study with similar studies

Examination	Dose Characteristics	This study	EC (2014)	Ogbole& Obed (2014)	Muhammad (2016)
Head	CTDIvol	43.2 ± 13.9	60	73.5	60
	DLP	973 ± 421.5	1000	1898	1024
Chest	CTDIvol	14.4 ± 4.9	30	22.7	10
	DLP	433.2±162.3	400	1189	407
Abdomen	CTDIvol	14.0 ± 5.31	35	37.9	15
	DLP	699.1±322.4	800	1902	757

Discussion

Comparison of mean scan parameters among all the three hospitals studied revealed that hospital C had the lowest scan parameters for their head examination but highest for their chest and abdomen scans. It is worthy to note that hospital C performs all head examination in axial mode with a pitch value of 1 compared to the others. Theoretical information indicates that high pitch values bring about decrease in radiation dose because of shorter acquisition time. The chest and abdomen scans of hospital C revealed high mAs values and this was accounted for by the pitch values and shorter scan lengths in comparison with the other two hospitals. Hence, making the output exposure from hospital C the lowest for all their routine CT examinations. Hospital B on the other hand showed considerably high values of DLP for head examination in comparison with the other two hospitals due to the pitch and mAs values; these parameters directly influence the dose. Hospital A on the other hand recorded highest values of DLP for both chest and abdomen examinations in comparison with the other two hospitals. Comparison of mean

CTDIvol and DLP from this study with similar studies and with the EC (2014) reference dose limits expressed in table 8, showed that the values from this study was below the studies of recent related studies [8, 9] while within acceptable limit with the EC (2014).

In the CT dose index measurements, the default head examination protocol for each hospital was used to perform the free-in-air measurements and comparison of the normalized CTDIair values with the CTDIvol values obtained during typical head examination, showed wide variations. Although, the mean CTDIvol values for all three hospitals was in the range of 40-50mGy, these values were larger than the normalized CTDIair values by more than 100%. Hospital B had the highest CTDIvol and DLP values for their head and abdomen examinations and this effect was also evident in their values for organ doses for head examination. Dose limits are applied to workers and to the members of the public. Dose limit for effective dose for individual radiation workers and individual members of the public are set at 20mSv/yr and 1mSv/yr respectively [10]. In this study, the values of effective dose obtained were the mean effective dose per procedure which implies the radiological risk to the population for each examination. These values were used to estimate the risk of cancer for a specified population exposed in each procedure.

Risk of carcinogenesis per procedure indicates that for hospital B, there was a risk of cancer among 29 persons in a 10,000 population exposed to head CT examinations in the hospital. Likewise, a risk of cancer in the stomach region is likely among 24 persons in a 1000 population exposed to abdomen CT examinations in hospital A. Carcinogenic and genetic effects (Stochastic) which can be a resultant effect of some level of risk following a radiological procedure. This effect which has no threshold value of exposure to radiation dose implies that any small amount of radiation involves an increase in cancer risk and the probability increases linearly with increasing radiation dose. The most widely accepted model for the stochastic effect is the 'Linear Non-threshold Model'. On the other hand, deterministic effect (tissue reactions) has a threshold of dose (below this threshold, the effect is not produced) and the severity increases with the dose (e.g skin injuries, cataracts etc.) [6, 11].

Conclusions

Organ and effective doses from routine CT examinations of the head, chest and abdomen examinations from 3 hospitals in South-West Nigeria have been used to estimate risk of cancer for patients. The mean exposure values from this study were found to be lower than values obtained in literature and also lower than the EC reference values of 2014. Although the values were within acceptable ranges, there is still need to constantly apply the ALARA principle in the design of scan protocols so as to keep doses within acceptable limit. Any medical procedure involving ionizing radiation should be based on the clinical benefit (Justification) without forgetting the radiological risk to the patient [12]. There is need for the design of patient-specific and indication-based protocols as steps towards optimization. Furthermore, periodic CT dose index measurements should be carried out as part of quality assurance/control checks in addition to image quality checks to maintain a balance between image qualities and dose output.

Abbreviations

CT: Computed Tomography; ED: Effective Dose; CTDI: Computed Tomography Dose Index; IEC: International Electrical Commission.

Author Contributions

M. E. E. and R. I. O. contributed equally to this study. All authors gave their final approval.

Competing Interests

The authors have declared that no competing interest exists.

References

[1] National Council on Radiation Protection and Measurements (NCRP). Reference levels and Achievable Doses in Medical and Dental Imaging. Recommendations for the United States. Report no, 172. 2012.

[2] McCollough, C.H; Leng, S; Yu, L; Cody, D.D; Boone, J.M; McNitt-Gray, M.F. CT Dose Index and Patient Dose: They are not the same thing. Radiology. 259 (2): 311-316 (2011).

[3] McGale P, Taylor C, Effect of radiotherapy after mastectomy and axillary surgery on 10-year recurrence and 20-year breast cancer mortality: meta-analysis of individual patient data for 8135 women in 22 randomised trials. Europe PMC, 2014, 383(9935):2127-2135.

[4] Dowsett, David J; Kenny, Patrick A; Johnston R. Eugene. The Physics of diagnostic imaging (2nd ed). London: Hodder Education p430.

[5] AAPM report No 96. The measurement, reporting and management of radiation dose in CT. AAPM. Retrieved 12 Dec, 2016.

[6] International Commission on Radiological Protection (ICRP) publication. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. 37: 1-332, 2007.

[7] Huda, W., & Mettler, F. A. (2011). Volume CT dose index and dose-length product displayed during CT: what good are they? Radiology, 258(1), 236-242.

[8] Ogbole, G. I., & Obed, R. (2014). Radiation doses in computed tomography: Need for optimization and application of dose reference levels in Nigeria. West African Journal of Radiology, 21(1), 1.

[9] Abdulkadir, M. K., Schandorf, C., & Hasford, F. (2016). Determination of Computed Tomography Diagnostic Reference Levels in North-Central Nigeria. The Pacific Journal of Science and Technology, 17(2).

[10] Kovler, K., Friedmann, H., Michalik, B., Schroeyers, W., Tsapalov, A., Antropov, S., Bituh, T. & Nicolaides, D. (2017). Basic aspects of natural radioactivity. In Naturally Occurring Radioactive Materials in Construction (pp. 13-36). Woodhead Publishing.

[11] Committee to Assess Health Risks from Exposure to low levels of Ionizing Radiation. Health risks from exposure to low level of ionizing radiation. BEIR VII Phase 2, Washington DC: The National Academies Press: 2006.

[12] Heidbuchel, H., Wittkampf, F. H., Vano, E., Ernst, S., Schilling, R., Picano, E., & Mont, L. (2014). Practical ways to reduce radiation dose for patients and staff during device implantations and electrophysiological procedures. Europace, 16, 946-964.