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Radiation Doses and Radiological Risks Associated with Radiodiagnostic Examinations at a Tertiary Institutional Hospital, Ondo State, Nigeria

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ABSTRACT: The benefits of conventional x-rays imaging procedures in diagnostic radiology cannot be overemphasized despite modern advances in imaging technologies. This is because millions of conventional radiographs are produced annually in attempts to carry out diagnosis; however, like other fields of human endeavor, it has its attendant risks. Hence, the objective of this paper was to evaluate radiation doses and radiological risks associated with radiodiagnostic examinations at a tertiary institutional hospital in Ondo State, Nigeria, using appropriate standard techniques. This study examined the quality control test of the facility used at our institution, the dose delivered to patients during examinations, and the level of risks arising from the imaging. During the quality control tests, the mean filtration factor of 0.81 recorded is greater than the recommended limit of 0.75. This implies that there is adequate beam filtration; however, tube potential requires a little adjustment to enhance the quality image and optimized dose. The results of ESD for adult patients showed that the values in the following procedures: Chest AP/PA, Lumbar LAT, Knee AP/LAT, Thoracic Spine AP, and Abdominal AP are less than HPA (UK) and Canada published data. Additionally, the ESDs received by pediatrics in Head AP and Abdomen AP/PA are lower than the published values measured in Ethiopia (Jimma and Addis Ababa). The results of effective doses (for adults) recorded in Lumbosacral LAT, Cervical Spine AP, Thoracic Spine, Abdominal AP, and Hip are lower than the published values from Canada, the UK, and Serbia. Results of the inherent risk descriptions indicate that Chest AP/PA for adults and pediatrics have minimal risks (1 in 100,000), while other examinations such as Head AP, Lumbosacral LAT, Cervical Spine, Thoracic Spine, Abdomen AP, and Hip indicate negligible risks (1 in 1 million). Results presented indicate that the risks are to a greater extent negligible, but there is room for improvement in the practice.

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Imaging techniques such as conventional radiography, computed tomography, and fluoroscopy used in diagnostic radiology are still very important in developing countries. This stems from the benefits accruing from their usefulness in non-invasive diagnosis of diseases and abnormalities in humans and animals. However, these serve as the major sources of radiation doses to patients and personnel. The man-made source of radiation is estimated to contribute about 88% and 99% to collective effective doses in the US and UK, respectively (NCRP, 1987; Tung *et al*., 2001). Although there are risks associated

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with radiation exposures during imaging and treatment processes, there are potential benefits accruable from the use to patients. This made it acceptable in medical practice (Lee *et al*., 2010). However, research has shown that the probability of adverse effects is assumed to be directly proportional to the level of exposure without a dose threshold (NRPB, 2001). Different principles are used to protect patients and the public from excessive exposures to radiation. These include the principles of justification, optimization, and dose limitation. The principle of justification implies that the benefit from an imaging procedure must exceed the risk resulting from the examination. Moreover, the principle of optimization, otherwise known as the ALARA principle, indicates that the dose required to produce an acceptable diagnostic image must be as low as reasonably achievable (Rasuli *et al*., 2016). To achieve the goal of dose reduction, the National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP) were motivated to set up guidelines for limiting the amount of radiation received by patients, personnel and the public (Lee *et al*., 2010). Radiation dosimetry is a tool used to limit dose. This involves a method of regular dose measurement of a population to determine the typical dose of an individual. This helps to obtain information about the dose received and the likely reason for the pattern of dose received. The dose measured is compared with the established diagnostic reference dose level. The dose received is reviewed where necessary taking into account the factors responsible for the excess doses observed where it is necessary. Asides the fact that radiation doses are found to be greater than the reference dose level, there are variations in doses for similar procedures performed in the same hospitals (or in different hospitals). In an attempt to prevent this common variation in doses measured to a certain degree, ICRP introduced a dose optimization tool known as diagnostic reference level (DRLs) in the ICRP, 1996 report (ICRP, 2001). The International Atomic Energy Agency (IAEA) has also recommended a guidance level for the radiation dose to typical adult patient (IAEA, 1996). Guidance level was intended to act as the threshold to trigger investigation or corrective actions in ensuring optimized protection of patient and maintaining appropriate level of good practice (Tung *et al*., 2001). The corrective action can be taken on the personnel or equipment (remedial or suspension). Through the determination and the use of guidance level, a reduction in the dose level was recorded in the United Kingdom (NRPB, 1996). The reference level is derived from distribution of dose for average patient observed in a large institution, a region or a country. Dose measurement is essential in every diagnostic and therapeutic facility; however, this is difficult in developing countries where equipment is expensive. As a result of this, many hospitals fail to carry out quality control tests of their facilities. This trend could put the personnel and the public at risk. Hence, the objective of this paper was to evaluate radiation doses and radiological risks associated with radiodiagnostic examinations at a tertiary institutional hospital, in Ondo State, Nigeria.

MATERIALS AND METHODS

Data examined in this study were obtained from the Radiology Department of the University of Medical Sciences Teaching Hospital, Ondo between 2020 and 2021. Machine parameters such as tube potential (kVp), tube load (mAs), focus-to-skin distance (FSD), and focus-to-film distance (FFD) were recorded during the routine diagnostic examinations of the patient. Patient parameters such as the height, weight, age and the gender of patient were also recorded. Since dose measurement in a given facility is an essential part of a quality control program (Charnock *et al*., 2013), this was calculated in this study with the aid of equation 1 and OrgDose software (Osei and Barnett, 2009).

$$ESD = Op_{kVp-80,mAs-10}\ x\ \left(\frac{100}{FSD}\right)^2\ x\ mAs\ x\ BSF\ x\ \left(\frac{kV}{80}\right)^2 \quad (1)$$

Where ESD is the entrance surface dose (mGy), $Op_{kVp-80,mAs-10}$, the x-ray tube output (mGy/mAs) was measured at a distance of 100cm, tube load of 10 mAs and tube potential of 80 kVp. The backscatter factors ($BSFs$) of adult (1.35) and children (1.30) were used for the calculations of entrance surface doses.

Radiation output measurement was done by using a calibrated DIAVOLT UNIVERSAL Meter. This is a non-invasive kVp (practical peak voltage-PPV), dose and time measuring device for acceptance tests and quality control of diagnostic x-ray equipment. The meter was used to check the adequacy of filtration and to determine the half-value layer (HVL) of the x-ray tube. This was determined at different voltages (50-120 kVp). The constancy of the x-ray tube, radiation output, kVp and time accuracy were examined. The half-value layer was determined by using equation 2. A 1 mm aluminum plate was attached to the exit surface of the collimated x-ray tube with adhesive tape. The detector was placed at a distance of 100 cm, exposed to radiation using tube potential in the range of 50 and 120 kVp and recorded the radiation output. This procedure was repeated in the same range of kVp without the 1 mm

Al filter in place, and the radiation outputs were also recorded.

$$HVL = \frac{\tau ln(\frac{1}{2})}{\ln M} \quad (2)$$

Where τ is the thickness of the filter used (1 mm Al);

$$M = \frac{mR_{Al}}{mR_{NAl}} \quad (3)$$

From equation 3, mR_{Al} is the exposure when 1 mm Al filter is in place and mR_{NAl} is the exposure value measured when the filter is not placed at the exit of the x-ray tube. The adequacy of filtration was determined with the help of equation 3 (Papp, 2022). The constancy of the x-ray output was checked with a DIAVOLT UNIVERSAL meter.

By setting the tube potential to 80 kVp and 10 mAs, the exposure was recorded. The exposure was repeated for the same set of parameters several times. The coefficient of variation (*CV* as seen in equation 4) was obtained from the standard deviation (SD) and mean ($\bar{x}$) of the repeated readings (equation 5) of the set tube potentials (80 kVp, 10 mAs) (Kumar and Rehani, 1995). The coefficient of variation serves as a relative measure of dispersion. It assesses the degree of dispersion of a data set relative to its mean (Webster, 1998).

$$CV = \left(\frac{SD}{\bar{x}}\right) 100 \quad (4)$$

$$\bar{x} = \sum_{i=1}^{N} \frac{x_i}{N} \quad (5)$$

A comparison of results obtained in this work with those of UK (Health Protection Agency- HPA) and other published data for different projections was carried out.

Effective dose (E) was introduced by ICRP to provide a summation of radiation doses to tissues and organs for radiological protection (ICRP, 1991). This dosimetric parameter is a useful measure for comparing risks from various sources of exposure including those resulting from diagnostic procedures and background radiation.

In this study, the effective dose was determined from ESD and National Radiological Protection Board (NRPB) conversion coefficient (Hart *et al*., 1994); ICRP Report 60; ICRP Report 103 (ICRP, 1990, ICRP, 2007).

RESULTS AND DISCUSSION

Results in Table 1 show that the relationship between the tube potential and the HVL (columns 1 and 2) is linear and it assumes the form shown in equation 6

$$H = QK + \mu \quad (6)$$

Where H is the HVL, Q the slope (0.032) of the graph, K the range of tube potential used in diagnostic radiology and μ (0.622) is the intercept on the H axis.

Table 1: Half value layer and F factor determined at different tube potential

Tube potential (kVp)	HVL (mm Al)	Δm_R (mGy)	$F = \frac{m_{R2}}{m_{R1}}$
50	2.104	22.2	0.7293
60	2.676	29.0	0.7718
70	3.054	37.2	0.7969
80	3.225	48.7	0.8066
90	3.578	56.8	0.8239
100	3.883	66.2	0.8365
120	4.524	83.8	0.8830
Mean	**0.8069**		

The half-value layers (HVL) determined for the range of kVp (50 kVp – 120 kVp) used are shown in Table 1. These increased steadily from 2.104 to 4.524 mm Al. This result is in agreement with the published value determined at 2.3 mm Al in the work of Kumar and Rehani (1995). The last column of Table 1 shows the filtration factor (F factor) for the x-ray facility examined. The F factor determined in the range of tube potentials considered is between 0.7293 (50 kVp) and 0.8830 (120 kVp) with a mean of 0.8069.

Table 2: Shows the constancy of x-ray output, tube potential and timer at a distance of 1metre

S/N	Tube output (mGy)	Tube potential (kVp)	Timer (μs)
1	0.2536	84.8	55.6
2	0.2536	84.8	55.6
3	0.2540	84.8	55.3
4	0.2540	84.6	55.3
5	0.2543	84.8	55.3
6	0.2547	84.6	55.6
Mean	0.2540	84.7	55.5
CV (%)	0.15	0.12	0.29

If adequate filtration is present the factor obtained should fall within 0.5 and 0.75. If this is less than 0.5, the beam filtration is inadequate and if it is greater than 0.75, excess filtration exists (Papp, 2002). The mean value recorded in this study is 0.8069, an

indication of excess filtration. This is acceptable; however, it is attributable to pending x-ray tube failure resulting from excess tungsten deposits on the tube resulting from filament evaporation. The filtration quoted on the x-ray tube is 0.9 mm Al, but there is an indication that there is excess filtration which can be said to result from tungsten deposits on the inside of the x-ray tube. Adequate filtration reduces the patient dose burden resulting from low-energy photons (Allisy-Robert and Williams, 2007; Papp, 2002). Table 2 shows the constancy of the x-ray tube output and timer at a constant tube potential of 80 kVp and tube load of 10 mAs.

In the study, the mean radiation output measured was 0.02540 mGy/mAs at 80 kVp and 10 mAs with a coefficient of variation of 0.15%. The mean output was used to calculate the entrance surface dose (ESD) with the help of OrgDose V2 software. The coefficient of variation is within the acceptable value of 5% (Kumar and Rehani, 1995). Also, the coefficient of variation for both the tube potential (kVp) and the timer (T) is 0.12 % and 0.29 % respectively. The mean variation of the measured tube potential is 4.5 kVp and the percentage difference of ± 5.94% obtained is higher than the required ±5.0 % tolerance limit. This implies that a little adjustment of tube potential is required; otherwise, the Radiographer can take into consideration the difference during the imaging processes and adjust the tube potential appropriately to prevent suboptimal contrast, optical density and excessive patient doses (Papp, 2002). Fig. 1 shows the difference between filtered and unfiltered tube output (in mGy) for different tube potentials used in diagnostic radiology. The difference in radiation dose to the air (ΔD, between the unfiltered and filtered output) increases with tube potential (with a range of 0.1728 - 0.6522 mGy). However, the percentage of the undesirable radiation dose removed from the beam decreases with an increase in kVp (as shown in Fig. 2). This implies that the percentage of low doses is higher at lower tube potential than at higher potential. This could be attributed to more energetic photons produced at higher potential. Low doses (found on the left-hand side of Figure 2) could be useful in soft tissues such as breast tissues. The percentage reduction in the dose could be higher if extra filters are used. Table 3 shows that the range of mean age and weight of adult patients examined at our institution during this study are 32.9 - 43.2 yrs and 52.04 - 63.69 kg respectively. The mean weight of an adult falls below that of a standard man (70.1 kg). Table 4 shows the range of age (8.00 – 15.80 yrs) of pediatric patients who underwent routine radiographic examinations at the time of this study, while the range of the measured weight is 43.49 - 52.08 kg.

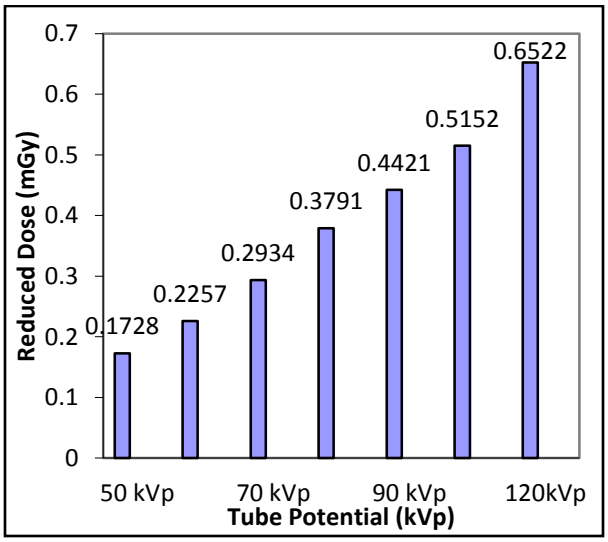

Fig. 1: Relationship between reduced dose due to filtration (1mmAl)and tube potential

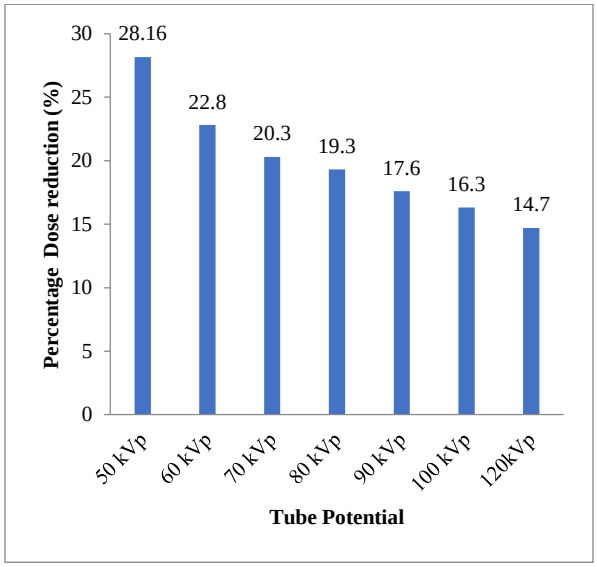

Fig. 2: Percentage Dose Reduction as a function of Tube Potential (with filter of 1 mm Al)

Table 5 shows the comparison of the tube potential (kVp) and tube load (mAs) measured in this work with those of HPA (UK). The result of kVp used for imaging Head AP recorded is higher than that of HPA (UK). The tube potentials recorded in this study are lower than those of HPA in Chest AP/PA, Lumbosacral LAT, Cervical Spine, Knee LAT, Thorax, and Abdomen AP. The results of tube loads (mAs) show that higher values are found in the following projections: Chest AP/PA, Head AP, Cervical Spine and knee LAT.

Table 3: Summary of adult patients' characteristics examined during the investigations

Examinations	Age (yr) SD(range)	Height(m) SD(range)	Weight (kg) SD(range)
Chest AP	41.4± 16.5 (18-80)	1.67±0.062 (1.52-1.88)	58.07±7.14(40.8-82.3)
Head AP	32.9±12.44(19-52)	1.73±0.132(1.59-1.94)	59.85±11.46(46.0-90.5)
Lumbosacral LAT	39.0±17.09 (18.0-75.0)	1.64±0.08(1.55-1.88)	63.69±6.56(44.9-75.0)
Cervical Spine AP	34.0±10.19(23.0-52.0)	1.62±0.063(1.53-1.67)	54.11±9.45(40.8-71.3)
HSG	34.4±2.75(31.0-39.0)	1.62±0.049(1.57-1.67)	55.8±5.24(47.3-62.9)
Knee	32.25±11.98(18.0-52.0)	1.64± (1.50-1.88)	60.7±12.6(44.9-82.3)
Thoracic Spine	43.2±13.80 (24.0-50.0)	1.65±0.0782(1.56-1.74)	56.18±0.0782(40.8-66)
Thorax	36.8±13.81(24.0-52.0)	1.67±0.0746 (1.57-175)	52.04±8.26(40.8-62.6)
Abdomen	40.75±17.07(18.0-62.0)	1.61±0.069(1.53-1.74)	55.06±8.35(40.8-71.8)
Ankle	34.9±16.14(18.0-85.0)	1.63±0.093(1.52-1.89)	60.3±17.33 (40.8-73.8)
Hip	47.8±17.4(24.0-70.0)	1.73±0.132(1.54-1.94)	59.85±12.07 (46.0-80.5)
Barium Swallow	45	1.56	47

Table 4: Summary of pediatric patients' characteristics examined during the investigations

Examinations	Age (yr)	Height (m)	Weight (kg)
Chest AP	8.00±4.55(3-17)	1.52±0.18(1.12-1.73)	49.00±12.02(32.0-70.0)
Head AP	15.00±2.16(12.00-17.00)	1.59±0.054(1.53-1.64)	52.08±6.163(45.0-60.0)
Lumbosacral LAT	15.8±1.26(14.0-17.0)	1.66±0.0780(1.56-1.75)	50.70±5.09(44.9-57.0)
Cervical Spine AP	12.8±3.19(9.0-17.0)	1.57±0.088(1.14-1.72)	50.02±6.19(31.0-60.0)
Abdomen AP	12.5 (9-16)	1.57 (15.4-1.61)	48.50 (45-52)
Ankle	12.6±3.20(9.0-16.0)	1.51±0.042(1.52-1.64)	43.49±5.35 (35-50)

Table 5: Summary of mean, standard deviation and range of examination technique parameters from adult patients' conventional radiographic examinations

Examinations	Number of patients (N)	Tube potential (kVp-this work)	Tube potential (kVp) Ref L	Tube load (mAs-this work)	Tube load (mAs) Ref. L
Chest AP/PA	55	75.3±5.38 (65-90)	83(62-104) AP	12.9±4.61 (10-28)	5(0.3-315) AP
Head AP	10	84.2±12.77 (60-100)	72(69-83) AP/LAT	34.4±8.42 (25-80)	20(1-246)AP/PA
Lumbosacral LAT	28	74.1±6.61 (55-90)	78(65-`109) AP	26.6 ±7.43 (11-40)	30(1-403) AP/PA
Cervical Spine AP	10	58.3±7.07 (52-70)	64(58-69)	16.1± 10.62 (6.3-40)	5(1-100) AP
HSG	10	74.6±8.19 (68-90)	--	17.24±11.69 (10-48)	--
Knee AP/LAT	16	58.06±8.09 (42-75)	61(52-68) AP 61(52-72) LAT	7.86 ±2.23 (5-11)	4(1-125) AP 4(1-96)
Thoracic Spine AP	5	59.8±6.90 (50-65)	--	21.0±5.78 (11-25)	--
Thorax	5	70.2 ±3.56 (65-80)	78(65-102) AP	19.4±7.96 (11-28)	30(1-403) AP
Abdomen AP	16	70.9±4.87 (63-80)	76(60-94)	25.0±8.64 (11-52)	41 (1-440) AP
Ankle	18	58.9±14.33 (50-70)	--	5.87±3.95 (5-7)	--
Hip	10	60.6±0.58 (50-70)	--	30±6.48 (13-36)	--

Ref. L: Hart *et al*., 2012, HPA (UK)

Table 6: Summary of examination technique parameters from pediatric patients' conventional radiographic examinations

Examinations	Number of patients (N)	Tube potential (kVp-this work)	Tube potential (kVp) Ref I	Tube load (mAs-this work)	Tube load (mAs-Ref.I
Chest AP/PA	12	64.6±11.48 (50-80)	70-90	18.54±9.13 (11-32)	1.4
Head AP	7	80.7±10.18 (65-90)	65-75	31.14±5.11 (25-40)	14
Lumbosacral LAT	4	76.5±2.38 (75-80)	--	31.0±2.00 (28-32)	--
Cervical Spine AP	8	63.4±8.38 (50-75)	65-75	25.06±15.84 (6-40)	5
Abdomen	2	50.0	60-70	30(28-32)	16
Ankle	7	54.29±4.11 (50-60)	55	7.11±2.68 (5-11)	2

Ref I: Earl *et al*., 2023 (Australia)

Table 7: Mean, standard deviation and range of entrance surface doses (ESD) of adult patients examined during conventional radiographic examinations

Examinations	ESD (mGy) This work	ESD (mGy) Ref. B	ESD (mGy) Ref. A	ESD (mGy) Ref. C
Chest AP/PA	0.72 ± 0.322 (0.27-1.64)	3.2 (AP) (0.8-8.3)	0.94(LAT) 0.14 (PA)	0.30 (PA)
Head AP	2.68 ± 0.65 (1.10-3.85)	1.8(AP/PA) (0.3-3.5)	1.67 (AP/PA)	2.2 (AP/PA)
Lumbosacral LAT	0.48 ± 0.206 (0.17-1.05)	4.6(LS, AP) (1.1-12.6)	6.28(LAT)	7.5 (LAT)
Cervical Spine AP	0.57±0.610 (0.25-2.14)	0.4(AP) (0.1-1.0)	0.25 (AP)	
HSG	0.39 ± 0.319 (0.15-1.19)	--	--	--
Knee AP/LAT	0.18 ± 0.0813 (0.0735-0.300)	0.26(0.33)AP/PA 0.09-0.9(0.1-0.9)	--	
Thoracic spine LAT	0.84 ± 0.302 (0.557-1.150)	--	1.65 (LAT)	--
Thoracic spine AP	0.76 ± 0.0472 (0.451-1.118)	2.9(AP) 0.7-16	2.21 (AP)	--
Abdomen AP	1.07 ± 0.337 (0.616-1.71)	3.6 (AP) (0.1-11)	1.82 (AP)	2.9 (AP)
Ankle	0.162 ± 0.0574 (0.0870-0.291)	--	--	--
Hip	1.01 ± 0.494	--	0.87 (AP)	--

Ref. A: Osei and Darko, 2013 (Canada) Ref. B: Hart *et al*., 2012 HPA (UK) -2010 Review, Ref C: Suliman and Mohammedzein, 2014 (Sudan), Ref. C:EU,

However, Table 6 shows that the results of the recorded mAs (for pediatrics) used in Lumbosacral LAT, Thorax and Abdomen AP are lower than those obtained from published data on HPA (UK). The tube potentials and tube loads selected for the examinations of pediatric patients were compared with results from Australia. The range of mean tube potential found in Head AP and Cervical spine in this study is comparable with that of Australia, while the range of Chest AP in this work is lower than that of Australia. Table 7 is the result of the mean, standard deviation and range of entrance surface dose (ESD) of adult patients examined. It shows a comparison of ESD calculated with the published data of HPA (UK), Canada and Sudan (Africa). The results of Lumbosacral LAT (0.48 mGy), knee AP/LAT (0.18 mGy), Thoracic Spine LAT (0.84 mGy) Thoracic spine AP (0.76 mGy) and Abdomen LAT (1.07 mGy) in Table 7 indicate that the ESD of Chest AP/PA is lower than that of HPA (UK), Canada and Sudan. However, the ESD in this study is higher than those published in the UK, Canada and Sudan in Head AP (2.68 mGy) and Cervical spine (0.57 mGy). The relatively higher doses reported here could be attributed to the higher value of exposure parameters used during the examination. The higher doses recorded in Head AP and Cervical Spine AP call for dose optimization to ensure that the dose delivered to the patient is as low as reasonably achievable (ALARA).

Table 8 shows the mean doses, standard deviation and range of pediatrics ESD measured in this study and compared with the published dose data recorded in Ethiopia, the UK and Sudan.

Doses calculated in this study show that the ESD obtained in Chest AP/PA (0.51 mGy) is lower than the published data of Ethiopian Hospital (Jimma) and higher than the one measured in Addis Ababa (another Ethiopian Hospital). For Head AP, the pediatrics dose measured is lower than that of Ethiopia (Jimma and Addis Ababa), but higher than the published NRPB and Sudan data. In Abdomen AP, the doses recorded in this study are lower than published Ethiopian (Jimma and Addis Ababa) and NRPB data. However, the Abdomen AP dose is higher than the published Sudanese hospital data. A comparison of pediatrics ESD with adult indicates that, the pediatrics doses recorded in Lumbosacral LAT (0.64/0.48 mGy), and Cervical spine (0.90/ 0.57 mGy) are higher than those of adult patients. This calls for restraint in the examination of pediatrics. The dose received by pediatric patients must be optimized, and be mindful of the radiosensitive nature (Earl *et al*., 2022), age and body size of pediatric patients. It is important to avoid unnecessary exposure resulting from poor and repeated imaging.

Table 9 is a comparison of mean effective doses of adult patients calculated from the exposure parameter used during the examinations in our facility based on the ICRP 103 Report. Effective dose is considered a good indicator of radiological risk (ICRP, 2007; ICRP, 1990; Osei and Darko, 2013). It was created to

provide a dose quantity that is related to the probability of health detriment due to stochastic effects from exposure to low doses of ionizing radiation (Martins, 2007).

In this study, the effective dose calculated in Chest AP (0.166 mSv) is higher than all published data shown in Table 9 (Osei and Darko, 2013; Ciraj *et al*., 2005; HPA-UK) for which comparisons were made. The effective doses for other examinations: Head AP (0.0351 mSv), Lumbosacral LAT (0.00279 mSv) Cervical spine (0.0035 mSv), Thoracic spine (0.0164 mSv), Abdomen AP (0.060 mSv) and Hip (0.032) mSv are lower than the published data. For effective doses of pediatric patients, the value estimated in Chest PA is 0.51 mSv. This is lower than the published values (Ethiopia-Jimma). The effective dose for Head AP (1.38 mSv) is less than the published data from Ethiopia (Jimma and Addis Ababa) and NRPB (HPA) but is higher than the published data from Sudan (Africa). A similar trend is found in the Abdomen examination (0.57 mSv).

The effective doses calculated (adult and pediatric patients' examination) in this study lend insight into the radiological practice at our institution, and the information provides an opportunity to improve the imaging technique, dose optimization and to ascertain the level of risks the examinations involve.

In an attempt to communicate effectively the risks involved in exposure during imaging, it is important to use clear and understandable language. This is done by using the appropriate terminology (Martins, 2007; Earl *et al*., 2022; Calman, 1996) that can be understood by all, such that, patients and caregivers can choose the mode of imaging they want based on their perception of the level of risks involved during the examinations. Knowledge of the risks and their choice helps to allay their fear.

Table 8: Mean, standard deviation and range of entrance surface doses (ESD) of pediatric patients examined during conventional radiographic examinations

Examinations	ESD (mGy) This work	ESD (mGy) (Ethiopia, Jimma)[x]	ESD (mGy) (Ethiopia, Addis Ababa)[y]	ESD (mGy) NRPB+	ESD (mGy) Brazil*
Chest AP/PA	0.51	5.87	0.12	--	--
Head AP	1.38	11.97	1.52	1.10	0.81
Lumbosacral LAT	0.64	--	--	--	--
Cervical Spine AP	0.90	--	--	--	--
Abdomen AP/PA	0.57	11.12	1.55	1.20	0.45

Ethiopia- Jimma: Zewdu *et al*., 2017, Teferi *et al*., 2011: Ethiopia- Addis Ababa, + Hart *et al*., 2000 (NRPB); *Mohammadain *et al*., 2009 : Brazil.

Table 9: Comparison of mean effective doses (E) of adult patients examined during conventional radiography

Examinations	E (mSv) This work (based on ICRP document)	E (mSv) Ref.[A]	E (mSv HPA, UK Ref B	E (mSv) Ref. C
Chest AP/PA	0.166	0.066	0.014 (PA) 0.038 (LAT)	0.04 (AP) 0.03 (LAT)
Head AP	0.0351	0.0202	0.020 (PA) 0.016 (LAT)	--
Lumbosacral LAT	0.00279	0.13	0.169	0.04
CervicalSpine AP	0.0035	0.023	0.018	0.06
Thoracic spine LAT	0.0164	0.32	0.144	--
Thoracic spine AP	0.0702	0.22	0.238	0.14
Abdomen AP	0.0601	0.14	0.429	--
Hip	0.032	0.034	0.087	--

Ref A: Osei and Darko, 2013 (Canada), Ref B: Hart *et al*., 2012, HPA (UK), Ref C: Ciraj *et al*, 2005 (Serbia)

Table 10: Comparison of mean effective doses (E) of pediatric patients examined during conventional radiography

Examinations	E (mSv) This work (based on ICRP document)	E (mSv)- (Australia) Ref. D
Chest AP/PA	0.122	0.024
Head AP	0.0123	0.028
Lumbosacral LAT	0.0209	--
Cervical Spine AP	0.0365	0.034
Thoracic spine LAT	--	0.144
Thoracic spine AP	--	0.035
Abdomen AP	0.0657	0.178

Ref. D: Earl *et al*., 2022 (Australia)

In this study, the terminologies for estimating the level of risk were adapted from the works of Martins (2007) and Earl *et al*. (2022). Effective doses calculated (using OrgDose V2 software) and reported in Table 9 and Table 10 were used for adult and pediatric examinations respectively. We also calculated the total nominal cancer risk of adult patients by using the same software.

The inherent risks depicted by the effective dose of adult patients for different examinations considered are as follows: Chest PA (Minimal risk: 1 in 100,000), Head AP, Lumbosacral LAT, Cervical spine, Thoracic LAT, Thoracic spine, Abdomen AP, Hip (Negligible risk: 1 in 1million). For pediatric patients examinations, the following is the summary of patient risk: Chest AP/PA (Minimal risk: 1 in 100,000), Head AP, Lumbosacral LAT, Cervical spine AP and Abdomen AP (Negligible risk: 1 in 1 million).

Table 11 and Table 12 are the results of the nominal risk and detriments estimates from adult and pediatric patient dose information in Tables 9 and 10.

Table 11: The results of total nominal risk of cancer and detriment associated with the examination (adult patients) based on ICRP 103

Examinations	Increase nominal cancer risk and detriment (all cancer)	
	Total nominal cancer risk ($x10^{-5}$)	Risk of radiation detriment ($x10^{-5}$)
Chest AP/PA	3.29	1.20
Head AP	0.695	0.253
Lumbosacral LAT	0.0552	0.0201
Cervical Spine AP	0.0693	0.0252
Knee AP/LAT	--	--
Thoracic spine LAT	0.326	0.118
Thoracic spine AP	1.39	0.505
Abdomen AP	1.19	0.433
Hip	0.634	0.230

Table 12: The results of total nominal risk of cancer and detriment associated with the examination (pediatric patients) based on ICRP 103

Examinations	Increase nominal cancer risk and detriment (all cancer)	
	Total nominal cancer risk ($x10^{-5}$)	Risk of Radiation detriment ($x10^{-5}$)
Chest AP/PA	2.42	0.878
Head AP	0.291	0.106
Lumbosacral LAT	0.414	0.150
Cervical Spine AP	0.723	0.263
Abdomen AP	1.30	0.473

The range of the total cancer risk is 0.055 x 10^{-5} (Lumbosacral) to 3.29 x 10^{-5} (Chest PA), while the range of the risk of radiation detriment is 0.0201 x 10^{-5} ((Lumbosacral LAT) to 1.2 x 10^{-5} (Chest PA). The values are extremely small and may not be understood by patients and caregivers. This may be understood by a Physician (Radiologist), Medical Physicists and Radiographers who are experts in the field of radiation applications and protection.

The range of total nominal cancer risk for pediatric patients is 0.291x10^{-5} (Head AP) -2.420 x10^{-5} (Chest PA), while the risk of radiation detriment ranged between 0.101 x10^{-5} (Head PA) and 0.878 x 10^{-5} (Chest PA).

Since risk communication on the one hand assists experts handling radiation applications and protection through dose optimization, and on the other side helps the public to understand the extent of risks involved when they are examined. It is important to adopt the best terminologies that express the extent of the risks involved during their examinations and treatments. This mode of communication allays their fears and informs the choice of examination mode during their treatment.

Conclusion: Quality control tests and dose monitoring are essential in diagnostic radiology. This is to ensure that the justified examinations are carried out without additional dose burden to personnel and patients while maintaining quality images. In this study, both the quality control test of the facility used at our institution and dose delivered to patients during routine examinations were monitored. The likely risks were also estimated to ascertain patients' level of safety.

The results of this study showed that adequate filtration was used. However, tube potential requires adjustment to ensure quality images and optimized doses. Results of the inherent risk descriptions indicate that Chest AP/PA for adults and pediatrics have minimal risk (1 in 100,000), while other examinations such as Head AP, Lumbosacral LAT, Cervical Spine, Thoracic spine, Abdomen AP and Hip indicate negligible risks (1 in 1 million).

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