Radiation Science and Technology
2016; 2(1): 6-12
http://www.sciencepublishinggroup.com/j/rst
doi: 10.11648/j.rst.20160201.12

Entrance Surface Air Kerma for Skull, Pelvis and Abdomen X-ray Examinations in Some Diagnostic Radiology Facilities in Akwa Ibom State, Nigeria

Imeh Edet Essien[1, *], Samuel OkonInyang[2], Nneoyi Egbe[3]

[1]Department of Physics, Faculty of Sciences, University of Uyo, Uyo, Nigeria

[2]Department of Physics, Faculty of Sciences, University of Calabar, Calabar, Nigeria

[3]Department of Radiography, Faculty of Basic Medical Sciences, University of Calabar, Calabar, Nigeria

Email address:
imeessien27@yahoo.com (I. E. Essien)
[*]Corresponding author

To cite this article:
Imeh Edet Essien, Samuel Okon Inyang, Nneoyi Egbe. Entrance Surface Air Kerma for Skull, Pelvis and Abdomen X-ray Examinations in Some Diagnostic Radiology Facilities in Akwa Ibom State, Nigeria. *Radiation Science and Technology.* Vol. 2, No. 1, 2016, pp. 6-12.
doi: 10.11648/j.rst.20160201.12

Received: August 2, 2016; **Accepted**: August 29, 2016; **Published**: September 30, 2016

Abstract: This study estimates entrance surface air kerma(ESAK) for Skull, Pelvis and Abdomen X-ray examinations in selected diagnostic radiology facilities in AkwaIbom State, Nigeria.Eight (8) facilities in eight hospitals were investigated.Six hundred and thirty threeadult patients who presented for these examinations under study were investigated. Gender distribution shows that 263 (41.5%) were males while 370 (58.5%) were females.For skull examination the calculated ESAK range was between 0.07 to 0.57 mGy for males and females patient respectively, ESAK range of 0.03 to 0.28 mGy for males and females respectively in pelvis examination while in abdominal examination the ESAK for male varied between 0.05 to 1.16 mGy and 0.04 to 0.73 mGy for female patients. Mean organ doses indicate that the eyes absorbed a dose of 10.19 mGy,the gonads absorbed the highest dose, uterus and prostate gland absorbed 0.43 mGy and 0.33 mGy respectively. Liver absorbed 1.51 mGy, ovaries, 2.62 mGy, testes, 0.08 mGy. The meaneffective dose (ED) range of 0.02 - 0.11 mSv in skull examination while ED for pelvis and abdomen examinations ranges are (0.07 - 0.52) mSv and (0.78 - 5.37) mSv respectively. The evaluated cancer incidence and mortality risks were very low and minimal.

Keywords: Diagnostic Radiologic Facilities, Skull, Pelvis, Abdomen, Entrance Surface Air Kerma, Body Organ Dose and Effective Dose

1. Introduction

The phenomenon of deposition of energy from X-ray in tissues and its differential attenuation as it traverses the tissues has been utilised for decades in medical practice for diagnosis and therapy.The need for protection and safety of patients during X-ray examination without compromising the diagnostic information required is paramount in diagnostic radiologic practice. This underscores the reasons that regulatory bodies are set up to ensure that the basic principles of justification and optimization of procedures are adhered to in order to ensure that the dose of radiation delivered is as low as reasonably achievable (ALARA). These regulatory bodies consequently set up control measures such as, setting of references dose, dose limits, facility shielding, quality assurance and quality control, personnel and patients dosimetry (ICRP 1996, NNRA 2006).

In Nigeria, the use of ionizing radiation in medical imaging has been on for some time now, hence to enhance the monitoring of the application of ionizing and non-ionizing radiation in Nigeria; the Nigerian Nuclear Regulatory Authority (NNRA) was established in compliance with the international best practices. The Nigerian Nuclear Regulatory Authority (NNRA) was enacted in 1995 by act (NNRA, 1995) with the sole responsibility for nuclear safety and radiological protection in Nigeria.To monitor and ensure the safety of the patientsduring X-ray examinations, NNRA recommends continuous patient dose measurements to determine when the particular facility is delivering radiation dose above a permissible level.

The aim of this study is to estimate the entrance surface air kerma delivered by selected diagnostic radiology facilities in Akwa Ibom State, Nigeria, during Skull, Pelvis and Abdomen examination.

2. Materials and Methods

Patient dose could be measured directly or estimated indirectly. Direct measurement of the dose is done with thermoluminiscent dosimeter (TLD) as reported in the literature (Nyathi *et al.,* 2009, Egbe *et al*., 2009, Ogundare *et al.,* 2004). Indirect method of measuring patient dose is through the evaluation of entrance surface dose (ESD) from measured X-ray exposure technique factors, peak kilovoltage, miliampere seconds and the focus to skin distance (kVp, mAs, and FSD) using the semi empirical formula as adopted by (Osibote and Azevedo, 2008).It is reported that, dose derived from TLD measurement and through calculation methods agrees to within± 10% (Heggie, 1990 and Martin *et al.,* 1993).

In this study, indirect method (Inyang *et al,* 2015) is used to estimate the entrance surface kerma on patients who presented for Skull, Pelvis and Abdomen X-ray examinations in the selected diagnostic radiologic facilities in Akwa Ibom State. Nigeria

$$ESAK = Y(d)\times mAs\times\left(\frac{d}{FFD-BT}\right)^2\times BSF \qquad (1)$$

Where FFD is the focus to film distance and BT the body thickness, BSF is the backscatter factor, and mAs is the tube loading factor.

The radiation output Y (d) for different type of x-ray machine at a source to target distance of 100 cm and canbe obtained using equation 3(Kothan and Tungjai, 2011). The radiation output for single phase, three phase and high frequency generator X – ray machines are given as $2.86\times10^{-6}\frac{mGy}{mAs}$, $4.58\times10^{-6}\frac{mGy}{mAs}$ and $5.73\times10^{-6}\frac{mGy}{mAs}$ respectively.

The body thickness (BT) of the patient is calculated using the following relationship (Nyathi, *et al* 2009)

$$BT = 2\sqrt{\frac{W}{\pi\times h}} \qquad (2)$$

Where W is the body weight. Entrance surface dose (ESD) and ESAK are reported to be numerically equal in the diagnostic energy range, but vary if the medium differs (Muhogora *et. al.,* 2008).

The functional radiology facilities located in Akwa Ibom State selected for this study were grouped as tertiary facility (TF), Secondary facility (SF) and Private facility (PF). Tertiary facility consisted of radiologic facilities in University Teaching Hospitals, Specialist Hospitals or Federal Medical Centres. Radiology facilities within State Government General Hospitals were considered as secondary facilities while PF were those in private clinics or stand alone privately owned facilities. Afterpreliminary assessment of the facilities, eight (8) took part in the investigation. Hospitals 1-3 are general hospitals, 4-7 are private hospitals and facility 8 is a University teaching hospital.

Information on the type, model, functionality and year of purchase of machine were obtained from the most senior radiographer in the facility using a predesigned equipment form also information on number of professionals in the facility, their qualification and year of experience were obtained from the head of the facility using a personnel form as previously reported by these authors (Essien and Inyang 2015). The examinations considered were skull anterior – posterior (AP), pelvis anterior –posterior (AP) and abdomen anterior –posterior (AP).

Exposure factors used in this study include tube potential (kVp), tube loading factor (mAs) and focus to skin distance (FSD). The exposure factors were selected on the machine panel by the radiographer on duty whorecorded same in a form designed for the purpose. The mean of the recorded exposures was calculated and used in the ESAK estimation using eqn 1. The mean body organs and the effective dose for each of the examinations were evaluated using the Caldose software (Inyang *et al.,* 2015).

3. Results and Discussion

Patient information which includes number of patients, sex, mean age, mean weight and body thickness are shown in tables 1-3. Six hundred and thirty three (633) patients who presented for these examinations under study were investigated. Gender distribution shows that 263 (41.5%) were males while 370 (58.5%) were females. Distribution by type of examination shows that, 95 male patients, 66 female patients underwent skull X- ray examination in the facilities investigated, with height range between 1.5-1.7 m and body thickness of 6.5-7.8 Kg /m. Ninety five (95) male patients and 86 female patients underwent pelvis X-ray examination in the facilities investigated, with height range between 1.5-1.7 m and body thickness of 7.3-8.0 Kg /m while 73 males and 118 females were involved in abdominal examination. The patients involved in this study were all adults with age range between 45-83 years. Tables 4-6 report the exposure factors used in the examination, the calculated radiation output andcorresponding entrance surface dose. The facility in hospitals 1 and 5 is single phase (SP) while facility 3 is high frequency generator (HFG) and others are three phase (TP).

For skull examination (Table 4) the calculated ESAK range between 0.07 – 0.57 mGy for males and females patients respectively, Table 5 shows an ESAK range of 0.03-0.28 mGy for males and females respectively in pelvis examination while in abdominal examination dose for male ranged between 0.05-1.16 mGy and 0.04-0.73 mGy for female patients.

Table 1. *Gender distribution and mean values of patient parameters for Skull examination.*

FacilityNo	Patient parameters					
	No. of Male	No. of Female	Age(Yrs)	Mass(kg)	Height(m)	BT(kg m^{-1})
1	13	6	45	57	1.7	6.5
2	14	8	45	69	1.6	7.5
3	10	10	46	69	1.6	7.5
4	12	11	50	69	1.7	7.2
5	4	5	50	70	1.5	7.7
6	12	5	60	65	1.6	7.6
7	10	11	66	72	1.7	7.8
8	20	10	65	68	1.7	7.5

Table 2. *Gender distribution and mean values of patient parameters for Pelvis examination.*

FacilityNo	Patient parameters					
	No. of males	No. of females	Age(Yrs)	Mass(kg)	Height(m)	BT(kg m^{-1})
1	15	11	46	72	1.6	8.0
2	10	10	45	72	1.7	7.5
3	10	10	60	78	1.7	7.5
4	10	11	72	68	1.7	7.4
5	11	10	66	63	1.5	7.3
6	12	11	60	68	1.7	7.8
7	12	10	51	60	1.7	7.3
8	15	13	45	74	1.7	7.3

Table 3. *Gender distribution and mean values of patient parameters for Abdomen examination.*

FacilityNo	Patient data					
	No. of males	No. of females	Age(Yrs)	Mass(kg)	Height(m)	BT(kg m^{-1})
1	15	12	46	70	1.7	7.4
2	9	15	45	78	1.7	7.2
3	9	10	60	78	1.7	6.8
4	6	14	72	83	1.7	8.0
5	6	10	52	78	1.6	8.0
6	5	13	53	68	1.5	7.8
7	8	14	49	65	1.7	7.7
8	15	30	45	68	1.5	7.3

Table 4. *Mean exposure parameters and calculated ESAK for Skullexamination.*

FacilityNo	Gender	Exposure parameters				ESAK (mGy)
		kV_P	mAs	FSD (cm)	Y(d)*10^{-6}(mGy/mAs)	
1	Male	74.0	24.0	86.0	2.86	0.11
	Female	75.0	24.0	83.0	2.86	0.12
2	Male	70.0	20.0	84.0	4.58	0.13
	Female	70.0	25.0	85.0	4.58	0.16
3	Male	62.0	24.5	107.0	5.73	0.10
	Female	65.0	25.0	107.0	5.73	0.11
4	Male	80.0	90.0	100.0	4.58	0.57
	Female	86.0	63.0	91.0	4.58	0.57
5	Male	65.0	45.0	100.0	2.86	0.11
	Female	70.0	25.0	100.0	2.86	0.07
6	Male	62.0	29.0	128.0	4.58	0.07
	Female	65.0	30.0	128.0	4.58	0.07
7	Male	73.0	17.0	85.0	4.58	0.12
	Female	70.0	16.0	85.0	4.58	0.11
8	Male	90.0	45.0	87.0	4.58	0.49
	Female	90.0	45.0	85.0	4.58	0.51

Table 5. *Mean exposure parameters and calculated ESAK for Pelvis examination.*

FacilityNo	Gender	Exposure parameters				ESAK (mGy)
		kV$_P$	mAs	FSD (cm)	Y(d)*10^{-6}(mGy/mAs)	
1	Male	74.0	6.0	86.0	2.86	0.03
	Female	75.0	6.0	83.0	2.86	0.03
2	Male	70.0	5.8	85.3	4.58	0.04
	Female	70.0	7.8	86.0	4.58	0.05
3	Male	67.0	50.0	95.0	5.73	0.28
	Female	50.0	45.0	93.0	5.73	0.16
4	Male	60.0	7.0	100.0	4.58	0.02
	Female	60.0	18.0	100.0	4.58	0.06
5	Male	65.0	45.0	100.0	2.86	0.11
	Female	70.0	25.0	100.0	2.86	0.03
6	Male	53.0	25.0	152.4	4.58	0.03
	Female	56.0	26.0	158.0	4.58	0.03
7	Male	80.0	25.0	83.0	4.58	0.23
	Female	80.0	23.0	72.0	4.58	0.28
8	Male	75.0	15.0	85.0	4.58	0.12
	Female	70.0	13.0	86.0	4.58	0.08

Table 6. *Mean exposure parameters and calculated ESAKfor Abdomen examination.*

FacilityNo	Gender	Exposure parameters				ESAK (mGy)
		kV$_P$	mAs	FSD (cm)	Y(d)*10^{-6}(mGy/mAs)	
1	Male	80.0	25.0	100.0	2.86	0.10
	Female	80.0	25.0	90.0	2.86	0.12
2	Male	75.0	29.0	80.0	4.58	0.25
	Female	74.0	33.0	80.0	4.58	0.28
3	Male	71.0	60.0	109.0	5.73	0.31
	Female	71.0	50.0	95.0	5.73	0.34
4	Male	90.0	141.3	100.0	4.58	1.16
	Female	88.0	115.0	100.0	4.58	0.73
5	Male	50.0	25.0	83.0	2.86	0.05
	Female	55.0	25.0	83.0	2.86	0.06
6	Male	63.0	34.0	145.0	4.58	0.06
	Female	55.0	31.0	155.0	4.58	0.04
7	Male	77.0	28.0	80.0	4.58	0.24
	Female	75.0	34.0	82.0	4.58	0.28
8	Male	75.0	33.0	82.0	4.58	0.27
	Female	76.0	32.0	85.0	4.58	0.24

The backscatter factors (BSF) were obtained from BSF published by IAEA (2007). The BSF for these examinations was ranged between 1.26-1.41 with the highest value of 1.41for abdomen examination.The mean weight of most of the patients was within (70±13kg) as recommended by IAEA (IAEA, 2007, IAEA 2004). The recommendation of these analytical techniques is based on the direct relationship between these exposure parameters and dose and the calculated dose could be more reliable because the real attributes of the patients are used. The kVp and mAs are directly proportional to the ESAK while there is an inverse square relationship with the FFD. The analytically evaluated dose as presented infigs 1–3 show a variation in mean organ doses for each of the irradiated part of the body, fig. 4 reports the mean dose for the radiosensitive organs associated with the examined part, fig. 5 reports the mean gonadal dose and the comparison with the UK values while fig. 6 show the distribution of mean effective dose for all the examination and comparison with other studies. The effective dose (ED) for the respective examinations was obtained as arithmetic mean of the sex specific weights dose (Kramer, *et al.,*2008) as given in eqn. 3 below

$$ED = \frac{1}{2}(E^m + E^f) \quad (3)$$

Where the terms in the bracket are the male adult mesh (MASH) and female adult mesh (FASH) phantoms specific weights dose used for male and female patients respectively.

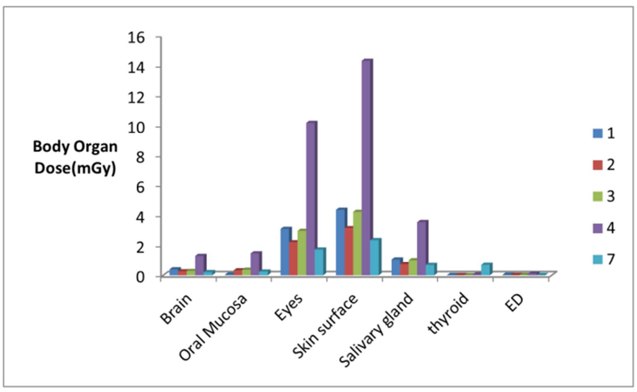

Fig. 1. *Body organ dose (mGy) for Skull examination in the different Facilities.*

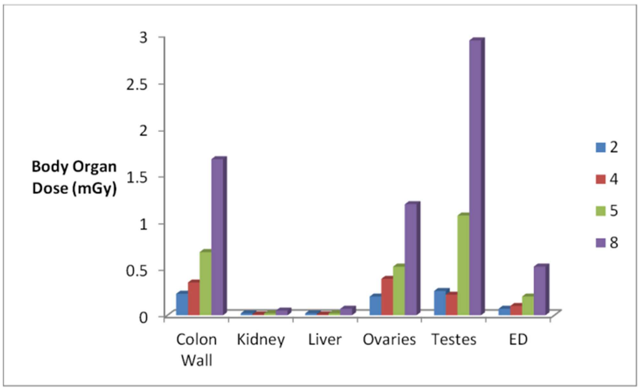

***Fig. 2.** Body organ dose (mGy) for Pelvis examination in the different Facilities.*

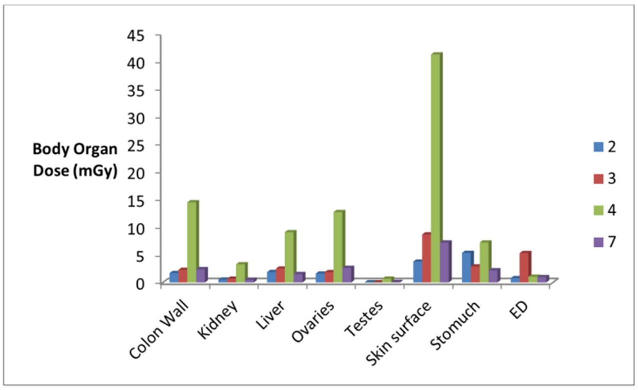

***Fig. 3.** Body organ dose (mGy) for Abdomen examination in the different Facilities.*

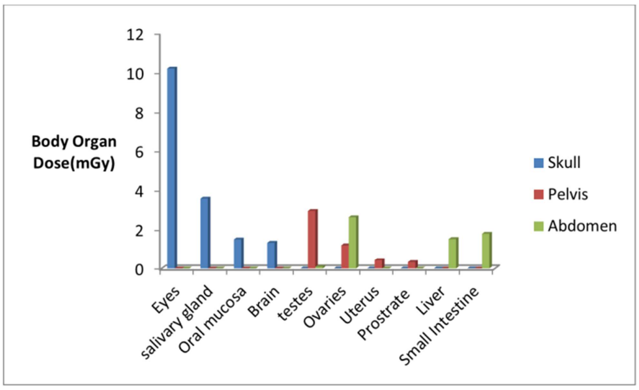

***Fig. 4.** Highest four radiosensitive organ doses (mGy) for each type of examination.*

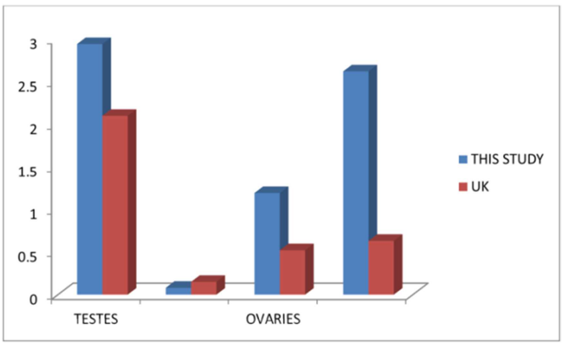

***Fig. 5.** Mean gonadal dose (mGy) for Pelvis and Abdomen examinations and comparison with UK value.*

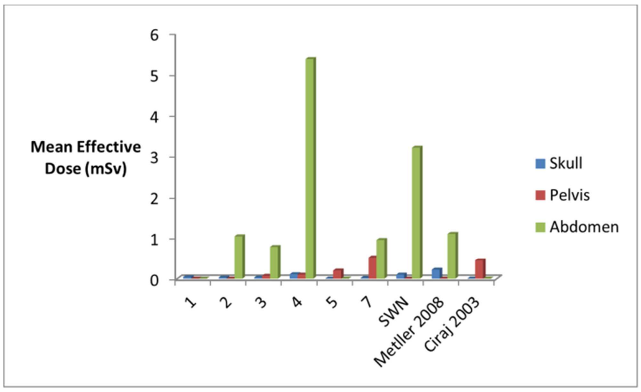

***Fig. 6.** Distribution of mean effective doses (mSv) for all the examinations in all the facilities and comparison with other studies.*

The entrance surface air kerma (ESAK) values for the different medical examinations considered in this study were estimated from Caldose software (Kramer et al, 2008, Inyang*et al,* 2015). The ESAK values for all the examinations obtained were used in the estimation of the body organ doses(BOD), effective dose (ED) and the gonadal dose and the results reported in figs 1-6 and the comparison of the mean gonadal dose with the UK values in fig.5. Mean organ dose distributions tabulated in fig. 4indicate that for skull examination, the eyes absorbed the largest dose of 10.19 mGy, followed by salivary glands of 3.57 mGy and 1.49 mGy for oral mucosa and the brain 1.32 mGy (fig. 1, facility 4).In pelvis examination, the gonads (ovaries and testes) absorbed the highest and the second highest dose of 2.94 mGy and 1.19 mGy respectively while uterus and prostate gland absorbed 0.43 mGy and 0.33 mGy respectively.In abdomen examination, liver absorbed 1.51 mGy, ovaries 2.62 mGy, testes 0.08 mGy and SMI absorbed 1.78 mGy of radiation dose.

The distributions of mean effective dose (ED) for all the examinations in the facilities investigated reported in fig. 6 shows that the mean ED (mSv) values obtained for the different examinations in the different facilities show an ED range of 0.02-0.11mSv in skull examination while ED for pelvis and abdomen examinations ranges are (0.07-0.52) mSv and (0.78-5.37) mSv respectively. The highest mean ED range of 0.95-5.37 mSv was recorded in abdomen examination in all the hospitals investigated with facility 4 delivering the highest ED of 5.37 mSv and facility 2 delivering the least ED of 0.78 mSv. The high body organ dose (BOD) and ED from facility 4 could be as a result of the application of high mAs and high kVp in the abdomen examination.

However, wide variations in dose levels in diagnostic radiology facilities is a common feature as seen in the ESD values from other studies (Milatovic, *et al.,* 2011, Nyathi, *et al.,* 2009). In a similar studies carried out elsewhere,skull ESD ranged 0.48 -3.25 mGy and ED ranged of 0.004-0.02 mSv, in abdomen examination mean ESD of 0.96-4.28 mGy and ED of 0.10-0.46 mSv were obtained (Osibote and Azevedo, 2008)

In the comparison of mean gonads dose with values obtained from other studies as tabulated in fig. 5, the highest gonads dose is from pelvis examination, this is because the gonads are the most exposed to ionising radiation in pelvis examination (Ofori, *et al.,* 2012). The mean gonads dose obtained in this study compared with values from adult patient in UK (Wall *et al.,* 2011) shows that in pelvis examinationtestes dose in this study is greater than the UK value by 29% while the ovaries dose is greater than the UK value by 67%.Similarly, there is variation between the gonads dose obtained in this study and the UK value for abdomen examination.Thisvariation in the gonads dose in abdomen examination could be attributed to the radiographic technique factors selected for this examination and the sex specific conversion coefficient for the organ in the phantoms used by the software. Equally, the FSD (equal to difference between the FFD and BT) used in this study for skull examination was less than the recommended values in CEC guidelines (100-150) cm. This non-compliance with optimal FSD could increase patient skin dose (Poletti, 1994).

The effective doses (ED) obtained in this study are less than those obtained in South Western Nigeria, (SWN) (8.5-23.4) mSv (Olowookere, *et al.,* 2011) for all examination except in abdomen examination, where the ED in facility 4 is greater than the values by a factor of 1.7. Further comparisons of EDs in this study and other studies reveal that the ED for skull examination in this study (0.02-0.11) mSv is within the range of (0.03-0.22) mSv obtained in the literature (Mettler, *et al.,* 2008) and for pelvis examination, the ED for this study is (0.07-0.52) mSv within the range of ED (0.29-0.45) mSv reported elsewhere (Ciraj, *et al.,* 2003).

It is worthy of note that this differences in EDs in same examination by different facilities i indicate the difference in radiographic procedures used by the different facilities andreflected the non-application of optimal procedures to enhance dose reduction. This could be both human and equipment factors which could be corrected through implementation of adequate quality control programme in these facilities.

The risk of cancer incidence and cancer mortality for these examinations are obtained from the Caldose softwareand presented in Table 7.

Table 7. *Cancer incidence and mortality cases for each examination.*

Examination	Facility number	Cancer incidenceCases per 10^5	Cancer mortality cases per 10^5
Skull	1	0.6	0.4
	2	0.3	0.3
	3	0.5	0.5
	7	0.3	0.2
Pelvis	7	5.0	2.1
Abdomen	7	3.0	1.8

The results show that,inthe skull examination,the cancer incidence and cancer mortality were 0.6 cases in hundred thousand and0.4 cases in hundred thousand respectively in facility 1,0.3 cases in hundred thousand respectively in facility 2, 0.5respectively in facility 3, while the cancer incidence and mortality in facility 7 are 0.3and 0.2 cases in hundred thousand.In facility 7 the risk of cancer incidence and cancer mortality in pelvis examination were 5.0and 2.1 cases in a 100000 respectively while the risks values for abdomen examination were 3.0 and 1.8 cases in 100000. Other facilities also present valuesthat are minimal and very low and are within the recommended very low broad risks band (Wall *et al* 2011).

4. Conclusion

It is obvious that there are variations in the selection of radiographic technique factors by the radiographers for the same examination within the same facility and in inter-facility. This occurrence is not typical of diagnostic radiology facilities in AkwaIbom State only rather a global trend in diagnostic radiology. This is expected because there are no universal standards for selecting technique factors. Even where the CEC criteria have been implemented, variations in the selection of the technique factors are also observed. However, the radiographers in the facilities studied have tried their best in adopting good radiological practice that produces dose that present minimal or very low risk to the patients. To further reduce the dose it is recommended that adequate implementation of quality control programmes in these facilities.

References

[1] Ciraj, O. Markovic, S &Kosutic, D (2003). Patient dosimetry in diagnostic radiology, *Nuclear Technology and Radiation Protection* 1, 28-36.

[2] Egbe, N. O, Inyang, S. O, Eduwem, D. U. &Ama, I (2009). Doses and image quality for Chest Radiography in three Nigerian Hospitals, *European Journal of radiography,*1, 30-36.

[3] Essien, Imeh Edet and Inyang Samuel Okon (2015). A Survey of Radiation Exposure Techniques Factors Used for Common Diagnostic X-Ray Examination in Akwa Ibom State, Nigeria. *International Journal of Medical Imaging* 3 (4) 69-74.

[4] Heggie, J. C. P (1990). A Survey of Doses to Patient in a large Public Hospital resulting from common Plain Film Radiographic Procedures; *Australia Physics in Engineering, Science and Medicine,* 13 71-80.

[5] IAEA (2004). Optimization of radiological protection of patients undergoing radiography, fluoroscopy and computed tomography, a final report of coordinated research projects in Africa, Asia and Eastern Europe, IAEA-TECDOC-1423, Vienna.

[6] IAEA (2007). Dosimetry in diagnostic radiology, International Code of Practice, IAEAtechnical report series 457, Vienna.

[7] ICRP (1996). Radiological Protection and Safety in Medicine, Oxford, InternationalCommission on Radiological Protection Publication.

[8] Jabbari, N. Zeinali, A. &Rahmatnezhad, L (2012). Patient Dose from Radiographic Rejects/Repeats in Radiology Centers of Urmia University of Medical Sciences, Iran, *Journal of Health,* 4 94-100.

[9] KothanSuchart and MontreeTungjai (2011). An Estimate of X-Radiation Output using Mathematic model, *American Journal of Applied Sciences*, 8 (9), 923-926.

[10] Kramer, R, Khoury, H. J & Vieira J. W (2008). Caldose_ X-5.0 a software tool for the assessment of organ and tissue adsorbed doses, effective dose and cancer risks in diagnostic radiology, *Physics Medicine Biology,* 53, 6437-6459.

[11] Martin, C. J (2007). The importance of radiation quality for optimization in radiology, *Biomedical Imaging and Intervention Journal*, 3 (2) 1-14.

[12] Mettler, F. A, Huda, W. Yoshizumi, T. T & Mahesh, M (2008). Effective dose in radiology and diagnostic nuclear medicine, *Radiology,* 248: 254-263.

[13] Milatovic, A, Ciraj-Bjelac, O, Ivanovic, S. Jovanovic, S &Spasic- Jokic, V (2011). Patient dose measurements in diagnostic radiology procedures in Montenegro, *Radiation Protection Dosimetry,* 1-10.

[14] Muhogora, W.E, Ahmed, N. A, Almosabihi, A. Alsuwaidi, J. S, Benganovic, A. Olivera, C. B.Kubuya, F. K, Krisanachinda, A. Milakovic, M. Mukwada, G. Ramanandraibe, M. J, Rehani, M. M, Rouzitalab, J. &Shandorf, C (2008). Patient doses in radiographic examinations in 12 Countries in Asia, Africa, and Eastern Europe: Initial Results from IAEA projects. *American Roentgen Ray Society*, 190, 1453-1461.

[15] NNRA (2006). Nigeria radiation safety in diagnostic and interventional radiology regulations, Federal Government Press, Lagos, Nigeria.

[16] Nyathi, T, Nethwadzi, L. C. Mabhengu, T, Pule, M. L &Merwe, D. G (2009). Patient dose audit for patient undergoing six common radiography examinations: Potential dose reference levels, *South African Radiography,* 9-13.

[17] Ofori, E. K, Antri, W. K, Skutt, D. N & Ward, M (2012). Optimization of patient radiation protection in pelvic x-ray examination in Ghana, *Journal of Applied Clinical Medical Physics, 1*3 (4), 20-26.

[18] Ogundare, F. O, Uche, C. Z &Balogun, F. A (2004). Radiological parameters and radiation doses of patients undergoing abdomen, pelvis and lumbar spine x-ray examinations in three Nigerian hospitals, *The British Journal of Radiology*, 77, 934-940.

[19] Olowookere, C. J. Obed, R. I. Babalola, I. A & Bello, T. O (2011). Patient dosimetry during chest, abdomen, skull and neck radiography in South West Nigeria. *Radiography*, 245-249.

[20] Osibote, O. A. &Azevedo, A.C.P (2008). Estimation of adult patient doses for common diagnostic x-ray examinations in Rio de Janerio, Brazil; *PhysicaMedica*, 21-2.

[21] Poletti, J. C (1994). Factors affecting patient dose in diagnostic radiology, *Natural Radiation*11, 17-18.

[22] Inyang, S. O. Essien, I. E., and Antia, A. D (2015). Entrance surface air kerma for chest examination in some diagnostic radiologic facilities in AkwaIbom State, Nigeria; *Advances in Physics Theories and Applications* 48, 28-35.

[23] Wall, B. F. Haylock, R. Jansen, J. T. M, Hillier, M. C, Hart, D &Shrimpton, P. C (2011). Radiation risks from medial X-ray examination as a function of the age and sex of the patient; *Health Protection Agency*, 1-66.