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Estimation of the Risk of Cancer Associated with Pediatric Cranial Computed Tomography

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Authors' contributions

This work was carried out in collaboration between all authors. Author OMA conceived the study idea, designed the study, wrote the protocol, and proof read the drafts of the manuscript. Author BIA participated in the study design, performed the statistical analysis and did literature search and together with author AJA wrote the initial manuscript. Author AJA participated in the study design and supervised the data collection and wrote part of the initial manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Background: The role of Computed Tomography (CT) in the medical diagnosis of diseases has greatly expanded, despite the potential risk of cancer following exposures to ionising radiation (X-Ray) from this modality. This risk is particularly of great concern in children, who are more radiosensitive and have many years to manifest radiation effect than adults.
Aims: To estimate risk of cancer induction from Pediatric cranial CT.
Materials and Methods: A total of 203 patients, who were referred from various pediatric clinics and wards for cranial CT in a teaching hospital in the South Western Nigeria between the year 2011 and 2013 were considered. All patients were grouped into four age (year) groups: less than 1, 1-5, 5-10 and 10-15. A mathematical method was used to estimate the risk of cancer from the

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effective dose(ED) calculated from volume computed tomography dose index (CTDIvol), dose length product (DLP) and standard conversion factor.
Results: The range of CTDIvol (mGy) received by all patients was 10–250 mGy while majority of the patients received 50–100. The range of DLP (mGy.cm) received by all patients and majority of patients was 500–5000 and 2001–2500 respectively. The range of ED (mSv) received by all patients and majority of the patients was 1–25 and 5–10 respectively. The risk estimated with respect to patients' age showed that patient in the age group 1–5 years have the highest risk of cancer induction while the risk based on gender showed no significant difference.
Conclusion: Over 60% of pediatric patients received more than the recommended values of CTDIvol, DLP and ED from cranial CT. Urgent steps must be taken to ensure compliant with international recommended precautions for dose reduction in pediatric medical imaging.

Keywords: Pediatric Imaging; computed tomography dose index; dose length product; effective dose; risk of cancer induction; cranial CT.

1. INTRODUCTION

Computed Tomography (CT) is a life-saving tool for diagnosing illness and injury in children (0 – 12 years). The use of computed tomography scan of the head, abdomen/pelvis, chest or spine in children has increased over the last three decades [1]. Approximately 5 to 9 million CT examinations are performed annually on children in the United States [2]. The increased use of CT in pediatrics, combined with variability in radiation doses, has resulted in many children receiving a high dose of radiation during diagnostic examination. Radiation dose is of particular concern in pediatric patients because children's rapidly dividing cells are more radiosensitive than those of adults [3]. Also, children have a longer lifetime to manifest potential radiation injuries, some of which have long latency periods before they are expressed. The potential for expression of radiation-induced cancer later in life is the primary concern in medical x-ray examination of pediatric patients [3]. The benefits of properly performed and clinically justified CT examinations should always outweigh the associated risks for an individual child, because unnecessary exposure is always associated with unwarranted risk. Minimizing radiation exposure from pediatric CT, whenever possible, will reduce the projected number of CT-related cancers. If adult scan parameters are used to scan pediatric patients, typical radiation dose that would be received by a child will be at least doubled that of the adult [4-6].

Inherent in the design of advanced (high-technology) CT scanners providing many new applications are features that have the potential to increase radiation exposures to patients. This applies to the new multi-slice CT scanners now in use in the work-place. Various publications have estimated the typical surface radiation doses to adults from multiple CT slices, and they have documented doses as high as 30 – 70 mGy per head scan series and about 20 – 50 mGy per abdominal scan series [7-9].

It is important to note that because of the high radiation exposure potential of the present-day helical and multi-slice helical CT, Radiologists should be aware of the radiation risks of CT and work actively to keep patient's radiation exposure from CT as low as reasonably possible while achieving the required image quality and medical benefit.

Although controversy exists about the carcinogenic potential of the relatively low levels of ionizing radiation exposure associated with some CT examinations. But taking into consideration the fact that the latency time for cancer induction in the range of doses received from CT is estimated to be 10 – 30 years [4] and the critical need for protection of patients from radiation hazards, estimation of the risk associated with CT exposure of patients, especially the pediatric age group, is justified. This study is aimed at estimating the risk of cancer incidence associated with pediatric cranial CT scan from a multi-slice CT scanner, newly installed in one of the teaching hospitals in Nigeria.

2. MATERIALS AND METHODS

2.1 Study Design and Setting

This is a cross-sectional study which was carried out at the Radiology Department, University College Hospital, Ibadan Nigeria. This center is a teaching (tertiary) hospital that renders medical

services to about 4–5 million population in the South Western part of Nigeria. The requests of all pediatric patients referred for cranial CT were reviewed and justified by the attending Radiologists before the procedure was carried out. Ethical approval was duly obtained from the institutional ethical review committee before the commencement of the study.

2.2 Study Population

A total of 203 pediatric patients (aged 6 months – 12 years) who had cranial CT scan between the year 2011 and 2013 for various head injuries and ailments, such as recurrent convulsion, meningitis, hearing loss, intracranial abscess, seizure disorder, macrocephaly, acute encephalopathy, respiratory distress etc., were considered in this study. Only patients who were newly referred for cranial CT were recruited and had their CT examination considered for this study, while follow up examinations were excluded for uniformity.

2.3 Data Collection

The CT scanner used for all patients is a 64 multi-slice Aquilion scanner manufactured by Toshiba, USA. The examination data/technical parameters and dose quantity parameters, such as age, sex, tube voltage (kVp), total tube loading (mAs), slice thickness, number of slices, $CTDI_{vol}$, Dose length product (DLP) and other relevant data were extracted from the summary report stored in the hard disk of the CT scanner computer system for each patient and properly entered into a data collection sheet, prepared for this study. The effective dose (mSv) was thereafter determined using the extracted DLP and conversion factor from DLP to effective dose [10]. This conversion factor incorporated the data from the recent publication by the International Commission of Radiation Protection Report 103 [11] and is a function of the applied voltage and the age of the patient. The risk of cancer incidence from pediatric cranial CT was estimated from the effective dose and the sex-specific risk coefficient. The values of sex-specific risk coefficient used in this study were 13.7 % per Sv for female and 9.0 % per Sv for male as shown in the risk index (an index of total cancer incidence risk) equation [12] below:

$$RiskIndex_{female} = effectivedose(mSv)x13.7(\%/Sv)$$

$$RiskIndex_{male} = effectivedose(mSv)x9.0(\%/Sv)$$

All the dose quantities ($CTDI_{vol}$, DLP, effective dose and cancer risk) estimated in this study were analyzed using the software statistical package, IBM SPSS version 21, and the results are presented in tables and bar charts.

3. RESULTS

A total of 203 pediatric patients were considered in this study. Of these patients, 8 (4%) were of ages less than 1 year, 84 (41%) were in the age range of 1- 5 years, 50 (25%) in the age range of 5–10 years and 61 (30%) in the age range of 10–15 years. In terms of gender, there were 95 (47%) female and 108 (53%) male patients in this study. The Computed Tomography dose index ($CTDI_{vol}$) received by different pediatric age groups from the cranial CT scan is presented in Table 1. The range of CTDIvol received by patients of all age groups showed that 36 (18%) patients had 10–50 mGy by, 94 (46%) patients received 50–100 mGy, 45 (22%) patients had 100–150 mGy. Also 23 (11%) patients had 150–200 mGy while 5 (3%) patients received 200–250 mGy. The dose length product (DLP) obtained from the procedure by different age group is presented in Table 2. Six (3%) patients (all ages) received DLP value that is less than 500 mGy.cm, 28 (14%) patients received DLP in the range of 500 – 1000 mGy.cm, 41 (20%) patients received DLP in the range of 1001-1500 mGy.cm, 38 (19%) patients received 1501-2000 mGy.cm, 44 (22%) received 2001–2500 mGy.cm, 20 (10%) received 2501–3000 mGy.cm, 16 (8%) received 3501– 4000 mGy.cm, 3 (2%) had 3501-4000 mGy.cm, 3 (2%) had 4001– 4500 mGy.cm and 4 (2%) patients had 4501– 5000 mGy.cm. The effective dose obtained from the product of DLP and the conversion factor is presented in Table 3. In all ages, 55 (27%) patients had effective dose of 1 – 5 mSv, 108 (53%) patients had 5 –10 mSv, 32 (16%) patients had 10 – 15 mSv, 7 (3%) patients had 15- 20 mSv and only 1 (0.5%) patient had 21 – 25 mSv. The risk of cancer induction (per million) estimated from Pediatric Cranial CT with respect to age group and sex is presented in Table 4 and Table 5 respectively. The estimated risk (per million) of cancer induction with respect to ages: less than 1 year, 1-5 years, 5–10 years and 10–15 years are 100–2500, 100–3000, 100–2000 and 100-2000 respectively. There is no significant difference in the risk of cancer induction estimated with respect to the sex of patients, except that the number of male (108) pediatric patients considered in this study is more than the female (95) pediatric patients.

Table 1. CTDIvol received from pediatric cranial CT scan

Age group	CTDIvol (mGy)					Total
	10 – 50	50 - 100	100 – 150	150 - 200	200 – 250	
< 1	0	8	0	0	0	8
1 – 5	21	31	25	6	1	84
5 – 10	10	28	11	0	1	50
10 – 15	5	27	9	17	3	61
Total	36	94	45	23	5	203

Table 2. Dose length product (DLP) from pediatric cranial CT scan

Dose length product (DLP) mGy.cm	Age grp				Total
	< 1	1 – 5	5 – 10	10 – 15	
< 500	0	3	1	2	6
500 – 1000	0	19	8	1	28
1001-1500	7	19	8	7	41
1501 – 2000	1	16	14	7	38
2001 – 2500	0	14	15	15	44
2501 – 3000	0	6	2	12	20
3001 – 3500	0	3	2	11	16
3501 – 4000	0	1	0	2	3
4001 – 4500	0	2	0	1	3
4501 – 5000	0	1	0	3	4
Total	8	84	50	61	203

Table 3. The effective dose received from pediatric cranial CT scan

Age group	Effective dose (mSv)					Total
	1 – 5	5 – 10	10 – 15	15 - 20	21 – 25	
< 1	0	5	3	0	0	8
1 – 5	20	36	21	6	1	84
5 – 10	19	29	2	0	0	50
10 – 15	16	38	6	1	0	61
Total	55	108	32	7	1	203

4. DISCUSSION

Most cancers can be induced by ionizing radiation, and a linear dose-response relationship has been noted for most solid cancers [13]. The risk of cancer obeys a linear no threshold risk model, which means that the smallest dose of radiation has the potential to cause an increase in cancer risk to humans. Risk of radiation-related cancer is greatest for individual exposed to radiation early in life and this risk appears to persist throughout life [13]. Several factors affect the risk of cancer following radiation exposure. These include gender status (male or female), age at the time of exposure to radiation, underlying disease and other potential carcinogenesis [13]. In this study, the age at exposure is found to be more significant to cancer induction than the gender status of the patient.

Table 4. Estimated risk of cancer induction from pediatric cranial CT with respect to Age

Age range	Risk per million (x 10^{-5})
< 1 year	100 – 2500
1 – 5 year	100 – 3000
5 – 10 year	100 – 2000
10 – 15 year	100 – 2000

Also, multiple exposures to ionizing radiation has been found to induce cancer in patient as reported by Morin et al. [14], where multiple diagnostic x-ray examination was found to increase the risk of cancer among the exposed patients with increasing radiation dose. The most radiosensitive organs in children are thyroid gland, breast, bone marrow, brain and skin.

In the light of rapidly increasing frequency of pediatric CT examinations in most diagnostic

centers in Nigeria, this study did estimate the risk of cancer in children following exposure to ionizing radiation from a multiple slice CT scanner. Some of the measurable quantities used in this study to estimate the risk of cancer associated with pediatric cranial CT scan are namely, volume computed tomography dose index (CTDIvol), dose length product (DLP) and effective dose.

As seen in Table 1, the range of CTDIvol received by patients of all age groups was 10–250 mGy while the range received by majority of patients (46%) was 50 – 150 mGy. This value is higher than the values 60 mGy and 20 – 60 mGy, published in literature for pediatric head CT in the UK [15] and Switzerland [16] respectively. In this study only few pediatric patients (18%) received optimum CTDIvol of 10 – 50 mGy that is within the internationally acceptable dose for head CT scan while the rest of the patients (82%) received higher CTDIvol.

Table 5. Estimated risk of cancer induction from pediatric cranial CT with respect to Sex

Risk per million (x 10^{-5})	Sex	
	Female	Male
100 – 500	8	15
500 – 1000	32	36
1000 – 1500	34	34
1500 – 2000	13	15
2000 – 2500	5	6
2500 - 3000	3	3
Total	95	108

In Table 2, the DLP values from all patients ranged from about 500 – 5000 mGy.cm. This range is higher than the range of DLP (about 930 – 1300 mGy.cm) published in literature for pediatric head CT scan [15]. It can be seen in Table 2 that the DLP (mGy.cm) received by the highest number (frequency) of patients from various age groups were 1001 – 1500 for age < 1 year, 500 – 1500 for ages 1 – 5 years, 2001 – 2500 for ages 5 – 10 years and 2001 – 2500 for ages 10 - 15 years. In all, only 37% of pediatric patients received optimal value of DLP while the rest of the patients (63%) received higher value.

The effective dose (ED) is a quantity that was introduced for radiation protection purposes and especially for radiation workers. However, it has been extensively used to report the risk of radiation exposure from medical examinations involving ionizing radiation [17]. In this study, the range of ED received by patients of all age groups was 1 – 25 mSv, whereas majority of the patients (53%) received 5 – 10 mSv. This ED is thrice the value (1.71 – 2.74 mSv) reported in literatures [18 - 19] from pediatric head CT. Going by this value, only 27% of patients considered in this study received optimal effective dose from cranial CT while the rest of the patients (73%) received higher ED.

From this study, the estimated risk of cancer induction in patients in the age group 1-5 years was the highest with a cancer risk of 100 – 3000 per million. However, when the risk of cancer induction was estimated with respect to the sex [20] of patients, it was observed that there was no significant difference in frequency in both sexes.

Several precautions have been suggested in literatures [4-6] for dose reduction practice in pediatric CT imaging. These include adjustment of technical parameters (mAs, kVp, pitch factor and others), the use of alternative medical imaging if the diagnostic yield of CT is expected to be small, judicious selection of scan parameters that will provide acceptable images at lower radiation exposure to patient, spacing of CT slices and slice thickness while maintaining diagnostic image quality among others.

In this study, the high risk of cancer incidence observed from the estimated value can be attributed to high exposure parameters used for pediatric patients that are almost similar to those selected for adult patients. Also a pre-set pediatric protocol was used for all pediatrics patients regardless of the age. This may be due to lack of dedicated pediatric CT scanner and trained pediatric CT scanner operator at the center. Further study is aimed at establishment of safe protocols for pediatric CT imaging to assist operators in their choice of technical parameters for patient exposure during medical X-ray examination.

5. CONCLUSION

This study showed a high risk of cancer incidence among pediatric patients referred for cranial CT examination in our hospital. This is majorly due to lack of appropriate exposure parameters for different pediatric age groups on the CT scanner and non-availability of trained pediatric CT operator. This calls for a concerted effort by the Government and the hospitals to provide CT scanners with appropriate protocol

approved for pediatric studies and to put necessary emphasis on training of CT operators in pediatric imaging. We also suggest the involvement of Medical Physicist in CT dose measurement in centers where pediatric imaging is carried out, to stem this tide.

CONSENT

All authors declare that written informed consent was obtained from the parents or legal guardians of the children considered in this study.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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