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Radiological Implications of Radiation Dose Distribution in Paediatric Patients Undergoing Diagnostic X-Ray Examination in Some Nigerian Teaching Hospitals

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***Abstract*:- This work aimed at calculation of effective dose and estimation of cancer risk from X-ray exposure in three Nigerian teaching hospitals. Personal Computer X-Ray Monte Carlo Software (PCMXC) 2.0 program was used to compute the organ doses, effective doses and the patient's risk of death due to radiation-induced cancer according to the sex- and age-dependent risk model of the BEIRVII.**

The mean effective dose calculated for various hospitals using ICRP 60 range from 0.201 to 0.294 mSv while that of ICRP 103 range from 0.174 – 0.253 mSv. The result of the cancer risk estimate showed that for patients who did abdominal X-ray, bladder has the highest risk of developing cancer, the value ranging from 0.028% – 0.061% patients while leukemia risk has the least value ranging from 0.004% – 0.008% patients. In patients who did chest examination breast cancer risk is the highest ranging from 0.112% – 0.388% patients while ovary cancer risk is the least ranging from 0.0005% – 0.0013% patient. The risk of developing cancer of the blood (leukemia) is highest in the patients who did X-ray examination of the skull.

The risks estimated in this work are higher than the ICRP recommended value. The result shows that there is urgent need for the standardization of the procedures for paediatric undergoing X-ray examinations in the country in view of their sensitivity to radiation induced harzards.

Keywords: Paediatric radiology, cancer risk, effective dose and organ dose.

INTRODUCTION

Paediatric radiology is a subspecialty of radiology involving the imaging of foetuses, infants, children, adolescents, and young adults up to the age of 15 years. The use of ionizing radiation adopted in diagnosis of emergency that includes life threatening conditions and in management of ill or injured paediatric. Exposure to ionizing radiation is one of the few established risk factors for childhood cancers [1]. Research has shown that children are more susceptible to the effects of ionizing radiation than adult [2,3]. This is because the probability that there may be late radiation effects is higher in paediatric. Firstly, children are much more radiosensitive than adults according to International Commission on Radiological Protection (ICRP) [4] if the same dose of radiation is given to a 1–year-old infant and a 50-year-old adult the probability of developing a malignancy is 10-15 times in paediatric than the adult. Secondly, for a given radiological procedure, the effective dose is larger in a small infant than in an adult, because the effective dose decreases with age [5]. The risk estimations for medical imaging in both adults and paediatric radiology came from four sources consisting of studies of populations exposed to atomic bombs (the Radiologic Effects Research Foundation-RERF), occupational exposures, medical exposures, and environmental exposures, such as the Chernobyl accident [5]. It has been established that increasing the X-ray film to focus distance will optimise the radiological protection in paediatric patients undergoing common conventional radiological procedures [6]. It has also been established that there are variations in the entrance skin dose (ESD) from one Nigerian teaching hospital to the other and the variations depend on the parameters and the techniques used at the hospitals [7]. The amount of organ doses and the radiation risks involved in paediatric radiology undergoing conventional X-ray examinations in terms of the age and sex of patients have been determined by Nahangi H. et al. and Akinlade et. Al. [8,9]. Research has also been done on the implications of ionizing radiation in the paediatric urology patients by Kelly L. Stratton et. Al. [10]. It has been established that radiation risks depend on age, gender, genetic susceptibility and that there is a significant risk of developing cancer at doses below 100 mSv [11-13]. Ogbole et. al. conducted a survey in Nigeria that showed that majority of physicians and patients are not aware of the radiation associated with common radiological examinations, its risk of carcinogenesis, or the importance of limiting exposure among younger patients [14].

The National Academy of Sciences' National Research Council (NASNRC) comprehensively reviewed biological and epidemiological data related to health risks from exposure to ionizing radiation, published as the Biological Effects of Ionizing Radiation (BEIR) [15]. Exposure to ionizing radiation is of concern because evidence has linked exposure to low-level ionizing radiation at doses used in medical imaging to the development of cancer [15]. The paediatric radiology should be performed with full knowledge of the possible harmful effects, considering that infants are particularly susceptible to radiation-induced cancer.

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In some Nigerian primary and secondary schools, chest X-ray examination is a compulsory requirement for admission for the pupils [16]. Aborisade et. al. has established that there is need for the standardization of radiological X-ray examination in Nigeria because the doses were higher that the ICRP [7]. Paediatric radiology is very important because of the delay for expressing radiogenic cancers as consequence of longer life expectance and high radiosensitivity of actively growing tissues. Medical exposure during paediatric radiology attracts particular interest because of the increased opportunity for expression of delayed radiogenic cancers as a consequence of relative longer life expectancy and the high radiosensitivity of the actively growing tissue [17]. Diagnostic radiograph is associated with an increased risk of cancer induction and exposure to ionizing radiation is one of the few established risk factors for childhood cancers [17]. Because of the significant variation in ESD in Nigerian teaching hospitals for paediatric there is need to estimate the risks for proper enlightenment of the radiation health workers, Propertius of the primary and secondary schools and the public. To the best of my knowledge, in Nigeria no work has been done to estimate the life time attributable risk of cancer in paediatric and this work address such.

MATERIALS AND METHODS

Materials

A commercially available computer software by name, Personal Computer X-Ray Monte Carlo Software (PCMXC) 2.0 program was used to compute the organ doses and effective doses. The PCXMC is used in medical x-ray examinations for radiography and fluoroscopy. Originally, PCXMC was developed by Tapiovaara M and Siiskonen T (STUK-Radiation and Nuclear Safety Authority in Finland) for its own research purposes, but the program has been made available for others at the price. The PCXMC program uses the Monte Carlo method, the user only needs to enter the examination data. The user interface includes graphic displays for visual checking of proper examination conditions. PCXMC is a program for calculating patients' organ doses and effective doses in medical x-ray examinations. The organs and tissues considered in the program are: active bone marrow, adrenals, brain, breasts, colon (upper and lower large intestine), extra-thoracic airways, gall bladder, heart, kidneys, liver, lungs, lymph nodes, muscle, oesophagus, oral mucosa, ovaries, pancreas, prostate, salivary glands, skeleton, skin, small intestine, spleen, stomach, testicles, thymus, thyroid, urinary bladder and uterus [18].

Methods

Calculation of the Organ Doses and Effective Doses

The dose calculation for a given examination was done by imputing the required parameters namely patient age, patient size and exposure parameters as obtained from the three teaching hospitals into the PCXMC. The program calculated organ dose for a specified x-ray spectrum from the patient's entrance skin dose obtained using the calibrated dosimeters for each hospital was presented by Aborisade et. al. [7]. The same PCXMC program was used in this work to evaluate the risk. The program calculates the effective dose with both the present tissue weighting factors of ICRP Publication 103 (2007) [19] and the old tissue weighting factors of ICRP Publication 60 (1991) [20]. This work was carried out on paediatric radiology only and the anatomical data used by the software are based on the mathematical hermaphrodite phantom models [21] which describe patients of six (6) different ages: new-born to age less than 1 year are referred to as zero (0) year, "1", "5", "10", "15" year-old and adult patients.

The program can incorporates adjustable-size for paediatric and adult patient, and allows a free choice of the x-ray examination technique, the hermaphrodite paediatric phantom model was used for the estimation of risk. The program simultaneously estimated the patient's risk of death due to radiation-induced cancer according to the sex- and age-dependent risk model of the BEIRVII [22].

Calculation of Risk of Exposure-Induced Cancer

The program used the calculated organ doses for the assessment of the risk of exposure-induced cancer. The risk estimates were based on the combined absolute and relative risk models of BEIR VII committee (BEIR 2006) [22]. PCXMC calculates the risk of exposure-induced death for leukaemia, cancers in colon, stomach, lung, urinary bladder, prostate, uterus, ovaries, breast, liver, thyroid and for all other solid cancers combined. The risk calculation module was used for estimating the cancer risk resulting from a single exposure or multiple exposures simulated in PCXMC. The ICRP specifically stresses that effective dose should not be used for, e.g., the assessment of individual risk, assessment of the probability of causation of cancer, or for epidemiological studies. Absorbed doses to irradiated tissues should be used for these purposes. However, the ICRP acknowledges that the effective dose can be of value for comparing doses from different diagnostic procedures and for comparing the use of similar technologies and procedures in different hospitals and countries as well as the use of different technologies for the same medical examination (ICRP 2007) [19]. Effective dose has widely been used for such purposes as assessing the population dose from diagnostic x-ray examinations [23-25].

The PCXMC calculates the effective dose for allowing easy comparisons between different diagnostic procedures. This risk model is based on the report of BEIR VII committee, [22] and considers, the sex, age at exposure and attained age of the patient.

Comparisons of PCXMC with other data

The data calculated with PCXMC versions 1.2–1.5 have been earlier compared to the organ dose conversion factors calculated in NRPB by Jones and Wall[26] and Hart et al. [27,28] and were found to agree well. This agreement was to be expected, because also their data were calculated using the phantom models of Cristy [29]. Reasonable agreement of PCXMC results has also been found in many comparisons with other dose calculations and phantom models or dose measurements [30-33]. The agreement with the

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NRPB data still exists for PCXMC 2.0 for most irradiation conditions. Small differences are evident in some irradiation conditions, because the composition and density of the phantom tissues have been changed and the phantoms have been modified from the earlier versions of the program.

RESULTS.

The results of the organ doses (µGy) and effective dose (mSv)

The results of the patient's entrance skin dose used in this work was obtained with the calibrated dosimeters for each hospital was presented by Aborisade et. Al. [7]. The values of the effective doses (ICRP 60 and ICRP 103) calculated by the program for those who undergone X-ray examination of abdomen, chest, head, neck and pelvic are presented in Table 1.

Table 1: The Mean Effective Dose (mSv) Calculated for Various Hospitals Using PCXMC.

CENTER	Chest		Head		Neck		Pelvic		Abdominal	
	ICRP60	ICRP 103	ICRP 60	ICRP 103	ICRP 60	ICRP 103	ICRP 60	ICRP 103	ICRP 60	ICRP 103
OAUTHC	0.232	0.320	0.045	0.060	0.038	0.035	-	-	0.294	0.253
UITHC	0.184	0.255	0.022	0.03	0.025	0.023	0.081	0.048	0.28	0.242
LUTH	0.109	0.154	0.012	0.015	0.025	0.023	0.098	0.058	0.2011	0.1735

Table 2: Organ Dose (µGy) Calculated for Various Hospitals Using PCXMC for various Examinations.

	Bone marram	Breast	Colon	Heart	Kidneys	liver	Lung	Oesophagus	Ovary	Prostate	Skull	Pelvic	Stomach	Urinary bladder	Uterus	Brain	ED (µSv)
Abdominal Examination.																	
OAUTHC	101	7.10	619	250	171	320	19	35	438	543	0.52	847	460	833	677	2.0	254
UITH	84.5	5.5	477	190	131	247	14.9	26.6	378	418	0.403	653	354	642	522	0.12	196
LUTH	75	4.88	423	16.8	116.6	219	13.2	23.6	299	370.9	0.358	579	314	700	463	0.11	174
Chest Examination																	
OAUTHC	100	1090	23.6	648	102	391	506	304	12.5	3.9	25.3	20.8	412	5.4	4.6	4.5	320
UITH	80	833	18.5	503	74.5	288	394	228	19.8	2.8	21	16.9	306	3.1	11	3.8	246
LUTH	49	512	11.4	309	45.8	177	242	140	12.2	1.7	12.9	10.4	187.8	1.87	6.79	2.33	151
Skull Examination																	
OAUTHC	135	513	NA	2.5	5.1	0.8	1.8	11.6	12.3	NA	NA	1893	0.144	0.946	NA	1.3	60
UITH	67.9	255	0.274	0.088	3.03	0.51	0.72	5.81	5.21	NA	NA	953	NA	0.84	NA	NA	29
LUTH	32.3	120	0.15	0.04	1.65	0.17	0.37	3.4	1.7	0.23	NA	450	0.07	0.35	0.07	NA	15

Estimation of Risk of Fatal Cancer from Different X-Ray Examinations at the Three Hospitals

The PCXMC was also used to estimate the cancer risk (per million patients) and the results are presented in figure 1 to 3.

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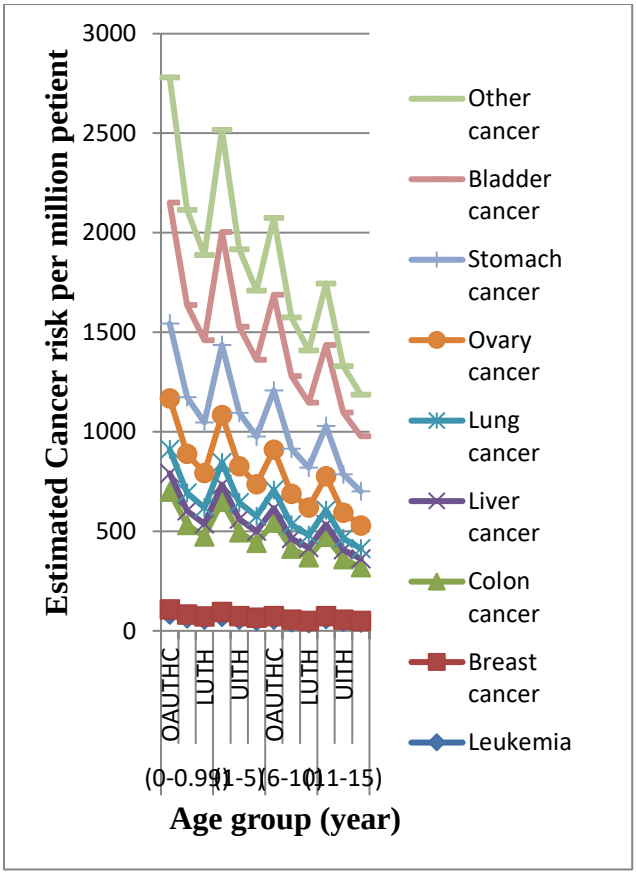

Figure 1: The Estimated Risk (per Million) for Patients who Undergone Abdominal Examination. (new-born is referred to as zero (0) year)

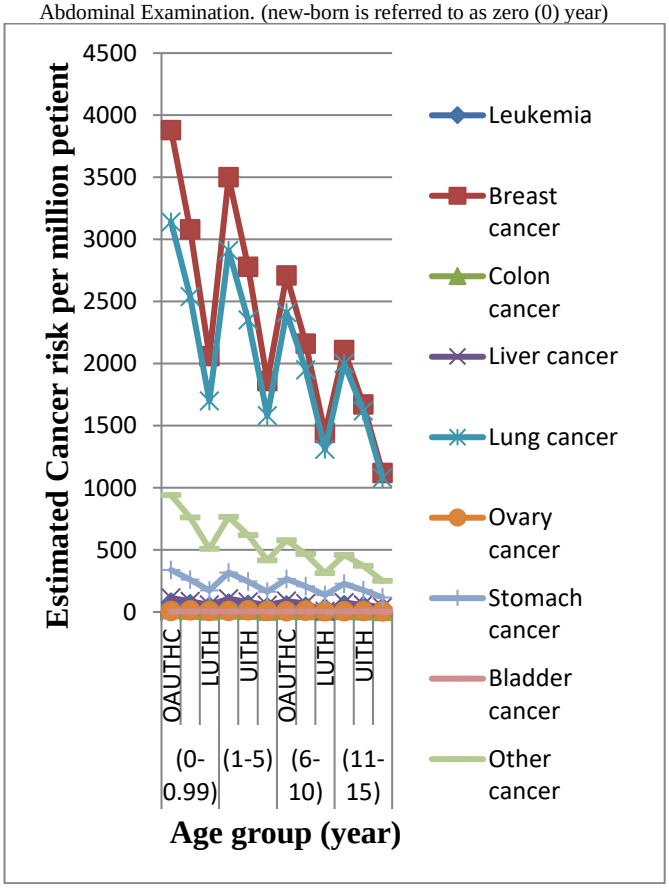

Figure 2: The Estimated Risk (per million) for Patients who Undergone Chest Examination. (new-born is referred to as zero (0) year)

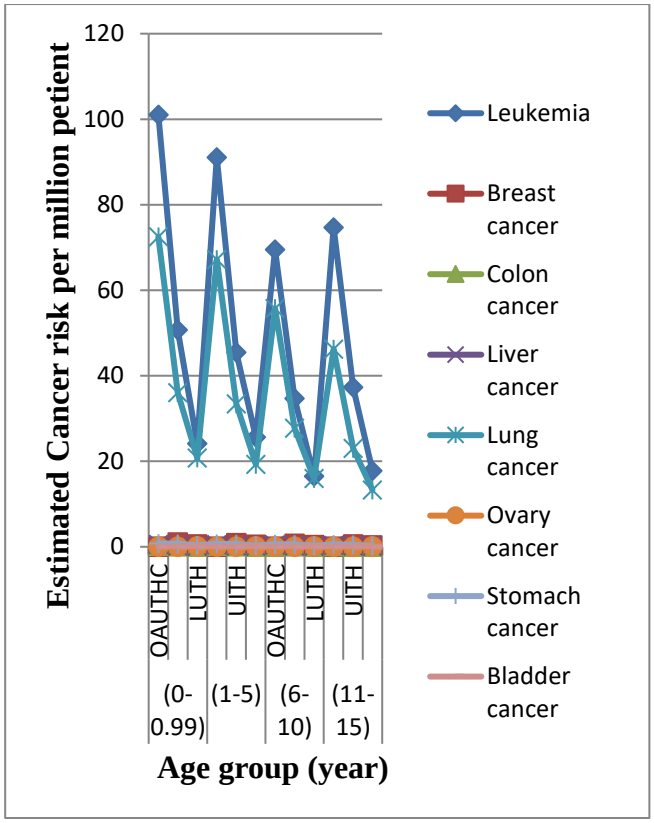

Figure 3: The Estimated Risk (per million) for Patients who Undergone Skull Examination. **(new-born baby is referred to as zero (0) year)**

Risk of Exposure-induced Cancer Death (RIED)

The results of the risk of exposure-induced cancer death (RIED) are presented in figure 4 to 7.

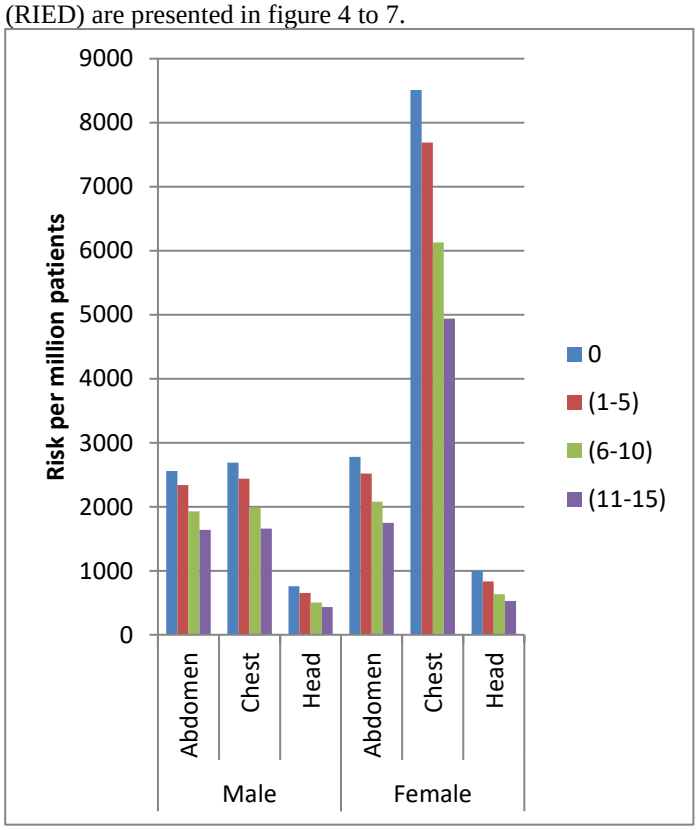

Figure 4: Comparison of Risk of Exposure-induced Cancer Death (RIED) between Male and Female for Conventional X-ray. [new-born baby to age less than 1 year are referred to as zero (0) year]

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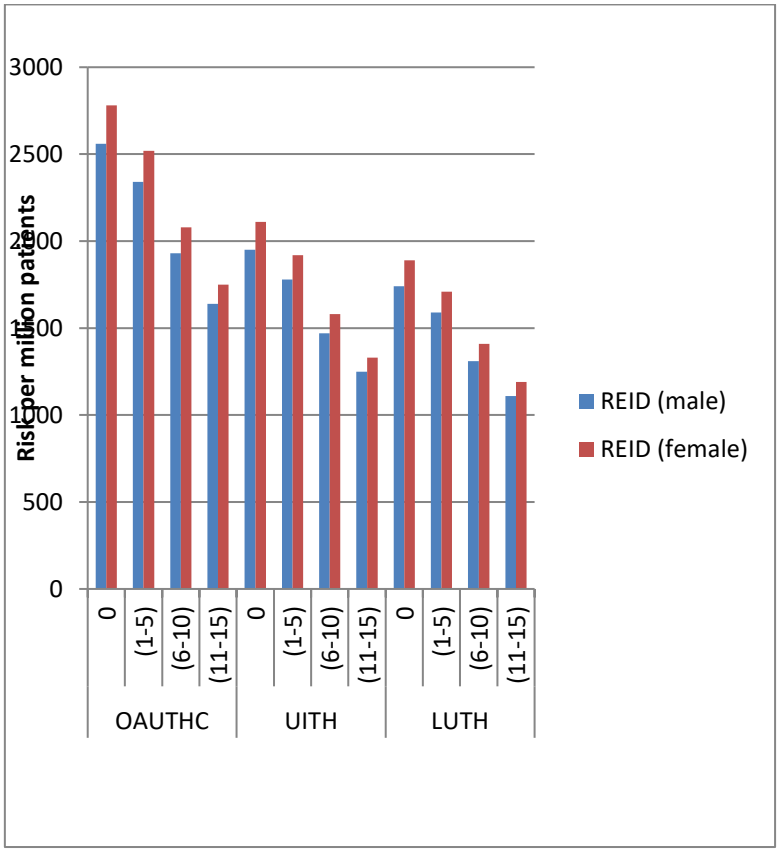

Figure 5: Risk of Exposure-induced Cancer Death (RIED) for Abdominal X-ray. [new-born baby to age less than 1 year are referred to as zero (0) year]

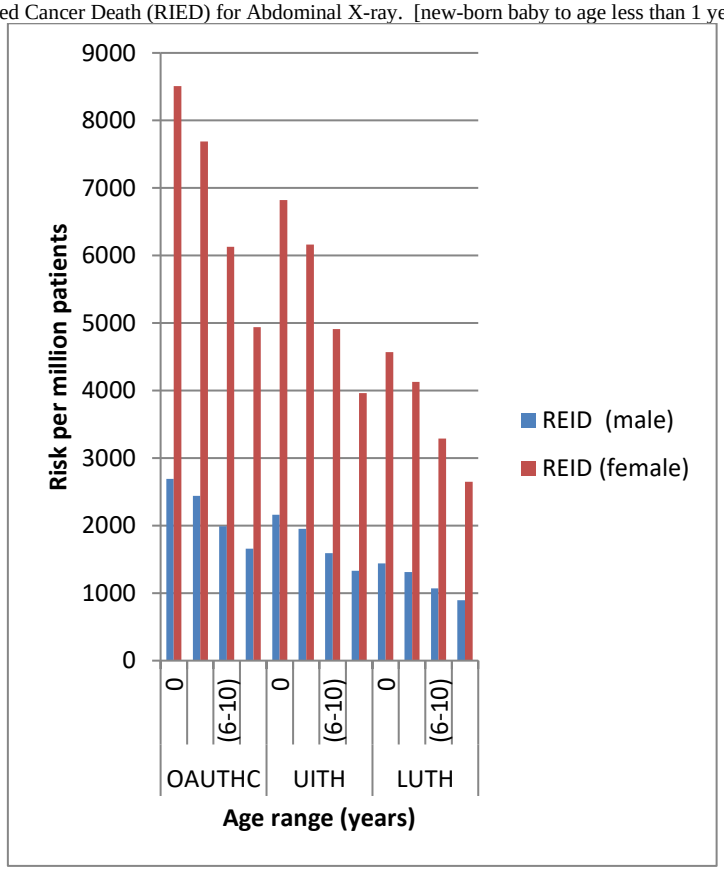

Figure 6: Risk of Exposure-induced Cancer Death (RIED) for Chest X-ray. [new-born baby to age less than 1 year are referred to as zero (0) year]

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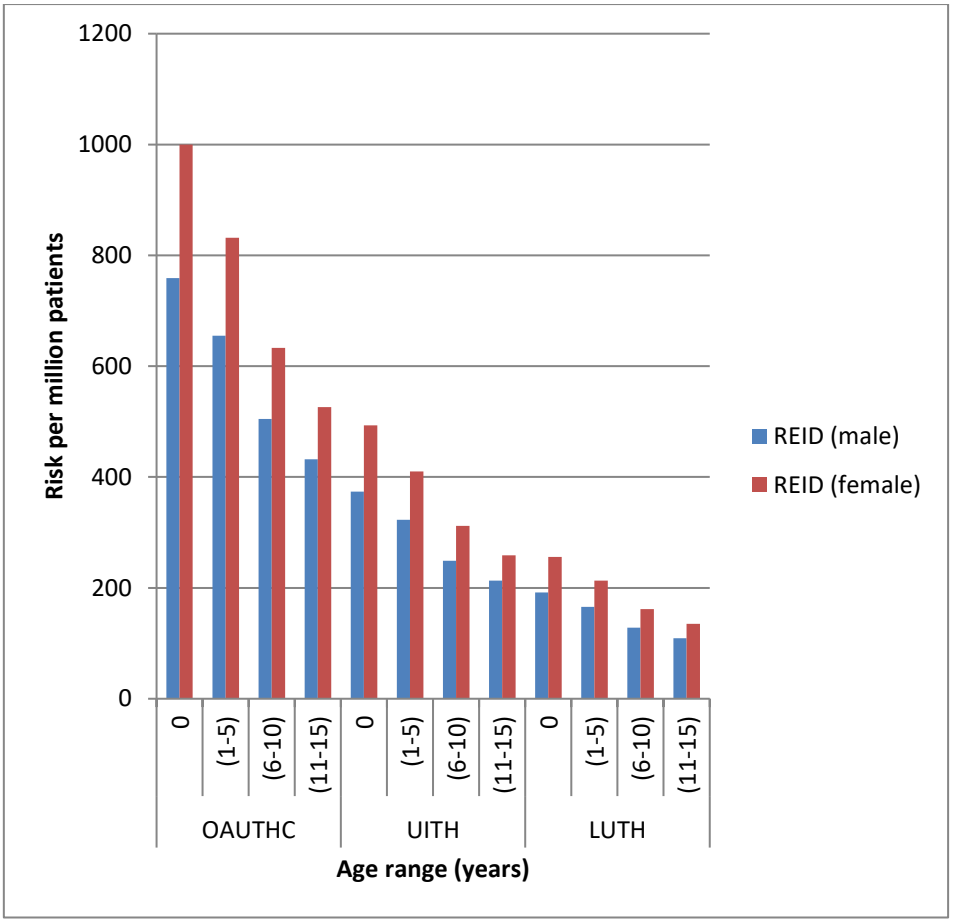

Figure 7: Risk of Exposure-induced Cancer Death (RIED) for Head X-ray. [new-born baby to age less than 1 year are referred to as zero (0) year]

DISCUSSION

The values of the effective doses for paediatric patients presented in table 1 and the organ doses presented in table 2 shows that these values are very high when compares with those reported by Geleijns [34] but low when compare with those of Cornelia while values of both organ dose and effective dose from OAUTHC are very high because the combinations of kVp and mAs selected by the operators at the OAUTHC are higher than any UITH and LUTH this is related to factor such as film processing techniques while that of the LUTH is the lowest in this work this is because the combinations of kVp and mAs selected by the operators are low when compare with other centers [24,25, 34,35]. The estimated fatal cancer risks for paediatric patients who had abdominal/pelvic, chest, and skull X-ray examinations presented in figures 1 to 3 show that for female paediatric patients who did the abdominal radiographic examination, the risk of bladder cancer, stomach cancer and oval cancer are very high when compared to the work by Rolf [36]. Figure 2 shows that the female paediatric patients who undergone chest X-ray examination have high risk of breast and lung cancer when compared with other cancers. Figure 3 shows that for paediatric patient who undergone head X-ray examination, leukemia and lung cancer are at high risk. It is worth to note that for all estimated risk of cancer, the risk value at OAUTHC is the highest follow by UITH. These estimated cancer values are higher when compared with the result of Brindhaban [37].

Figures 5 to 7 show the estimated risk of exposure-induced death (REID) for X-ray of examination of the abdomen, chest and head. Figure 4 shows the result of REID by gender and type of paediatric radiology performed. The results showed that there is a clear gender difference, with the females been more radiosensitive than the males. The results showed that the REID for female is higher than that of male, it decreases with age. The highest REID is obtained in chest X-ray examinations while value for female paediatric is a factor of 3 higher than the male in all centers. In all the three (3) teaching hospitals considered in this study, the estimated REID is higher than the ICRP.

CONCLUSION

The risks estimated in this work are age and sex dependent. This study showed that there is an urgent need for standardization of paediatric radiology procedures in Nigeria. This can be achieved through a concerted effort at ensuring comprehensive quality control and quality assurance program, including training of all personnel involved in paediatric X-ray examinations and calibration of X-ray in all radiology departments.

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ETHICAL APPROVAL

The patient's written consent has been collected and the Ethics and Research Committee approval from the three teaching hospitals were obtained.

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