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ESTIMATION OF DOSE REFERENCE LEVELS IN COMPUTED TOMOGRAPHY PROCEDURES IN SOME HOSPITALS IN FCT- NIGERIA

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Abstract

There has been increasing use of Computed Tomography (CT) as a diagnostic modality in the country with its major concern of delivering high radiation dose and potential source of increased cancer risk. To address this concern, CT patient absorbed dose and Quality Control (QC) parameters during CT examinations at various radiological centres in Abuja were estimated in five hospitals at Abuja, FCT- Nigeria using Polymethyl Methacrylate phantom, ion chamber and integrated electrometer respectively. The results obtained for body phantom for Computed Tomography Dose Index (CTDI) in air ranged from 5.04±0.001 mGy to 12.85±0.002 mGy and its estimated dose index ($CTDI_w$) ranged from 3.29±0.001 mGy to 10.29±0.32 mGy. While the CTDI for head phantom in air ranged from 20.8±0.001 mGy to 67.46±0.3 mGy and its estimated dose index ($CTDI_w$) ranged from 11.19±0.001 mGy to 34.84±0.3 mGy. The dose ratio for the body phantom ranged from 1.24±0.32 mGy to 1.58± 0.002 mGy, while that of the head phantom ranged from 1.30±0.001 mGy to 1.94± 0.3 mGy. Also the Dose Length Product (DLP) for the body phantom ranged from 79.36± 0.001 mGy.cm to 438.13±0.32 mGy.cm and that of head phantom ranged from 427.30±0.001 mGy.cm to 1165.73 ±0.3 mGy.cm. The results indicate that body phantom for centres 1-5 were within the acceptable limits of 10-40 mGy. While that of head phantom, the results were within the acceptable limits of 40-60 mGy for centres 1,2,3 and 5 except centre 4 (67.46 mGy) that had values above the accepted limits. Similarly, the Dose Length Product (DLP) for body phantom for the five centres were within the European Diagnostic Reference Levels set at 650mGy.cm and that of the head phantom were equally within the set limits except centre 4 (1165.73mGy.cm) that had values above the European Diagnostic Reference Levels set at 1050mGy.cm. The differences in the results of the study suggest a need for optimization of computed tomography examinations protocol and quality control measures in some computed tomography facilities under study.

Keywords: *Computed Tomography, Phantoms, Radiation Dosage, Quality Control, Dosimetry*

Introduction

The introduction of Computed Tomography (CT) into clinical practice has revolutionized the practice of medicine. The modality of short image acquisition time and its unique ability to offer clear images of bone, muscle, blood vessels, and different types of tissue where other imaging techniques are limited in the quality of images they can provide (Bushberg, *et al*., 2002). Additionally, it can be used to plan specific operations, direct biopsies, assess bone mineral density, find injuries to internal organs, and it has been shown to be an invaluable tool for the identification and management of numerous musculoskeletal conditions. However, the function of CT in the therapy of cancer is arguably its most significant feature (Treier, *et al.*, 2010).

The practice aids in the process of arranging radiation therapy by enabling doctors to precisely detect and localize various cancer kinds. To optimize patient imaging methods, CT is also employed to create a hybrid technology. Undoubtedly, the use of CT technology is essential for the diagnosis and treatment of patients, and as technology advances, patient care will continue to get better (Bushberg, et *al*., 2002).

However, compared to other diagnostic imaging modalities, CT is associated with high radiation, which has prompted worries about the health dangers of high patient radiation doses (Abrokwa, 2016). Data from 1991 to 1996 reveals that, globally, CT dosage made up roughly 34% of the total annual dose from medical exposures (Bauhs, *et al.*, 2008).

Computed tomography dose over a region can be explained by a number of factors, including volume computed tomography dose index (CTDI), dose length product (DLP) and effective dose (E). However, there are two ways to measure specific organ doses: directly or experimentally using phantoms and detectors, and by virtual stimulation or indirect measures using specialized computer software (such as CT-EXPO, CT DOSE, Impact Dose, and Virtual Dose). The human or polymethyl methacrylate phantom is used for the direct assessment of organ doses utilizing radiation dosimeters such as ionization chambers or more compact gadgets like thermo-luminescence detectors.

Materials and Method

The CT machines used for this work in five centres were situated in Abuja, FCT. Measurements of CTDI were carried out by a pencil shaped ionization chamber of active length 100 mm inserting in standard CT Polymethyl methacrylate (PMMA) materials with PTW chamber type 30009, Freiburg, Germany dosimetry phantoms that is used frequently in CT dose measurement compose of a 32cm-diameter phantom to represent an adult chest, and a 16cm-diameter version to represent an adult head. Both are 15 cm thick (in the z-axis direction) and contain 1 cm diameter holes for insertion of the CT ion chamber probe. The holes on the phantoms are at the centre and at 1 cm depth at the 90^0, 180^0, 270^0 and 0^0 normal clock positions referred to as the peripheral sites.

The body phantom was first set up on the CT couch and centered at the isocenter of the scanner with the long axis of the phantom aligned with the z-axis of the scanner. The PTW pencil ion chamber which is connected to an electrometer with a cable was placed in the central hole of the phantom. Two horizontal lasers in the CT room were adjusted to be visible on the mid-line of the ion chamber and a vertical laser was also set to be visible at the middle of the phantom. This was done to properly align the phantom and the chamber on the couch. A piece of tape was put along the probe, attaching it on to the phantom to ensure that the probe is not dislodged within the phantom during scanning. A topogram image of the phantom was taken and used to select the volume to be scanned. The CTDI quality assurance measurements was activated for the first scan with the standard protocol of body examination for three readings at each point (one in centre and four points on peripheral of a phantom) at 90^0, 180^0, 270^0 and 0^0 normal clock positions represented as P1, P2, P3, P4 and C and subsequently the head phantom respectively as shown in (Tables 1 and 2). Charges were measured and recorded in each scan. The charges measured and recorded from the electrometer in charge mode, corrected for temperature and pressure were used to estimate $CTDI_w$ and DLP values and compare with CTDI and DLP console display on the CT in the study with the use of mathematical equations:

$$k_{TP} = \frac{(273.2+T)P_0}{(273.2+T_0)P} \quad (1)$$

$$C_{PMMA,100,c} = \frac{10}{NT} M_c N_{PKL,Q_0} k_Q k_{TP} \quad (2)$$

$$C_{PMMA,100,P} = \frac{10}{NT} M_P N_{PKL,Q_0} k_Q k_{TP} \quad (3)$$

$$CTDI_w = \frac{1}{3}(C_{PMMA,100,c} + 2C_{PMMA,100,P}) \quad (4)$$

$$DLP = CTDI_{vol} \times Scan\ length \quad (5)$$

Results and discussion

The study carried out and calculations leading to CT dose index, temperature and pressure corrections and Dose Length Product at Abuja hospitals are presented in Tables1, 2 and 3 and Figures 1-4 respectively.

Table 1. Dosimetry phantom readings for body at some hospitals in Abuja

Hospitals	CTDI(mGy)	$CTDI_w$ (mGy)	Dose ratio
1	8.93±0.002	5.66±0.002	1.58±0.002
2	7.95±0.01	5.08±0.01	1.56±0.01
3	5.04±0.001	3.29±0.001	1.53±0.001
4	12.74±0.32	10.29±0.32	1.24±0.32
5	12.85±0.002	9.92±0.002	1.29±0.002

Table 2. Dosimetry phantom readings for head at some hospitals in Abuja

Hospitals	CTDI(mGy)	$CTDI_w$(mGy)	Dose ratio
1	30.18±0.001	23.30±0.001	1.30±0.001
2	39.81±0.1	25.12±0.1	1.58±0.1
3	38.52±0.1	20.61±0.1	1.87±0.1
4	67.46±0.3	34.84±0.3	1.94±0.3
5	20.8±0.001	11.19±0.001	1.86±0.001

Table 3. Mean calculated DLP and readout on CT Scanners examined at Abuja Hospitals for body and head phantoms

Hospitals	Body phantom (mGy.cm)	Head Phantom (mGy.cm)
1	141.36±0.002	439.12±0.001
2	127.36±0.01	597.12±0.1
3	79.36±0.001	599.33±0.1
4	438.13±0.32	1165.73±0.3
5	250.33±0.002	427.30±0.001

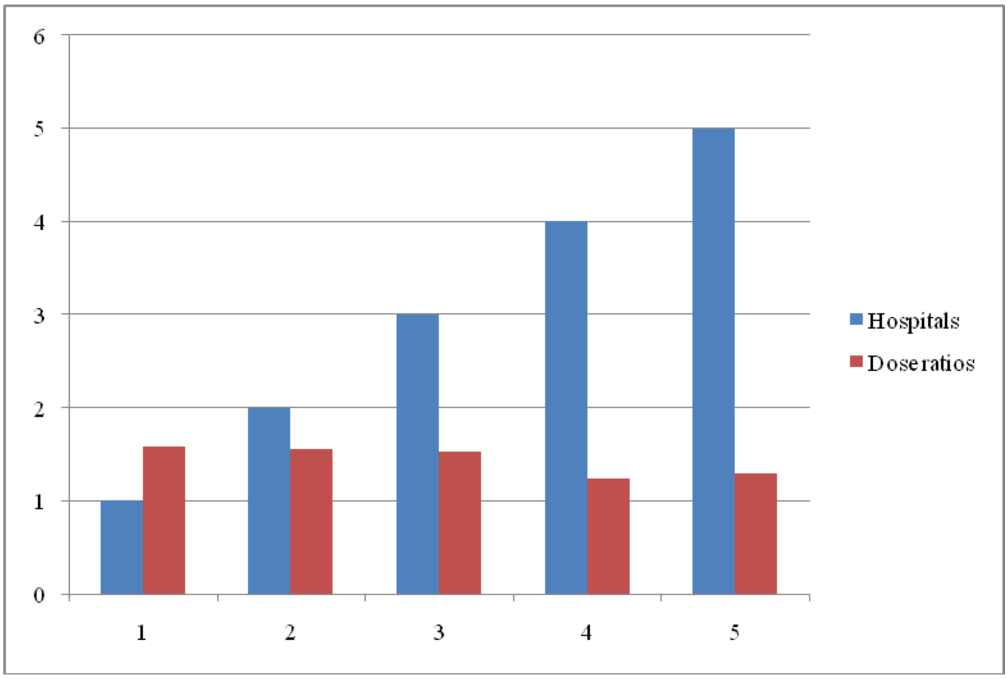

Figure 1. Dose ratios to some hospitals for body phantom at Abuja

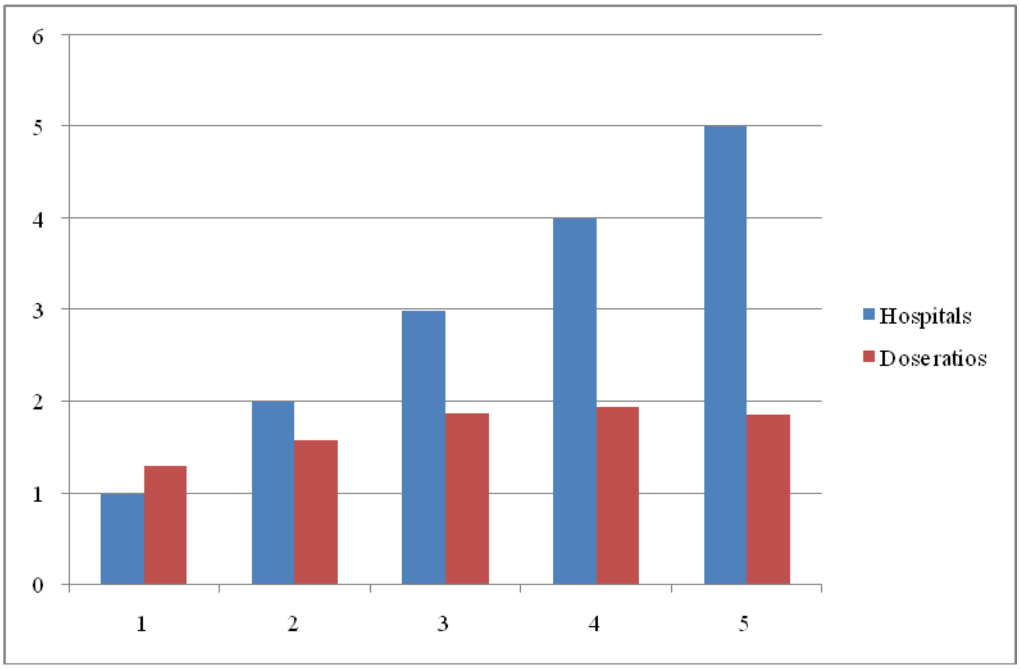

Figure 2. Dose ratios to some hospitals for head phantom at Abuja

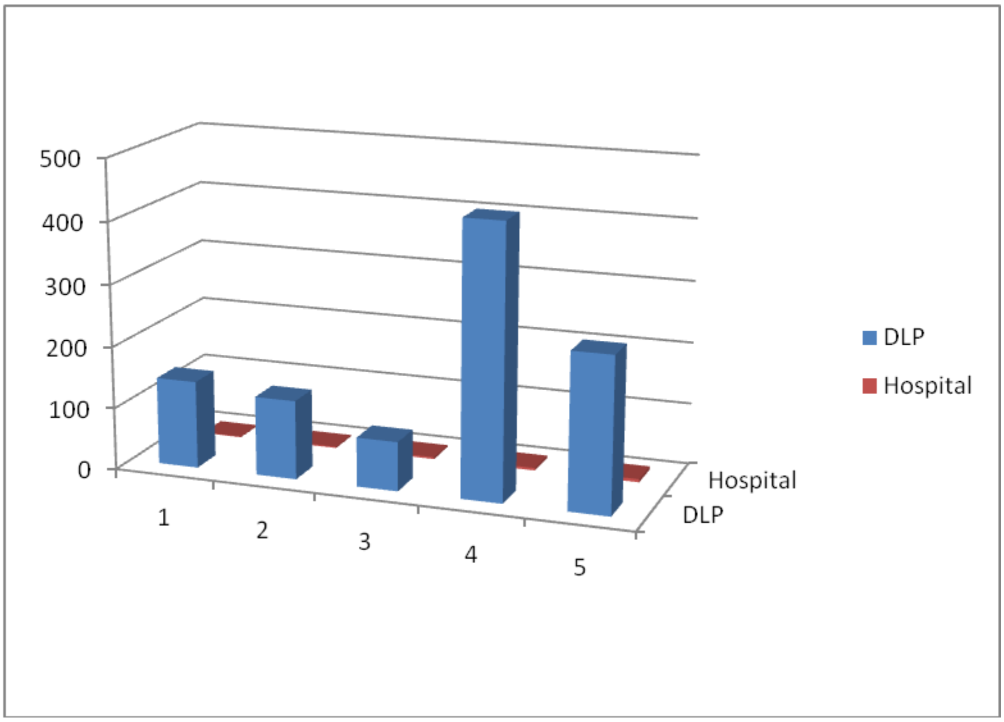

Figure 3. Dose length products to some hospitals for body phantom at Abuja

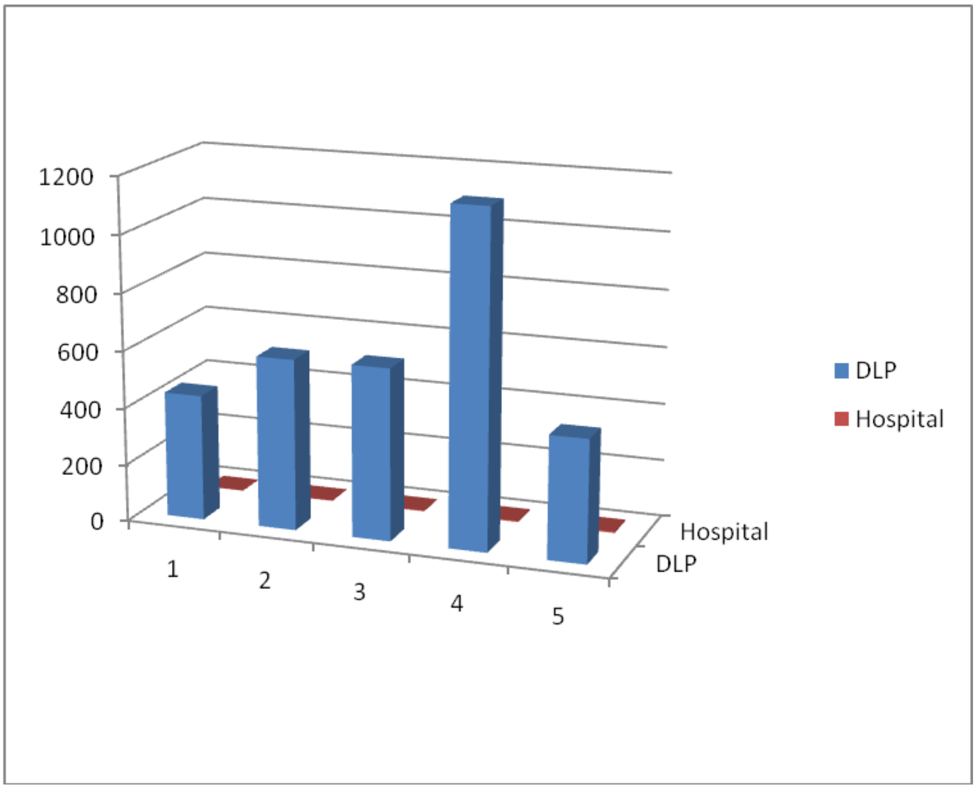

Figure 4. Dose length products to some hospitals for head phantom at Abuja

The results show that doses for the same examinations varied from hospital to hospital as shown in Tables 1 and 2. The results indicate that only centres four for body phantom and one for head phantom had the acceptable percentage dose limits of 24% and 30% respectively, set at ±20% to ± 40% American Association of Physicists in Medicine (Barnes, *et al*., 1994). This probably may be due to discrepancy of different types of protocols, user selection parameters (such as kVp, mAs, pitch, and slice thickness) and differences in the design of computed tomography devices by the manufacturers (Afzalipour, *et al*., 2013).

In general, computed tomography dose index (CTDI) appears to be an exponential function of phantom diameter, kVp and mA. The radiation doses for small phantoms with the same kVp and mA values are greater than those for large-sized phantoms (Edward, et *al*., 2013; Huda, and Ogden 2007), which means that doses to the organs in the head are twice as high as those to the organs in the body using the same technique as shown in Tables 1 and 2. Other inconsistencies in the results obtained in this work, such as variation in measured doses for the same values of kVp and mAs, increase in kVp and mAs not yielding a corresponding increase in dose sometimes may be as a result of the workload of the machine- as the electrons released hits the focus on the anode, a lot of heat is experienced at the point which increases the scattered radiation and reduces the transmitted rays, which in turn decreases the efficiency. However, the study was found to be consistent with the reported values for CTDI of 49.6 mGy (Barnes, *et al*., 1994), 42.40 mGy (Hasford, et *al*., 2015; Sinclair, *et al*., 2015; Mahur, *et al*., 2017) and 40 mGy (Aweda and Arogundade 2007). Most of the results met the American College of Radiology (ACR) CT accreditation requirement that the CTDI should be within the range of 40-60 mGy for the adult head protocol (Winslow, *et al*., 2009). Similarly, the estimated CTDI measurement from a standard body phantom is used as a reference for a normal adult torso phantom, which includes the chest, abdomen, and pelvis body phantom for some computed tomography (CT) manufacturers (Shrimpton, 2004). This outcome was also reliable with the values reported by 27.8 mGy (Barnes, *et al*., 1994), 19.49 mGy (Hasford, *et al.*, 2015] and 12 mGy (Aweda and Arogundade 2007). The results meet the American College of Radiology CT accreditation requirement that the CTDI should be within the range of 10–40 mGy for the adult body protocol (Winslow, *et al*., 2009). Dose length product (DLP) values differ significantly between the five hospitals in all of the examination results. The head examination for centre four (1165.73mGy.cm) exceeded International Recommended Values of 1050mGy.cm. This was because of the differences in CTDI and scan length among hospitals as shown in Tables 3, respectively, which indicates that scan length has a significant impact on patient dose and should be limited to areas of clinical interest (Treier, *et al*., 2010).

Conclusion

The results of this study can be introduced to hospitals and CT users to become aware of their activities and also scan protocols used in other centres. Dose measurement should be performed after appropriate period of time and compared with standard established protocols. In this study, only five CT examinations were evaluated. Therefore, additional researches on other CT facilities are required to determine reference doses for all CT examinations.

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