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RESEARCH ARTICLE

EVALUATION OF PATIENT ABSORBED DOSE OF CONVENTIONAL X-RAYS USING DIRECT METHOD IN SOME HOSPITALS IN PORT HARCOURT, NIGERIA

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ABSTRACT

In this work, entrance skin dose was used to evaluate patient absorption dose of conventional X-rays using a direct method in some hospitals in Port-Harcourt, Rivers State. The method was based on the guidelines established by the NBIRR protocols. Questionnaires were distributed to two (2) X-ray facilities in Port Harcourt, Rivers State with code names GHC and UPTH in order to obtain information about X-ray machines such as type, model, waveform, filtration, etc., and radiological parameters used during two common diagnostic procedures such as Kilo Peak Voltage (kVp) and Milli Ampere Times Seconds (mAs). The two types of X-ray exams considered were chest (PA) and abdomen (AP). The weight and height of each patient totaling one hundred (100) were measured and two TLD badges were used on each patient to record the patient's dose while a TLD reader (Harshaw 6600) was used to read the chips and an oven (annealing machine) was also used to anneal the chips. Mean ESD (mGy) was estimated and compared with International Established Reference Values. It was found that the mean ESD (mGy) for chest (PA) was 1.40, which is higher than the standard values of 0.17, 0.40, and 0.30 for USA, IAEA, and NRP, respectively. While the mean ESD (mGy) for the abdomen (AP) was found to be 1.62, which was higher than the standard values of 0.56, 1.02, and 102 for the USA, IAEA, and NRP, respectively. Generally, it was observed that there was a wide variation in patient dose for the two different types of x-ray examinations, which could be attributed to several factors, such as the type of x-ray machine used, radiographic techniques.

KEYWORDS

Absorbed Dose; Entrance Skin Dose (ESD); Radiation; Transmitted Dose

1. INTRODUCTION

Radiology has earned a vital place in modern medicine where it has become one of the most powerful and indispensable diagnostic tools (Davies et al., 1997). It has been estimated that about 30 % – 50 % of critical medical decisions are based on x-ray examinations (Talpos-Niculescu et al., 2021). In diagnostic radiology, x-rays are used to reveal the shape, size, position, and distribution of matter in organs of interest, thereby revealing the condition of such organs. X-rays are used to show the bones of mammals to diagnose possible problems that are not obvious when viewed from outside the body. This is usually done in common diagnostic regions of the body (chest and abdomen). The images are thus formed and appear on the photographic film or screen (Doyle et al., 2005).

The International Commission on Radiological Protection (ICRP), in its 1999 recommendation, recommended that all medical exposures should be subjected to the radiation safety principles of justification and optimization. Optimization requires that the magnitude of radiation doses be as low as reasonable and achievable (ALARA) social and economic factors are taken into consideration. In 1982 and 1983, the National Radiation Laboratory (NRL) in New Zealand carried out a survey of patient doses for chest radiography, and it was revealed that there was a wide range of doses for the same procedure. Eckardt and Lind also conducted research on the influence of patient size on organ doses in diagnostic radiology at the University of Munich Neuherberg, Germany using a phantom (Eckardt and Lind, 2015). Four diagnostic examinations were considered (skull, thorax, abdomen, and pelvis).

In Nigeria, Ajayi and Oresegun in 1994 conducted a survey of gonadal and chest skin entrance doses to patients at the University College Hospital in Ibadan using the thermoluminescence dosimetry method. The research was aimed at determining skin-entry doses to both the gonads and chests of patients during chest examinations, and it was found that the mean skin-entry gonadal dose is 0.02 mGy and the chest dose is 0.20 mGy, which is within the recommended dose of 2.00 mGy recommended by the ICRP for members of the public (ICRP communication 60, 1999). In their study of dose evaluation for pediatric chest x-ray examinations in Brazil and Sudan, they found that children are more susceptible to ionizing radiation and that ESD varies widely from hospital to hospital. This variation may be due to the performance of the equipment and processor, radiographic techniques used in each hospital (kVp, mAs, and filtrating), film screen combination, and the skill of the staff and patient size.

Therefore, in order to facilitate measurement and optimization of patient dose, ESD was recommended by the International Atomic Energy Agency as the dose descriptor for guidance level in diagnostic radiography. Because of its simplicity and indication of the maximum skin dose, it was used for the periodic checking of the patient doses (Ogbole, 2010). Also in 2001, the International Commission on Radiological Protection (ICRP) publication 85 recommended recording the patient radiation dose in the medical record for certain procedures. The record can be valuable for quality assurance purposes as well as for patient safety. Another reason

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for evaluating skin doses is that the dose is greatest at the surface, where radiation enters the body, and the skin is therefore the main organ for which there is a possibility of deterministic effects. (Safi et al., 2017). Therefore, the quantity that is generally of greatest importance in routine measurement of the patient dose in diagnostic radiology is termed the entrance skin (surface) dose (Green et al., 1999).

For dosimetry in x-ray radiography, it is convenient to measure the ESD at the point where the x-ray central beam first strikes the body (Rong et al., 2001). The quantities measured are, for example, the entrance skin dose in radiography. Kerma-area-product (KAP) in fluoroscopy and Dose-Length-Product (DLP) in computed tomography (CT). The damage or benefit to organs or tissues is therefore a function or measure of the entrance skin dose. The likelihood and severity of radiation-induced skin injury to the patients as a whole are functions of the highest dose at any point on the patient's skin (Neves et al., 2012). For the abovementioned reasons, measurement or estimation of ESD is of major importance. Threshold doses differ among individuals as a result of biological variation (the differences among individuals in the threshold dose required to produce a deterministic effect). The threshold dose for skin injury also differs in different anatomic sites in the same individuals (Neves et al., 2012).

Therefore, ESD is expected to be age-dependent and also depend on technical data of the x-ray equipment. The effects of exposure to ionizing radiation are dependent on the age at which exposure occurs (Launder et al., 2002). The patient dose will be dependent upon the performance of the x-ray equipment, which will have been checked at installation (Green et al.,1999). Entrance Skin Dose is used for simple plain radiography examinations and is directly measured on a sample of patients using thermoluminescent dosimeters (TLDs). As in the case of hospitals under study), entrance skin dose can be estimated from the tube's radiation output with a standard backscatter factor. As a minimum, for the calculation of ESD, the required data includes tube identification details and values for focus to film distance (FFD), the tube potential (kV), and current (mAs) for each type of examination (George et al., 2003).

The purpose of this study is to determine the patient absorbed dosage of conventional x-rays at several hospitals in Port Harcourt, Nigeria, using a direct technique. This research looked at a total of 100 patients. Sixty-five percent of the 100 patients had chest (PA) examinations and thirty-five percent had abdomen (AP) tests. The goal of this research is to assess the patient's entry skin dosage for the chest and abdomen so that standards of good practise may be established and checked to help improve patient protection. It's important to evaluate the danger by estimating the absorbed dosage to the patient's tissues and organs, so diagnostic procedures can be appropriately justified, and incidents of accidental overexposure can be thoroughly explored.

2. METHODOLOGY

Thermoluminiscent dosimeter (TLD) chips were used to record patients' doses during this survey. A TLD reader was used to read the chips (Harshaw, 6600). An oven (annealing machine) was used to anneal the chips. Black polythene was used to house the chips. The kVp and mAs values for each examination were read directly from the control panel of the x-ray machine. Machine specific data such as model number, inherent filtration, and manufacturer was read from the manufacturer's information written on the machine, and other data such as year of manufacture and installation of the machine, and added filtration were supplied by the radiologist. The method used for this work was based on the guidelines established by the NBIRR protocols.

During this survey, specific data such as type, model, waveform, filtration, film-screen combination, and output were recorded. In this research, only the posterior anterior (PA) view was considered. For each patient, the following parameters were recorded: sex, age, weight, height, focus-to-skin distance (FFD), field size, chest thickness, kVp, and mAs. The two types of x-ray examination that were considered are chest (PA) and abdomen (AP). The weight of each patient was measured with a personal scale with a maximum capacity of 120 kg and an error of +1.2 kg for weights below 60 kg and +2.0 kg for weights above 60 kg. Patient height was taken with a two-meter rule marked on the wall. A summary of the technical parameters of the machine used for the patients included in this project is presented in tables 1 and 2.

A total of 100 patients from GHC and UPTH x-ray centers were included in this study. Table 3 shows the summary of the patient's information such as age, weight, and height for the chest and abdomen X-ray examinations. The absorbed doses received by 100 patients were included in this study. This was gotten from the ESD and the transmitted skin dose received by the 100 patients. EDS for each patient was calculated by multiplying the patient's air kerma by a backscatter factor of 1.35, as suggested in European guidelines (EC, 1996). Following standard procedure, air kerma measurement was carried out using LIF and thermoluminescent dosimeters (TLD). The TDL chips were first exposed to a known dose of 5 mGy at the Secondary Standard Dosimetry Laboratory of the National Institute of Radiation Protection and Research (NIRPS), University of Ibadan.

It was taken to the University of Ife Department of Physics and Engineering Physics for the first calibration, then some golden chips were sorted out and the chips were brought back to NIRPS for the second irradiation. The TDL chips were calibrated at the dosimetry laboratory of the department of physics and engineering physics, Obafemi Awolowo University, Ile-Ife. The chips were annealed at 400 °C for 1 hour and cooled inside the oven at 80 °C for 18 hours before being taken into the field for measurement. The TLD reader was used at the department of physics and engineering physics, Obafemi Awolowo University, Ile-Ife, for obtaining the air kerma from the TLDs (Harshaw, 6600). Two TLD chips were placed on the skin of each patient to determine ESD and transmitted dose. The first chip was placed directly on the patient's skin at the central axis of the beam, to determine the ESD. The second chip was placed directly on the other side of the patient to determine the transmitted dose. The Absorbed dose was determined from the difference between the ESD and the Transmitted Dose.

Table 1: Specific data of x-ray machines used in the hospitals.

Item	Machine 1	Machine 2
Manufacturer	G.E.C Medical matchet x-ray, U.K	G.E.C Medical matchet x-ray, U.K
Model/Type	Allengers - 525	Allengers - 525
Year of manufacture		
Year of installation	1993	1993
Inherent filtration		1.5mm AL
Film type	Kodak	Kodak
Processor	Manual	Manual
Number of radiologist	2	2
Number of radiographer	3	3
Use of Grid	No	No
Target angle	16°	16°

Table 2: Summary of the machine parameters including the mean and range used for the examinations

Examination	kVp	mAs	FSD (cm)
Chest (PA)	87.9 (83 – 90)	24.0 (19 – 24)	165.0 (150 – 170)
Abdomen (AP)	90.0 (90 – 94)	80.0 (55 – 80)	100.0 (90 – 120)

Table 3: Machine parameters for the two examinations in Two-Tees medical center	
Generator	**Elinos 90/40**
Tube type/model no.	Allengers-525
Tube filtration mm (Al)	1
Kvp Range	
Chest (PA) Adults	70 – 75
Children	40 – 45
Abdomen Adults	90 – 94
Children	60
mAs Range	
Chest (PA) Adults	19 – 22
Children	12 – 15
Abdomen Adults	80
Children	50 – 55

Two different projections of the x-ray examination were studied: the chest (PA) and the abdomen (AP). Only cases with diagnostically acceptable images were used in this project.

Microsoft Excel was used to store and manipulate data, calculate doses, and produce tables and charts for each examination.

3. Results and Discussion

A total of 100 patients were examined in this study. Out of the 100 patients, 65 % had chest (PA) examinations and 35% had abdominal (AP) examinations. Average radiographic parameters and patient's data for the two examinations are presented in Tables 4 and 5. Tables 4 – 5 show statistical data with respect to the patient anthropometrical data, i.e., age, weight, and height of the patients and their corresponding kVp, mAs, and FSD for all the projections considered and tabulated according to adults and children. In Table 4, the average radiographic parameters and patient data for chest (PA) are presented. For adults, the average age is 36.8 years, the average height is 169.45 cm, and the average weight is 60.33 kg. The average tube voltage is 72.3 KVp, the average current-time is 20.8 mAs, and the average FSD is 168.05cm. For children, the average age is 9.6 years, the average height is 122.24 cm, and the average weight is 28.76 kg.

The average tube voltage is 43.4 KVp, the average current-time is 13.64mAs, and the average FSD is 163.04 cm. In Table 5, the average radiographic parameters and patient's data for abdominal pain (AP) are presented. For adults, the average age is 32.9 years, the average height is 169.45 cm, and the average weight is 59.5 kg. The average tube voltage is 60 KVp, the average current time is 52.07 mAs, and the average FSD is 90.0 cm. In Tables 4 and 5 below; Mean is the mean dose to patients in the group, MIN is the minimum dose in each age group, MAX is the maximum dose in each age group, The median dose is the same for each age group, The number of patients in each age group is referred to as the sample size.

Table 6 shows the absorbed dose for the chest (PA) projection for adults and children. The minimum absorbed dose for adults and children is 153.76 uGy and 132.25 uGy, respectively. The maximum absorbed dose for adults and children is 678.66 uGy and 370.92 uGy, respectively. The mean absorbed dose for adults and children is 338.09 uGy and 212.91 uGy, respectively. Table 7 shows the absorbed dose for the abdomen (AP) projection for adults and children. The minimum absorbed dose for adults and children is 252.48 uGy and 246.1 uGy, respectively. The maximum absorbed dose for adults and children is 438.72 uGy and 359.96 uGy, respectively. The mean absorbed dose for adults and children is 356.13 uGy and 287.45 uGy, respectively. Table 8 shows the ESD for the chest (PA) projection for adults and children. The minimum ESD for adults and children is 1106.353 uGy and 1106353 uGy. The maximum ESD for adults and children is 2046.94 uGy and 1658.638 uGy, respectively.

Table 4: Average radiographic parameters and patient's data for Chest (PA) projection for Adults and Children.

	Adults						Children					
	Age	Weight	Height	KVp	mAs	FSD	Age	Weight	Height	KVp	mAs	FSD
Mean	36.83	60.33	169.45	72.30	20.80	168.05	9.64	28.76	122.24	43.4	13.64	163.04
Min	20.00	50.00	160.00	70.00	19.00	163.00	7.00	26.00	110.00	40.00	12.00	160.00
Max	80.00	85.00	180.00	75.00	22.00	170.00	12.00	32.00	136.00	45.00	15.00	165.00
Median	35.00	59.00	168.50	72.00	20.50	170.00	10.00	29.00	122.00	45.00	13.00	165.00
Sample size	40.00	40.00	40.00	40.00	40.00	40.00	25.00	25.00	25.00	25.00	25.00	25.00

Table 5: Average radiographic parameters and patient's data for Abdomen (AP) projection for Adults and Children.

	Adults						Children					
	Age	Weight	Height	KVp	MAs	FSD	Age	Weight	Height	KVp	mAs	FSD
Mean	32.90	59.50	169.45	90.60	80.00	100.00	10.20	28.67	123.13	60.00	52.07	90.00
Min	22.00	52.00	162.00	90.00	80.00	100.00	07.00	25.00	110.00	60.00	50.00	90.00
Max	43.00	70.00	176.00	94.00	80.00	100.00	15.00	33.00	135.00	60.00	55.00	90.00
Median	34.00	58.00	169.00	90.00	80.00	100.00	10.00	29.00	124.00	60.00	50.00	90.00
Sample size	20.00	20.00	20.00	20.00	20.00	20.00	15.00	15.00	15.00	15.00	15.00	15.00

The mean ESD for adults and children is 1403.430 uGy and 1300.864 uGy, respectively. Table 9 shows the ESD for the abdomen (AP) projection for adults and children. The minimum ESD for adults and children is 1528.667 uGy and 1486.737 uGy, respectively. The maximum ESD for adults and children is 1794.861 uGy and 1597.789 uGy. The mean ESD for adults and children is 1621.080 uGy and 1532.165 uGy. Table 10 shows the transmitted dose for the chest (PA) projection for adults and children. The minimum transmitted dose for adults and children is 748.724 uGy and 874.753 uGy, respectively. The maximum transmitted dose for adults and children is 1606.483 uGy and 1432.235 uGy, respectively. The mean transmitted dose for adults and children is 1059.831 uGy and 1087.958 uGy, respectively. Table 11 shows the transmitted dose for the abdomen (AP) projection for adults and children. The minimum transmitted dose for adults and children is 1203.218 uGy and 1207.693uGy, respectively. The maximum transmitted dose for adults and children is 1327.576 uGy and 1300.248 uGy, respectively. The mean transmitted dose for adults and children is 1268.272 uGy and 1244.713 uGy, respectively.

Table 6: Absorbed Skin Dose for chest (PA) projection in GHC and UPTH.		
Absorbed Dose (mGy)	Adult	Children
Mean Dose	0.338	0.212
Minimum Dose	0.154	0.132
Maximum Dose	0.678	0.370
Sample Size	40.000	25.000

Table 7: Absorbed Skin Dose for abdomen (AP) projection in GHC and UPTH.		
Absorbed Dose (mGy)	Adult	Children
Mean Dose	0.356	0.287
Minimum Dose	0.252	0.246
Maximum Dose	0.438	0.359
Sample Size	20.000	15.000

Table 8: ESD for Chest (PA) projection in GHC and UPTH.		
ESD (mGy)	Adult	Children
Mean Dose	1.403	1.300
Minimum Dose	1.106	1.106
Maximum Dose	2.046	1.658
Sample Size	40.000	25.000

Table 9: ESD for abdomen (AP) projection in GHC and UPTH.		
ESD (mGy)	Adult	Children
Mean Dose	1.621	1.532
Minimum Dose	1.528	1.486
Maximum Dose	1.794	1.597
Sample Size	20.000	15.000

Table 10: Transmitted Dose for Chest (PA) projection in GHC and UPTH.		
ESD (mGy)	Adult	Children
Mean Dose	1.059	1.087
Minimum Dose	0.748	0.874
Maximum Dose	1.606	1.432
Sample Size	40.000	25.000

Table 11: Transmitted Dose for abdomen (AP) projection in GHC and UPTH.		
ESD (mGy)	Adult	Children
Mean Dose	0.356	0.287
Minimum Dose	0.252	0.246
Maximum Dose	0.438	0.359
Sample Size	20.000	15.000

There is a wide variation in the absorbed dose from patient to patient for the two projections considered in this study. For example, the highest close for the chest (PA) is 678 mGy and the lowest is 0.153 mGy. Launder et al., 2002 reported a wide variation in absorbed dose among patients. For chest (PA) and abdomen (AP), the mean is a positively skewed distribution. A similar situation has also been reported in the National Radiation Protection Board (NRPB), 1983 – 1985 survey. The mean values are compared with the international established reference dose values from the US Center for Devices and Radiological Health (CDRH) 1992, the National Radiation Protection Board (NRPB) 1994, the International Atomic Energy Agency (IAEA) 1996 and the Malaysia survey of patients' dose results in 1998. The mean values of the two projections considered in this study were compared. The entrance skin dose (ESD) of the chest (PA) and abdomen (AP) is higher than the reference dose values. Table 12: Comparison of mean ESD (mGy) with international established reference values

Table 12: Comparison of mean ESD (mGy) with international established reference values

Radiograph	Projection	Present work mean values	USA (CDRH) 1992 mean values	IAEA Basic safety standar4d (1996)	NRPB (1994)
Chest	PA	1.40	0.17	0.40	0.30
Abdomen	AP	1.62	0.56	1.02	1.02

Figure 1 - 3 shows the comparison of the mean of Absorbed Dose (mGy), ESD (mGy) and Transmitted Dose (mGy) for the two projections respectively. Figure 4 shows the comparison of the mean ESD (mGy) with International established reference values.

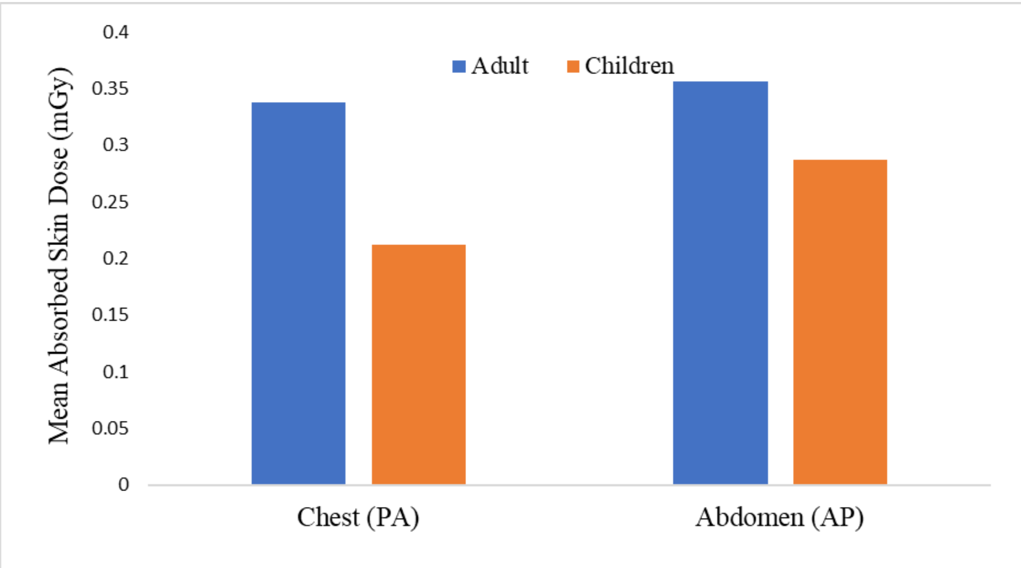

Figure 1: Comparison of mean ASD (mGy) for the two projections

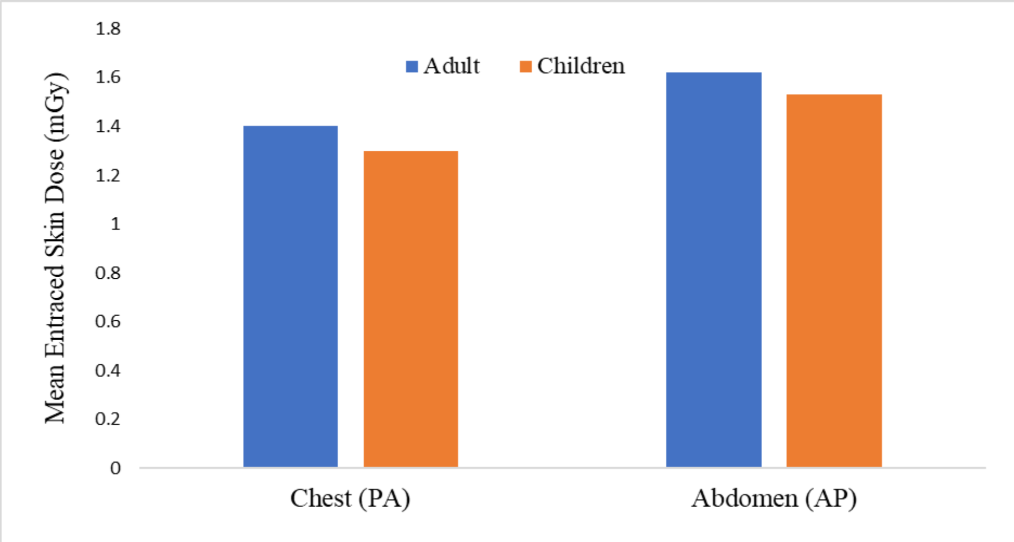

Figure 2: Comparison of mean ESD (mGy) for the two projections

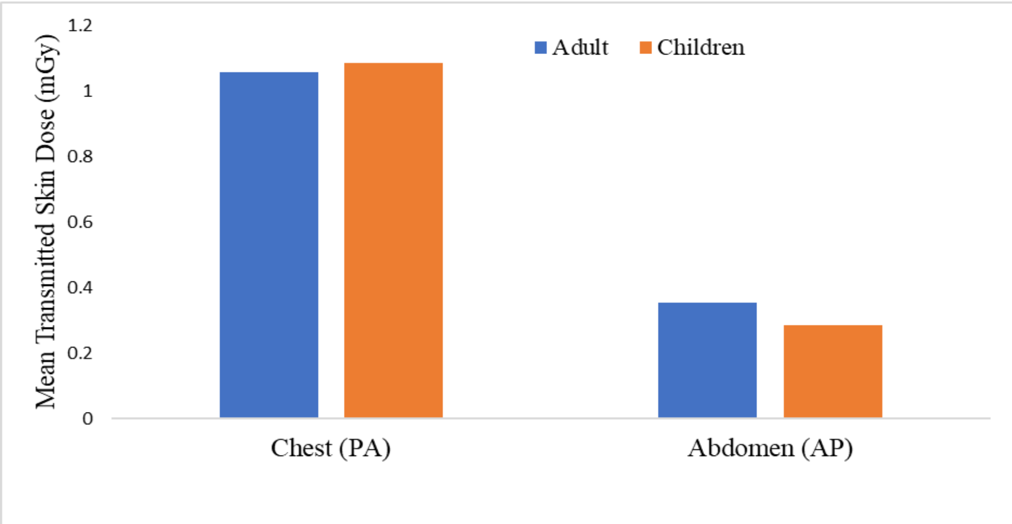

Figure 3: Comparison of mean Transmitted Dose (mGy) for the two projections

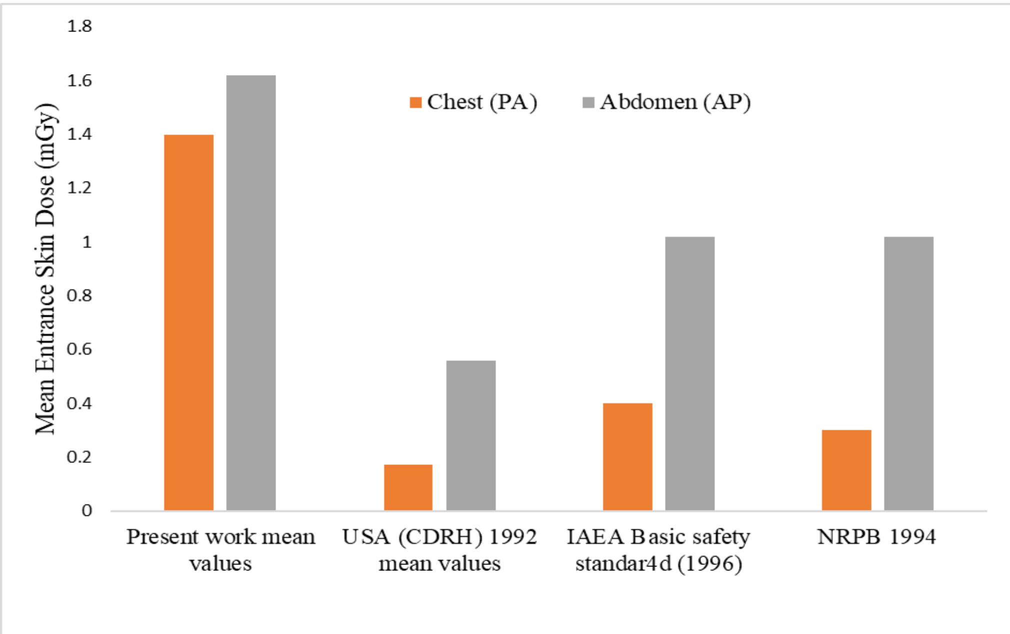

Figure 4: Comparison of mean ESD (mGy) with international Established reference Values

4. Conclusion

This work revealed a wide variation in patient dose for the two different types of x-ray examinations carried out in both GHC and UPTH, respectively. The reasons are due to the performance of the equipment, the types of x-ray machine used, the processing system, radiographic technique used for the two types of examinations, i.e., kVp, mAs, filtration, focus-to-skin distance, as well as the training and skills of the staff in the center. Generally, a wide range of exposure levels has been observed due to the large variety of radiographic techniques, processing conditions, and film-screen speeds. In this research, mAs have been identified with high dose values. The mAs used for the chest (PA) examination range from 19 – 22 mAs for adults to 13 – 15 mAs for children. For the abdomen (AP) examination, mAs used are 80 mAs for adults and it varies between 50 and 55 mAs for children.

The most important parameter considered by the technicians is the image quality. Therefore, high mAs values are normally used in order to obtain good image contrast, causing the delivery of a higher, avoidable dose to the patients. Another factor that contributed to the wide variation in dose is the focus-to-skin distance (FSD). Generally, the lower the FSD, the higher the dose. The FSD for the two types of examinations it varies widely; it is between 165 – 170 cm for chest (PA) projection and 80 cm for abdomen (AP) projection. For all age ranges, GHC and UPTH presented the highest doses for chest (PA) radiography. This may be due to the low sample size (number of patients) included in this survey at the hospital due to the equipment age or processing condition. It may also be due to the high mAs used and the low skill of the staff.

These factors: high mAs, low kVp, low FSD, irregular patient size, processing condition, low skill of staff, low sample size, and the age of the x-ray generators all contributed to making the absorbed dose evaluated in this work higher than the standard reference levels. The percentage increase in organ doses at the beam entrance is stronger than the percentage rise in organ doses a little thickness distant from the beam entrance because x-ray attenuation is proportional to the thickness of the medium. In general, the organ dosage rises as the thickness of the organ grows. This rise is greatest for organs closest to the beam entrance, such as the eyes or skin, and gradually diminishes as one moves deeper into the body. It should be remembered that because of the increased patient thickness and the resulting increased.

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