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Increasing Radiation Doses from Computed Tomography versus Diagnostic Reference Levels: How Compliance Are We?

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Authors' contributions

This work was carried out in collaboration between all authors. Author HUC conceptualized and designed the study, carried out the data collection and wrote the first draft of the manuscript. Author EIB wrote the protocol and audited the first draft of the manuscript. Author OSOI performed the statistical analysis. Author NCC sourced the TLD chips and provided some other instruments used for the study. Authors OAE and UDC managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To assess the radiation dose received in a clinical/real life setting by patients visiting selected radiological centres in Enugu, Enugu State, southeast of Nigeria for diagnostic computed tomography (CT) scans of the heads and thus assess compliance to the diagnostic

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reference levels (DRL).
Study Design: A prospective cross-sectional survey design.
Place and Duration of Study: CT Units of University of Nigeria Teaching Hospital, Memfys Hospital for Neurosurgery and Conquest Medical Imaging Limited in Enugu, Enugu State, Nigeria between April 2012 and January 2013.
Materials and Method: Radiation doses absorbed by 98 patients (60 males and 38 females, age range 3-65years) that presented for CT scans of the head at the study centres were prospectively measured using lithium fluoride thermoluminescent dosimeter, LiF-TLD (TLD-100) chips. The mean absorbed dose, mean effective dose, collective dose and the per caput dose with their standard deviations were obtained.
Results: The mean absorbed dose was 4.315 ± 3.815mSv (range 1.005-17.607mSv) and the mean effective dose was 2.244±1.984 mSv. In children (0-15years) the mean absorbed dose was 5.604±4.904mSv and mean effective dose, 2.914±2.278 mSv and these doses were higher than that of the adults. The annual collective dose was 224.40±198.4 person-mSv and the annual per caput dose was 5.9 x 10^{-7}mSv. The calculated mean organ effective doses were 0.147±0.056mSv, 0.884±0.334mSv, 0.147±0.056mSv, 0.3540±0.134mSv and 0.147±0.056mSv for the brain, eye lenses, thyroid gland, red bone marrow and breast respectively.
Conclusion: TLD chip were used to assess patients' radiation dose in a clinical setting. The overall mean effective dose (2.244mSv) was in compliance with the recommended DRL. The radiation dose received correlated positively with the tube current (mA) and number of images obtained but negatively with the scan time, patients' head AP dimension and age. Radiation risks from CT can be reduced through justification of the procedure and dose optimization.

Keywords: Radiation; absorbed dose; effective dose; computed tomography; head; thermoluminescent dosimeter.

1. INTRODUCTION

Radiation is energy that can be transferred from one medium to another across empty space, either in association with electromagnetic waves or with subatomic particles travelling at high speed. Computed Tomography (CT) is a medical imaging procedure which uses a computer to reconstruct images of structures obtained by passing highly collimated beam of x-ray radiation through the body from multiple directions. The increasing frequency of CT examinations is well documented, likewise the associated increase in radiation risks for patients undergoing CT investigations [1-3]. The predicted total number of deaths attributable to CT examinations [induced cancer] in the United States annually was approximately 700 from CT head, about 1800 from CT abdomen, and of these figures, 170 from head CT and 310 abdominal CT were in children below 15 years of age at the time of the CT examination [2].

Although the radiation dose from CT is higher than the dose from conventional radiography [4], the perceived advantages of CT over conventional radiography and conventional tomography are responsible for its increasing use since the last two decades. Consequent upon the increase in the use of CT as well as the fact that it is the major contributor to medical exposure doses, the National Radiation Protection Board (NRPB) recommended the estimation of typical patient doses from commonly used local scanning protocol while, in pursuit of optimization of radiation dose to patients, the International Commission on Radiological Protection (ICRP) in 2007 set out what is termed "Diagnostic Reference Levels" (DRL) to be used in medical diagnosis to indicate whether in routine conditions the level of patients' doses from diagnostic procedures are unusually high or low for the procedure. The use of DRL has been implemented in many European countries but no existing DRL in Nigeria. In Nigeria large radiation doses to patients were observed from ordinary x-ray exposures. And large variations in the radiation doses to patients were also observed both within and among hospitals [5-6]. It is therefore, most likely that similar situations exist with CT. The increase in radiation doses implies more risks which can be genetic or somatic.

For a number of reasons it became necessary to investigate the radiation dose received by patients undergoing diagnostic CT examinations of the head. Firstly, CT of the head is the most frequent of all CT examinations [7-9] accounting for about one third of all scans [3]. Secondly, majority of the CT of the head is for the

investigation of the brain. Thirdly, other radiosensitive organs are irradiated during head CT. CT of the head is done in situations such as skull fracture/ brain injury/bleeding, suspected ruptured aneurysm in patients with sudden severe headache, suspected intracranial bleeding/blood clot in patients with recent symptoms of stroke, hydrocephalus, skull malformation/diseases, patients for surgical reconstruction following facial trauma to evaluate the extent of bone/soft tissue involvement, to diagnose diseases of the paranasal sinuses, radiotherapy planning for carcinoma of the brain or other tissues, to guide insertion of biopsy needles for obtaining samples from the brain etc.

Contrary to the earlier assumption that the brain is composed of highly differentiated radio resistant nervous tissues, evidences abound to show that even low doses of radiation can inflict injuries to the brain and other organs which are inevitably irradiated during irradiation of the head. Radiation doses of less than 1 Sv were shown to be associated with incidence of nervous system tumors and even death [10]. Low doses of radiations could induce a number of cancer (meningiomas) and non-cancer effects such as neurovascular and neurodegenerative effects [10-11] and cataract of the lens of the eye [12]. Dana et al. [13] observed several hypocampal changes including neuroin-flammation and marked reduction in neurogenesis in irradiated paediatric and young adult rodents. No such changes were observed in older rats. Rather, the older rats suffered impaired cognitive ability. Using Magnetic Resonance Imaging (MRI), Zou et al. [14] compared the activity of the visual cortex of irradiated childhood cancer survivors with that of unirradiated siblings and unirradiated adults during a visual task. The result showed more decrease in visual activity in the irradiated siblings in which the effect was also more in those receiving irradiation of the brain and the spinal cord. No such decrease was observed in those treated with chemotherapy [thus implicating the irradiation received]. Recent publications also showed that irradiation of the brain have direct irradiation effects on the thyroid glands as well as on the hypothalamic-pituitary-adrenal axis and the hypothalamic, pituitary-gonadal axis [15]. For these observed effects of radiation, the ICRP in 2007 assigned a weighting factor of 0.01 to brain tissue which was hitherto grouped among the remainder tissues, and in 2011, slashed the threshold dose limit for the lens of the eye from 150mSv to 20mSv [12,16].

In Nigeria, to the best of my knowledge, there was yet no record of the radiation doses from CT examinations but there is evidence of proliferation of CT facilities in the country.

This study therefore, aimed at assessing the radiation doses to patients from computed tomography examinations of the head in Enugu, Nigeria, using Lithium Fluoride Thermo-luminescence Dosimeter (TLD).

The basic operation of TLD is that in some materials (semi conductors) ionization creates electron–hole pairs. These materials have “electron traps”. During exposure to radiation, trapped charges accumulate in the trapping levels or bands in the TLD crystal and at ordinary temperatures, the trapped charges are more or less permanently stored. For LiF Crystals excited electrons may be trapped for periods of up to 80 years (Safety Office University of Waterloo. www.uwaterloo.ca). Heating the crystal causes the crystal lattice to vibrate and release the trapped electrons. The released electrons return to the original ground/stable state, releasing the energy absorbed from ionization with emission of light which can be counted using a photomultiplier tube, and the photon count is proportional to the amount of radiation energy absorbed by the crystal. This energy in the TLD material appears as a photon in the visible light wavelength range of the electromagnetic spectrum-which is between $4.0x10^{-10}$ and 7.5×10^{-10}m (400-750nm).

In this study the researchers’ aim was to use the principle of thermoluminescent to assess the radiation doses to patients from computed tomography examinations of the head in Enugu, Nigeria using LiF-TLD chips.

2. MATERIALS AND METHODS

2.1 Research Design/Study Area

The prospective cross-sectional survey research design was adopted. The study was carried out between April 2012 and January 2013. The first three established CT centres in Enugu were used for the study to ensure that an established protocol for procedures was in existence at each centre.

2.2 Equipment

The equipments used were products of General Electric Medical Systems (Hispeed Nxli and

Hispeed Fx/I, both manufactured in 2003, maximum Kvp of 140kvp and maximum tube current of 350 MA and inherent filtration of 2.7Al equivalent) and Ceretm™ Neurologic which is the product of Neurologic Corporation. It was manufactured in 2007, with maximum kvp of 140kvp and maximum tube current of 24mA. All the equipments are of Multislice design with rotating gantry, anode target of Tungsten–Rhenium alloy and ring detectors.

2.3 Ethical Approval

Ethical approval was obtained from the Ethical Committee, Faculty of Health Sciences and Technology, College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Nnewi, Anambra State and from the management of each of the CT centres used for the study. Informed consent was also obtained from all the 98 patients who participated in the research.

One hundred and ninety-six (196) LiF-TLD (TLD-100) chips (annealed to 0.000mGy to wipe out previous data on them) were obtained from the Radiation Safety Adviser (RSA), Nigerian Nuclear Regulatory Authority (NNRA), Abuja and were used for the study.

2.4 Data Collection

All patients who consented to participate and whose condition allowed the placement of the TLD chips used for data collection were included in the study. The background radiation of each of the CT centres was recorded with a survey meter before data collection.

Data were collected using the LiF–TLD (TLD-100) chips. For each patient two LiF-TLD chips were used. The two TLD chips were each enclosed in a sachet and labelled “FRONT” and “BACK” respectively.

With the patient in the appropriate supine position for the scan, the TLD in the sachet labelled “FRONT” was taped to the anterior part of the patient’s head at the beam entrance point (the glabella) using adhesive tape. The TLD marked “BACK” was similarly taped to the corresponding exit point at the posterior part of the patient’s head (the occipital protuberance). The head was strapped to prevent movements and scanned with the selected scanning protocol. The TLDs were exposed while scanning the head.

Axial scans were performed at each of the study centres.120KVp was used for 94 patients. 140KVp was used for only 4 patients (at centre A). Centre ‘A’ used mA range of 10-140, slice thickness of 3mm and scan time ranging from 26-72 seconds. Centre ‘B’ used mA range of 6-24, slice thickness of 5mm and scan time of 60-300 seconds while centre ‘C’ used a constant mA of 150, slice thickness of 3mm and scan time of 98-420 seconds. Centre ‘A’ has a routine of using contrast media (Ultravist 300) for its patients. Contrast medium was used for 28 (71.8%) of the 39 patients scanned at the centre. The other centres used contrast media only when it was judged essential.

The two sachets of TLD chips (front and back) were removed from the patient after the exposure and put together into another sachet labelled with the patient’s hospital/CT identification number, name of the hospital, date of investigation, patient’s age and sex and the exposure parameters used.

2.5 Reading/Processing the TLD

Each batch of the exposed TLD chips was taken to the Centre 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 Centre for Energy, Research and Training (CERT) of the Ahmadu Bello University, Zaria, Nigeria. The reading involved heating the chips 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 WinREMS ™ and software as:

2.5.1 Dose algorithms

- Glow curve Analyzer which determines the quality of the glow curve.
- Glow curve deconvolution, which segregates the glow curves into their individual glow peaks
- Chain-of -custody and Health Physics Record System, which updates and maintains dose data.

The peak values of the glow curves produced (Plate 1) were automatically converted to dose using the formula:

$$\text{Dose} = \frac{Q \times ECC}{RCF}$$

Where

Q= Charge (the glow peak value, in nano Coulomb),
ECC=Element correction coefficient = 3749
RCF=Reader calibration factor =0.0171

The value of the background radiation was subtracted from the exit dose (EXTD) for each patient after obtaining the dose readings from the glow curves to get the absorbed dose which was then used to compute the effective dose.

The effective dose E was obtained as the summation of the products of the equivalent dose H_T and the tissue weighting factor W_T.

The effective dose was calculated using the formula:

$$E=\sum H_T.W_T$$

Where E= Effective dose,

H_T= equivalent dose to each organ/tissue T
W_T=Tissue weighting factor for each organ/tissue T.

The equivalent dose H_T is the product of the absorbed dose in tissue D_T (mSv) and the radiation weighting factor W_R. Since for X-rays, W_R=1, the absorbed dose here is numerically equal to the equivalent dose.

Hence the effective dose

$$E=\sum H_T.W_T = \sum \text{Absorbed dose}.\ W_T.$$

Therefore, absorbed dose is given by:

ENTD − (EXTD + BGR)

where

ENTD =Entrance dose (Front TLD reading)
EXTD=Exit dose (Back TLD reading) and
BGR=Background radiation of the room

In the calculation of the effective dose, the absorbed dose is assumed to be equally distributed over the whole body.

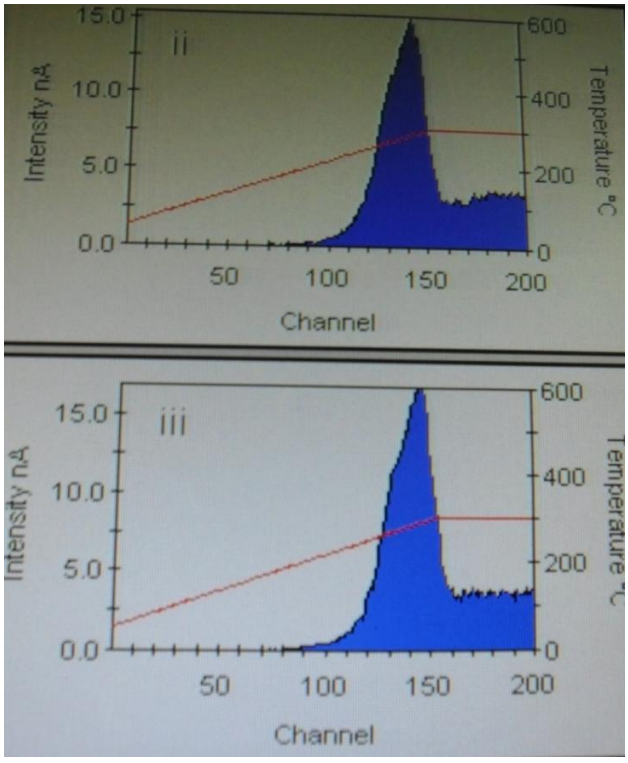

Plate 1. TLD Glow curves for TLD-100 (LiF-TLD). A) The glow curve for the TLD in front of the patient. B) The glow curve for the TLD chip at the back of the patient

2.6 Data Analysis

Data were categorized according to hospital/CT Centre, date of examination, patient's identification number (CT No/Hospital No), patients age (in years), sex, number of images, slice thickness, slice increment, Kvp, mA, scan time(sec), mAs, use of contrast e.t.c. Data analysis was carried out using a computer software package -Statistical Package for Social Sciences (SPSS) version 15. Both inferential and descriptive statistics were obtained. Various statistical tests were used as appropriate to test the significance of the results obtained. KrusKal-Wallis test was used to test for the difference in the effective dose to patients among the study centres and Pearson's correlation analysis was use to test for the correlation between the absorbed dose and the mA, mAs, age, scan time, head AP dimension and the number of images obtained.

3. RESULTS

Result showed that 60 (61.22%) of the 98 patients were males while 38 (38.78%) were females. Twenty-three patients (23) were within the age range of 0-15 year (children). 20 patients were in the 46-60 years age group; 21 patients in the 61-75 year age group and only 6 patients were 76 years and above. Patients in the 0-15 years age group received the highest mean dose followed by patients in the 76 years and above age range (Table 1).

CT examination of the head contributes a mean effective dose of about 2.244 ± 1.984, a collective dose of about 224.40 ± 198.36 person-mSv and annual per caput dose of about 5.9 x 10^{-7} ± 5.2 x 10^{-7} mSv (Table 2).

The result showed that there was variation in the radiation dose received by patients among the three studied CT centres. Patients in center 'A' received the highest dose (Table 3). KrusKal-Wallis test showed that there was a significant difference (*P=0.001*) in mean absorbed dose/mean effective doses among the study centres.

Pearson's correlation indicated that the absorbed dose has a weak positive significant correlation with the mA (r=0.257*; P=0.010*), a weak negative significant correlation with the head AP dimension (r = -0.135; *P =0.000*) but with no significant correlation with mAs (r=0.120; *P=0.241*), number of images (r=0.301; *P=0.002*), exposure time (r = -0.142; *P=0.164*) and age of the subjects (r = -0.106*; P=0.301)* respectively (Table 4).

Table 1. Mean absorbed dose and mean effective dose according to age group of subjects

Age range (years)	Total no of subjects sampled	Mean absorbed dose ± SD (mSv)	Mean effective dose ± SD (mSv)
0-15	23	5.604±4.381	2.914±2.278
16-30	12	3.002±1.491	1.561±0.775
31-45	16	4.628±3.780	2.407±1.966
46-60	20	3.240±2.457	1.685±1.278
61-75	21	4.094±4.178	2.129±2.173
76 and above	6	5.528±5.211	2.875±2.229
Overall	98	4.315±3.815	2.244±1.984

Table 2. Contribution of head CT dose to the medical radiation exposure of patients sampled at the three study centres

Dose unit	Mean ± SD
Mean effective dose[a] (mSv)	2.244±1.984
Mean Expanded effective dose[b] (mSv)	2.935±2.594
Collective dose[a] (person -mSv)	224.403±198.360
Expanded collective dose[b] (person-mSv)	293.450±259.394
Annual Per Caput dose (mSv)	5.9x 10^{-7}±5.2 x 10^{-7}

[a]*Based on dose to the principal organs-brain, eye lenses, thyroid, red bone marrow*
[b]*Includes all the other organs*

Table 3. Mean absorbed dose and Mean effective dose from each of the study centres

Study centre	No sampled (%)	Mean absorbed dose ±SD(mSv)	Mean effective dose ±SD(mSv)
A	39(39.80)	6.525±4.905	3.393±2.550
B	50(51.02)	2.978±1.869	1.549±0.972
C	9(9.18)	2.171±0.774	1.129±0.403

Table 4. The correlation coefficient for the relationship between absorbed dose (mSv) and mA, scan time, mAs, number of images produced, head AP dimension and age of the patients

Variables	Correlation coefficient, r	Pearson's P-value
mA	0.257	0.010
mAs	0.120	0.241
Age (yrs)	-0.106	0. 301
Time (sec)	-0.142	0.164
Head AP (cm)	-0.135	0.000
No of images	0.304	0.002

The use of contrast medium resulted in increased dose to patients. Thirty nine (39) subjects were examined with the use of contrast medium (50ml of Ultravist 300) and received a mean absorbed dose of 6.147±4.857 mSv as compared to 59 subjects examined without use of contrast medium, who received a mean absorbed dose of 3.105±2.266 mSv. Dose to "small parts" also differed. The dose to the lenses of the eyes was the highest (0.884±0.334 mSv) followed by the dose to the red bone marrow (Table 5). The brain and thyroid received equal doses of 0.147±0.056 each (Table 5).

Table 5. Mean organ effective dose of patients sampled

Organ	Mean effective dose ±SD (mSv)
Brain	0.147±0.056
Eye lenses	0.884±0.334
Thyroid	0.147±0.056
Red bone marrow	0.354±0.134
Total	1.532±0.580

4. DISCUSSION

Although ionizing radiation plays very important roles in medical diagnosis, it could be harmful when it is not properly used. The need for exercising care in the application of ionizing radiations is that very small doses have the probability of causing some health detriments even many years after they were received. Proper care in the application of ionizing radiations entails justification of the procedure and optimization of the dose of radiation. From this study, CT examinations of the head contributed a mean effective dose of 2.244mSv, collective dose of 224.40person-mSv and per caput dose of $5.9x10^{-7}$ mSv to the medical radiation exposure dose in Enugu State. There was no significant difference (*P>0.05)* between the mean effective dose obtained in this study and the values recorded by the two institutional bodies including the RCR and the EC and Robbins [16] who independently obtained an effective dose of 2.0mSv. The result however differed significantly (*P<0.001*) from what was obtained by some other individual researchers [17-19] who obtained effective doses of 2.8mSv, 2.8mSv, and 1.3mSv respectively. Since the mean effective dose obtained in this study agreed with the findings of the recognized institutional bodies (RCR and EC), the centres used for the study showed compliance with the DRLs. Although the doses obtained from this study - a mean effective dose of 2.244mSv, collective dose of 224.40person-mSv and per caput dose of $5.9x10^{-7}$ mSv appeared insignificant, they should be of concern because the results were recorded from CT scan of the head alone. The variation in dose among the study centres is in agreement with the findings of Shrimpton et al. [7] and Olerud [20] who independently found a variation in doses between centres to be up to a factor of 10-40 in UK and a variation by a factor of 8-20 in Norway. The implication of the higher dose to patients in the 0-15 years age group and the higher mean effective dose to lenses of the eye and bone marrow is the higher radiosensitivity of children to radiation risks as noted by Chodick et al. [21]. Such risks include cataracts of the eyes, brain tumors (especially meningiomas) and leukaemia [1-3,11-12,15]. The higher doses

to this age group agreed with the findings of Fearon and Vucich [22], Huda and Vance [23] and Brenner et al. [2]. The non significant difference between the mean dose to male and female agreed with the findings made by Brenner et al. [2] and by Reza et al. [24] in UK for brain cancer risks from head CT. This study revealed a significant, negative but weak correlation ($r = -0.135$; $p=0.000$) between absorbed dose (mSv) and head anteroposterior (AP) dimensions (cm). This agrees with the findings of Wong et al. [9] who proposed using the maximum AP dimension of the child's head on a lateral scanogram to determine the appropriate tube current for paediatric procedures. The implication is that if a non-opaque material of the same attenuation coefficient and scattering property as the head can be put to increase the head AP dimension, this may be used to reduce radiation dose to the patient. The positive correlation between absorbed dose and mA, mAs and the number of images obtained in this study agreed with the findings of [1-3] and Acquah et al. [25] who observed that the radiation dose to patients from CT scans could be reduced through justification of the procedure and careful minimization in the scanning factors ((KVp and mAs) especially for children and thinner adult patients without compromising image quality.

This is especially important because some of the patients may require radiotherapy treatments and could in the course of treatment undergo several CT scans. Radiotherapy techniques such as intensity modulated radiotherapy (IMRT), volumetric modulated radiotherapy (VMRT) and proton therapy (PT) [26] use CT dataset for dose calculation purposes. Again, for the same cancer patient in radiotherapy, it is possible that multiple CT scans will be performed in the course of treatment both for diagnosis and for follow-up evaluation of patient. Such multiple scans will increase the total radiation dose to the patient [26]. The absorbed dose obtained in this study showed no significant correlation with the scan time which agreed with the findings of Rehani et al. [1] which observed that decreasing the data acquisition time does not necessarily lead to reduction in dose, but disagrees with the findings of Fahey [27] that the use of shorter scanning time would bring about reduction in dose to the patient. The negative correlation coefficient between absorbed dose and scan time in Table 4 could be an error resulting from the wide range in the scan time (26-420 seconds).

5. CONCLUSION

This study has documented the radiation doses received by patients undergoing CT investigations of the head in a real life/clinical setting and has thus provided a baseline data for setting the diagnostic reference dose level in Nigeria. Effective dose of 2.244 mSv was obtained in this study, and was comparable with the recommended Diagnostic Reference Levels in some countries; 2.0 mSv was obtained in the UK and the European Union [7], 1.8 mSv in Italy [19], 2.8 mSv in Germany and British Columbia [28]. The higher mean effective doses in children than in adults (for the same scanning parameters) should be expected because of less attenuation of the beam within the child resulting in a more uniform radiation dose to the child-patient. The fact that children are more radiosensitive than adults calls for adopting measures to reduce radiation dose to paediatric patients. Such measures includes justification of every CT examination, adopting paediatric protocol especially by using the lowest possible kVp and mAs, using the highest slice thickness possible without compromising image quality, use of automatic exposure control (AEC) and using contrast media only when it is very necessary. This is because the use of contrast medium calls for acquisition of greater number of images and more doses to the patient.

The absorbed dose and effective dose were observed to correlate positively with the mA, mAs and number of images obtained but negatively with the age of patient, scan time and patient's head AP dimension. Studies similar to this one can be carried out in other states of the country (and results obtained compared with results from other methods) to produce a national diagnostic reference level.

6. LIMITATIONS OF THE STUDY

This study was limited to three CT centres in a state of Nigeria. It is necessary that other states of Nigeria and more CT centres be studied to set up a reference diagnostic level for the country. Another limitation is that it was not possible to place dosimeters into the respective organs to obtain the organ doses since the study was carried on actual human patients. Frequent equipment breakdown and repair in some centres occurred during the period of study and these might have affected the machine output and/or dose but it was not possible to investigate such effects. So, assumption is made that the

machine output is constant for particular set of exposure factors. Some patients rotated their heads during the scanning (exposure of the TLD) resulting in poor quality images. Such examinations were usually cancelled and the scanning repeated. This could affect the radiation dose received by the TLD because the TLD chips still remained in place during the periods of scanning. Such TLD chips were not excluded because the study is aimed at what is obtained in actual clinical setting. It was not possible to evaluate individual radiographers/imaging scientists at the various study centres to ascertain the effects of technique on dose so as to account for the observed variation in dose to patients at the study centres.

CONSENT

All authors declare that informed consent was obtained from the patient or other approved parties who signed a consent form - written in English language and in the native language (Igbo language.) (Specimen attached here).

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. (The ethical approval letters are also submitted with the manuscript).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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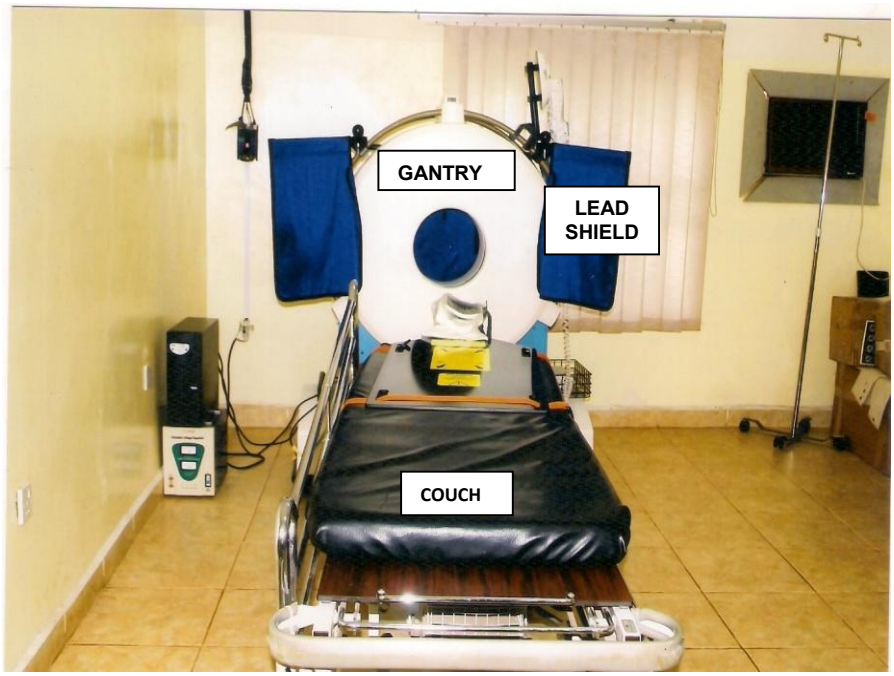
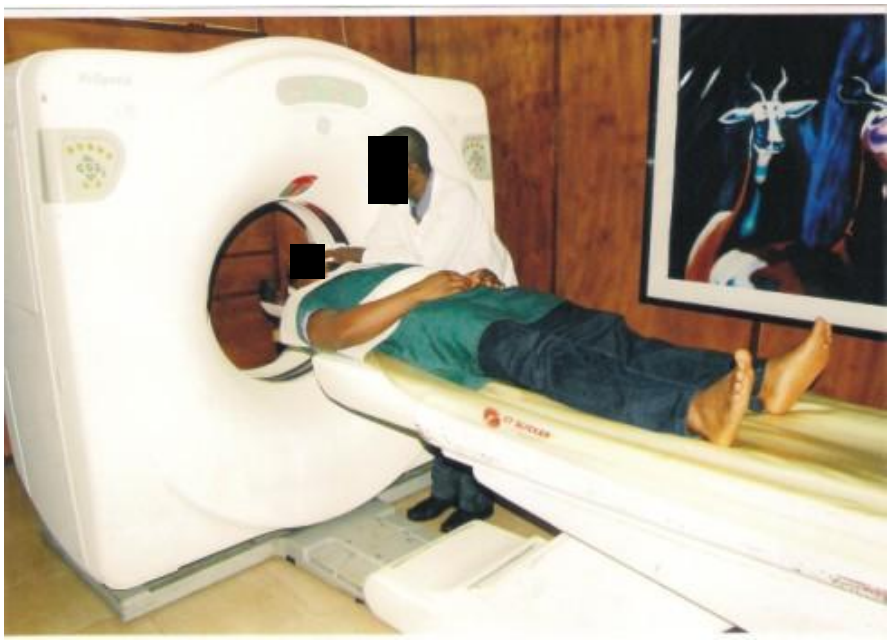
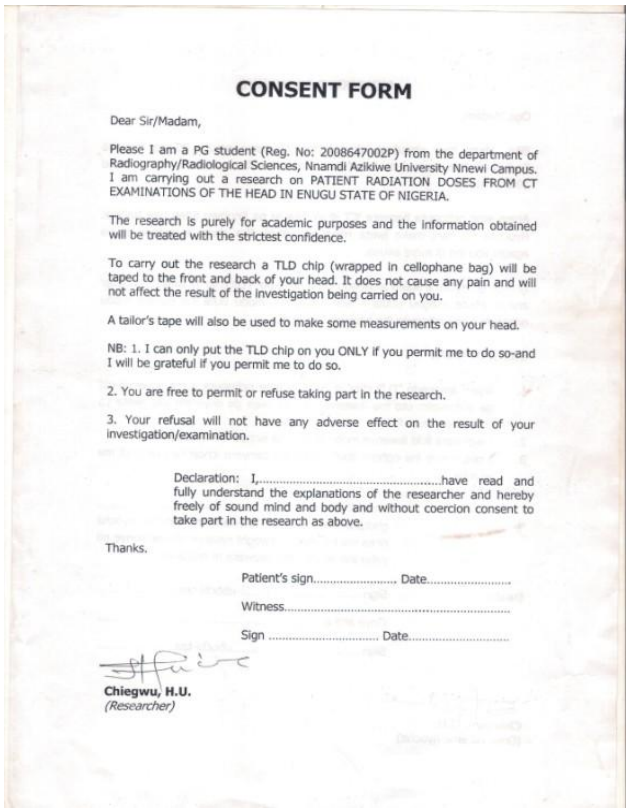
APPENDIX



A. Ceretom™ Neurologic Simulator at one of the study centres



HiSpeed FX/i CT simulator



CONSENT FORM

Dear Sir/Madam,

Please I am a PG student (Reg. No: 2008647002P) from the department of Radiography/Radiological Sciences, Nnamdi Azikiwe University Nnewi Campus. I am carrying out a research on PATIENT RADIATION DOSES FROM CT EXAMINATIONS OF THE HEAD IN ENUGU STATE OF NIGERIA.

The research is purely for academic purposes and the information obtained will be treated with the strictest confidence.

To carry out the research a TLD chip (wrapped in cellophane bag) will be taped to the front and back of your head. It does not cause any pain and will not affect the result of the investigation being carried on you.

A tailor's tape will also be used to make some measurements on your head.

NB: 1. I can only put the TLD chip on you ONLY if you permit me to do so-and I will be grateful if you permit me to do so.

2. You are free to permit or refuse taking part in the research.

3. Your refusal will not have any adverse effect on the result of your investigation/examination.

Declaration: I,.....have read and fully understand the explanations of the researcher and hereby freely of sound mind and body and without coercion consent to take part in the research as above.

Thanks.

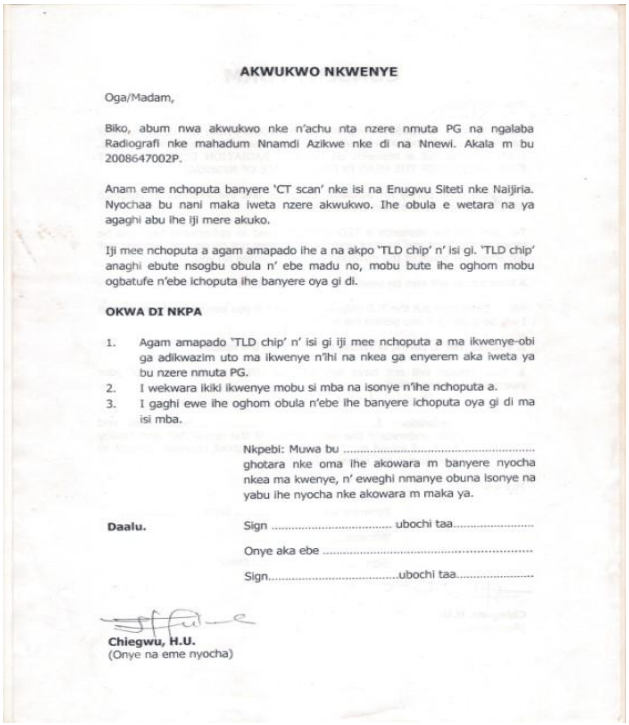
Patient's sign....., Date.....

Witness.....

Sign ..... Date.....

Chiegwu, H.U.
(Researcher)

1A. Consent form written in English language



AKWUKWO NKWENYE

Oga/Madam,

Biko, abum nwa akwukwo nke n'achu nta nzere nmuta PG na ngalaba Radiografi nke mahadum Nnamdi Azikwe nke di na Nnewi. Akala m bu 2008647002P.

Anam eme nchoputa banyere 'CT scan' nke isi na Enugwu Siteti nke Naijiria. Nyochaa bu nani maka iweta nzere akwukwo. Ihe obula e wetara na ya agaghi abu ihe iji mere akuko.

Iji mee nchoputa a agam amapado ihe a na akpo 'TLD chip' n' isi gi. 'TLD chip' anaghi ebute nsogbu obula n' ebe madu no, mobu bute ihe oghom mobu ogbatufe n'ebe ichoputa ihe banyere oya gi di.

OKWA DI NKPA

1. Agam amapado 'TLD chip' n' isi gi iji mee nchoputa a ma ikwenye-obi ga adikwazim uto ma ikwenye n'ihi na nkea ga enyerem aka iweta ya bu nzere nmuta PG.
2. I wekwara ikiki ikwenye mobu si mba na isonye n'ihe nchoputa a.
3. I gaghi ewe ihe oghom obula n'ebe ihe banyere ichoputa oya gi di ma isi mba.

Nkpebi: Muwa bu .....
ghotara nke oma ihe akowara m banyere nyocha nkea ma kwenye, n' eweghi nmanye obuna isonye na yabu ihe nyocha nke akowara m maka ya.

Daalu.

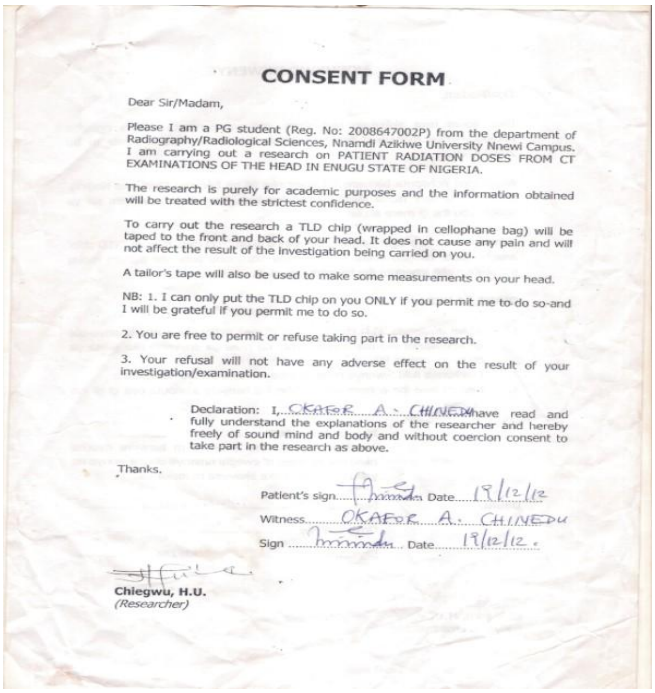
Sign ..... ubochi taa.....

Onye aka ebe .....

Sign.....ubochi taa.....

Chiegwu, H.U.
(Onye na eme nyocha)

1B. Consent form written in Igbo language



CONSENT FORM

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NB: 1. I can only put the TLD chip on you ONLY if you permit me to do so-and I will be grateful if you permit me to do so.

2. You are free to permit or refuse taking part in the research.

3. Your refusal will not have any adverse effect on the result of your investigation/examination.

Declaration: I, OKAFOR A. CHINEDU have read and fully understand the explanations of the researcher and hereby freely of sound mind and body and without coercion consent to take part in the research as above.

Thanks,

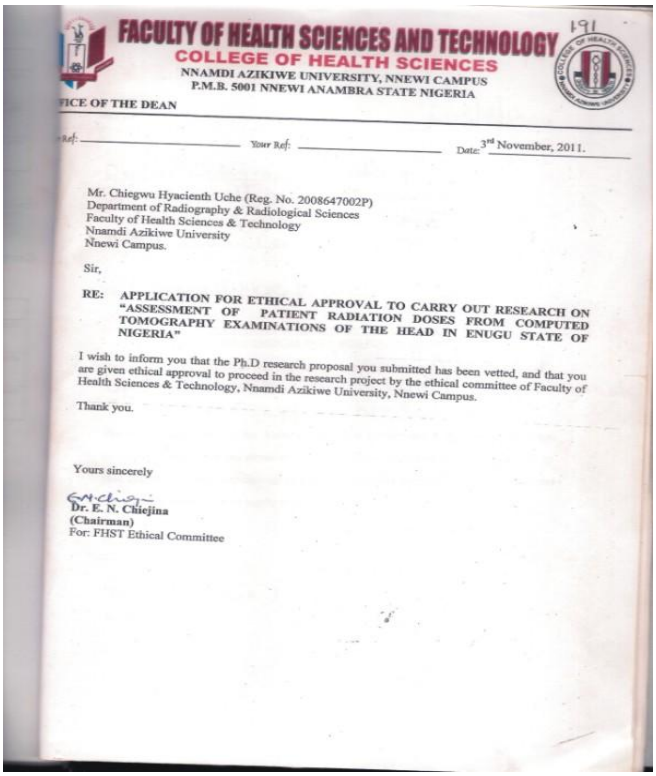
Patient's sign..... Date 19/12/12

Witness OKAFOR A. CHINEDU

Sign ..... Date 19/12/12.

Chiegwu, H.U.
(Researcher)

1C. Consent form signed by a participant



FACULTY OF HEALTH SCIENCES AND TECHNOLOGY
COLLEGE OF HEALTH SCIENCES
NNAMDI AZIKIWE UNIVERSITY, NNEWI CAMPUS
P.M.B. 5001 NNEWI ANAMBRA STATE NIGERIA

191

FICE OF THE DEAN

Ref: _____ Your Ref: _____ Date: 3rd November, 2011.

Mr. Chiegwu Hyacienth Uche (Reg. No. 2008647002P)
Department of Radiography & Radiological Sciences
Faculty of Health Sciences & Technology
Nnamdi Azikiwe University
Nnewi Campus.

Sir,

RE: APPLICATION FOR ETHICAL APPROVAL TO CARRY OUT RESEARCH ON "ASSESSMENT OF PATIENT RADIATION DOSES FROM COMPUTED TOMOGRAPHY EXAMINATIONS OF THE HEAD IN ENUGU STATE OF NIGERIA"

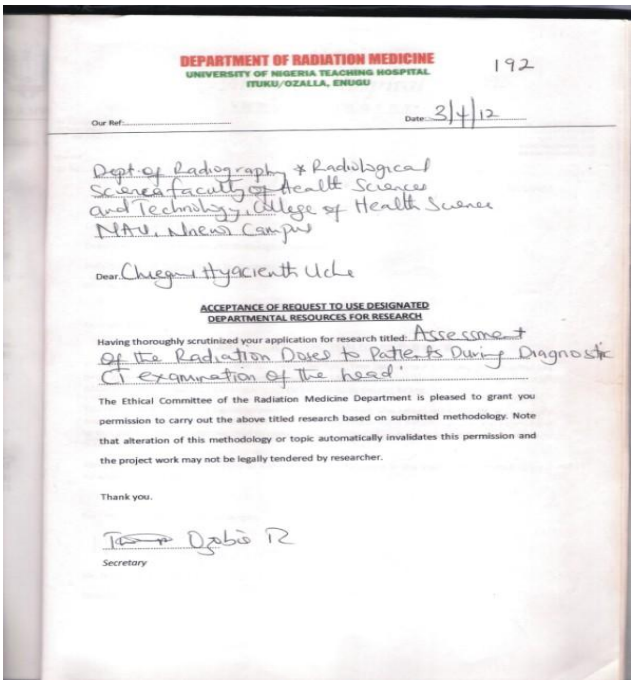
I wish to inform you that the Ph.D research proposal you submitted has been vetted, and that you are given ethical approval to proceed in the research project by the ethical committee of Faculty of Health Sciences & Technology, Nnamdi Azikiwe University, Nnewi Campus.

Thank you.

Yours sincerely

Dr. E. N. Chiejina
(Chairman)
For: FHST Ethical Committee

2A. Ethical approval letter from Faculty of Health Sciences and Technology Nnamdi Azikiwe University, Nnewi Campus



DEPARTMENT OF RADIATION MEDICINE
UNIVERSITY OF NIGERIA TEACHING HOSPITAL
ITUKU/OZALLA, ENUGU

192

Our Ref:

Date: 3/4/12

Dept of Radiography & Radiological Science Faculty of Health Sciences and Technology, College of Health Science NAU, Nnewi Campus

Dear Chiegwu Hyacienth Uche

ACCEPTANCE OF REQUEST TO USE DESIGNATED DEPARTMENTAL RESOURCES FOR RESEARCH

Having thoroughly scrutinized your application for research titled: Assessment Of The Radiation Doses to Patients During Diagnostic CT examination of the head'

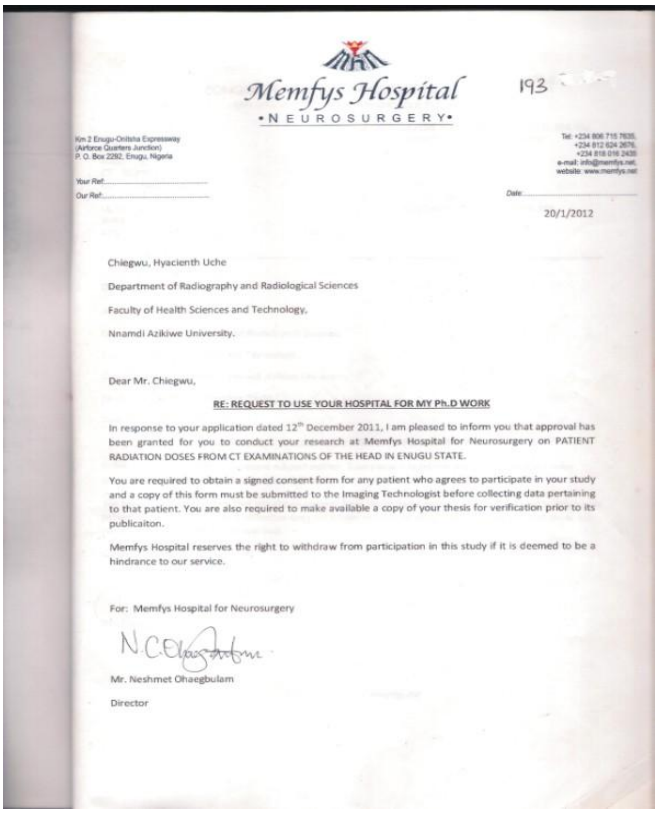
The Ethical Committee of the Radiation Medicine Department is pleased to grant you permission to carry out the above titled research based on submitted methodology. Note that alteration of this methodology or topic automatically invalidates this permission and the project work may not be legally tendered by researcher.

Thank you.

Dgabia R

Secretary

2B. Ethical approval from the Department of Radiation Medicine, University of Nigeria Teaching Hospital, Ituku-Ozalla, Enugu



Memfys Hospital
•NEUROSURGERY•

193

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P. O. Box 2282, Enugu, Nigeria

Tel: +234 806 715 7835,
+234 812 624 2676,
+234 818 016 2406
e-mail: info@memfys.net,
website: www.memfys.net

Your Ref:
Our Ref:

Date:

20/1/2012

Chiegwu, Hyacienth Uche

Department of Radiography and Radiological Sciences

Faculty of Health Sciences and Technology,

Nnamdi Azikiwe University.

Dear Mr. Chiegwu,

RE: REQUEST TO USE YOUR HOSPITAL FOR MY Ph.D WORK

In response to your application dated 12th December 2011, I am pleased to inform you that approval has been granted for you to conduct your research at Memfys Hospital for Neurosurgery on PATIENT RADIATION DOSES FROM CT EXAMINATIONS OF THE HEAD IN ENUGU STATE.

You are required to obtain a signed consent form for any patient who agrees to participate in your study and a copy of this form must be submitted to the Imaging Technologist before collecting data pertaining to that patient. You are also required to make available a copy of your thesis for verification prior to its publicaiton.

Memfys Hospital reserves the right to withdraw from participation in this study if it is deemed to be a hindrance to our service.

For: Memfys Hospital for Neurosurgery

N.C. Ohaegbulam

Mr. Neshmet Ohaegbulam

Director

2C. Ethical approval from Memfys Hospital for Neurosurgery, Enugu

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Date: 8/08/2013

Mr. Chiegwu, Hyacinth .U.

Department of Radiography and Radiological Sciences

Faculty of Health Sciences and Technology

College of Health Sciences, Nnamdi Azikiwe University

Nnewi Campus, Nnewi, Anambra State.

Dear Mr. Chiegwu,

RE: REQUEST TO USE YOUR HOSPITAL FOR MY PhD WORK

Referring to your letter on the above subject matter, I am pleased to inform you that approval has been granted you to use our facilities for your PhD work.

You however, have to ensure that you obtain consent from the patients before collecting data pertaining to any patient and also that your data collection does not hinder services to our patients. Failure in any of these will result in the withdrawal of the approval.

Congratulations.

Yours Faithfully,

Dr. Chibuzor Onyema

Chief Executive Officer.

Conquest medical imaging ltd

2D. Ethical approval from Conquest Medical Imaging Limited, Enugu

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/10184