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# Real-time Radiological Practice: Dose Descriptors and Fatal Risk of Cancer Estimates in Adult Patient from Most Frequent Radiological Procedures in Ondo State, Nigeria

**Fredrick O. Adeyemi[1]*, Christopher J. Olowookere[2]**

**[1]Department of Physical Sciences, Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria**

**[2]Department of Physics, University of Medical Sciences, Ondo -Town, Ondo State, Nigeria**

***Corresponding Author**

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## ABSTRACT

**Background**: The inspiration in establishing dosimetric methods for radio-diagnosis is based on the curiosity to estimating health risks to patient subjected to a given type of examination, using ionizing radiation. So, to establish strong relation between risks and benefits of a new diagnostic modality, study assessed real-time radiological practice by evaluating dose descriptors and fatal risks of cancer from most frequent radiographs.

**Patients and Methods:** Mathematical approach was adopted to determine dose to 3,587 adult patients while PCXMC version 2.0, was employed in estimating their effective dose equivalent.

**Results:** Low ESD and DAP recorded as 0.618 mGy (Ankle) and 0.124 Gycm$^2$ (Hand AP) while high as 6.263 mGy (LS LAT) and 2.866Gycm$^2$ (LS AP). The average estimated effective doses across radiographs confirmed Knee joint LAT and Ankle AP recording same low value of 0.001mSv and high as 0.822mSv from LS LAT. The range factor for the probability of fatal risks of cancer evaluated across radiographs was 10.142. Thus, low average lifetime risks of cancer ratio recorded as 1:27,778(Ankle AP) and high for LS LAT as 1:2,739, and the risks of cancer inducement estimates from this study fall within very low and low category of risks. Comparison of study results with some published values show good geometry but revealed high spread in values across radiographs studied. The study trend demonstrates the significance for awareness creation among the radiographic staff and the policies maker on quality control testing of equipment and adjustment of protocols.

**Conclusion:** The need to bring the radiological practice in the State in line with National and European guidelines on quality criteria for diagnostic radiological images becomes very essential, for good radiological practice to be embraced.

**Keywords**: Real-time radiological practice, Dose descriptors, fatal risks of Cancer, Radiological procedures

## INTRODUCTION

X-rays usage in modern medical practice is requisite, and has been clinically used for diagnosis and therapeutic purposes. This, continuously play a leading and significant role in spite of other imaging techniques both in developed and developing areas, globally. [1][2]. However, x-ray examination had constituted the most important man made source of radiation exposure of the world population [3]. Although, x-ray procedure are design to provide net benefit, the potential for radiation induced injury to the patient, staffs and the environment, and the deleterious effect increased with dose. The contribution of diagnostic radiology towards the annual radiation dose to population has been well documented [4]. So, understanding the absorbed dose and factors that affect these, becomes very noteworthy [5].

In view of the important benefit to patients from properly conducted medical exposures, the radiological protection concern focused on reduction of the irrational exposure, which are examination that are either unlikely to be helpful to the patient management or involve doses that are not 'As Low As Reasonably Achievable' (ALARA) in order to meet specific clinical objectives. So, reduction of unnecessary exposure will transform to reduction of deleterious effects associated with the use of the atom, and this embrace the justification for optimization process in patient dosimetry.

In diagnostic radiology, assessment of patient dose and quality control test on x-ray machine are required periodically to ensure compliance with recommendations [6][7][8]. So, the major lesson learned from these valuations is the recognition of the significant variations in patient's dose among radiological department for same type of examinations [9], and these variations, be seen as justifying dose measurement in order to optimize diagnostic practice [10]. Thus, the need for radiological practice and dose to patient assessment arises, especially among the identifiable radiation least monitored areas, as specified by the Nigerian Nuclear Regulation Authority (NNRA). So, this study assesses radiation dose descriptors and fatal risks of cancer from frequently performed x-ray examinations and compare its average estimated parameters values, as a standard to patient from real-time radiological practice in the state with some local and internationally published values. Comparison of obtainable values becomes relevant, since there is no acceptable local diagnostic reference limits established in the state, as the time of study for evaluation.

## MATERIALS AND METHODS

### 2.1. Study area

Ondo state is a developing state within the Southwestern region of a developing country, Nigeria. It lies amid longitudes $4^0$ 30" and 6" east of the Greenwich meridian, $5^0$ 45" and $8^0$ 15" north of the equator, meaning that it entirely in the tropics. It has a population of about 3.46 million, comprising of 1.75 and 1.72 million for male and female respectively as at 2006 (Ondo State bureau of statistics) with land mass / area of about 14,788.732 $km^2$ [11]. It made up of 18 local government areas and healthcare establishment, comprises of Federal medical centre, State specialist/general hospitals, Comprehensive health centres, and

Registered private hospitals which sum up to 223 in numbers. Present in each local government of the state is at least one specialist/general hospital, comprehensive, and basic healthcare centres. In the state, no assurance that patient protection during routine x-ray examinations has been given much attention nor any local diagnostics reference limits, established.

### 2.2. Study sample and sampling technique

This study was conducted in seventeen (17) selected hospitals, spread across eleven (11) of the 18 local governments in the State, with appropriate Health Research and Ethics Committee approval issued from the State Ministry of Health (Reg. no. ODMOHREC 06/07/2021). The selected hospital includes eleven (11) public (i.e. State Specialist/General Hospital (SSH)-7, Federal Medical Centre (FMC) – 2, Teaching Hospital (GFHDC)-1, a higher institution of learning Health Centre (OAUSTECH)-1) and six (6) registered private hospitals coded as indicated in Table 1, with criteria for choice of diagnostic centre includes good

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representation of x-ray procedure studied, geographical location, and hospital workload which are recommendable [12]. Centre's x-ray machine information was considered appropriately (Table 1) and the exposure parameters used during clinical examinations were duly recorded. Statistical population of 3,587 adult patients exposed for different radiographs [13], considered and respective patient's characteristics information recorded. The basic methodology adopted for this study was indirect dosimetry approach, supported by IAEA and ICRP in the absent of the use of thermoluminiscense dosemeter (TLD). So, quantities required for ESD and DAP collated for clinically examined patient including their exposure factors as tube loading (mAs), tube potential (kVp), focus to skin distance (FSD), focus to film distance (FFD), beam size (field size area) together with x-ray machine beam output $D_o$ ( ). The beam output of each machine were determined using x-ray test device (Noninvasive evaluation of radiation output, model 4000 TM Victoreen Inc. USA), and as at the time of this study, the calibration of the x-ray test device as issued by the manufacturer was still valid. The reproducibility and linearity of the x-ray machines were checked at focus to detector distance of 1metre with constant tube voltage potential of 80 kVp (voltage at which anode current is assumed to be stabled) and tube loading of 10 mAs. The measured beam output in was converted to using conversion factor of $8.73\times10^{-3}$ [13], and values (beam output) was used alongside others in equations 1 and 2 for patient ESD and DAP estimates. So, this study determined radiation dose of patient that has undergone radiographic examinations and judged locally at each selected centre by individual radiographer to have achieved the required image quality for diagnosis. Here, the performance of the manufacturer's cassettes with screen-film combination speed ranged (between 200 and 800) was not assessed, since study aimed at estimating patient dose based on their anatomical data and exposure parameters used during clinical examination.

### 2.3. Patient dose assessment

Study's patient entrance skin surface dose (ESD) was calculated using [14] [15]:

$$ESD = D_o\,(mGy/mAs).q\,(mAs).\,(FDD/FSD).\,(kV/80)^2.\,f^{-1} \qquad 1$$

Where, f, the backscattered factor used ('f' for standard adult =1.35), 'kV' and 'q' are the tube potential voltages and tube loading respectively, used during clinical examination. The respective dose-area product (DAP) was determined using [16]:

$$DAP = D_o\,(mGy/mAs).\,q\,(mAs)\,.\,(A)_{FSD}(cm)^2 \qquad 2$$

Where, $(A)_{FSD}$ is the cross sectional area of the x-ray beam on patient skin, which was determined by [16]:

$$(A)_{FSD} = (FSD/FFD)^2\,A\,(FFD) \qquad 3$$

Where, A (FFD) is the field size area. However, equation 3 holds, when inverse square law is not considered during quality control measurement and consequently, measured DAP on patient's skin. Accredited dosimetric software (PCXMC version 2.0), for calculating patient dose in medical x-ray examinations, designed by STUK (Radiation and Nuclear Safety Authority, Helsinki, Finland) was employed to estimates patient's effective doses (ED). The software generate x-ray spectrum, based on the real input parameters (kVp, anode angle setting, total filtration, etc). During stimulation, maximum energy setting was 150 keV for the required number of photons. The dose calculation method by the software was based on Monte Carlo stimulation, which was in accordance with the stochastic model of interactions between photons and matter. So, PCXMC calculated effective dose (ED) to patient, using anatomical data from the mathematical phantom models, based on tissues weighting factors of ICRP publication 103[17]. The required input data for these calculation includes: definition of all projections (location and size of the radiation field and projection angle) and the exposure factors related to different x-ray examinations. The performance and stimulation of each x-ray projection was based on standard guidelines. On inputting the required data, resultant effective doses (ED) at the radiation field were obtained for every projection for each examination, subject to anode angle setting of $10^0$ and average filter length of 2.5mmAl which was made constant. Selected skin and focus points was made constant for each radiograph by sex. Subsequently, calculated ESD was converted to tissue dose equivalent ($H_T$) using conversion factor of 1.06 [8], which was used to assessed probability of fatal cancer incidence for each radiograph by sex and averaged over sexes, using [18]:

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Where, $R_f$ is the probability of fatal risk of cancer incidence and the risk of fatal cancer inducement for adult population ($5.5\times10^{-5}$ $mSv^{-1}$). Patient related data were collated during clinical examination, to provide real-time feedback on relative magnitudes to the radiographer during process and influence the conduct of the procedure, so as to collate the quantity of the most interest (AAPM, 2002) [19]. So, result presented in this study was made averaged over groups by sex and averaged over sexes for the representation of the state result at 95% CL, suitable for risk analysis and diagnostic dose reference limit creation [17].

# RESULTS

Table 1(a): X-ray machines specific radiographic data for Group A selected centres studied

| Hospitals | X-ray tube model | Year of Installation | Filter length (mmAl) | Beam Output (µGy/mAs) | Film type | Film screen speed | Servicing frequency |
|---|---|---|---|---|---|---|---|
| SSHK | Ralco (Static) | 2005 | 2.5 | 44.71 | Kodak | 200 | On intervention of repair |
| SSHR | Ralco (Static) | 2005 | 2.5 | 46.55 | Kodak | 200 | On intervention of repair |
| SSHO | Ralco (Static) | 2005 | 2.5 | 40.10 | Kodak | 200 | On intervention of repair |
| SSHA | Ralco (Static) | 2005 | 2.5 | 49.05 | Kodak | 200 | On intervention of repair |
| SSHID | Ralco (Static) | 2009 | 2.5 | 39.82 | Kodak | 200 | On intervention of repair |
| SSHON | Ralco (Static) | 2005 | 2.5 | 51.42 | Kodak | 200 | On intervention of repair |
| SSHIGB | Ralco(static) | 2010 | 2.5 | 48.22 | Kodak | 200 | On intervention of repair |
| FMCO | Ralco(mobile) | 2013 | 2.0 | 38.59 | Kodak | 400 | Yearly |
| FMCA | Ralco(static) | 2013 | 2.5 | 43.11 | Agfa | 200 | Yearly |
| OAUSTECH | GEC Medical(static) | 2014 | 1.5* | 74.28** | Kodak | 400 | On intervention of repair |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| GFHDC | Roentgen 501 (siemen) (static) | 2009 | 2.5 | 25.05 | Carest Ream | 800 | Bi-annually |

Table 1(b): X-ray machines specific radiographic data for Group B selected centres studied

| Hospital | X-ray tube model | Year of installation | Filter length (mmAl) | Beam output (µGy/mAs) | Film type | Film screen speed | Servicing frequency |
|---|---|---|---|---|---|---|---|
| HSMCA | Rountge 501 (125kv) static mAs | 2013 | 2.5 | 35.78 | Agfa | 400 | Yearly |
| BNMRSO | Reta practice (philips) mobile (125kV, 500mAs) | 2011 | 2.0 | 51.10 | Kodak | 200 | Yearly |
| NHMO | GEC (MX-4) static 125kV,500mAs | 2004 | 1.7* | 45.35 | Kodak | 200 | Yearly |
| KMCA | Philip Capasitor Discharge mobile (100kV) | 2012 | 1.5* | 45.91 | Agfa | 400 | Bi-annually |
| MEDRO | Mediroll-4, Neodic fnomax (medicor) static 125 kV , 500mAs | 2015 | 2.5 | 35.47 | Carest ream | 800 | Quarterly |
| TCHO | Roentge (sienens) static 125kV, 500mAs | 2013 | 2.5 | 37.44 | Agfa | 400 | Bi-annually |

Note: All centre x-ray machine studied were single phase with either 1 or 2 pulse/s, and used grid (r = 12/ 40 ).

*X-ray machine with low filter length;

**X-ray machine with High beam output (Recommended beam output for a single phase x-ray machine generally ranged as [(4.0 ± 1.5) = (35.92 ± 13.10) (µGy)/mAs)] [20] [21].

Table 2: Patients' characteristics information by sex, averaged over sexes and radiographs, presented in mean (male and female), and averaged over sexes in mean and SEM (in bracket)

| Radiograph | Sex | | | Age (yrs.) | | | Weight ($W_T$) (kg) | | | Height ($H_t$) (cm) | | | BMI ($kgm^{-2}$) | | | Depth (tcm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Both | Male | Female | Both | Male | Female | Both | Male | Female | Both | Male | Female | Both | Male | Female | Both |
| **Chest PA** | 221 | 349 | 570 | 40.5 (7.5) | 35.5 (11.5) | 38.0 (2.5) | 63.3 (5.1) | 56.4 (4.3) | 59.9 (3.5) | 159.9 (7.5) | 154.9 (7.9) | 157.4 (2.5) | 24.8 (0.4) | 23.5 (0.6) | 24.2 (0.7) | 22.5 (0.4) | 21.5 (0.3) | 22.0 (0.5) |
| **Chest AP** | 33 | 43 | 76 | 28.3 (4.1) | 42.6 (8.5) | 35.0 (7.2) | 58.1 (0.0) | 50.6 (0.0) | 54.4 (3.8) | 161.7 (0.0) | 158.3 (0.0) | 160.0 (1.1) | 22.1 (1.9) | 20.2 (2.0) | 21.2 (1.0) | 21.4 (1.0) | 20.2 (1.0) | 20.8 (0.6) |
| **ABD AP** | 83 | 140 | 223 | 31.6 (3.6) | 30.3 (2.8) | 31.0 (0.7) | 63.9 (0.9) | 64.2 (7.0) | 64. (0.2) | 159.6 (8.5) | 158.8 (0.6) | 159.2 (0.4) | 25.3 (2.4) | 25.5 (2.6) | 25.4 (0.1) | 22.6(0.5) | 22.7 (1.2) | 22.7 (0.1) |
| **Pelvis AP** | 38 | 80 | 118 | 46.5 (0.0) | 36.5 (1.6) | 41.5 (5.0) | 63.7 (2.5) | 60.8 (17.7) | 62.3 (1.5) | 160.1 (8.2) | 155.2 (6.0) | 157.7 (2.5) | 24.9 (1.6) | 24.8 (5.4) | 24.9 (0.1) | 22.6 (0.2) | 22.1 (2.9) | 22.4 (0.3) |
| **Chest PA** | 221 | 349 | 570 | 40.5 (7.5) | 35.5 (11.5) | 38.0 (2.5) | 63.3 (5.1) | 56.4 (4.3) | 59.9 (3.5) | 159.9 (7.5) | 154.9 (7.9) | 157.4 (2.5) | 24.8 (0.4) | 23.5 (0.6) | 24.2 (0.7) | 22.5 (0.4) | 21.5 (0.3) | 22.0 (0.5) |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chest AP** | 33 | 43 | 76 | 28.3 (4.1) | 42.6 (8.5) | 35.0 (7.2) | 58.1 (0.0) | 50.6 (0.0) | 54.4 (3.8) | 161.7 (0.0) | 158.3 (0.0) | 160.0 (1.1) | 22.1 (1.9) | 20.2 (2.0) | 21.2 (1.0) | 21.4 (1.0) | 20.2 (1.0) | 20.8 (0.6) |
| **ABD AP** | 83 | 140 | 223 | 31.6 (3.6) | 30.3 (2.8) | 31.0 (0.7) | 63.9 (0.9) | 64.2 (7.0) | 64. (0.2) | 159.6 (8.5) | 158.8 (0.6) | 159.2 (0.4) | 25.3 (2.4) | 25.5 (2.6) | 25.4(0.1) | 22.6(0.5) | 22.7 (1.2) | 22.7 (0.1) |
| **Pelvis AP** | 38 | 80 | 118 | 46.5 (0.0) | 36.5 (1.6) | 41.5 (5.0) | 63.7 (2.5) | 60.8 (17.7) | 62.3 (1.5) | 160.1 (8.2) | 155.2 (6.0) | 157.7 (2.5) | 24.9 (1.6) | 24.8 (5.4) | 24.9 (0.1) | 22.6 (0.2) | 22.1 (2.9) | 22.4 (0.3) |
| **Pelvis LAT** | 38 | 80 | 118 | 46.5 (0.0) | 36.5 (1.6) | 41.5 (5.0) | 63.7 (2.5) | 59.5 (16.4) | 61.6 (2.1) | 160.1 (8.2) | 156.2 (7.0) | 158.2 (2.0) | 24.9 (1.6) | 24.8 (5.4) | 24.9(0.1) | 34.5 (0.8) | 31.7 (2.6) | 33.1 (1.4) |
| **Skull (AP/PA)** | 40 | 26 | 66 | 24.8 (3.5) | 41.4 (1.3) | 33.1 (8.3) | 51.4 (0.4) | 56.7 (7.0) | 54.1 (2.7) | 154.2 (6.0) | 150.4 (3.2) | 152.3 (1.9) | 21.7 (1.5) | 24.0 (2.1) | 23.4(1.7) | 18.8( 0.3) | 17.9 (1.2) | 18.4 (0.5) |
| **Skull LAT** | 11 | 3 | 14 | 25.2 (3.2) | 40.1 (4.8) | 32.7 (7.5) | 56.8 (5.8) | 63.1 (0.6) | 60.0 (3.2) | 155.7 (7.5) | 153.5 (0.0) | 154.6 (1.1) | 23.4 (0.2) | 27.0 (0.1) | 25.2(1.8) | 16.1 (9.3) | 11.2 (7.2) | 13.7 (2.5) |
| **Hand AP** | 83 | 124 | 207 | 21.2 (0.9) | 33.8 (7.2) | 27.5 (6.3) | 62.6 (5.4) | 54.1 (6.1) | 58.4 (4.3) | 160.2 (7.0) | 146.0 (3.5) | 153.1 (7.1) | 24.7 (1.8) | 25.6 (4.1) | 25.2(0.5) | 8.1 (0.2) | 6.7 (1.5) | 7.4 0.7) |
| **Knee Joint (LAT)** | 146 | 139 | 285 | 43.1 (4.1) | 29.6 (8.6) | 36.4 (6.8) | 58.6 (3.6) | 55.1 (0.1) | 56.9 (1.8) | 162.3 (7.1) | 158.7 (11.4) | 160.5 (1.8) | 24.8 (2.5) | 22.2 (3.2) | 23.5(1.3) | 14.7 (0.4) | 11.3 (1.2) | 13.0 (1.7) |
| **LSJ AP** | 102 | 191 | 293 | 47.5 (0.5) | 53.1 (1.1) | 50.3 (2.8) | 71.2 (0.9) | 65.3 (3.0) | 68.3 (3.0) | 162.1 (1.0) | 161.7 (6.4) | 161.9 (0.2) | 27.1 (0.0) | 25.0 (0.8) | 26.1(1.1) | 23.7 (0.1) | 22.7 (0.1) | 23.2 (0.5) |
| **LSJ LAT** | 102 | 191 | 293 | 47.5 (0.5) | 53.1 (1.1) | 50.3 (2.8) | 71.2 (0.9) | 65.3 (3.0) | 68.3 (3.0) | 162.1 (1.0) | 161.7 (6.4) | 161.9 (0.2) | 27.1 (0.0) | 25.0 (0.8) | 26.1(1.1) | 34.7 (5.1) | 34.9 (9.1) | 34.8 (0.1) |
| **Thoracolumbar PA** | 47 | 80 | 127 | 29.8 (6.8) | 46.6 (7.5) | 38.2 (8.4) | 54.9 (0.9) | 59.5 (2.8) | 57.2 (2.3) | 159.3 (5.1) | 152.3 (7.3) | 155.8 (3.5) | 21.9 (2.4) | 26.0 (3.7) | 24.0(2.1) | 21.0(0.5) | 22.4 (1.1) | 21.7 (0.7) |
| **Thorax PA** | 56 | 43 | 99 | 34.5 (8.5) | 35.9 (2.1) | 35.2 (0.7) | 53.8 (0.1) | 58.0 (7.2) | 55.9 (2.1) | 161.9 (6.6) | 155.7 (8.7) | 158.8 (3.1) | 20.8 (2.7) | 24.5 (5.7) | 22.7(1.9) | 20.7 (0.7) | 21.8 (2.0) | 21.3 (0.6) |
| **LS AP** | 79 | 115 | 194 | 45.6 (3.5) | 38.8 (0.3) | 42.2 (3.4) | 60.9 (0.7) | 63.2 (4.9) | 62.1 (1.2) | 167.1 (4.1) | 158.7 (0.6) | 162.9 (4.2) | 21.9 (0.9) | 25.1 (1.8) | 23.5(1.6) | 21.6 (0.2) | 22.5 (0.8) | 22.1 (0.5) |
| **LS LAT** | 79 | 115 | 194 | 45.6 (3.5) | 38.8 (0.3) | 42.2 (3.4) | 60.9 (0.7) | 63.2 (4.9) | 62.1 (1.2) | 167.1 (4.1) | 158.7 (0.6) | 162.9 (4.2) | 21.9 (0.9) | 25.1 (1.8) | 23.5(1.6) | 33.4 (2.6) | 34.4 (3.8) | 33.9 (0.5) |
| **Shoulder AP** | 63 | 52 | 115 | 24.1 (2.9) | 29.1 (6.1) | 26.6 (2.5) | 54.4 (0.8) | 55.9 (4.4) | 55.2 (0.8) | 156.0 (6.3) | 152.5 (4.5) | 154.3 (1.8) | 22.5 (2.1) | 23.8 (2.9) | 23.2(0.7) | 21.1 (0.6) | 21.5 (1.1) | 21.3 (0.2) |
| **Ankle AP** | 262 | 333 | 595 | 45.5 (7.5) | 33.6 (7.6) | 39.6 (6.0) | 59.2 (3.0) | 58.9 (9.4) | 59.1 (0.2) | 158.7 (3.7) | 155.1 (7.1) | 156.9 (1.8) | 23.6 (2.3) | 25.0 (6.2) | 24.3(0.7) | 21.8 (0.8) | 22.0 (2.3) | 21.9 (0.1) |
| **ALL/Range** | 1483 | 2104 | 3587 | 21.2 - 47.5 | 29.1-53.1 | 26.6 - 50.3 | 51.4 - 71.2 | 50.6-65.3 | 54.4 - 68.3 | 154.-167.1 | 146.0-161.7 | 152.3-162.9 | 20.8 - 25.3 | 20.2 - 27.0 | 21.0- 26.1 | 8.1- 34.7 | 6.7-34.9 | 7.4-34.8 |

Note: $D_e$ is the radiation thickness of penetration through patient skin during clinical examinations.

Table 3: Average radiographic parameters setting during examination by sex, averaged over sexes and radiograph, presented in mean and SEM (in bracket)

| Radiograph | kVp | | | mAs | | | FSD (cm) | | | FFD (cm) | | | Avg. A(FFD) ($cm^2$) (Range) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **M** | **F** | **B** | **M** | **F** | **B** | **M** | **F** | **B** | **M** | **F** | **B** | |
| Chest( PA) | 8.7 (6.4) | 80.9 (6.4) | 79.8 (1.1) | 38.7 (13.4) | 37.0 (11) | 37.9 (09) | 27.6 (0.4) | 128.5 (0.3) | 128.1 (0.5) | 150.0 (0.0) | 150.0 (0.0) | 150.0 (00) | $32.0^2$ ($5.2^2$-$34.2^2$) |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chest( AP) | 5.3 (0.0) | 76.2 (0.0) | 75.8 (0.5) | 18.3 (0.0) | 14.8 (0.6) | 16.6 (1.8) | 78.6 (0.0) | 79.8 (0.0) | 79.2 (0.6) | 100.0 (0.0) | 100.0 (0.0) | 100.0 (0.0) | 30.0$^2$ (5.2$^2$-34.2$^2$) |
| Abdo. (AP) | 77.4 (3.6) | 76.9 (1.7) | 77.2 (0.3) | 49.6 (13.4) | 52.7 (15.3) | 51.2 (1.6) | 77.5 (0.5) | 77.3 (1.2) | 77.4 (0.1) | 100.0 (0.0) | 100.0 (0.0) | 100.0 (0.0) | 23.2$^2$ (17.1$^2$-38.5$^2$) |
| Pelvis (AP) | 79.3 (5.7) | 82.1 (6.0) | 80.7 (1.4) | 47.9 (10.4) | 51.7 (9.4) | 49.8 (1.9) | 71.3 (3.5) | 78.5 (2.4) | 70.2 (8.4) | 90.0 (0.0) | 100.0 (0.0) | 950.0 (5.0) | 28.3$^2$ (25.0$^2$-32.0$^2$) |
| Pelvis (LAT) | 85.2 (4.9) | 87.1 (5.0) | 86.2 (1.0) | 42.0 (0.0) | 43.6 (1.6) | 42.8 (0.8) | 65.5 (0.3) | 68.3 (2.1) | 66.9 (1.4) | 100.0 (0.0) | 100.0 (0.0) | 100.0 (0.0) | 23.7$^2$ (12.5$^2$-17.1$^2$) |
| Skull (AP/PA) | 70.2 (1.9) | 70.6 (5.5) | 70.4 (0.2) | 40.1 (1.9) | 39.2 (3.1) | 39.7 (0.5) | 71.2 (2.1) | 72.1 (5.1) | 71.7 (0.5) | 90.0 (0.0) | 90.0 (0.0) | 90.0 (0.0) | 21.5$^2$ (17.3$^2$-25.6$^2$) |
| Skull (LAT) | 67.6 (7.6) | 75.1 (0.0) | 72.9 (3.8) | 47.7 (2.7) | 50.3 (0.0) | 49.0 (1.3) | 73.9 (6.0) | 78.8 (0.0) | 76.4 (0.6) | 90.0 (1.8) | 90.0 (5.0) | 90.0 (5.0) | 21.5$^2$ (17.3$^2$-25.6$^2$) |
| Hand (AP) | 62.6 (2.5) | 64.1 (1.0) | 63.4 (0.8) | 31.9 (5.9) | 33.0 (4.9) | 32.5 (0.6) | 80.7 (12.9) | 80.6 (13.8) | 80.7 (0.1) | 95.0 (5.0) | 95.0 (5.0) | 95.0 (0.0) | 9.3 $^2$(3.5$^2$-13.2$^2$) |
| Knee-Joint (LAT) | 63.0 (7.4) | 61.7 (10.4) | 62.4 (0.7) | 21.2 (10.9) | 23.2 (11.2) | 22.2 (1.0) | 75.3 (14.7) | 78.7 (14.9) | 77.0 (1.7) | 90.0 (5.0) | 90.0 (5.0) | 90.0 (0.0) | 11.5$^2$ (8.9$^2$-15.9$^2$) |
| LSJ (AP) | 75.0 (15.0) | 78.1 (14.1) | 76.6 (1.6) | 51.8 (16.4) | 50.9 (20.3) | 51.4 (0.5) | 76.4 (0.1) | 77.4 (0.1) | 76.9 (0.5) | 100.0 (0.0) | 100.0 (0.0) | 100.0 (0.0) | 35.0$^2$ (32.0$^2$-42.0$^2$) |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LSJ (LAT) | 80.5 (3.5) | 81.8 (4.8) | 81.2 (0.4) | 56.9 (21.5) | 57.8 (27.2) | 57.4 (0.5) | 65.3 (0.8) | 65.1 (1.3) | 65.2 (0.1) | 100.0 (0.0) | 100.0 (0.0) | 100.0 (0.0) | 30.5$^2$ (27.0$^2$-32$^2$) |
| Thoraco-Lumbar (PA) | 72.3 (0.2) | 72.5 (3.8) | 72.4 (0.1) | 20.4 (0.9) | 24.2 (2.9) | 22.3 (5.9) | 76.8 (1.8) | 78.3 (1.7) | 77.6 (0.8) | 100.0 (0.0) | 100.0 (0.0) | 100.0 (0.0) | 19.3$^2$ (10.0$^2$-14.5$^2$) |
| Thorax (PA) | 71.6 (0.8) | 74.3 (1.2) | 73.0 (1.4) | 32.0 (0.0) | 27.2 (3.5) | 29.6 (2.4) | 104.2 (25.9) | 103.2 (27.0) | 103.7 (0.5) | 125.0 (25.0) | 125.0 (25.0) | 125.0 (0.0) | 25.5$^2$ (20.0$^2$-30.5$^2$) |
| LS (AP) | 85.4 (5.4) | 85.6 (5.6) | 85.5 (0.1) | 61.8 (16.5) | 61.8 (13.6) | 61.8 (0.0) | 78.5 (0.2) | 77.5 (0.8) | 78.0 (0.5) | 100.0 (0.0) | 100.0 (0.0) | 100.0 (0.0) | 32.7$^2$ (28.0$^2$-42.5$^2$) |
| LS (LAT) | 90.1 (4.1) | 90.5 (5.5) | 90.3 (0.2) | 65.2 (14.8) | 68.4 (14.7) | 66.8 (1.6) | 66.6 (0.3) | 65.6 (1.7) | 66.1 (0.5) | 100.0 (0.0) | 100.0 (0.0) | 100.0 (0.0) | 30.5$^2$ (27.0$^2$-34.0$^2$) |
| Shoulder (AP) | 59.9 (0.3) | 60.8 (0.1) | 60.4 (0.5) | 19.9 (0.4) | 21.8 (3.3) | 20.9 (1.4) | 73.7 (1.5) | 72.2 (2.1) | 73.1 (0.9) | 90.0 (0.0) | 90.0 (0.0) | 90.0 (0.0) | 15.5$^2$ (10.5$^{-2}$-17.3$^2$) |
| Ankle (AP) | 60.0 (3.4) | 61.9 (4.3) | 61.0 (1.0) | 19.2 (3.1) | 21.0 (4.1) | 20.1 (0.4) | 78.1 (1.6) | 77.9 (1.2) | 78.0 (0.1) | 90.0 (0.0) | 90.0 (0.0) | 90.0 (0.0) | 14.2$^2$ (10.3$^2$-18.0$^2$) |

Table 4: Estimated parameters (Dose descriptors and Effective dose) by sex, averaged over sexes and radiographs

| **Radiograph** | **ESD (mGy)** | | | **ESD** | **DAP (mGy cm²)** | | | **DAP** | **ED (mSv)** | | | **ED/DAP (mSv/Gycm$^2$)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **M** | **F** | **B (SEM)** | **RF** | **M** | **F** | **B (SEM)** | **RF** | **M** | **F** | **B (SEM)** | **M** | **F** | **B** |
| **Chest (PA)** | 0.740 | 0.736 | 0.738 (0.002) | 13 | 1718.7 | 1634.2 | 1676.5 (42.3) | 21 | 0.117 | 0.113 | 0.125 (0.008) | 0.068 | 0.069 | 0.069 (0.001) |
| **Chest (AP)** | 0.885 | 0.711 | 0.798 (0.087) | 17 | 750.0 | 606.6 | 678.3 (71.7) | 39 | 0.237 | 0.205 | 0.221 (0.016) | 0.316 | 0.338 | 0.327 (0.011) |
| **Abdo. (AP)** | 2.483 | 2.618 | 2.551 (0.068) | 21 | 1157.8 | 1230.2 | 1194.0 (36.2) | 21 | 0.354 | 0.374 | 0.364 (0.010) | 0.306 | 0.304 | 0.305 (0.001) |

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| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Abdo. (AP)** | 2.483 | 2.618 | 2.551 (0.068) | 21 | 1157.8 | 1230.2 | 1194.0 (36.2) | 21 | 0.354 | 0.374 | 0.364 (0.010) | 0.306 | 0.304 | 0.305 (0.001) |
| **Pelvis (AP)** | 2.974 | 2.839 | 2.907 (0.068) | 10 | 1663.8 | 1795.8 | 1729.8 (66.0) | 29 | 0.352 | 0.356 | 0.354 (0.002) | 0.212 | 0.198 | 0.205 (0.007) |
| **Pelvis (LAT)** | 3.567 | 3.559 | 3.563 (0.004) | 11 | 1043.4 | 1083.2 | 1063.3 (19.9) | 15 | 0.018 | 0.022 | 0.020 (0.002) | 0.017 | 0.020 | 0.019 (0.002) |
| **Skull (AP/PA)** | 1.996 | 1.924 | 1.960 (0.036) | 22 | 819.9 | 801.5 | 810.7 (9.2) | 18 | 0.011 | 0.013 | 0.012 (0.001) | 0.013 | 0.016 | 0.015 (0.002) |
| **Skull (LAT)** | 2.004 | 2.293 | 2.149 (0.145) | 19 | 975.2 | 1028.4 | 1001.8 (26.6) | 11 | 0.006 | 0.009 | 0.008 (0.002) | 0.006 | 0.009 | 0.008 (0.002) |
| **Hand (AP)** | 0.964 | 1.048 | 1.006 (0.042) | 9 | 122.0 | 126.2 | 124.1 (2.1) | 10 | 0.013 | 0.014 | 0.014 (0.001) | 0.107 | 0.111 | 0.109 (0.002) |
| **Knee Joint (LAT)** | 0.831 | 0.875 | 0.853 (0.022) | 5 | 124.1 | 135.7 | 129.9 (5.8) | 13 | 0.001 | 0.001 | 0.001 (0.000) | 0.008 | 0.007 | 0.008 (0.001) |
| **LSJ (AP)** | 2.506 | 2.601 | 2.554 (0.048) | 18 | 2752.0 | 2704.2 | 2728.1 (23.9) | 22 | 0.471 | 0.555 | 0.513 (0.042) | 0.171 | 0.205 | 0.188 (0.017) |
| **LSJ (LAT)** | 4.341 | 4.581 | 4.461 (0.120) | 21 | 2295.6 | 2331.9 | 2313.8 (18.2) | 16 | 0.131 | 0.177 | 0.154 (0.023) | 0.057 | 0.076 | 0.067 (0.010) |
| **Thoracolumbar (PA)** | 0.908 | 1.042 | 0.975 (0.067) | 16 | 336.2 | 398.7 | 367.4 (31.3) | 14 | 0.007 | 0.006 | 0.007 (0.001) | 0.021 | 0.015 | 0.018 (0.003) |
| **Thorax (PA)** | 0.758 | 0.708 | 0.733 (0.025) | 6 | 920.3 | 782.3 | 851.3 (6.9) | 19 | 0.045 | 0.041 | 0.043 (0.003) | 0.049 | 0.052 | 0.051 (0.002) |
| **LS (AP)** | 3.672 | 3.785 | 3.729 (0.057) | 23 | 2865.9 | 2865.9 | 2865.9 (0.0) | 26 | 0.828 | 0.815 | 0.822 (0.007) | 0.289 | 0.284 | 0.287 (0.003) |
| **LS (LAT)** | 5.990 | 6.535 | 6.263 (0.273) | 23 | 2630.5 | 2759.6 | 2695.1 (64.6) | 21 | 0.367 | 0.378 | 0.373 (0.006) | 0.140 | 0.137 | 0.139 (0.002) |
| **Shoulder (AP)** | 0.660 | 0.776 | 0.718 (0.058) | 5 | 211.5 | 231.7 | 221.6 (10.1) | 25 | 0.006 | 0.007 | 0.007 (0.001) | 0.028 | 0.030 | 0.029 (0.001) |
| **Ankle (AP)** | 0.569 | 0.666 | 0.618 (0.049) | 8 | 171.2 | 187.3 | 179.3 (8.1) | 16 | 0.001 | 0.001 | 0.001 (0.000) | 0.006 | 0.005 | 0.006 (0.001) |

Table 5: Average Tissue dose equivalent and the probability of fatal risk of cancer incidence by sex, averaged over sexes and examination

| Radiograph | Tissue Dose Equivalent (HT) (mSv) | | | Probability of fatal risk of cancer x 10-5 | | | Lifetime cancer risk equivalent [Averaged over sexes (Both)] | Risk category |
|---|---|---|---|---|---|---|---|---|
| | **M** | **F** | **B(SEM)** | **M** | **F** | **B** | | |
| Chest (PA) | 0.784 | 0.780 | 0.783(0.002) | 4.314 | 4.291 | 4.303 | 1 : 23,240 | Very Low |
| Chest (AP) | 0.938 | 0.754 | 0.846(0.092) | 5.160 | 4.145 | 4.653 | 1 : 21,492 | Very Low |
| Abdo. (AP) | 2.632 | 2.775 | 2.704(0.072) | 14.476 | 15.263 | 14.870 | 1 : 6,725 | Low |
| Pelvis (AP) | 3.152 | 3.009 | 3.081(0.072) | 17.338 | 16.551 | 16.945 | 1 : 5,902 | Low |
| Pelvis (LAT) | 3.781 | 3.773 | 3.777(0.043) | 20.796 | 20.749 | 20.772 | 1 : 4,814 | Low |
| Skull (AP/PA) | 2.074 | 2.000 | 2.037(0.037) | 11.409 | 11.0011 | 11.205 | 1 : 8,925 | Low |
| Skull (LAT) | 2.124 | 2.431 | 2.277(0.153) | 11.683 | 13.368 | 12.526 | 1 : 7,983 | Low |
| Hand (AP) | 1.022 | 1.111 | 1.066(0.045) | 5.620 | 6.110 | 5.865 | 1 : 17,050 | Very Low |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Chest (AP) | 0.938 | 0.754 | 0.846(0.092) | 5.160 | 4.145 | 4.653 | 1 : 21,492 | Very Low |
| Abdo. (AP) | 2.632 | 2.775 | 2.704(0.072) | 14.476 | 15.263 | 14.870 | 1 : 6,725 | Low |
| Pelvis (AP) | 3.152 | 3.009 | 3.081(0.072) | 17.338 | 16.551 | 16.945 | 1 : 5,902 | Low |
| Pelvis (LAT) | 3.781 | 3.773 | 3.777(0.043) | 20.796 | 20.749 | 20.772 | 1 : 4,814 | Low |
| Skull (AP/PA) | 2.074 | 2.000 | 2.037(0.037) | 11.409 | 11.0011 | 11.205 | 1 : 8,925 | Low |
| Skull (LAT) | 2.124 | 2.431 | 2.277(0.153) | 11.683 | 13.368 | 12.526 | 1 : 7,983 | Low |
| Hand (AP) | 1.022 | 1.111 | 1.066(0.045) | 5.620 | 6.110 | 5.865 | 1 : 17,050 | Very Low |
| Knee Joint(LAT) | 0.881 | 0.928 | 0.904(0.023) | 4.845 | 5.101 | 4.973 | 1 : 20,109 | Very Low |
| LSJ (AP) | 2.656 | 2.757 | 2.707(0.050) | 14.610 | 15.164 | 14.887 | 1 : 6,717 | Low |
| LSJ (LAT) | 4.602 | 4.856 | 4.729(0.127) | 25.311 | 26.708 | 26.010 | 1 : 3,845 | Low |
| Thoracolumbar(PA) | 0.963 | 1.105 | 1.034(0.071) | 5.294 | 6.075 | 5.684 | 1 : 17,593 | Very Low |
| Thorax (PA) | 0.804 | 0.751 | 0.777(0.027) | 4.419 | 4.128 | 4.274 | 1 : 23,397 | Very Low |
| LS (AP) | 3.892 | 4.012 | 3.952(0.060) | 21.408 | 22.067 | 21.737 | 1 : 4,601 | Low |
| LS (LAT) | 6.349 | 6.927 | 6.383(0.290) | 34.920 | 38.099 | 36.510 | 1 : 2,739 | Low **(H)** |
| Shoulder (AP) | 0.700 | 0.823 | 0.761(0.062) | 3.848 | 4.525 | 4.186 | 1 : 23,889 | Very Low |
| Ankle (AP) | 0.603 | 0.823 | 0.655(0.052) | 3.317 | 3.883 | 3.600 | 1 : 27,778 | Very Low **(L)** |

Note: Risk coeff.($f_r$) = 5.5 x $10^{-5}$ $mSv^{-1}$ used in this study for probability of fatal risk of cancer incidence calculation (Proposed nominal life-time radiation risk ranged as **(2-10 x $10^{-2}$ $Sv^{-1}$)** [17][18]

Table 6: Comparison of the average estimated parameters for reference person studied with some published values

| **Radiographs** | **This Study** | | | **Ref.[33]** | | **Ref.[34]** | **Ref. [32]** | |
|---|---|---|---|---|---|---|---|---|
| | **ESD (mGy)** | **DAP ($Gycm^2$)** | **ED (mSv)** | **ESD (mGy)** | **DAP ($Gycm^2$)** | **ESD (mGy)** | **DAP ($Gycm^2$)** | **ED (mSv)** |
| **Chest (PA)** | 0.738 | 1.676 | 0.125 | 0.16 | 0.12 | 3.01 | 3.06 | 0.42 |
| **Chest (AP)** | 0.798 | 0.678 | 0.221 | 0.16 | — | — | — | — |
| **Abdo. (AP)** | 2.551 | 1.194 | 0.364 | 4.70 | 3.00 | 5.67 | 17.16 | 1.82 |
| **Pelvis (AP)** | 2.907 | 1.730 | 0.354 | 4.20 | 3.00 | 2.84 | 3.28 | 0.52 |
| **Pelvis (LAT)** | 2.727 | 1.063 | 0.020 | — | — | — | | — |
| **Skull (AP/PA)** | 1.960 | 0.811 | 0.021 | 2.30 | — | 3.93 | 4.53 | 0.14 |
| **Skull (LAT)** | 2.149 | 1.002 | 0.008 | 1.35 | — | — | — | — |
| **Hand (AP)** | 1.006 | 0.124 | 0.014 | — | — | 1.44 | 0.92 | — |
| **Knee Joint (LAT)** | 0.853 | 0.130 | 0.001 | 0.29 | — | 1.73 | 1.53 | — |
| **LSJ (AP)** | 2.554 | 2.728 | 0.513 | 28.10 | 3.00 | — | — | — |
| **LSJ (LAT)** | 4.461 | 2.314 | 0.154 | — | — | — | — | — |
| **Thoracolumbar (PA)** | 0.975 | 0.367 | 0.007 | — | — | — | — | — |
| **Thoraxis (PA)** | 0.733 | 0.851 | 0.043 | — | — | — | — | — |
| **LS (AP)** | 3.729 | 2.866 | 0.822 | 5.90 | 1.60 | 3.79 | 2.72 | 0.66 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **LS (LAT)** | 6.263 | 2.695 | 0.373 | 14.00 | 3.00 | — | — | — |
| **Shoulder (AP)** | 0.718 | 0.222 | 0.007 | 0.19 | — | — | — | — |
| **Ankle (AP)** | 0.618 | 0.179 | 0.001 | — | — | — | — | — |

## DISCUSSION

This study examined 3,587 adult patients undergoing most frequent radiographs involving 17 different procedures from 17 health care centres. These healthcare centres were divided into groups which comprises of public (Group A) and private (Group B). Table 1(a&b) revealed specific features of x-ray units included in the study. The beam output (µGy$(mAs)^{-1}$ ) of the investigated centre's x-ray machine range between 25.05 and 74.28 µGy $(mAs)^{-1}$ and their filtrations range between 1.5 to 2.5 mmAl. Among the x-ray machines studied, twelve satisfied the minimum filtration requirement of 2.5 mmAl, for a good practice [22], for machines operating at a peak voltage of 70 kV [23]. However, use of filtration below the minimum legal requirement of 2.5 mmAl for peak tube potential values greater than 70 kV [23], may have contributed as a factors to relatively higher patient doses. Reference to some studies as, [24] filtration recorded were [(UCH:2.7, OAUTHC:1.7, TDC:2.7) mmAl, NHA:(1.0 mmAl+0.1mmCu)] [25], ($H_1$: 3.0, $H_2$: 1.0, $H_3$: 2.0 mmAl) indicated that the case is not just limited to this study area alone but the country centres at large used relatively low filtration compared to the filtrations reported in Sudan [8], ranged between 2.5 and 5.0 mmAl, and the age of the x-ray machines assessed based on their year of installation, range between 18 and 22yrs.

Total of 3,587 dose measurements on most frequent radiographs were recorded during study. The gender ratio were 41.3% and 58.7% for males and females respectively as shown in Table 2, and this may likely be reflecting the demography of the study area (Ondo State), Nigeria. The average age, weight and BMI of patients studied ranged (21.2 – 53.1) yrs., (50.6 – 71.2) kg and (20.2 – 27.0) $kgm^{-2}$. So, the mean weight recorded from this study is far different from those recorded in the IAEA study [12] on patient undergoing radiographs in European and Asian countries. In IAEA study, average weight (70 ± 10) kg and (65±10) kg were considered appropriate for European and Asian countries respectively while the average for the only African country included in the study was not specified. So, it is relevant to compare adequately, the estimated parameters in the study with the published values based on the average weight recorded in Nigeria. The depths of beam penetration recorded ranged (6.7-3.9) cm, reflects the thicknesses of the area exposed and average mass-energy absorption coefficient's estimating distant for each examination, and so, the real-time radiological practice for the state, deduced. It is equally evident from the average BMI range of the patient recorded, that the average size of the patient exposed to different radiological examinations are closely related (range factor of 1.35).

The summary of the average radiographic exposure data used during radiological examination are reported (Table 3). The average technical factors selection (kVp, mAs, FSD, FFD and the field size area) as determined for study, ranged as (59.9 – 90.5) kVp, (19.2 – 68.4) mAs, (90 -150 cm) FFD and ($9.3^2$ – $35.0^2$ $cm^2$) for the beam size. So, averagely low kVp and mAs were recorded from Shoulder AP and Ankle AP and high for LS LAT. Therefore, study revealed inconsistencies in the use of FFD compared to EC quality criteria, recommendations [26].The EC criteria recommends an average FFD of 115 cm and ranged (100-150) cm, but the hospitals studied used FFD below the recommended averaged except in Chest PA, where the FFD used cut across. As entrance surface dose (ESD) is considered an inverse proportionality of the square of FFD, if EC criteria is considered the yardstick, then, for same kV and mAs, dose reaching the patient skin surface is expected to be high. But the observable trends across centres studied tend to using lower FFDs, and in part, this may illuminate higher ESDs. Though, possibility of some centres using low FFDs, presenting considerably low mean ESD cannot be ruled out. It is therefore, expedient to know that changing FFD at time may be seen as good effort, but will still not unravel all the discrepancies noted in this study. So, it is ideal that compliance to policies on quality control and assurance monitoring programs, be adhere and enforce in the hospitals to protect patient against irrational exposure from repeat examinations. However, if images are considered created and ranked in term of signal-noise ratio (SNR) [27], from low to high quality, with exposure factors selection varying as (75 -105) kVp, (20 -50) mAs and FFD (110cm) for standard adult (diameter 'D'≥20 cm) during examination, together with some identified type of films [28][29], then averagely high SNR may be generated from almost all the centres studied. Hence, averagely highimage quality may be expected.

The averaged over centres estimated parameters (ESD, DAP and ED) across radiographs studied by sex and averaged over sexes are reported (Table 4). Generally, along the line of data analysis by centre, considerable variations noted between centres for same type of examinations, even from same room. When values were made averaged over centres for each radiograph, the ESD values across gender, reflects low and high standard error of the mean (SEM) being 0.002 and 0.273 (highlights of spread across radiograph) from Chest PA and LS LAT radiographs, and the range factor across all centre studied for each radiograph, show moderately high spread with low and high values recorded approximately as 5 (Knee Joint LAT and Shoulder AP) and 23 (LS generally). These variations were still comparable to some studies. Generally, across radiographs, low and high, averaged over sexes ESD recorded from Ankle PA (0.618 mGy) and LS LAT (6.263 mGy) with range factor of 10.1 across radiographs. These shows geometry agreement with IAEA study [12], but the difference in values may be ascribed to technical factors selections, patient sizes, x-ray machine beam output, and dosimetric method adopted. Also, low and high averaged over sexes DAP were recorded from Hand AP (0.124 $Gycm^2$) and LS AP (2.866 $Gycm^2$) while for the ED, Knee joint (LAT) and Anxle AP recorded same low value of 0.001 mSv and LS AP recorded high value of 0.822 mSv. The low and high ED/DAP, made averaged over sexes was 0.006 and 0.327 $mSv/Gycm^2$ from Ankle AP and Chest AP respectively.

The average probability of fatal risk of cancer incidence by sex and averaged over sexes and examination presented in Table 5. So, low and high probability of fatal risk of cancer incidence, averaged over sexes recorded as (3.600 and 36.510) **x** $10^{-5}$ from Ankle AP and LS LAT respectively while the low and high Lifetime cancer risk equivalent ratio was 1: 27,778 and 1: 2,739 from Ankle AP and LS LAT respectively. Therefore, from study, it is evident that the Lifetime risk of cancer equivalent recorded fall within low (1:1,000) and very low (1:10,000) category of risk, as indicated in four broad risk band [30]. This notwithstanding do not justified the best radiological practice, but the need for adequate monitoring of dose to patients for further optimization of the practice.

Comparison of the estimated parameters from this study with some published values, established in Table 6. The observable trend from this study do not necessarily mean the best practice but calls for the establishment of legal framework on dose optimization and overview of same in the entire healthcare within the state, adopting direct dosimetry method for diagnosis purposes. Nonetheless, dose recorded from this study when compared with other published values, show geometric agreement, but the noticeable difference may be ascribed to technical factors selection, patient sizes, radiological practice, x-ray beam output generation and the choice of dosimetry method adopted. However, it has been established that where quality dose database are used in dose to patient monitoring, the difference in dose values between direct and indirect dosimetry will range as (±20% and 25%) [31]. Thus, the need for the variations recorded between this study and others, published. So, the range factors (RF) of the estimated parameters from this study were 10.10, 15.94 and 820 for ESD, DAP and ED respectively which signified high spread in values, especially in ED compared to [32] and [34] with RF of 2.73, 18.65 and 13.00 and [33] with RF as 175.63 and 25.00 for ESD and DAP respectively. Therefore, observable trend justified expected variation in dose to patient from radiographic rooms or across centres [9], which are traceable to patient sizes, technical factors selection and adopted dosimetric method. So, to guarantee adequate radiation protection of patients, dose to patient through diagnostic exposure in the state, be optimized periodically to promote good radiologic practice. Hence, the need for adequate monitoring in terms of the personnel, equipment, and techniques of exposure, and dosimetric exercise, embraced.

## CONCLUSION

The results presented in this study, provide current state of radiological practice in the study area. It displayed variation in technique, exposure factors and radiation doses for same and the different type of radiographs studied, which strongly support the need for further optimization. Almost seventy percent of the centres studied recorded low ESD and DAP values below UK national reference values with high spread in dose to patients. Hence, the urgent need for appropriate and realistic QA program to be implemented, which is currently absent in almost all the hospitals surveyed. The variation in the data obtained, equally validates the importance for awareness creation among the radiographic staff and the policies maker on regular quality control testing of equipment and standardization of protocols. Thus, the need for intervention and appropriate corrective actions to improve and standardized practice, enhancing the quality of the radiographs, and avoid illogical risks of increased radiation dose to patients and staff, advised. Therefore, bringing the standard of the radiological practice in the state in line with national and European guidelines on quality criteria for diagnostic radiological images becomes highly imperative, in order to protect patients and staff against irrational exposure.

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