



Estimation of Radiological Doses to Organs around the Head and Neck Region in a Radiological Centre in Jos, Plateau State, Nigeria

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ABSTRACT: This study estimates the radiological doses absorbed by organs around the head and neck regions during x-ray examinations in a radiological centre in Jos, Plateau State, Nigeria. The exposure parameters of 60 adult patients (30 male and 30 female) were used to estimate the doses. The results showed that the male head radiograph had an average ESD of 1.36 mGy, while the female head radiograph had an ESD of 1.07 mGy. The absorbed doses for the brain, oral mucosa, eye lens, bone_{cranium} and mandible, skin_{head}, salivary gland, thyroid, esophagus, bone_{cervical}, and skin_{neck} were 0.416, 0.262, 0.472, 2.21x10⁻¹⁶, 0.303, 0.439, 0.296, 0.214, 1.1x10⁻¹⁶, and 0.303 mGy, respectively. The effective dose was 0.092 mSv for the head region and 0.021 mSv for the neck region. Comparing the ESD and effective doses with regulatory standards and existing literature, it was observed that the patients were not exposed to any significant radiation risk.

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The application of X-rays in the twenty-first century has been incredible. It has become a vital tool in radiology and radiotherapy due to its significance in patient care. However, exposure to ionizing radiation from patients increases the total dose to the population. The ability of ionizing radiation to interact with living things can cause damage to essential molecules, such as DNA. The damage that an individual tissue or organ sustains during X-ray procedures is determined by the amount of radiation received by the patient. Therefore, to determine the probability of the patient experiencing harm, it is necessary to measure the amount of the absorbed dose. The quantity that measures the amount of radiation absorbed by a patient's skin during a specific radiological examination is called the "entrance surface dose." This dose has a significant impact on the amount of radiation received by a patient during radiological

imaging and can potentially cause radiosensitivity in tissues or organs. The ESD can be measured directly using dosimeters or indirectly through mathematical formulations that involve modality-related dose parameters related to the modality (Tsapaki *et al.*, 2007; Sharma *et al.*, 2015; Ahmadi *et al.*, 2020; Bly, 2021; Melboom *et al.*, 2021). The effective dose (ESD) is greatly affected by the penetrating power of the X-rays used, which varies depending on the patient's body size and the specific area being examined (Ibrahim *et al.*, 2014). It was necessary to use externally detectable practical quantities because it is impossible to directly measure the doses in the body's internal organs. The International Committee on Radiation Units and Measurements (ICRU) has established operational limits for radiation fields outside the body. Before the development of the radiation weighting factor, quality factors were used to

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explain these numbers about linear energy transfer instead of the radiation weighting factor. However, in most real-world scenarios, these field values still accurately reflect the protection numbers used by the International Commission on Radiological Protection (ICRP, 1995). Patient exposure to diagnostic X-rays must be measured in terms of tissue or organ dose. The International Commission on Radiological Protection (ICRP) introduced the concept of effective dose (ICRP) in 1990, which is derived from the dose values for critical tissues and organs (ICRP, 2007).

The primary concern with radiological exposure is to minimize the dose to the absolute minimum while still benefiting from medical benefits. Radiological patient doses should be minimised to the greatest extent possible. Dose optimisation involves measuring the radiation doses administered to patients (Ibrahim *et al.*, 2014). The measurement of patient dose is crucial for establishing dose limits, evaluating the patient's risk, and justifying the necessity of radiological tests. The effective dose to an organ, which is a risk-weighted measurement of the radiation's impact on the body's organs, accurately predicts the radiological risk associated with an examination (Cruces *et al.*, 1998; ICRP, 2007; EC, 1999). The effective dose of a specific human body model provides an estimate of risk (McCullough *et al.*, 2010; Ernest and Johnson, 2013). The distribution of doses to different tissues and organs resulting from a specific exposure is determined by a single parameter known as the effective dose (ICRP, 2007; EC, 1999). The ICRP (International Commission on Radiological Protection) established effective measurement techniques in 2007, as well as in 1990 and 1995. Radiological techniques rely heavily on the ability to predict the dose to radiosensitive organs. Measurable values, such as the entrance surface dose (ESD) or dose-area product (DAP), from the radiological examination, are used to estimate organ doses in radiological examinations. Due to the variation in radiological practices across different facilities, it is extremely challenging to accurately assess the radiation dose for comparable scans. The effective dose for a given estimate can vary depending on factors such as the patient's size, examination technique, clinical procedures, and the level of experience of the radiologist or radiographer. In addition to assessing risks during radiological practice, this requires a more targeted dose for patients. Previous research has provided valuable information on determining dosages for radiological exams (Ernest and Johnson, 2013; Shrimpton *et al.*, 2005; McCullough *et al.*, 2010; Toossi & Dastgherdi *et al.*, 2004; Ngaile and Msaki, 2006). The methodology for radiological tests can vary greatly between different

facilities, so it is essential to conduct a facility-specific inquiry for more specialised information. The objective of this work was to estimate the radiation doses absorbed by organs in the head and neck regions during x-ray examinations at a radiological centre in Jos, Plateau State, Nigeria.

MATERIALS AND METHOD

Study population: The exposure parameters from sixty (60) adult patients, comprising (30 females and 30 males) between the ages of 35 and 57 years, were used for this study to determine the doses to the organs in the head and neck region during radiological examinations. Organ dose estimation from radiographic procedures makes use of the measured or calculated free-in-air entrance surface dose (ESD in rad) and technique parameters used for the examination.

Method: In this study, a direct measurement of the ESD rad was employed using a dose meter (Unfors Multi-O-Meter 710L with serial number 125295 by Unfors Instrument Sweden). The meter was well calibrated by the National Institute of Radiation Protection and Research (NIRPR) in Ibadan, Nigeria. The detector was positioned on a phantom to mimic standard radiological protocol for head and neck examinations while machine technical parameters, kVp, mAs, field size, FFD, based on the patient's age and size, were considered in the determination of the ESD rad. Before ESD rad measurements, the x-ray machine performance tests such as voltage output (kV), dose, dose rate, timer reproducibility, and accuracy were checked to comply with international standards. After the determination of the free-in-air entrance surface dose (ESD_{rad}), the mean absorbed dose to the organs/tissue or organ dose (DT) was calculated by using the following formula (equation 4):

$$D_T = ESD_{rad} \times DCC \quad 4$$

Where DCC is the organ absorbed dose conversion coefficient found from the report of ICRP 116 which relates ESD rad to organ dose. The equivalent dose in an organ or tissue is calculated according to equation 5 for male (H_T^M) and female (H_T^F) by summing the product of absorbed dose in that organ or tissue and the radiation weighting factor over all types of radiations involved.

$$H_T^M = \sum_R W_R D_T \quad \text{and} \quad H_T^F = \sum_R W_R D_T \quad 5$$

The equivalent dose to the remainder tissues is computed as the arithmetic mean of the equivalent doses to the 13 tissues for each sex as listed in the in the ICRP publication 116 (ICRP, 2010). The equivalent dose to the remainder tissues for Male, H_{rem}^M and Female, H_{rem}^F were determined as their sum as shown in equation 6:

$$H_{rem}^M = \frac{1}{13} \sum_T^{13} H_T^M \text{ and } H_{rem}^F = \frac{1}{13} \sum_T^{13} H_T^F \quad 6$$

Where T is a remainder tissue given in ICRP- 116. The effective dose is calculated according to equation 7 by summing the product of the sex-averaged equivalent dose and tissue weighting factor over organs and tissues of the human body considered in its definition (ICRP, 2010).

$$E = \sum W_T \left(\frac{H_T^M + H_T^F}{2} \right) \quad 7$$

In this study, the organs/tissues considered for head radiological examinations were the brain, oral mucosa, lens of the eye, bone, skin, and salivary gland and for neck radiological examination were thyroid, oesophagus, bone and skin which are entirely or partially exposed to radiation.

RESULTS AND DISCUSSION

Organ doses were estimated in adult patients. Table 1 below shows a summary of the number of male and female patient distributions and the technical parameters selected for head and neck radiological examinations. The technical parameters of the machine shown in Table 1 were used in obtaining the ESD. The obtained ESD was gender-based and for male head radiography, it was 1.36 mGy, while that of the female was 1.07 mGy. The ESD for male neck radiographs was 0.87 mGy, while the ESD for female patients studied was 1.12 mGy. It can be observed from Table 1 that there is a significant variation in ESD values for the head between male and female patients; however, the variation in the neck ESD was slightly significant, with both male and female patients having approximately an ESD of 1.0 mGy. The results of this study showed that the entrance surface dose of patients was comparable to the results reported in similar studies. In Iran, the value of ESD for the head was 7.59 mGy (Shahbazi-Gahrouei, 2006). In contrast, the value of ESD measured here was significantly similar to the Akbar *et al.* study in Iran in 2015, with an ESD to the head of 1.01 mGy, and the UK study of Hart *et al.* in 2010, with an ESD of 1.1 mGy to the skull.

Table 1: Summary of patients' information and examination technical parameters from radiographic examinations.

Examination	No. of Patients		Mean Patient age (year)		Examination Technical Parameters				Free-In-Air Entrance Surface Dose (ESD rad) (mGy)	
	Male	Female	Male	Female	kVp (mean)		mAs (mean)		Male	Female
Head	20	20	43	55	87	81	25	25	1.36	1.07
Neck	10	10	49	52	81	85	20	25	0.87	1.12

Table 2: Absorbed and equivalent doses to the organs of the head and neck during radiological examination.

Examination	Organ Dose (mGy)	Absorbed Dose (mGy)		Equivalent Dose (mSv)	
		Male	Female	Male	Female
HEAD					
Brain	0.416	0.333	0.416	0.333	
Oral Mucosa	0.262	0.256	0.262	0.256	
lens of the eye	0.472	0.371	0.472	0.371	
Bone (cranium and mandible)	2.21E-16	1.74E-16	2.21E-16	1.74E-16	
Skin	0.303	0.244	0.303	0.244	
Salivary gland	0.439	0.360	0.439	0.360	
NECK					
Thyroid	0.296	0.135	0.296	0.135	
Oesophagus,	0.214	0.247	0.214	0.247	
Bone (cervical)	1.1E-16	8.68E-17	1.1E-16	8.68E-17	
Skin	0.303	0.244	0.303	0.244	

Table 3: Effective dose to the head and neck during radiological examination.

Effective Dose (mSv)		
Region	Head	Neck
Male	0.100	0.023
Female	0.085	0.018
Sex averaging for effective dose	0.092	0.021

Table 4: Comparison of the mean ESD (mGy) for the study with those of regulatory standards (NNRA, IAEA, EC and UK).

X-RAY Examinations	MEAN ESD (mGy) This Study	ESD (mGy) IAEA/NNRA	ESD (mGy) EC	ESD (mGy) UK
Head (Skull)	1.2	3.0	3.0	2.8
Neck	1.0	-	-	5.0

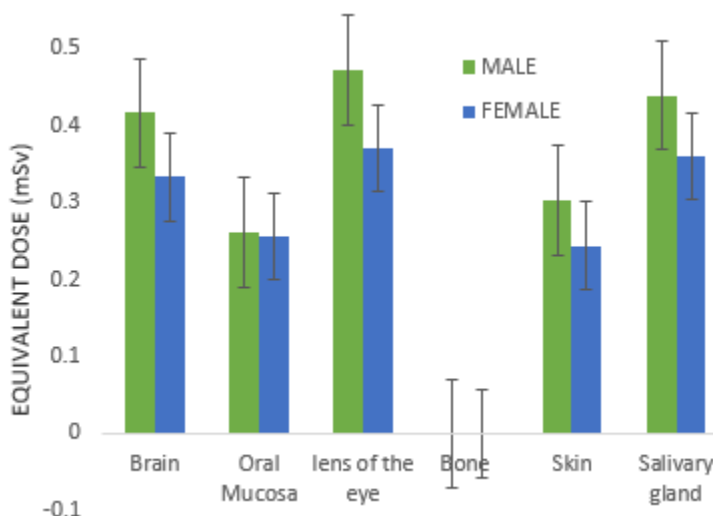


Fig 1: Equivalent doses to the organs of the head for male and female radiological patients.

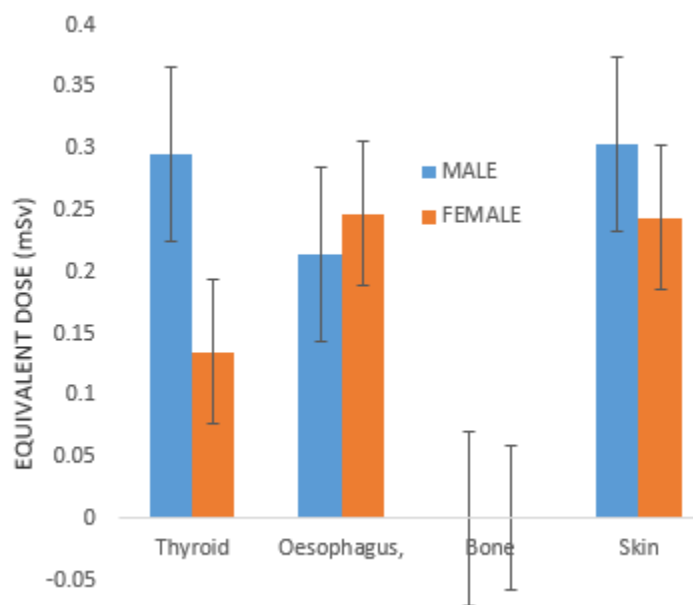


Fig 2: Equivalent doses to the organs of the neck for both male and female radiological patients.

The results obtained for both the organ-absorbed dose and equivalent doses for the head and neck radiological examinations in the male and female groups were the same as shown in Table 2. The absorbed dose for the organs in the male head was 0.416, 0.262, 0.472, 2.21×10^{-16} , 0.303, and 0.439 mGy, while the absorbed dose for organs in the female head was 0.333, 0.256, 0.371, 1.74×10^{-16} , 0.244, and 0.360 mGy, corresponding to the brain, oral mucosa, eye lens, bone (cranium and mandible), skin, and

salivary gland, respectively. The absorbed doses to the organs of the neck, i.e., the thyroid, esophagus, bone (cervical), and skin, were 0.296, 0.214, 1.1×10^{-16} , and 0.303 mGy, respectively, for male patients and 0.135, 0.247, 8.68×10^{-17} , and 0.244 mGy, respectively, for female patients. The equivalent doses for males and females to the corresponding organs were the same as the organ-absorbed doses (D) since the radiation weighting factor is unity for X-rays.

The effective dose for both head and neck radiological examinations in male patients was higher in the male patients than the female ones, as depicted in Table 3. The sex average effective dose to the head was 0.092 mSv, while for the neck region, it was 0.021 mSv. Comparing the effective dose result with other works in literature (Akbar *et al.*, 2015; Hart *et al.*, 2010; Wall *et al.*, 2011) for similar radiological examinations revealed that the effective dose to the head for this study was on the high side. These findings suggest that there may be differences in radiation exposure between male and female patients for head and neck radiological examinations. Further research is needed to investigate the factors contributing to these differences and their potential implications for patient safety. The comparison of the ESD in this study with that of the International Atomic Energy Agency (IAEA), Nigerian Nuclear Regulatory Authority (NNRA), European Commission, and the United Kingdom recommendations presented in Table 4 shows ESD values of the head and neck within international limits. Figures 1 and 2 showed that the organ equivalent doses for the male patients were seen to be higher than that of the female except for the oesophagus which could be attributed to their body mass index, body surface area, and possibly physiological structure

Conclusion: The organ absorbed dose, effective dose, and equivalent dose to the head and neck regions were investigated. Based on the exposure settings utilized for the examination, the entrance surface dose (ESD) was measured. The computed organ absorbed and equivalent doses were compared to those made public by several national and international standards and were found to be within the set limits. Hence, the results obtained show that radiological practices at the study centre poses no significant health risks to both patients and staff.

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REFERENCES

- Ahmadi, A; Negarestani, A; Sina, S; Sarshough, S (2020). Measurement of Entrance Skin Dose and the dose received by differentorgans in Panoramic Dental Imaging. *J. Biomed Phys Eng.* 10(5): 569-574.
- Akbar, A; Ehsan, M; Mahboubeh, M; Morteza, S; Mehran, M (2015). Measurement of Entrance Skin Dose and Calculation of Effective Dose for Common Diagnostic X-Ray Examinations in Kashan, Iran. *Global J. Health Sci.* 7(5).
- Bly, R (2021). Patient exposure levels and collective effective dose to the population from radiological examinations. Published academic dissertation, University of Eastern Finland, Finland.
- Cruces, RR; Garcia-Granados, J; Diaz Romero, FJ; Hernandez, AJ (1998). Estimation of effective dose in some digital angiographic and interventional procedures. *Bri. J. Rad.* 71:42-47
- Ernest, KO; Johnson, D (2013). A Survey of Organ Equivalent and Effective Doses from Diagnostic Radiology Procedures. International scholarly research notices ISRN Radiology, Hindawi Publishing Corporation, Article ID 204346, 1-9.
- European Commission (EC) (1999). European guidelines on quality criteria for computed tomography EUR, 16262 EN, Luxemburg. Office for Official Publications of the European Communities.
- Hart, D; Hillier, M; Shrimpton, P (2010). HPA CRCE-034. Doses to patients from radiographic and fluoroscopic X-ray imaging procedures in the UK-2010 review.
- Ibrahim, U; Daniel, IH; Ayaninola, O; Ibrahim, A; Hamza, AM; Umar, AM (2014). Determination of Entrance Skin Dose From Diagnostic X-Ray Of Human Chest at Federal Medical Centre Keffi, Nigeria. *Sci. World J.* 9 (1).
- ICRP (1995). Conversion Coefficients for use in Radiological Protection against External Radiation. ICRP Publication 74, Annals of the ICRP 26(3/4), Pergamon Press, Oxford.
- ICRP (2007). The 2007 Recommendations of the International Commission on Radiological Protection ICRP Publication 103. Annals of the ICRP 103 (17–23). Published by Elsevier Ltd.
- ICRP (2010) Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures. ICRP Publication 116, Ann. ICRP 40(2–5).
- McCullough, CH; Christner, JA; Koer, JM (2010). How effective is effective dose as a predictor of radiation risk? *Am. J. Roent.* 194(4) : 890–896.
- Melboom, MF; Hoffman, W; Weitmann, K; Von Boetticher, H (2021). Tables for effective dose assessment from diagnostic radiology (period 1946

- 1995) in epidemiologic studies. *PLoS ONE*, 16(4): e0248987
- Ngaile, JE; Msaki, PK (2006). Estimation of patient organ doses from CT examinations in Tanzania. *J. Appl. Clin. Phy.* 7(3): 80–94.
- Shahbazi-Gahrouei, D (2006). Entrance surface dose measurements for routine X-ray examinations in Chaharmahal and Bakhtiari hospitals. *Iran. Rad. Res.* 4(1):29-33.
- Sharma, R; Sharma, SD; Pawar, SI (2015). Radiation dose to patients from X-ray radiographic examinations using computed radiography imaging system. *J. Med. Phy.* 40(1): 29–37.
- Shrimpton, PC; Hillier, MC; Lewis, MA; Dunn, M (2005). National Radiological Protection Board, Doses from Computed Tomography (CT) Examinations in the UK—2003 Review,” Tech. Rep., Chilton, Didcot, UK.
- Toossi, MTB; Dastgherdi, SM (2004). An assessment of organ and effective dose of patients who undertake CT examinations in two teaching hospitals of Mashhad & Isfahan,” in Proceedings of the 11th International Congress of the International Radiation Protection Association, 1–7, Madrid, Spain.
- Tsapaki, V; Tsalafoutas, IA; Chinofoti, I (2007). Radiation doses to patients undergoing standard radiographic examinations: a comparison between two methods. *Brit. J. Rad.* 80:107–112.
- Wall, B; Haylock, R; Jansen, J; Hillier, M; Hart, D; Shrimpton, P (2011). Radiation risks from Medical X-ray examinations as a function of the age and sex of the patient: Centre for Radiation, Chemical and Environmental Hazards, Health Protection Agency.