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Original Research Article

Evaluation of scatter radiation to the thyroid gland attributable to brain computed tomography scan in Port Harcourt, Nigeria

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ABSTRACT

Background: Computed tomography (CT) is an axial imaging modality that uses X-ray. The study is to determine the amount of X-radiation that reaches the thyroid glands during brain CT.
Methods: A prospective study was carried out in Rivers State University Teaching Hospital's Radiology Department with 60 participants sent for brain CT scan. A 64 slice helical GE Optima CT machine was used while radiation dose reaching the thyroid gland was measured with themoluminiscent dosimeter (TLD) chips (TLD LiF-100). The TLD chip was placed on the anterior aspects of the neck at the level of 6th cervical vertebra (C6) and held in place with adhesive tapes. The TLD chip was later sent to the radiation dosimetric laboratory for reading. Collected data was analyzed using SPSS windows version 22.0 statistical software. A descriptive statistical tool was used to determine central tendencies. Pearson correlation and linear regression analysis models were also used to evaluate correlation between variables.
Results: The mean (±SD) CTDI, DLP and brain Effective Dose were 37.265±13.098mGy, 662.451±230.782mGy-cm and 1.667±0.603mSv respectively. The Scatter X-Radiation reaching the thyroid gland and resultant Effective Dose were 5.26±3.13mSv and 0.26±0.16mSv respectively. A positive correlation between brain and thyroid gland effective doses yielded a Pearson's correlation coefficient (r) of 0.892 within a confidence interval of 0.01 (p value of 0.01) showing significant correlation.
Conclusions: The amount of radiation received by the thyroid gland during brain computed tomography scan is significant. Therefore, it is pertinent to protect the thyroid gland during the procedure.

Keywords: Brain Computed Tomography, Effective dose, Scatter radiation, Thyroid gland

INTRODUCTION

Diagnostic medical radiation exposure constitutes the greatest source of man-made exposure to ionizing radiation.[1,2,3] According to ionizing radiation medical exposure regulations, medical radiation exposure is the largest contributor to artificial exposure to ionizing radiation.[4]

Computed tomography (CT) can provide images of internal organs of the body including bones, soft tissue and blood vessels with a good tissue contrast when compared with other modalities.[5,6] Therefore, the imaging modality is required for a range of clinical conditions of the brain and has been found to be particularly of great importance in head injuries, stroke, brain tumors and other brain diseases. However, more than a third of all

CT scans investigations involve the head and neck region.[6,7]

Significant exposure to x-rays following computed tomography scan is increasing exponentially, and the risk of cancer at doses equivalent to that used in computerized tomography has been made epidemiological evidence.[1,8,9] The radiation dose involved in Computed Tomography (CT) is much larger than that used in conventional x-ray imaging procedures.[1,10,11] The 2009 ionizing radiation exposure of the population of the United States; Report no. 160, states that between 1980 and 2006 there was 5 times increase in the average exposure to medical x-rays, from an estimated 0.4 to 2.2 mSv while the fraction of man-made sources in 2006 (3 mSv) due to CT imaging increased dramatically to 48% (1.5 mSv), whereas the fraction from nuclear medicine, mostly for cardiac imaging, rose to 24% (0.74mSv).[1]

The thyroid gland is a small butterfly-shaped endocrine organ located in front of the trachea in the lower part of the neck.[12] The organ comprises of right and left lobes and an isthmus with the right larger and vascular than the left.[12] It is an exquisitely sensitive gland, which enlarges and becomes more active during puberty, pregnancy, or times of great stress as well as alteration of its size and shape during women's menstrual cycles. During CT examinations exposure is continuous (multiple exposures) around the patient in other to examine the entire volume of the desired region.[5] A study to estimate thyroid radiation dose and the associated risk for thyroid cancer induction from common head and neck computed tomography (CT) examinations during childhood showered that the scattered dose to thyroid from head CT examinations varied from 0.6 mGy to 8.7mGy depending upon the examination region, the age of the patient and the mode of image acquisition.[13] It was also documented that during a CT scan of the neck the primary irradiation dose of the thyroid gland ranges from 15.2-52.0mGy.[13] In this the Monte Carlo N-particle transport code was employed to simulate the routine CT scanning of the brain, paranasal sinuses, inner ear and neck which were performed on spiral modes.

CT examinations expense more radiation doses than conventional radiography1. The effective dose from CT scans may range from approximately 2 to 20mSv, which implies that a CT scan with a dose of 10mSv is equivalent to 500 plain chest radiographs assuming a dose of 0.02mSv per chest radiograph.[14] According to Mettler et al, computed tomography of the head is equivalent to 100 PA chest radiograph.[7] Data from the United Kingdom showered that CT scans account for 7% of all radiological investigations and contribute 47% to the collective diagnostic radiation dose.[15] The Computed Tomography Dose Index (CTDI) and Dose Length product (DLP) are metrics for dose output that is displaced by default by modern CT machine at the end of each examination. The CTDI and DLP can be converted to effective dose by multiplying the dose-length products by a uniform weighting factor of 0.0023 or by multiplying the CTDI with the tissue weighting factor of 0.05 according to Christner et al.[16]

There is paucity of data among African population and our local environment; therefore, it is imperative to evaluate the amount of scatter radiation reaching the thyroid gland during a brain Computed tomography scan in Nigerian population with a view to recommend the used of protective devices in other to prevent stochastic radiation effect.

METHODS

A prospective study design was adopted. The study was carried out from March 2018 to September 2018 in the CT suite of Radiology Department in Rivers State University Teaching Hospital Port Harcourt, Rivers State in Nigeria. Patient referred for computed tomography scan of the brain that meets the inclusion criteria were adopted for the study. In line with the Helsinki declaration, ethical approval was obtained from the ethical committee of the Rivers State Health research ethics committee. All the participants in the study provided informed consent.

The target population was patients referred for brain CT scan examination. The population of seventy (70) being the number of brain CT examination from January 2016 to June 2016 was used to the estimated sample population yielding a sample size of sixty (60) which was derived from the Yamane formula.[17]

After obtaining informed consent participants were requested to change and wear a gown. The weight and height were measured then the Body Mass Index was obtained by dividing the weight (kg) by square of the height (m2). A 64 slice helical GE Optima CT machine having current quality control measurements and calibration was used. The examination was done with the patient in supine position on the CT gantry table, according to standard protocols for brain CT. Patient was centered as such that the external auditory meatus (EAM) is at the center of the gantry. Straps and pillows were used to stabilize patient neck position during the examination.

Two already annealed TLDs were used for each patient to obtain the radiation dose to the thyroid gland, one placed on the anterior aspect of the neck at the level of 6th cervical vertebra (C6) and the other posteriorly at a corresponding level. The TLD is held in place with a transparent (radiolucent) adhesive tape before the exposures. Background radiation in the CT examination room was recorded with a well calibrated survey meter before the examination which readings were consecutively negligible. The TLD was removed immediately after the examination for each patient and labelled appropriately against the patient's name. The detached TLD was carefully sealed in tiny transparent cellophane bag with the name of the patient abbreviated in letters to maintain confidentiality. The transparent cellophane bag was later inserted into a black bag (to prevent spurious exposures from background radiation) and sent to the radiation dosimetric laboratory of the Regional Centre for Energy Research and Training for reading.

Computed Tomography Dose Index (CTDI) and Dose Length product (DLP) were displaced by default by the CT machine at the end of each examination. The entrance surface dose of the TLD placed anteriorly was subtracted from the exist dose recorded by the posteriorly placed TLD to obtain the absorbed dose to the thyroid gland. A tissue weighting factor of 0.0023 for the brain was used to convert the DLP to effective dose in Sievert (Sv) whereas a tissue weighting factor of 0.05 as recommended by the International Commission on Radiological Protection (ICRP) for the thyroid was used to convert the absorbed dose to Effective Dose in Sievert (Sv). Patients were monitored for few minutes by the radiologist before allowed to leave the CT suite.

The data was analyzed using Statistical Package for Social Sciences (SPSS) windows version 22.0 statistical software (SPSS Inc, Chicago, Illionois, USA). The results obtained were presented in tables, charts and graphs.

RESULTS

The mean scatter X-ray radiation and corresponding effective doses (mean±standard deviation) received by the thyroid gland were 5.26±3.13mSv and 0.26±0.16 mSv respectively.

The thyroid absorbed dose is highest at age group 48-57 years (6.85+3.96 mSv) and the amount of radiation reaching the thyroid gland is not a function of age and BMI as shown in Table 1 and Figure 2.

The radiation dose to the thyroid gland (mean±standard deviation) in females (5.96+3.44mSv) is higher than that in males (4.65+2.74 mSv) while the mean effective dose of the thyroid gland in males and females was 0.23±0.14 mSv and 0.30±0.17 mSv respectively (Table 1).

Table 1: X-ray dose characteristic of participants according to age group, BMI and sex.

Variables Age group (years)	N	CTDIc (mGy) Mean±SD	DLP (mGy-CM) Mean±SD	ED brain (mSv) Mean±SD	ABS thyroid (mSv) Mean±SD	ED thyroid (mSv) Mean±SD
38-47	4	40.17± 13.71	706.33±221.73	1.74± 0.55	6.10±1.85	0.31±0.09
48- 57	15	39.21± 16.34	708.97±293.86	1.80±0.78	6.85±3.96	0.34±0.20
58-67	31	35.62± 11.76	633.67±206.73	1.60±0.54	4.64±2.85	0.23±0.14
68-77	10	36.20±9010.61	637.34±182.04	1.60±0.49	4.46±2.21	0.22±0.11
BMI						
Normal	28	2.881±13.296	587.130±238.399	1.476±0.607	4.73±2.87	0.29±0.14
Overweight	26	41.90±15.20	726.144±192.840	1.832±0.544	5.76±3.39	0.29±0.17
Obese	6	40.918±11.277	737.95±275.55	1.83±0.662	5.57 ±3.25	0.28± 0.16
Sex						
Male	32	32.881±13.296	587.130±238.399	1.476±0.6069	4.65±2.74	0.23±0.14
Female	28	41.90±15.20	726.144±192.840	1.832±0.544	5.96±3.44	0.30±0.17
Composite	60	37.265±13.098	662.451±230.782	1.667±0.603	5.26±3.13	0.26±0.16

CTDI: Computed tomography Dose index, DLP: Dose Length Product, TLD: Thermoluminisecent Dosimeter, ED: Effective dose, ABS: Absorbed dose.

Table 2: Comparison of present study X-radiation dose characteristic with other studies.

Variable	Present Study	Nzotta et al	Adullahi et al	Ogbole and obed	European commission
Location	Port Harcourt Nigeria	Nnewi, Nigeria	Abuja, Nigeria	Ibadan, Nigeria	Europe
Year	2017	2015	2015	2014	1999
CTDI (mGy)	37	59	38	74	60
DLP (mGy.cm)	662	1301	1477	1898	1050
Brain ED (mSv)	1.67	2.7	3.10	4.0	2.2

CTDI: Computed Tomography Dose Index, DLP: Dose Length Product, ED: Effective dos

The Computed Tomography Dose Index (CTDI) and Dose Length product (DLP) mean values displaced by default from the CT machine with their respective standard deviations are 37.265±13.098mGy and 662. 451±230.782mGy-cm while the brain effective dose (mean±standard deviation) is 1.667±0.603mSv as shown in tables 1 and 2. The KVp used in the index study range from 80 to 120kv while the mA ranges from 100-120. The mean KVp was 86.67±10.84 while the mean mA was 110±7.48 (mean±standard deviation) as shown in table 3A positive correlation between brain effective dose and scatter X-radiation dose to the thyroid gland with a Pearson's correlation coefficient (r) of 0.892 within a confidence interval of 0.01 (p value of 0.01) as shown in table 4.

Table 3: Technical parameters of participants.

Parameter	Technical		
	Range	Mode	Mean
KVp	80-120	80	86.67±10.84
mA	100-120	110	110±7.48

KVp:- kilovoltage peak, mA:-milliampere.

Table 4: Pearson's correlation between Brain and thyroid effective doses and weight.

Variable		Brain ED	Thyroid ASD	Thyroid ED	Weight
Brain ED	Pearson correlation	1	.892**	.892**	0.132
	Sig. (2-tailed)		.000	.000	0.313
	N	60	60	60	60
Thyroid ASD	Pearson correlation	.892**	1	1.000**	0.072
	Sig. (2-tailed)	.000		.000	0.582
	N	60	60	60	60
Thyroid ED	Pearson correlation	.892**	1.000**	1	1
	Sig. (2-tailed)	.000	.000		
	N	60	60	60	60
Weight	Pearson correlation	.132	0.072	1	1
	Sig. (2-tailed)	.313	.582		
	N	60	60	60	60

**Correlation is significant at the 0.01(2-tailed) ED: Effective.

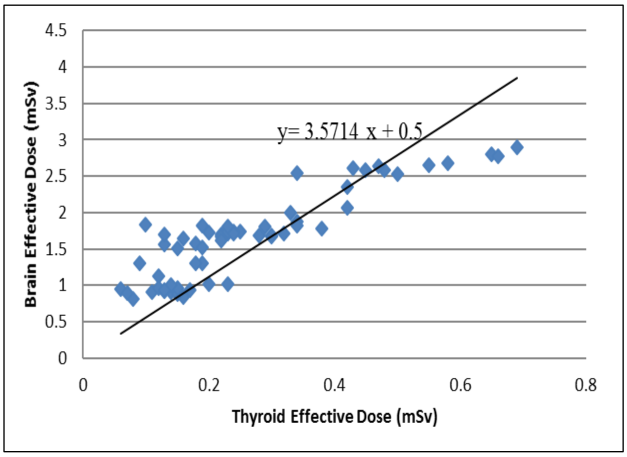

Figure 1: Scatter plot showing the distribution of brain and thyroid effective doses.

y= 3.5714 x + 0.5 (r=0.892; p= 0.01 equation 1).

Linear regression analysis yielded a linear equation (equation 1) where y is brain effective dose and x is thyroid effective dose both in miliSievert (Figure 1). As also shown in table 4 there is no positive correlation between Brain and thyroid effective doses with weight.

Figure 1 shows a scatter plot of the correlation distribution of brain and thyroid effective doses.

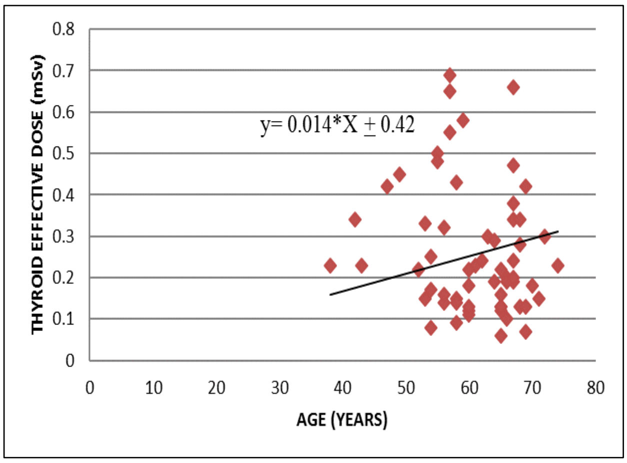

Figure 2: Scatter plot showing the distribution of thyroid effective dose and age.

The plot shows a relatively even distribution along the midline due to positive correlation between the brain and thyroid effective doses whereas the contrary was seen in the Scatter plot showing the distribution of thyroid effective dose and age as shown in Figure 2. Figures 3 and 4 show the thermoluminiscent dosimeter Glow curve readings obtained from the Radiation Dosimetric Laboratory of the Regional Centre for Energy Research and Training. The TLD Profile reading is also shown in figure 5. The values of the radiation doses to the thyroid gland obtained were derived from the Glow curves and readings.

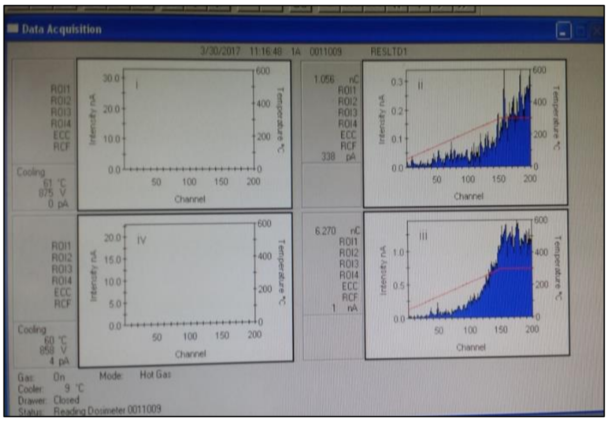

Figure 3: Thermoluminiscent dosimeter TLD-100 (LiF-TLD) Glow curves from CERT.

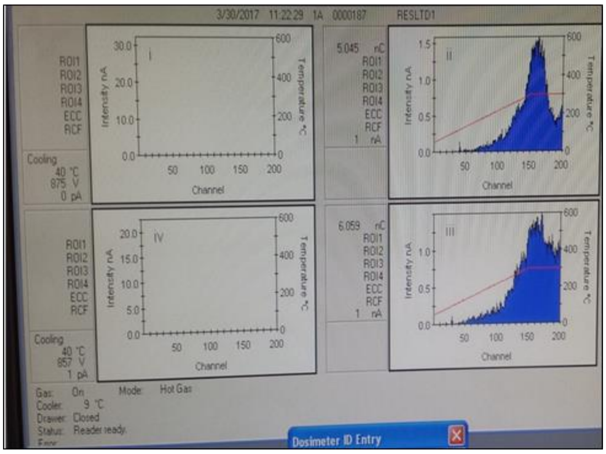

Figure 4: Thermoluminiscent dosimeter TLD-100 (LiF-TLD) Glow curves from CERT.

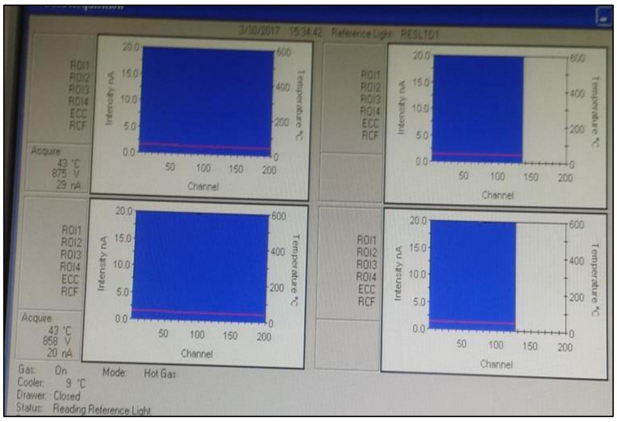

Figure 5: One of the thermoluminiscent dosimeter profile reading from CERT.

DISCUSSION

Computed tomography (CT) is a cross sectional (axial) diagnostic imaging modality that uses x-rays to produce image of organs and body tissues following the attenuation characteristic of the organ or tissue.[5] More than a third of all CT scans investigations involve the head and neck region7 this makes CT scan of the brain the commonest CT evaluation and the radiation dose involved in Computed Tomography (CT) is much larger than that used in conventional x-ray imaging procedures.[1]

In this study the mean Computed tomography dose index (CTDI) and dose length product (DLP) values obtained were 37.27±13.10mGy and 662.45±230.78 mGy-cm which produced a mean brain effective dose of 1.67±0.60 mSv. The CTDI obtained in the index study was very close to the value obtained by Abdullahi et al, in Abuja (38 mGy).[18]

These values were lower than that recorded in the study conducted by Nzotta et al, in Akwa, where the mean CTDI, DLP and effective doses were 54mGy, 1476mGy-cm and 3.1mSv19 (Tables 1 and 2).[19] The values are also lower than that recorded in the study conducted by Ogbole et al and Adejoh et al, The difference in CTDI and DLP values between their study and the index study may be due to the high exposure factors used (150-230mA and 100-140kvp) as against 80-120kvp and 100-120mA ranges used in the index study.[20.21] It was also contrary to the findings of Chiegwu et al, which also employed higher exposure intensity of 140kvp and 350mA (Table 3).[22] This implies that the mA used in their study is twice the value used in the present study.

The thyroid scatter X-ray radiation dose received, and corresponding effective doses were 3.433±2.787mSv and 0.193±0.212mSv respectively. From the result of the index study it can be extrapolated that the amount of radiation reaching the thyroid gland from a contrast administered CT scan of the brain is one seventh of the total dose which is approximately 12.8% of the total dose. The value in the present study was higher than that obtained in a study with children were the scattered dose to thyroid from head CT examinations varied from 0.6mGy to 8.7mGy. The variation may be due to age of the patient and the mode of image acquisition.[13] Although a similar study also revealed 15.2-52.0mGy as radiation dose to the thyroid gland from CT scan of the neck which is within range of what was obtained in the present study.[13] There is paucity of literature on the amount of x-ray reaching the thyroid gland in patients undergoing brain CT scan in our environment.

CONCLUSION

In this study the scatter X-ray radiation dose received by the thyroid gland and Effective Dose were 3.433±2.787mSv and 0.193±0.212mSv respectively. A positive correlation does exist between brain doses and scatter X-radiation dose to the thyroid gland. The derived equation y=3.5714x+0.5 can be used to determine the effective dose of the thyroid gland if the brain effective dose is known (where y and x are the brain and thyroid effective doses respectively). This suggests that the higher the radiation dose to the brain, the higher will the amount of scatter radiation dose received by the thyroid gland and other closely related structures.

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