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Radiation Dose to Breast During Head Computed Tomography Scan Among Nigerian Population: A Cross-Sectional Study

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Abstract

Background: The extent of the dose received by the breast during head CT, needs quantification to effectively predict the risk of carcinoma and gene mutation. **Objective:** The study aimed to evaluate the radiation dose to the breast during a head CT scan in Enugu State. **Methods:** This cross-sectional study which involved 52 adults women selected purposively, described the radiation doses received by shielded and unshielded breasts during head CT examinations. The relationship between the anthropo-technical parameters Age, height, weight, BMI, breast circumferences, and distance from the External Auditory Meatus (EAM) to the TLD, kVp, mA, and the DLP was determined using Pearsons' Correlation. **Results:** The mean of CTDIvol, DLP, and breast circumferences (left shielded and right unshielded) are 29.43 ± 40.0 mGy, 540.8 ± 107.03 mGy, and left shielded breast (4.71 ± 2.45 mGy) and right unshielded breast (5.0 ± 2.32 mGy). There were positive correlations but not statistically significance between breast absorbed dose and BMI ($r = 0.152$, $p = 0.291$), linear distance from EAM to TLD ($r = 0.032$, $p = 0.828$) and mAs ($r = 0.100$, $p = 0.492$), while there was negative correlation but not statistically significance exist with subjects' age ($r = -0.112$, $p = 0.439$). **Conclusion:** There was a significant difference in the amount of radiation doses received by shielded and unshielded breasts during head CT, with low radiation doses received by shielded breasts. Shielding of the breast greatly reduces the radiation dose received by the breast during head CT. Therefore, we recommend that shielding of the breasts during head CT should form a standard protocol in our setting.

Keywords: Computed Tomography, Dose, Radiation

1. Introduction

The last two decades have witnessed a surge in the use of computed tomography (CT) in radiological diagnosis and this method has become the major non-natural source of ionizing radiation to the population. CT investigations deliver to the patients more radiation than all other radiological imaging modalities and contribute disproportionately to the overall radiation dose. Radiation received by organs in the primary beam can be clinically

justified. However, the dose received by organs outside the primary beam cannot be justified when the organs are radiosensitive. Breast, thyroid, eyes and gonads receive a greater proportion of radiation due to increased scatter and lack of other overlying tissues to partially absorb some of the dose (Abuzaid et al., 2017).

Breast dose is high in CT examination with breast in scanning planes. Radiation dose to the breast is also significant when breast is exposed only to scatter radiation. Breast doses received through scatter radiation during CT scan of the head may account for up to one-fifth of an average mammographic dose per one view (Beaconsfield et al., 1998). Since, it is not possible to reduce radiation load to organs in CT scanning plane (Brnic et al., 2003), the tissues outside should be protected against scatter, whenever, it does not sacrifice image quality (Brnic et al., 2003). The breast is a gland in close proximity to the head which is considered the most common examination in CT (Adejoh & Nzotta, 2016). It is therefore at risk of scattered radiation during head CT procedures. The extent of dose received by the breast during head CT, needs quantification to effectively predict risk of carcinoma and gene mutation. To the best of the researcher's knowledge and based on literature search, there is paucity of data on radiation dose to the breast during head CT scan and the impact of the anthropometric parameters on the radiation received in this setting. The study aimed to evaluate radiation dose to the breast during head CT scan in Enugu State using TLD and to find out if any relationship exists between CT breast dose and anthropometric parameters as well as determine the extent to which lead sheet shielding reduces dose to the breast during head CT scan.

2. Materials and Methods

2.1. Study Design and Setting

This was a cross-sectional study carried out at the radiology unit of a private diagnostic center in Enugu, Enugu State, Nigeria.

2.2. Population and Sample Size Determination

This study population comprised of all patients referred for head CT scans at the selected study center within the study period (October 2018 to February 2019)

The sample size of 52 was determined using Yamani (1967) formula for known population.

$$n = \frac{N}{1+N(e)^2}$$

Where n = desired sample size
 N = population of study
 e = accepted error limit (0.05)

From the head CT reports' archives of the study centre, a total population of 60 female patients underwent Brain CT from March 2018 to December 2018.

This gave

$$n = \frac{60}{1+60(0.025)} = \frac{60}{1.15} = 52$$

2.3. Sampling Technique and Ethical Consideration

A purposive sampling method was adopted for selecting a sample size of 52 from the target population, since only female subjects with developed breasts without any history of mastectomy were selected and included in this study. Ethical approval (ERC/FHST/NAU/2018/2078) for the study was obtained from the Human Research and Ethical Committee of Faculty of Health Sciences and Technology, College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Nnewi Anambra State. A thorough explanation of the study procedures was made to the participants by the researchers and the entire participants signed a written consent form.

2.4. Inclusion and exclusion criteria:

Only female subjects from 18 years of age and above, subjects with developed breasts and who have not undergone mastectomy in any of the breast were included in this study. All subjects with any history of mastectomy and those below the age of 18 years were excluded from this study.

2.5. Equipment and accessories:

The equipment and accessories used in this study include; 1) General electric (GE) Bright speed CT scanner manufactured in July, 2007 and installed in 2015, with 8-slice per rotation capacity. The scanner was also self – calibrating and its software was activated daily. 2) One hundred and four LI-TLD (TLD-100) chips annealed before use were obtained from the radiation safety Adviser (RSA) Nigeria Nuclear Regulatory Authority (NNRA) Abuja and were used for the study. 3) ZT WHO standard scale and height meter with error level of 0.05 were used. It was manufactured by Halogic Incorporation United States of America in the year 2008. 4) Radalert 100 survey meter was used to record the background radiation. It was manufactured by Toshiba in the year 2009 in Germany. 5) Measuring tape was used to measure both breast circumferences. 6) Transparent cello tape. 7) Data capture sheet and 8) Lead sheet of 0.35mm lead equivalent.

2.6. Examination procedures and method of data collection

The subjects who consented to this study were asked to stand erect in an anatomical position and without shoes, and were made to empty pockets of any objects like mobile phones or bunch of keys that could add a gram or more to the weight. The subjects stood erect on the beam balance without resting hands or bodies on the table or wall. The weight, in (kg) was read to the nearest 0.5kg, while still standing erect and without motion, the heels, gluteal muscles and occipital protuberance touching the vertical bar of the height scale, the short, horizontal bar of the scale was adjusted to make firm contact with the vertex of the head. The height was then read off to the nearest 0.1 centimeter. The body mass index was obtained by dividing weight (in kg) by square of height (m²)

$$\text{BMI} = \frac{\text{weight (kg)}}{\text{Height (m}^2\text{)}}$$

The following information was collected; patients age, weight (Kg), Height (meters) Body mass index (BMI) kgm⁻¹), Distance from the External auditory meatus to TLD (cm), both breast circumferences (cm) and technical parameters. Data were entered by the researchers assisted by a radiographer in the facility.

The background radiation in the CT suit of the study centre was recorded by the researchers daily using Rad alert 100 survey meters prior to the patient's positioning for the CT scan throughout the period of the study. Before the commencement of CT examinations, the subjects were asked to change to the departmental gown made up of radiolucent materials to avoid image artifacts.

The subjects were properly positioned for the investigations and this was achieved by ensuring that the laser light crosses the outer cantus of the eye, which should be equidistant to the external auditory meatus. The subjects were immobilized using straps. The similar procedure used by Brinicz et al. (2003) was adopted for evaluating the radiation doses to the breast during head CT. For each subject, two TLD chips were used and each enclosed in cellophane and labeled "shielded" and "unshielded." With the subject in supine position, the TLD holder was attached by cello tape to the skin of the unshielded right breast, 2 cm above and 2 cm lateral to the nipple. The second TLD labeled "Shielded" was fixed underneath the lead sheet on the left breast at the same position as in the right breast. A lead sheet was also used to cover the area of the TLD and clavicle, extending to the mid axillary line. This was done so that each patient will serve as her own control. The band straps were ensured not to be on the chest region to ensure radiation was not attenuated. Then, standard non-contrast conventional head CT protocol consisting of initial scout view, axial scans was carried out at each study with exposure parameters of kVp of 120, mAs of 150, slice thickness of 5mm and gantry rotation time of 1 and scan duration 14 seconds. Finally, the two sachets of TLD chip labeled (shielded and unshielded) were removed from the patient after the exposure and put

together into another sachet labeled with the patient's hospital and CT identification number, date of investigation, patient age and exposure parameter used.

2.6.1 Reading/Processing of the TLD

Each batch of the exposed TLD chips was taken to the center for Energy, Research and Training (CERT), Zaria for reading. The reading was done using Harshaw 4500 dual channel TLD reader at the physics and protection section of the center for Energy, Research and Training (CERT) of the Ahmadu Bello University, Zaria, and Kaduna State Nigeria. The reading involved heating the chips to high temperature for them to give out luminescence which is proportional to the amount of radiation exposure received and stored by the TLD chips. The Harshaw 4500 TLD Reader is interfaced with windows Win REMS™ and software resident on a personal computer (PC), which is connected to the reader via a serial communication port.

2.7. Data Analysis

The Data were categorized into Anthropometric (measurements on subjects), technical data of the CT scanner and dose data. The anthropometric data included weight, height, body mass index both breast circumference and distance from the external auditory meatus to the TLD. The technical data however are exposure parameters, while dose data were CTDi vol, DLP and dose data from read TLDs. These data were analyzed with the aid of Statistical Package for the Social sciences (SPSS) version 20.0 (SPSS incorporated, Chicago, Illinois, USA) Mean, mode and range were used to summarize all anthropo-technical data. Results were given as mean \pm standard deviations. The relationship between the anthropo-technical parameters Age, height, weight, BMI, Both breast circumference and distance from the EAM to the TLD, kVp, mA, gantry tilt angle and the DLP was determined using a univariate Pearson correlation tests. All tests were carried out at an alpha level of 5% (0.05). The results are described into descriptive statistics displayed in tables.

3. Results:

3.1. Demographic characteristics of the subjects

The age range of the subjects was 18-50 years with mean age of 36 ± 8.0 years. The weight range was 60-80kg with BMI of $29.79 \pm 3.05 \text{ kg/m}^2$, and a mean breast size of $51.6 \pm 9.5 \text{ cm}$ (Table 1).

Table 1: Demographic characteristics of subjects

Parameters	n = 50			
	Range	Mean \pm Standard Deviation	Standard Error	Skewness
Age (years)	18 - 50	36 ± 8.0	1.13	- 0.204
Height (cm)	1.52 – 1.74	161 ± 4.0	0.01	0.900
Weight (kg)	55 - 89	77.6 ± 7.2	1.02	1.000
Body Mass Index (BMI)	21.8 – 34.6	29.72 ± 3.05	0.40	- 0.713
Right breast circumference (cm)	24 - 67	52.1 ± 8.7	1.23	- 0.810
Left breast circumference	25 - 67	51.9 ± 9.7	1.40	- 0.636

3.2. Dose characteristics of the subjects

The mean and standard deviations for the CTDIvol, DLP and breast circumferences (left shielded and right unshielded) are 29.43 ± 40.0 mGy, 540.8 ± 107.03 mGy, and left shielded breast (4.71 ± 2.45 mGy) and right unshielded breast (5.0 ± 2.32 mGy) (Table 2). The result of the paired-sample T-test between the left and right breast revealed that there were no significance differences in the mean circumferences of the breasts ($p = 0.747$) and the breast absorbed dose ($p = 0.612$). Also, the correlation analysis done revealed that there were positive correlations but not statistically significance between breast absorbed dose and BMI ($r = 0.152$, $p = 0.291$), Linear distance from EAM to TLD ($r = 0.032$, $p = 0.828$) and mAs ($r = 0.100$, $p = 0.492$), while there was negative correlation but not statistically significance exist with subjects' age ($r = -0.112$, $p = 0.439$) (Table 3).

Table 2: Dose characteristics of subjects

Parameters	Range	n = 50		
		Mean \pm Standard Deviation	Standard Error	Skewness
Distance of TLD from EAM (Cm)	21 – 35	30.9 ± 6.62	0.37	-1.028
CTDIvol (head)	Fixed	29.43 ± 0.0		
DLP (head)	451 – 1230	540.8 ± 107.03	15.15	5.6
Breast dose LB; shielded)	1.8 – 15.4	4.71 ± 2.45	0.35	2.41
Breast dose (RB; unshielded)	1.6 – 12.2	5.0 ± 2.32	0.33	1.1
Breast dose, mGy (combined)	1.60 – 15.40	4.84 ± 2.40	0.24	1.64
	0.09 – 0.80	0.24 ± 0.12	0.2	2.21
	0.08 – 0.60	0.25 ± 0.12	0.2	1.40
		0.24 ± 0.12	0.01	1.66

Key: LB= left breast, RB= Right breast

Table 3: Inferential statistics of the variables

Parameters	Mean \pm SD (Difference)	Paired-sample T-Tests of means		
		t-statistic	p-value	Remarks
RBC& LBC (cm)	0.22 ± 4.8	0.325	0.747	Not statistically significant
SLB&URB (mGy)	0.26 ± 3.6	0.511	0.612	Not statistically significant
SLB&URB (mSv)	0.10 ± 0.2	- 0.360	0.720	Not statistically significant
Correlations				
	n	Correlation coefficient (r)	p-value	Remarks
Age with breast circumference	50	-0.205	0.154	Not statistically significant
Age with mGy	50	-0.112	0.439	Not statistically significant
BMI with breast circumference	50	0.141	0.329	Not statistically significant
BMI with mGy	50	0.152	0.291	Not statistically significant
Distance from EAM to TLD& Breasts (mGy)	50	0.032	0.828	Not statistically significant
mAs& Breasts (mGy)	50	0.100	0.492	Not statistically significant

Key: RBC= Right Breast Circumference, LBC= Left Breast Circumference, SLB= Shielded Left Breast, URB= Unshielded Right Breast

4. Discussion

The result of this study showed that the mean absorbed dose for the shielded breast was slightly lower than that of the unshielded breast with reduction of 29%. This finding is in agreement with to the findings of the previous studies by Brinic et al. (2003), Hohl et al. (2018), Parker et al. (2008) and Gunn et al. (2009), which also reported reductions in the absorbed dose between the unshielded and shielded organs evaluated. They all reported that the absorbed dose of the shielded structures is usually lower than that of the unshielded structures. This implies that shielding of an organ during radiation investigations significantly reduces the amount of radiation absorbed dose received by the organ. In Hohl et al. (2008) study, which was conducted to evaluate the radiation dose of breast and thyroid gland, reported a mean dose without shield of $17.2 \pm 0.5\text{mSv}$ and $11.4 \pm 0.6\text{mSv}$ resulting in dose reduction of 33.7%. According to Hohl et al. (2008), plain Bismuth breast shield greatly decreases radiation dose in MDCT without altering the image quality. Similarly, Brinic et al. (2003) in their study, which evaluated the efficacy of breast shielding during CT head, reported mean doses of 0.28mGy and 0.13mGy for unshielded and shielded breasts respectively, with dose reduction of 57%. Parker et al. (2008) study, also documented reduction in absorbed dose between shielded and unshielded breast of 56-61% with the left and right unshielded breasts having mean absorbed doses range of 14.20-4.7mGy and 13.83-19.36mGy respectively, while the shielded right and left breasts absorbed doses were 6.64-8.12mGy and 6.7-8.03mGy respectively. In Gunn et al. (2009) study, they also found that the mean absorbed dose was higher with an unshielded breast than the shielded one. According to Gunn et al. (2009), great dose reduction was observed to the thyroid gland and breast with shield.

We found also that there was no significance difference in the mean of the right and left breast circumferences. There were positive correlations but not statistically significance between breast absorbed dose and BMI, Linear distance from EAM to TLD and mAs, while there was negative correlation but not statistically significance exist with subjects' age. This implies that increased in body mass index, linear distance from EAM to TLD and mAs also resulted in increase in the radiation dose received during CT head while as the age increases, the radiation dose received decreases.

4.1. Limitation of the study

The majority limitation of this study is that the findings cannot be generalized due to the small sample of this study.

5. Conclusion

There was significant difference in the amount of radiation doses received by shielded and unshielded breasts during head CT, with low radiation doses received by shielded breasts. Shielding of the breast greatly reduces the radiation dose received by the breast during head CT. Increased in body mass index, linear distance from EAM to TLD and mAs resulted in increase in the radiation dose received during CT head while radiation dose receives decreases with increased age of the patients. Therefore, we recommend that shielding of the breasts during head CT should form a standard protocol in our setting and the anthropometric parameters should be considered when selecting CT exposure factors.

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