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Population exposure to ionizing radiation from radiological examinations in a large Nigerian hospital (UCH) between 1998 and 2007: Necessity of dose data on the extremity examinations.

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Abstract

Data on medical radiation exposure to population due to diagnostic x-ray procedures at University College Hospital (UCH), Ibadan Southwestern Nigeria between 1998 and 2007 are presented. Information on annual frequencies of conventional X-ray procedures is obtained from the three X-ray rooms of the institution. Estimate of collective effective doses were calculated from the dose associated with each procedure and frequency data. Chest x-ray constituted the highest proportion (22.56%) of the total examination carried out at the hospital during the period of study, while the mean frequency of examinations during the same period was 13083. The estimated effective dose per annum was found to vary between 1523.80 and 1992.60 mSv. The total collective effective dose resulting from conventional x-ray examination at the hospital was 17954.87 mSv and the mean dose per examination was 0.15 mSv. The highest contributor to the effective dose was thoracic spine examination. The trend here is lower than those found in literature. Record of doses associated with skull, cervical spine, thoracic spine, foot, hand, leg, thigh, fore arm, humerus and knee for UCH were not found in any literature, indicating that doses associated with them probably have never been measured. The working age group (21-60 year) is the most examined age group (66%), while pediatric and teenagers constitute about 19% of the population exposed to the ionizing radiation. This study is seen to be helpful in financial and technical planning of the average procedures carried out at the hospital per year for various projections included in this work. Results of the calculated dose could be used to estimate the lifetime attributable risks (LAR) of cancer incidence and mortality per 10,000 population.

1.0 Introduction

The use of ionizing radiation for medical diagnosis and treatment is on the increase today in the medical field. X-ray remains the most frequently used ionizing radiation in medicine and it constitutes the most significant man made source of radiation exposure for the world population [1,2]. Because of the detrimental effects of ionizing radiation, it is expected that routine dose assessment be carried out regularly in every hospital to ascertain the nature of practice and optimize the justified examination in order to protect patients, personnel and general public. In Nigeria and like in many countries of the world, medical exposure to radiation occurs as a result of the use of conventional X-ray units, Computer Tomography (CT), Mammography, Fluoroscopy, nuclear sources for diagnosis, and treatment. Currently, the use of CT is gaining more prominence in diagnostic radiology in Nigeria most importantly in Teaching Hospitals and Federal Medical Centres. Globally, CT is said to be responsible for 34% of the annual collective dose from medical exposure.

Concerted effort has been made by various researchers to measure radiation dose imparted to patients and to assess occupational-based dose during diagnostic procedures in Nigeria [3,4,5,6,7,8]. Moreover, surveys on population exposure by medical x-rays are recommended as a useful tool in radiation surveillance and protection at both national and international

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levels [9]. According to the European Commission [10,11], the situation should be reassessed ideally every 5 to 10 years due to the pace of technological developments in the field of radiology and evolution of medical practices. At the international level, surveys on the exposure of the world population by medical radiology are conducted every decade by the United Nation Scientific Committee on the Effects on Atomic Radiation (UNSCEAR) [12]. Several countries have carried out nationwide surveys, these include: Spain [13], United State of America [14], United Kingdom [15] and Germany. Switzerland had earlier carried out the survey of the exposure of the population by medical x-rays since the late 1950s. The survey in that country was reevaluated in1998 [16]. The survey provided detailed information on the frequency of the X-ray examinations performed in Switzerland and the associated radiation doses. The updating came up later in 2003[17].

In Nigeria it is estimated that there are well over 5000 x-ray units spread across the six geopolitical zones of Nigeria. In specific terms, at Ahmadu Bello University (ABUTH) complex an average of 250 diagnostic x-ray examinations are carried out per day in three hospital facilities located in Zaria, Kaduna and Malunfasi [18]. One way of assessing the impact of increase in diagnostic radiology practice on the radiation exposure of the population and the potential health detriment is to monitor trends in the annual per caput effective dose. The dose descriptor known as annual per caput effective dose provides a better indication of overall trends in individual doses as medical imaging practice changes, than the annual collective dose, which is also influenced by changes in the number of people in the population. Although it comes in form of estimates, however it can be used to compare the contribution from diagnostic radiology with those from natural or other artificial sources of radiation and to see the differences in the contributions among countries states and regions. Such dose estimates as annual per caput effective dose is a necessity in Nigeria because it provides guidance on where best to concentrate efforts on dose reduction in order to optimize the protection of the public in the most cost effective manner [19].

As a result of the increase in the use of ionizing radiation in Nigeria, assessment of the annual collective dose to the patients, workers and members of the public is quite necessary. In southwestern geopolitical zone of Nigeria, University College Hospital (UCH) Ibadan is the largest and the foremost teaching hospital which houses one of the earliest Radiology Departments where many Radiologists were trained. This study was carried out at University Teaching Hospital (UCH), Ibadan. Patients are referred to this hospital from different parts of south-western, south-eastern, central and mid-western part of Nigeria. This study was aimed at assessing the number of patients (and their age groups) who were examined at UCH during the period of 10 years (1998-2007) and to determine the most frequent examination (projection) carried out at the hospital during the period in question and to determine the age group mostly irradiated so as to ensure that undue radiation exposure of the productive age group that could lead to higher cancer risk could be mitigated against. The age consideration is essential because it is a common knowledge that the probability of delayed radiation effects is critically dependent on the age distribution of the exposed population.

2.0 Materials and methods

Estimation of frequencies of radiological examination

The data used in this study span a period of ten years (January 1998-December 2007). The data were obtained from the patient’s register (records) of the Radiology Department of University College Hospital, Ibadan (Southwestern, Nigeria). Data collected include: patient age, and projection. Different projections (examination types) included in the study are: skull, chest (AP or PA), lumbosacral spine, cervical spine, thoracic spine, foot, hand, leg, thigh, pelvis, forearm, humerus, knee and abdomen. The age of patients were grouped into 0-10, 11-20, 21-30, 31-40, 41-40, 51-60,61-70, 71-80, 81-90, 91-100. Annual number of radiological examinations carried out for the period of investigation was recorded. In addition, total number of examinations and average number of examination for the 14 projections were determined in conventional radiology. An average value of the total annual number of examination was also determined. As at the time of this analysis examinations such as fluoroscopy, CT, angiography, mammography and others were not considered and may be subjects for future study as this present effort forms a foundation pilot study.

Estimation of effective dose

In this study we adopted the method described in NRPB-W4[19] for estimating total dose E_T and collective effective dose E_c. Using this method the estimate of total dose *(E_T)* for a specific examination (e.g. chest) was determined using equation (1) [20,21]:

$$E_T = \sum_{i=1}^{n=10} N_{pi} \, x \, E_m \qquad (1)$$

Where N_{pi} is the frequency of a specific type of examination for different age groups *i* and E_m is the mean effective dose for the specific examination (e.g. chest AP/PA). The collective effective dose (E_c) on the other hand was estimated using equation (2) [21]:

$$E_c = \sum_{j=1}^{m=14} E_{Tj} \qquad (2)$$

where *j* is the procedure type (i.e. chest, skull).

In order to determine the dose estimate descriptors, a typical effective dose was attributed to each one of the 14 procedures found in the frequency survey. To do these, estimates of the mean effective dose for each examination were obtained from a number of published works carried out at UCH within the period of the investigation [3 ,4, 5, 22]. In a situation where the values of effective dose associated with certain examinations were not available, but the entrance surface dose (ESD) values, available ESD data were converted to effective dose using NRPB conversion coefficient in NRPB-R262[24,20]. Where several mean doses for a given procedure was available, the mean value was calculated and taken as the typical dose for the procedure. Additionally, in specific cases where the value of effective dose and ESD were not available, published dose data from NRPB-W4 were used. This was done because record of radiation dose associated with certain procedures (at UCH) could not be found in any published work; probably it has never been measured. In procedures where doses associated with examinations at UCH were available (chest, lumbo sacral joint, Abdomen, pelvis) a rating of A1was assigned. However, where doses associated with the examinations were not found, values [21] contained in the National Radiological Protection Board (NRPB)-W4 report of March, 2002[19] were employed for the following examination types; skull, cervical spine, thoracic spine, foot, hand, leg, thigh, forearm, humerus and knee were assigned rating of A2 (indicating higher level of uncertainties in our dose estimation than A1 rating).

3.0 Results

The mean value of frequency of examinations for the period of ten years with the standard deviation is presented in Table 1. It is evident from Table 1 that chest radiography remains the most frequent examination in UCH. This is followed by the skull examination. Meanwhile, examination with the least frequency of occurrence is the hand. During the course of this investigation, the value of dose associated with nine out of thirteen procedures could not be found in any published work indicating that the doses are yet to be measured at UCH for the nine projections. Figure 1 shows the proportion of examination during the period of ten years at UCH. The chest X-ray constitutes the highest proportion of the examinations (22.56%) carried out during the period of ten years. This is followed by skull (16.92 %). Moreover, examinations such as cervical spine, lumbo sacral joints abdomen, leg, thigh, pelvis, forearm, humerus and knee constitute more than 5% each. However, thoracic spine, foot and hand constitute 3.42%, 4.08 % and 3.29 % respectively. Figure 2 illustrates the distribution of examinations at UCH between 1998 and 2007. The frequency of examination for chest is the highest in 1998 (above 4000 examinations). The frequency of examination of skull follows closely the chest examination in2002 and 2006. It is evident from Figure 2 that the largest number of examinations carried out was in skull in 2001 at UCH. Analysis of total number of examinations per year between 1998 and 2007 is reported in Figure 3. The frequency dropped in 1998 from 14795 to 14451 in 1999. The number of examination further dropped to12261 in 2000. A slight rise was recorded in 2001 and a small peak was reached in 2002 and this remains relatively stable until 2004, and it finally dropped to 12006 in 2007.

Table 1. Mean number of examinations during the period of ten years

Examination Categories	**Mean value of frequency of examinations for the period of ten years with the standard deviation**
Chest	2952 ± 472.07
Skull*	2214 ± 381.63
Cervical Spine*	677 ± 151.12
Thoracic Spine*	447 ± 93.25
Lumbo Sacral Joint	899 ± 140.22
Foot*	534 ± 90.53
Abdomen	724 ± 63.56
Hand*	430 ± 102.96
Leg*	740 ± 64.32
Thigh*	733 ± 61.46
Pelvis	687 ± 69.25
Forearm*	692 ± 32.21
Humerus*	676 ± 66.13
Knee*	678 ± 102.51

*Doses associated with the examinations were not found in published work carried out at UCH.

The calculated values of effective dose, ratings of the doses calculated are reported in Table 2. Percentage of the total dose of each procedure and range factors (ratio of the maximum to the minimum) of the dose are also shown. Table 3 shows the distribution of effective dose (mSv) and the corresponding frequency of examinations (number of patient) between 1998 and 2007. Dose per examination (mSv) is also reported. Average dose per patient is 0.15 mSv during the period of ten years. The estimate of the total dose delivered to patient per annum is reported in Figure 4. The mean value of the total dose per annum obtained is 1751.60 mSv. The distribution of total effective dose among different examinations is reported in Figure 5. It is interesting to note that chest which has the highest frequency of examination has a relatively low total dose of 271.62 mSv. In addition, the extremity examination such as foot, hand forearm, humerus and knee have low doses of 2.81, 2.15, 6.92, 5.40 16.96 mSv respectively. The total dose for all the fourteen procedures is shown as bar called **All.** Distribution of examination as a function of age group at UCH is presented in Table 4. The data show that approximately 66% of the examinations are related to the patients older than 20 years old while about 19% of the patients examined are paediatric (≤ 20 years) patients. Figure 6 is a graphical representation of the distribution of the number of patient examined for the period of ten years in terms of their age group. Figure 6 supports the trend reported in Table 4.

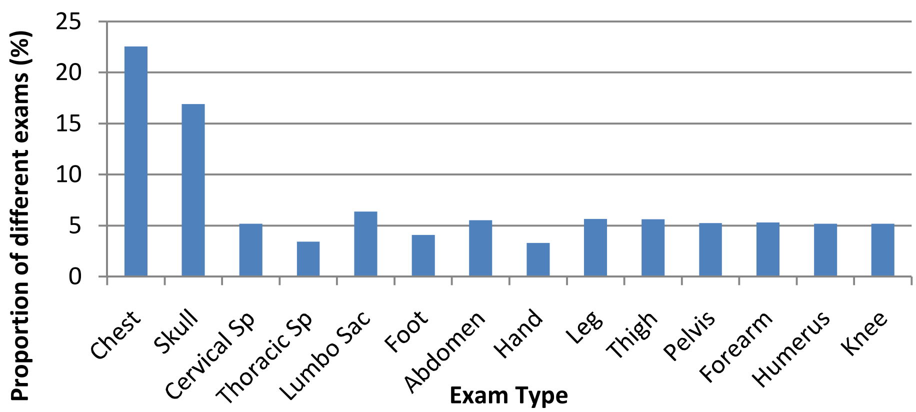

Figure 1. Histogram of percentage of different exams performed during the period of investigation

Discussion

It evident from Table 1 that the mean value of frequency of chest radiography is the highest in this study. This is an indication that it is the most frequent examination performed at UCH. This is also evident in Figures 1 and 2. This trend is in agreement with the one found in literature [24]. The high incidence of chest examinations could be attributed to the preventive diagnostic screening exercise carried out at the hospital and in certain instances assessment of extent of the damage done by disease like tuberculosis to the lung. There was a decrease in the number of chest examinations carried out in 2000, 2001, 2006and 2007. The unavailability of dose data associated with certain procedure at UCH shows that these has never been measured or the measurement carried on the nine projections have never been published. This is an indication that it is necessary to carry out the measurement of doses delivered to the nine projections at UCH during routine and special procedures as required by National Radiological Protection Board (NRPB) and Institute of Physical Sciences in Medicine (IPSM) [25, 26, 27,28]. This will enhance dose optimization in compliance with the directive of regulatory bodies. In addition, x-ray rooms with high doses will be discovered and technique parameters and machines causing high doses identified and corrected without compromising image quality. Although most of the projections with no record of measurement are the extremity examinations, yet measurements are required because of the presence of bone marrow in those parts of the body.

From Figure 2, it is indicative that the number of skull examination recorded in 2001 was the highest. An explanation for this could probably and partly be found in non- adherence to the required regulation and law concerning the compulsory use of crash helmet by the commercial motor cyclist prevalent in the country during the year 2001. The trend in Figure 1 could be used in financial and technical planning of the average procedures carried out at the hospital per year for various projections included in this study, that is, the number and type of cassettes required for a specific examination. Analysis of total number of examinations per year during the period under consideration as indicated in Figure 3 shows that between year 2000 and 2007 there was a slight variation in the number of examinations performed at the hospital for the period of eight years. The range factor is 1.12 , indicating a small variations in the number of examinations. A detail analysis in Table 2 shows the mean collective dose contributed by each procedure during the period of ten years. Although the x-ray examination of chest has the highest mean frequency of examinations (Table 1), their contribution to mean collective dose is low (1.5%). However, the major contributors to the mean collective effective dose are thoracic spine (555 mSv), lumbo sacral (279 mSv), thigh (257mSv), skull (190 mSv), pelvis (185 mSv) and abdomen (116 mSv). The contributions of the extremity examinations are very low. Hand is lowest contributor to the mean collective dose (0.25 mSv-0.01%). An average dose of 0.15 mSv per examination for the period of ten years is reported. Comparing this to other similar results [29,30], they are higher than this work by factor of 3.7 and 7.3 respectively. The highest dose/radiograph of 0.30 mSv is recorded in the year 2004.

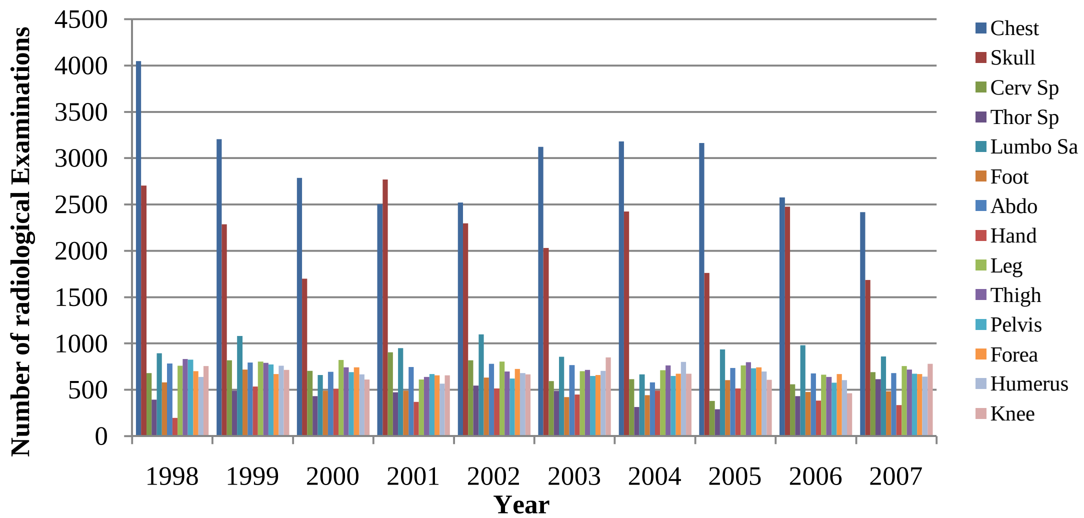

Figure 2. Number of Examinations for different procedures between 1997 and 2007

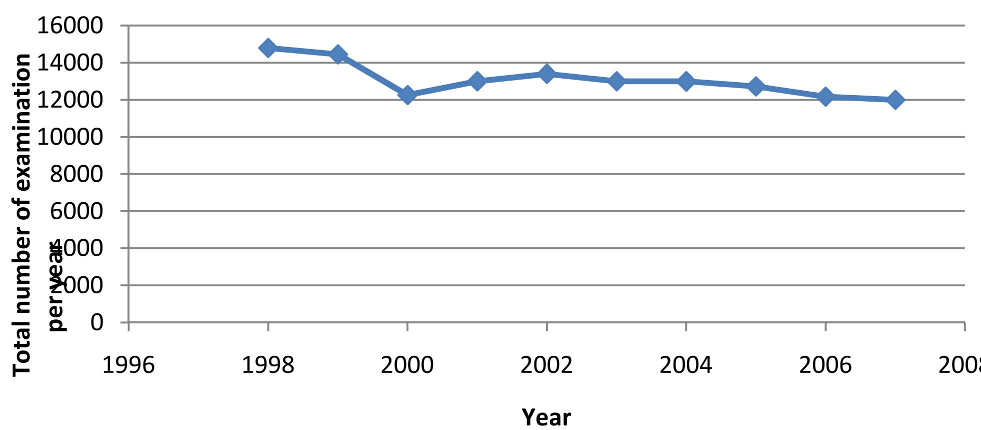

Figure 3. Analysis of total number of examinations per year between 1998 and 2007 at UCH

Figure 4 shows that the highest effective dose of 1992.59 mSv is recorded during the year 1999. Therelatively lower dose found between 1998 and 2001 could be attributed to the follow up of the corrective measure of the work of Ajayi and Akinwumiju and Ogunsehinde et al. [3,4] carried out at the University College Hospital (UCH) during the period of this investigation. The work was sponsored by IAEA . Additionally, the lower doses recorded in 2004 and 2005 are probably attributable to the recommendations of Ogundare et al. [5], they recommended that personnel who undertake the exposure of patient be further trained in order to further reduce patient dose in Nigeria. Furthermore, it could also be that in their recommendation to the hospital at that time bothered on the need for justification before the examinations were carried out, thereby leading to reduction in the number of examinations carried out at the hospital.

Extremity examinations: foot, hand, forearm, humerus and knee have low effective doses (2.81, 2.15, 6.92, 5.40, 6.96 mSv respectively). Effective dose may be taken as approximately measure of the stochastic radiation risk; it may be used to quantify the amount of radiation received by patients undergoing diagnostic examinations [31]. The estimate of effective dose recorded in this study as far as we know could serve as the dose data available for the extremity examinations at this hospital. There was no record of early measurement in the literature. It is estimated that 12.8 million upper extremity x-ray examinations and 15.7 million lower extremity x-ray examinations were performed in the United States in 1980 [32], however, effective dose data for extremity x-ray examinations are not available for either adult or pediatric patients [33]. Because of the unavailability of dose data for extremity examinations, it is necessary for a large hospital as UCH with three x-ray room to expedite action at measuring the dose delivered to the patients during extremity diagnostic examinations.

Table 2. Effective dose evaluated for each examination performed using the frequency of examination at the Radiological Department of UCH

Examination Categories	Mean effective dose (mSv)	Rating	Standard error on mean (SEOM)	Percentage of the total dose (%)	Range factor
Chest	27.16± 4.57	A1	0.027	1.5	1.67
Skull	190.37± 34.60	A2	0.24	10.6	1.63
Cervical Spine	47.39 ±10.58	A2	0.13	2.6	2.38
Thoracic Spine	554.53 ±121.90	A2	1.82	30.8	2.13
Lumbo Sacral Joint	278.54 ± 45.82	A1	0.48	15.5	1.66
Foot	0.28 ± 0.10	A2	0.0014	0.02	1.70
Abdomen	115.84±10.71	A1	0.15	6.5	1.37
Hand	0.25 ± 0.054	A2	0.00082	0.01	2.74
Leg	136.19 ± 12.47	A2	0.15	7.6	1.35
Thigh	256.66 ± 22.67	A2	0.26	14.3	1.30
Pelvis	185.38± 19.71	A1	0.23	10.3	1.43
Forearm	0.69± 0.034	A2	0.00043	0.04	1.13
Humerus	0.54 ± 0.058	A2	0.00071	0.03	1.42
Knee	1.69±0.27	A2	0.0032	0.09	1.84

Table 3. Distribution of examination frequency and effective dose per radiograph during the period of 1998 and 2007 at the Radiological Department of UCH

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Number of Patients	14795	14451	12261	13005	13406	13007	12996	12726	12177	12006
Dose per radiograph (mSv)	0.12	0.13	0.12	0.13	0.15	0.14	0.30	0.13	0.14	0.16

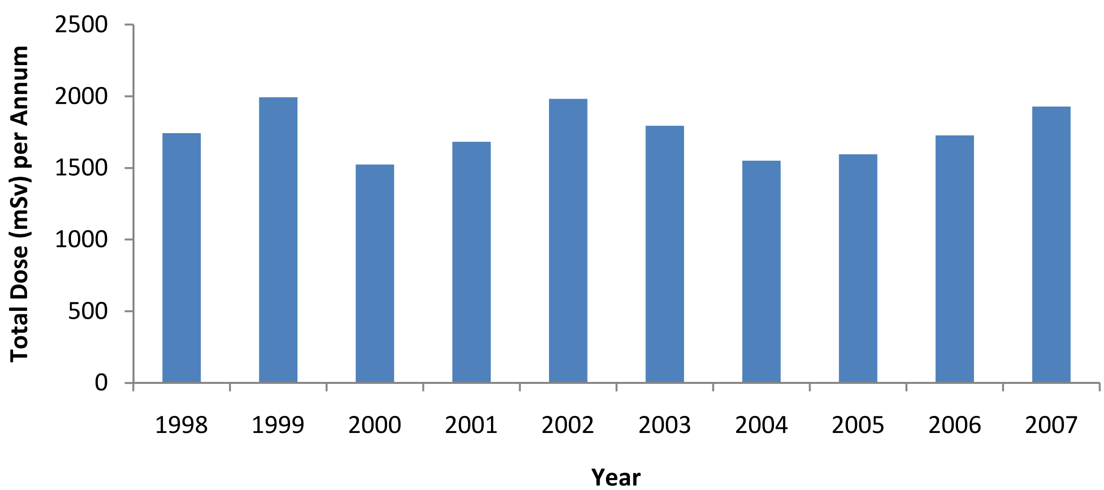

Figure 4. The estimate of total dose delivered to patient per year between 1998 and2007

The percentage of paediatric patient examined at the UCH within the period of investigation is greater than the adult patients above 60 years. This shows that more paediatric patients are exposed to ionizing radiation at UCH. Earlier study carried out on paediatric patient at this hospital indicates that the mean ESD values are generally higher than those found in UNSCEAR document and NRPB diagnostic reference levels [22]. The study on paediatric patient was carried out using high-speed films (400-600) and the equipment used was old. This could have caused high doses being delivered to the patients. Literature reports show that equipment age contribute to patient dose [34, 35, 36]. Furthermore, the use of the newly developed rare earth screen is required especially during paediatric examinations. It is essential and could be helpful in dose reduction. This is because the rare earth screens help to reduce radiation exposure required to produce a diagnostic radiograph. It could lead to the usage of lower mAs setting and shorter exposure times [37]. The rare earth intensifying screen has high x-ray absorption coefficient, high x-ray to light conversion effectiveness [38] and it increases the x-ray tube life [39,40].

Paediatric patients are more sensitive to ionizing radiation, have longer life expectancy than the adult patients (resulting in a larger window of opportunity for expressing radiation damage), possess smaller body size (result in higher radiation doses) and are more prone to radiation risks [41]. Early childhood exposure carries an enhanced radiation risk and the probability of induction of cancer especially leukemia is about two to three times as high as in adults [42]. Therefore with a large number of paediatric patient being examined at the hospital modern facilities for x-raying and adequately trained personnel with knowledge of methods of dose reduction are required to man the paediatric x-ray room to ensure dose optimization. Among the three categories of patients at the UCH (dependant, working age group and retirement age group), the working age group is the most frequently examined (about 66%) of the population during the period of ten years investigated. This could be assumed to be the trend in the country because patients visit the hospital from all over Southwestern, central and Midwestern Nigeria. This trend implies that the most productive set of people in the country are being exposed to ionizing radiation in the country. It is also evident that the same age group is in their most active reproductive stage of their lives. This portends a great danger to the present and coming generation. Analysis of epidemiological data show that; for radiation exposure in middle age, most radiation-induced cancer risks do not, as often assumed, decrease with increasing age at exposure. This observation suggests that promotional processes in radiation carcinogenesis become increasingly important as the age at exposure increases. The study concluded that radiation-induced cancer risks after exposure in middle age may be up to twice as high as earlier estimated and could have implications for both occupational exposure and radiological imaging [43].

The distribution of patient examined as a function of the age group is reported in Figure 6. The distribution appears to be normally distributed. This also indicates that the age group (21 - 60) is the group most frequently examined than the two other groups (dependant).

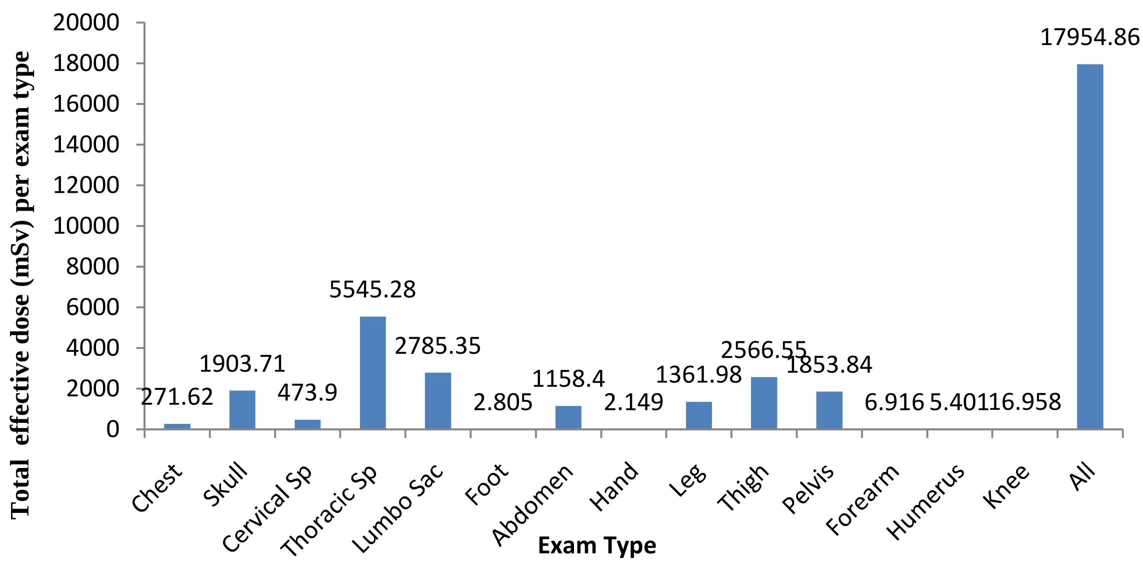

Figure 5. Histogram of effctive dose (mSv) contribution of each examination type and the total dose between 1998 and 2007 in coventional radiology at UCH

Comparison of result in Figure 6 (this study) with available result in literature on CT examinations carried out in Aosta Valley, Italy [44] shows that there is an overlap between the result of the studies in the age group with highest frequency of examination. In the report on CT from Italy, 70% of the examinations are related to the patient older than 50 years. However, the result of CT is skewed to the right indicating that more of the dependant population than the working group is being exposed.

Table 4: Distribution of examination as function of age group at UCH

Age group (year)	Total number of examinations	Percentage contribution of each age group (%)
0-10	11687	8.55
11-20	13951	10.22
21-30	22581	16.54
31-40	23539	17.24
41-50	23836	17.45
51-60	19748	14.46
61-70	12628	9.25
71-80	6473	4.74
81-90	1596	1.17
91-100	525	0.38
0-20*	25638	18.77
21-60**	89704	65.69
61-100***	21222	15.54

* Peadiatric patient (dependant), **Adult (working age group), *** Adult (Retirement age in Nigeria-dependant)

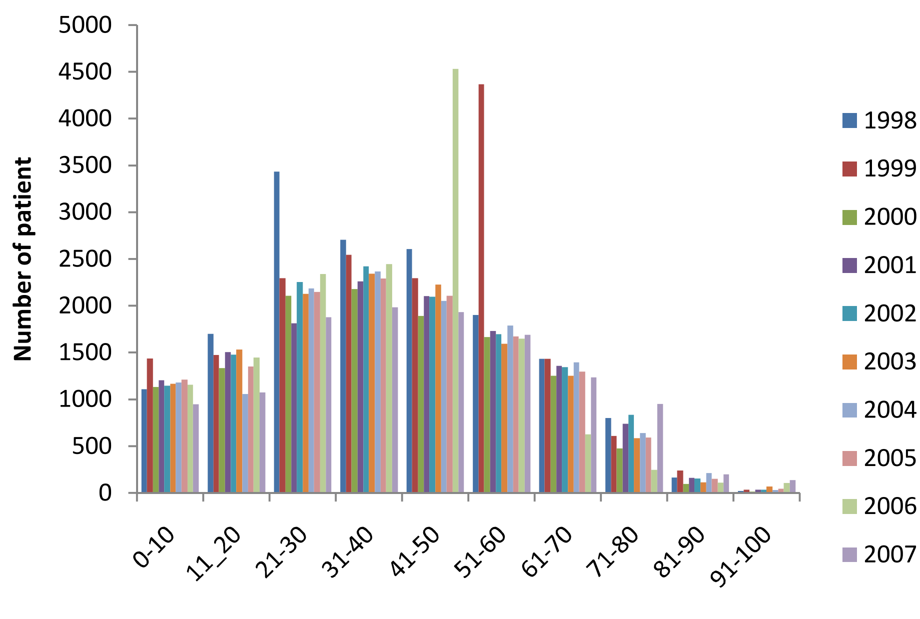

Figure 6: Graph of number of patient against different age groups

Conclusion

This study presents information about the number and the distribution of conventional x-ray examinations performed at the Radiology Department of the University Teaching Hospital (UCH) from 1998 to 2007. Estimates of the effective dose were obtained from the frequency of examinations. The distribution of examination indicates that the most frequently performed examination is chest x-ray examination. The study indicates that dose data of the extremity are grossly unavailable. This necessitated the measurement of dose to these parts of the body since excessive dose to the bone marrow could result in an increase in risk of leukemia. The study points to the fact that the productive population is being delivered more radiation doses, therefore it is necessary to apply the principle of justification and dose optimization at this hospital in order to reduce the incidence of cancer to this group of the population.

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