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Evaluation of Computed Tomography Doses in Patients in Selected Facilities in South-South and South-East Regions Nigeria

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Abstract: ***In this study, we evaluates the mean organ dose using imPACT software and compare the patient doses obtained with values from other international studies findings done with similar software. Seven Computed Tomography (CT) facilities were carefully selected in the south-south and southeast region of Nigeria. An imPACT Patient Dosimetry Calculator Software was used to determine organ dose to the head, chest, abdomen and pelvic region from 359 patients' CT parameters retrieved from the CT monitor. Data analysis was done using (T-test) Olivia et al (2011). Significant differences exist in similar organ doses among the 7 CT units selected in south-south and southeast indicating that there was harmonization in CT protocols considered.***

Keywords: Computed tomography, dosimetry, imPACT software, radiation

1. Introduction

Application of radiation in medicine could be with ionizing or non- ionizing radiation (IAEA 2002; NNRA 2003). The use of ionizing radiation in medicine is of great concern since it could cause harmful effect to the body. The radiation doses delivered to the patients, personnel and the public during Computed tomography (CT) examination should be of radiation protection concern own to non-uniformity in dose distribution and radio-sensitivity of different organs (Akinlade *et al.*, 2012; NCRP 2004). Computed tomography (CT) radiation imaging is a high source of radiation exposure, (UNCEAR 2008, NCRP 2004,). It is of great necessity that the radiation dose in computed tomography should be evaluated to reduce the over exposure or under exposure of patient during CT imaging (Sungita, 2006).

Despite the revolution in modern diagnostic imaging and analysis in medicine, through the advent of modalities such as computed tomography (CT), which can produce extremely detailed images by creating cross sectional images of high radiographic contrast of any part of the body in seconds. Many somatic effects of radiation could also be found evident a few months after the use of the X-ray in diagnostic medical application (UNCEAR 2008; NCRP 2004).

An assessment of the radiation risk should be based on organ doses or effective dose, according to International Commission for Radiological Protection (ICRP, 1996). Presently, radiation imaging and treatment are the largest source of medical radiation exposure, consisting of half of the total medical exposure (NCRP 2004). This may impose some radiation dose that is too risky to ignore. One of the diagnostic imaging techniques that expose the patient to high radiation doses is the head computed tomography (NCRP 2004).

Computed tomography is an x-ray based procedure that generates high quality cross sectional images of the body without any limitation on the imaging plane or field of view. It accounts for approximately 6% of all medical x-ray examinations and contributed 41% of collective dose in 1999-2004 (UNSCEAR 2008).

Hartz (2004) maintains that, CT examination form 9% of all medical x-ray examinations and 47% contribution to resultant collective dose in 2003-2004. Presently, CT accounts for up to 15% of the x-ray medical examination and 70% resultant collective dose (Sungita, 2006).

Quantitatively, head CT examinations may deliver radiation doses in excess of $20mSv$, which is substantially high (about 50 to 500 times compared to other radiological techniques (UNSCEAR 2008). In CT examinations, the radiation dose is closely linked to the diagnostic accuracy, because image quality on CT dominated by quantum noise (mottle), which implies that low doses will cause highly noisy image that are not useful. However, to minimize noise and obtain high quality images, some validated standardized protocol was employed to reduce the radiation exposure levels with an effective image also. This approach leads to wide variation in the radiation dose (Sungita, 2006).

The expected high dose of radiation from CT examination over a wide cross sectional area of the patients' head region could pose a significant risk to the patient. Reported incidents of radiation over exposure have brought about interest in evaluating doses delivered in CT examinations (UNSCEAR, 2008).
The evaluation of radiation dose in computed tomography is performed by estimating the computed tomography dose index (CTDI), which was introduced more than 30 years ago (Shope, 1981). The CTDI represents the absorbed dose along the z-axis of the CT scanner measured in a single rotation of

the x-ray source (AAPM 2002). During CT examinations, dose measurements are carried out on patients at the centre and at the periphery of the CT phantom. Subsequently, the two measurements are then combined as weighted average ($CTDI_w$), which is used to evaluate computed tomography dose index volume $CTDI_{vol}$ (AAPM 2002, Sungita, 2006). Impact dosimetry software has helped in the evaluation of organ dose from head computed tomography (CT) procedures.

In this studies, we used the impact dosimetry software (version 3.0 27/05/2015) to evaluate patients' doses (organ dose and effective dose) from computed tomography examinations to see if there will significant changes in doses when similar organ doses were subjected to other Computed Tomography (CT) units. We correlate our findings with international studies with similar software. Southeast and South-south regions of Nigeria were selected for having more centres where these facilities are situated.

2. Materials and Procedures

We recorded a one-year retrospective study of CT Scans of patients at selected CT facilities in South-South and Southeast region of Nigeria from Aug 2014 to Aug 2015. A total of 359 patients within a reproductive age and mean weight of 70kg was considered in this research, their details was recorded as follows: the type (model), year of manufacture, year of installation and status of facility used were also recorded. Three functional CT facilities was selected from facilities in densely populated area in Cross River State, Rivers State and Imo State, three other facilities where visited, two out of them were not functional and the management of one refused us access to their facility. Data on exposure factors parameters were acquired from the DICOM of the facilities. Based on the data acquired, imPACT patient dosimetry software was used to determine organ dose to the head region of the patients' with CT parameters retrieved from the CT monitor. The number of patients under went head CT procedure is maximum at CT centre A (52.92%), followed by the CT centre C (24.23%), and lowest in CT centre B (22.84%). The total of male head CT numbered 58.50% and the female head CT is 41.50% of the total procedure from the three facilities studied. The peak kilovoltage (KVp) and mAs vary among the three units considered. The kvp for male and female is (Male :127.47, female : 120.95) for center A, (male : 121.25, female : 120.00) for center B, and (male : 121.50, female : 130.00) for center C respectively. Similarly the mAs for male and female is (Male: 137.72, female: 139.05) for center A, (male: 140.72, female: 142.00) for center B, and (male: 122.50, female: 124.73) for center C respectively. There is variation in effective dose obtained in different centers but there is no significant difference of effective dose for male and female in each CT Unit considered. The whole body average effective dose (E) for the head CT is higher in CT unit B (male: 7.39 mSv, female: 7.24 mSv) , compare to unit A (male : 5.28mSv , female 5.26mSv) and unit C (male : 4.04mSv, female : 3.25mSv) respectively. A comparison of (T-test) dose obtained with other related studies indicated no relevant difference.

To calculate the organ dose and effective dose, technical factors such as tube potential (kVp) and tube loading (mAs) were recorded from the machine DICOM. Patients organs doses were determined using impact CT patient Dosmetry software (version 3.0 27/05/2015), which is in line with the analytical method as described by IAEA (2007). The software allows for the calculation of the following dose quantities

1) Weighted CTDI ($CTDI_w$)
2) Volume CTDI ($CTDI_{vol}$)
3) Dose Length Product (DLP)
4) Organ Doses
5) Effective Dose (according to ICRP 60 and 103)

In contrast to similar programs for CT calculations, other parameters such as the following were also taken care of by the software:

a) Dose calculation for different age groups.
b) Dose calculation for different gender
c) Dose calculation for different scanner models

Dose calculation for different body CT examination

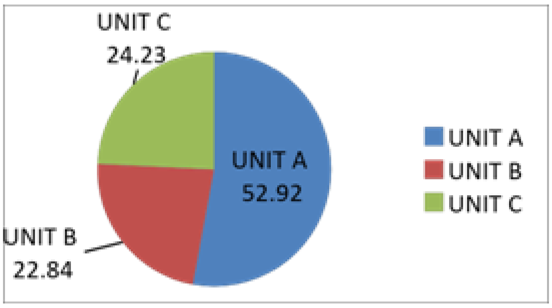

Figure 1: The distribution of patients head CT examination in different CT nits

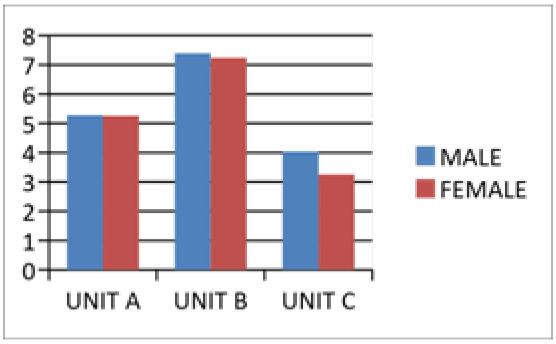

Figure 2: The mean effective dose value from the 3 CT units for head procedures

3. Results and Discussion

For statistical analysis, patients' dose obtained from different centres were compared using an appropriate statistical tool (T-test) Olivia et al (2011).

Computed tomography scanner data as measured is shown in (Table 1), F: functional, NF: not functional and NA (not accessible).

Table 2, show the average distribution of Head CT in unit A (52.92%), unit B (22.84%) and unit C (24.23%) performed for the 359 patients who underwent head CT procedures in the 3 radiology CT Units located in South-South and South-

East Nigeria in the study is as demonstrated in pie-chart as shown in (figure 1). Both the national and international regulatory bodies recommend regular measurement of patient doses in computed tomography facilities. The evaluation of patient dose is a very important requirement and tool in quality control, dose reduction and radiation protection in diagnostic radiology. Comparison of the mean technique factors selected in our study with the CEC recommended guidelines shows that the technique factors selected were either too low or high for some procedures while in some CT facilities the selected techniques factors were within the recommended range.

Furthermore, patients doses (Table 3), were evaluated in terms of body organ doses and effective dose estimated with imPACT dosimetry software. We observed that there were slight variations in radiation doses as obtained from the software for different CT facilities. The range of percentage deviation is 18.77%- 27.59% for head CT examinations. This variation could be because of parameters of the mathematical phantom of adult patients used in this study. In reality, we have varied weight and heights of adults but the software only used a reference mass of 70kg for adult and 176.0cm height for male phantom and 174.0cm height for female phantom. The mass and height of patients determines the body thickness, which is a major determinant for radiation dose penetration and absorption. Other factors necessary for these dose variations include, choice of CT exposure parameters, CT technique and processing, and processing performance (Mohamadain et al., 2004). Equipment type was not considered as a factor for the dose variation because they are all same type of machines (GE) (table 1).

We compared the patient doses obtained in this work with values from other studies (table 4), it was observed that CT examination centres A and C, which made up of 66.67% of the facilities considered had patient dose lower than the UK range, while in one (centre B) which made up of 33.33% of the facilities considered, some values appear to be above the UK range. The software evaluated whole body effective dose ranges from (2.1- 9.0) for male head CT; (1.8-9) mSv for female head CT; Some of these radiation dose values are higher than UK range of (0.09-6.00) mSv but none was above the maximum IAEA value of 10.0 mSv and they also fall within the radiation dose range value of (1.8-23.4) mSv from similar studies (Olowookere *et al.*, 2011; Osei *et al.*, 2013; Ogbole *et al.*, 2014) around the globe.

The various body radiation dose absorbed by the most radiosensitive organs of the body considered in this study and the effect of the selected CT technique factors on the patient doses are also discussed.

The mean effective dose delivered by CT Unit A to head, was 5.26mSv, for CT Unit B, (fig.2), the results were 7.29, and the CT Unit C results are 3.65 respectively. There was no statistical significance in dose delivered to male and female in all the centres considered. (P > 0.05)

Table 1: Computed tomography scanner data. F: functional, NF: not functional and NA (not accessible)

S/N	Centre	Scanner Model	Year of Manufacture	Year of Installation	Status of facility
1	A	GE	1997	2008	F
2	B	GE	1997	2005	F
3	C	GE	1997	2012	F
4	D	Simens	No records	2003	NF
5	E	GE	1997	2003	NF
6	F	-	-	-	NA

Table 2: Average scans factors of examinations. CT: Computed tomography, kVp : Peak Voltage, mAs : milliamper seconds

Examinations	CT Unit	kVp	MAs
Head	A	126.25 ± 35.35	131.2 ± 42.00
	B	120.65 ± 0.50	141.35 ± 7.00
	C	121.25 ± 1.50	130.75 ± 3.50

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Table 3: Mean Body Organ Dose per Organ

Organ	Average Effective Dose x 10 -3 (mSv)					
	UNIT A		UNIT B		UNIT C	
	Male	Female	Male	Female	Male	Female
	Mean ±SD	Mean ± SD	Mean ±SD	Mean ± SD	Mean ± SD	Mean± SD
Gonad	1.24 ± 2.04	1.05 ± 2.04	1.40 ± 0.74	1.20 ± 0.68	0.85 ± 1.03	0.79 ± 1.07
B/Marrow	467.73± 226.19	440 ± 31.11	655.00 ± 56.57	550.5± 21.21	313 ± 38.18	167.0 ± 39.60
Colon	10.7 ± 61.8	29.87 ± 13.38	14.9 ± 1.41	13.01 ±6.72	7.65 ± 9.26	7. 02 ± 9.62
Lung	2127.23 ± 17.25	2001.70 ±20.08	29750 ±28.28	2485.00 ±77.78	1330.00 ± 16.76	1026.70 ±16.97
Stomach	220.39± 13.45	214.20± 15.56	317.50 ±28.28	2 67.00 ± 9 8.99	149.00 ± 17.89	137.00 ± 18.60
Bladder	9.34 ± 84.84	8.47 ± 15.56	3.72 ± 3.39	0.26 ± 0.25	0.189 ± 0.23	0.15 ± 0.22
Breast	1552.61 ±102.5	1584.86 ± 13.35	2353.0 ±16.61	2095.0 ± 16.26	1160.90 ±17.97	1068.0 ± 18.02
Oesophagus	884.6 ±49.4	810.4 ± 83.09	1193.80 ± 77.78	1030.0 ± 84.07	1050.27± 60.18	509.00 ± 6 7.17
Thyroid	44.38± 38.18	40.67 ± 38.18	58.60 ± 4.95	49.95 ± 22.63	29.6± 36.06	27.30 ± 37.47
Skin	28.51± 26.16	55.45 ± 26.16	39.69 ± 3.54	34.35 ± 8.48	17.55 ± 21.85	16.07 ± 22.63
Bone surface	82.06 ± 41.72	78.99 ± 19.94	109.40 ±7.07	924.00 ± 26.87	49.82 ± 59.40	45.90 ± 61.52

Table 4: Comparison of the Average Whole Body Effective Dose of This Study to Dose From similar studies

Study	Year	Location	mSv	% Deviation
Present Study	2016	Nigeria	4.18	0.00
Nzota	2015	Nigeria	2.50	40.19
Ogbole	2014	Nigeria	1.80	56.94
Osei	2013	Canada	1.80	56.94
Origi	2006	Italy	2.80	33.01
Milatovic	2011	UK	6.50	55.50

4. Conclusions

The impact dosimetry software was a good tool for evaluation of patients doses in the 3 CT Units studied (A, B and C). There was variation in KVp, mAs, and effective dose but all were under the CEC recorded value. The effective dose obtained was in line with the value obtained in other similar works around the globe. It is also important to note that the variation in patients' doses may be as a result KVp, body size and different quality control.

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