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Assessment of Entrance Skin Dose, Estimated Effective Dose and Nominal Cancer Risk in Adult Skull and Chest Radiography at Federal Teaching Hospital, Gombe, Nigeria

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ABSTRACT

Diagnostic radiography plays an important role in medical diagnosis; however, exposure to ionising radiation requires regular patient-dose assessment to ensure radiation protection and optimisation of imaging procedures. This study assessed entrance skin dose (ESD), estimated effective dose and nominal radiation-associated cancer-risk indicators among adults undergoing skull and chest radiography at Federal Teaching Hospital, Gombe, Nigeria. Thermoluminescent dosimeters were used to measure ESD during 30 radiographic examinations, comprising 15 skull and 15 chest examinations. The recorded doses were analysed by age group, while effective doses were estimated using assumed examination-specific conversion coefficients of 0.003 mSv/mGy for skull and 0.020 mSv/mGy for chest radiography. The overall mean ESDs were 41.59 mGy and 3.85 mGy for skull and chest examinations, respectively. Across age groups, mean ESDs ranged from 33.40 to 50.03 mGy for skull examinations and 2.99 to 4.53 mGy for chest examinations. Corresponding estimated effective doses ranged from 0.1002 to 0.1501 mSv and 0.0598 to 0.0907 mSv, respectively. Nominal cancer-risk indicators were calculated using a radiation detriment coefficient of 0.055 Sv^{-1} but should not be interpreted as individual lifetime cancer probabilities. The relatively high skull ESD values warrant further investigation. Although the findings provide preliminary information on patient radiation exposure, their interpretation is limited by the small sample size, incomplete exposure and patient-characteristic data, and unverified dose-conversion coefficients. A comprehensive, quality-assured dosimetry assessment is recommended to validate the findings and guide radiographic dose optimisation.

INTRODUCTION

Diagnostic radiography is a fundamental component of modern healthcare because it provides rapid, non-invasive information for detecting disease, assessing injuries and guiding clinical decisions. Conventional chest radiography is routinely used to investigate pulmonary and cardiovascular conditions, while skull radiography may be requested for selected clinical indications. Both examinations employ ionising X-radiation and therefore require attention to the balance between diagnostic benefit and radiation exposure. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2022) identified medical procedures as the largest human-made source of population exposure to ionising radiation, with conventional radiology accounting for a substantial proportion of examinations worldwide. Although individual conventional radiographic examinations generally deliver relatively low effective doses, their frequency and variations in clinical technique make patient-dose monitoring an important component of radiation protection.

Radiation protection in medical imaging is guided primarily by justification and optimisation. Justification requires that an examination provide sufficient expected clinical benefit to outweigh the potential radiation detriment, while optimisation seeks the lowest reasonably achievable exposure consistent with diagnostically adequate image quality (International Commission on Radiological Protection [ICRP], 2007). Unlike occupational and public exposure, medically justified patient exposures are not subject to fixed dose

limits, because rigid limits could prevent necessary diagnostic procedures. Instead, the appropriate use of imaging protocols, equipment quality assurance and regular assessment of patient-dose indicators are central to safe practice (ICRP, 2017).

Entrance skin dose (ESD), commonly reported in milligray (mGy), is a practical quantity for evaluating exposure during projection radiography. In the context of diagnostic reference levels, the closely related quantity entrance-surface air kerma includes backscattered radiation and must be distinguished from incident air kerma, which excludes backscatter (ICRP, 2017). ESD can be assessed using calibrated thermoluminescent dosimeters placed at the beam-entry surface, provided the measurement geometry, beam quality, calibration and backscatter treatment are clearly documented. Patient dose depends on tube potential (kVp), tube-current–time product (mAs), filtration, source-to-skin distance, projection, field size, patient thickness and equipment performance. Consequently, differences in measured entrance dose cannot be attributed to patient age or examination type alone without accounting for these technical and anatomical factors (International Atomic Energy Agency [IAEA], 2018).

Diagnostic reference levels (DRLs) are widely used to identify examinations or facilities with atypically high typical patient doses and to trigger investigations into opportunities for optimisation. They are not regulatory dose limits, and an individual result above a DRL does not automatically imply inappropriate exposure. Meaningful comparison requires matching the examination, projection, patient group, dosimetric quantity and measurement conditions (ICRP, 2017). For hospitals operating conventional radiographic systems, systematic dose surveys can reveal variations in technique and help prioritise equipment checks, protocol review and staff training. Earlier work by Suliman et al. (2007) in Sudan illustrated the value of measuring entrance-surface doses for selected diagnostic X-ray examinations in an African clinical setting. However, findings from other facilities cannot be transferred directly to a particular hospital without considering differences in equipment, patients and imaging protocols.

Entrance skin dose and effective dose describe different aspects of radiation exposure. Effective dose, expressed in sievert (Sv), combines organ or tissue equivalent doses using tissue-weighting factors and is intended primarily for radiological protection comparisons rather than precise estimation of an individual patient's risk. Conversion from an entrance-dose measurement to effective dose requires an appropriate, examination-specific computational model, taking account of projection, beam spectrum, irradiated anatomy and patient characteristics. Applying a single fixed coefficient across all patients introduces uncertainty, particularly where exposure geometry and patient size are incompletely documented (ICRP, 2007; IAEA, 2018). Thus, calculated effective doses should be clearly identified as estimates rather than direct dosimeter measurements.

Potential stochastic effects, especially radiation-associated cancer, provide an additional reason to optimise medical exposures. ICRP (2007) proposed a nominal detriment-adjusted cancer risk coefficient of approximately 5.5×10^{-2} Sv^{-1} for a reference population. This population-level coefficient is not an individual lifetime cancer probability and does not capture the substantial dependence of radiation risk on age at exposure, sex, organs irradiated and baseline cancer incidence. Accordingly, multiplying an estimated effective dose by a nominal coefficient may provide an illustrative risk index, but it cannot establish a patient-specific cancer outcome or demonstrate that older patients have greater biological susceptibility. Risk indicators must also be interpreted in relation to the expected clinical benefit of the examination.

In Nigeria, locally documented patient-dose information remains important for assessing radiographic practice, supporting quality assurance and developing context-appropriate optimisation programmes. For Federal Teaching Hospital, Gombe, examination-specific measurements can help characterise existing skull and chest radiographic exposures and identify findings requiring closer dosimetric verification. The present study used thermoluminescent dosimeters to investigate 30 adult examinations, comprising 15 skull and 15 chest radiographs. Given the limited sample and the uncertainty associated with derived effective-dose and risk estimates, the findings should be treated as a preliminary single-centre assessment rather than a definitive evaluation of individual cancer risk. The study addresses the need for local measurement while providing a basis for subsequent larger surveys, validated dosimetry and comparison with appropriate DRLs.

This study aimed to measure entrance skin doses and estimate effective-dose and nominal radiation-risk indicators for adult patients undergoing skull and chest radiographic examinations at Federal Teaching Hospital, Gombe, Nigeria..

MATERIALS AND METHODS

Study design, setting and participants

This was a single-centre observational patient-dosimetry assessment conducted in the diagnostic radiology unit of Federal Teaching Hospital, Gombe, Nigeria. The source dataset comprises 30 adult radiographic examinations: 15 chest and 15 skull examinations.

X-ray equipment and exposure information

A conventional diagnostic X-ray unit was used. For each examination, the source tables provide age, tube potential (kVp), tube-current–time product (mAs) and entrance skin dose (ESD). The chest records show 70–71 kVp and 10–12 mAs, while the skull records show 80–82 kVp and 16–18 mAs. These technical and anatomical factors affect entrance dose and are necessary for meaningful comparison with diagnostic reference levels (ICRP, 2017; IAEA, 2018).

Thermoluminescent dosimetry and quality assurance

The entrance skin dose (ESD) was measured using thermoluminescent dosimeter (TLD) chips placed on the patient's skin at the radiation entrance surface during skull and chest radiographic examinations. After each exposure, the TLD chips were removed and their stored radiation signals were measured using a TLD reader. The readings were converted into dose values using the appropriate calibration factors, with background radiation taken into account. The resulting values were recorded as the entrance skin doses for the individual patients (IAEA, 2018).

Entrance-dose summaries

The individual ESD observations (mGy) were extracted separately for chest and skull examinations. Patients were grouped descriptively into four age bands: 20–29, 30–39, 40–49 and 50–59 years. For each examination type and age band, the arithmetic mean and sample standard deviation were recalculated from the individual measurements using the expressions $\bar{x} = (\Sigma x_i)/n$ and $SD = \sqrt{[\Sigma(x_i - \bar{x})^2/(n-1)]}$. It is important to state that no local diagnostic reference level was established from this small convenience sample (ICRP, 2017).

Estimated effective dose

The effective dose was estimated from the measured entrance skin dose (ESD) using fixed conversion coefficients of 0.003 mSv/mGy for skull radiography and 0.020 mSv/mGy for chest radiography. The calculation involved multiplying the ESD obtained for each patient by the corresponding coefficient, as expressed below:

For skull radiography:

$$E_{\text{est}}(\text{mSv}) = \text{ESD}(\text{mGy}) \times 0.003 \quad (1)$$

For chest radiography:

$$E_{\text{est}}(\text{mSv}) = \text{ESD}(\text{mGy}) \times 0.020 \quad (2)$$

Nominal radiation-risk indicator

The nominal radiation-induced cancer-risk indicator was estimated by multiplying the calculated effective dose, expressed in sieverts (Sv), by the nominal risk coefficient of 0.055 Sv^{-1} recommended by ICRP (2007). The calculation was performed using the following equation:

$$R_{\text{nominal}} = \frac{E_{\text{est}}(\text{mSv})}{1000} \times 0.055 \quad (3)$$

RESULTS AND DISCUSSION

Individual exposure records

Chest radiography

Table 1: Individual exposure parameters and entrance skin doses for adult chest radiography (n = 15).

Code	Age (years)	kVp	mAs	ESD (mGy)
GMB1	26	70	10	1.75
GMB2	28	70	10	2.72
GMB3	24	70	10	2.28
GMB4	32	71	11	3.08
GMB5	36	71	11	3.25
GMB6	38	71	11	3.47
GMB7	40	70	11	2.89
GMB8	52	70	12	4.22
GMB9	45	71	11	3.96
GMB10	55	70	12	4.52
GMB11	58	70	12	4.86
GMB12	48	71	12	5.05
GMB13	29	70	12	5.20
GMB14	39	70	12	4.98
GMB15	49	71	12	5.56

Skull radiography

Table 2: Individual exposure parameters and entrance skin doses for adult skull radiography (n = 15).

Code	Age (years)	kVp	mAs	ESD (mGy)
GMB1	26	80	16	29.90
GMB2	28	80	16	31.44
GMB3	34	80	17	32.69
GMB4	29	80	16	34.25
GMB5	43	80	16	35.11
GMB6	28	80	16	38.02
GMB7	32	81	16	40.31
GMB8	36	80	16	41.48
GMB9	38	82	17	43.71
GMB10	46	81	16	45.47
GMB11	53	82	18	46.54
GMB12	45	81	16	50.29
GMB13	49	82	17	51.11
GMB14	50	82	16	51.56
GMB15	51	82	16	51.98

Tables 1 and 2 present the individual exposure settings and entrance skin doses (ESDs) for chest and skull examinations, respectively. Across the 15 chest examinations, ESD ranged from 1.75 to 5.56 mGy, with a mean of 3.85 ± 1.17 mGy. For the 15 skull examinations, the corresponding range was 29.90–51.98 mGy and the mean was 41.59 ± 7.78 mGy. On average, the measured entrance dose for skull imaging was approximately 10.8 times that for chest imaging. This contrast is consistent with the different radiographic techniques required for these anatomical regions, although it cannot be explained by anatomy alone. Beam filtration, patient thickness, focus-to-skin distance, field size and equipment output also affect entrance dose.

Age-stratified entrance skin doses

Table 3: Age-stratified entrance skin dose for skull and chest examinations (mean ± sample SD).

Age group (years)	Skull n	Skull ESD mean ± SD (mGy)	Chest n	Chest ESD mean ± SD (mGy)
20–29	4	33.40 ± 3.57	4	2.99 ± 1.53
30–39	4	39.55 ± 4.78	4	3.70 ± 0.87
40–49	4	45.50 ± 7.36	4	4.36 ± 1.19
50–59	3	50.03 ± 3.03	3	4.53 ± 0.32

The age-group results are summarised in Table 3. Mean skull ESD rose from 33.40 mGy among patients aged 20–29 years to 50.03 mGy among those aged 50–59 years. The corresponding chest means were 2.99 and 4.53 mGy. Although the endpoint means differ by about 50% for skull examinations and 52% for chest examinations, these observations should not be taken to mean that increasing age itself raises X-ray dose. Only three or four patients contributed to each age band, and exposure settings, body size and clinical requirements may have varied between patients. ICRP (2017) stresses that patient and examination characteristics must be considered when interpreting dose comparisons.

The statistics in Table 3 were recalculated from the 30 individual records. For example, the skull ESD for ages 20–29 was 33.40 ± 3.57 mGy (n = 4), while the chest value was 2.99 ± 1.53 mGy (n = 4), where the uncertainty shown is the sample standard deviation.

Examination technique and implications for dose optimisation

Tables 1 and 2 also show that the recorded chest exposures used 70–71 kVp and 10–12 mAs, whereas skull exposures used 80–82 kVp and 16–18 mAs. These differences are relevant to the higher skull ESDs, but the recorded parameters alone cannot establish whether the techniques were optimised. In particular, the skull values of 29.90–51.98 mGy deserve careful verification of TLD calibration, background correction, beam-quality response, placement, backscatter treatment and X-ray output. Such an audit is a necessary first step before attributing the high measurements to poor technique or equipment malfunction.

Earlier African studies provide useful context. Obed et al. (2007) reported mean entrance skin doses of 6.7 mGy for skull AP and 0.4 mGy for chest PA examinations in selected Nigerian hospitals. These are approximately 6.2 and 9.6 times lower, respectively, than the present mean values. Suliman et al. (2007) reported skull AP/PA

values of 1.04–2.26 mGy and chest AP values of 0.17–0.27 mGy in Sudan. The present results are therefore notably higher than these published values. Nevertheless, the comparisons are indicative rather than definitive: projection, patient characteristics, dosimeter methods and X-ray equipment may differ, and the chest PA value in the Nigerian study is not directly interchangeable with an AP examination. Diagnostic reference levels are intended to prompt investigation and optimisation, not to function as individual patient dose limits (ICRP, 2017).

Derived effective dose

Table 4: Age-stratified estimated effective dose and nominal radiation-risk indices for skull and chest radiography.

Age group	Skull E (mSv)	Chest E (mSv)	Skull nominal index	Chest nominal index
20–29	0.1002	0.0597	5.511e-06	3.286e-06
30–39	0.1186	0.0739	6.525e-06	4.065e-06
40–49	0.1365	0.0873	7.507e-06	4.801e-06
50–59	0.1501	0.0907	8.254e-06	4.987e-06

Table 4 presents the effective-dose estimates and nominal risk indices calculated from the age-group ESD means. Applying the original manuscript's assumed conversion coefficients of 0.003 mSv/mGy for skull and 0.020 mSv/mGy for chest examinations gives effective-dose estimates of 0.1002–0.1501 mSv and 0.0598–0.0907 mSv, respectively. Unlike ESD, these values were not measured directly. They depend on fixed coefficients whose source and suitability for the recorded projection, beam quality, field size and patient anatomy have not yet been verified. They should consequently be regarded as provisional estimates rather than validated patient-specific effective doses (ICRP, 2007; IAEA, 2018).

Table 4 also makes the uncertainty in the derived quantities easier to interpret. Based only on the calculated ESD sample standard deviation, multiplication by 0.003 mSv/mGy would give approximately ±0.0107 mSv. Even that figure excludes uncertainty in TLD calibration and the conversion factor. The precision of the effective-dose estimates should therefore not be overstated.

Interpretation of the nominal cancer-risk index

The nominal cancer-risk indices in Table 4 range from approximately 5.51×10^{-6} to 8.25×10^{-6} for skull examinations and from 3.29×10^{-6} to 4.99×10^{-6} for chest examinations. These values were obtained by multiplying estimated effective dose by the same population-averaged coefficient of 0.055 Sv^{-1}. Their increase across the age bands is therefore a mathematical consequence of the higher estimated doses, not evidence that older patients have greater biological susceptibility. The ICRP coefficient is intended for radiological protection at a population level; individual lifetime cancer probability cannot be inferred from it without considering age at exposure, sex, organ doses and other factors (ICRP, 2007).

The clinical context is also essential. A justified radiograph can confer a diagnostic benefit that substantially outweighs the small modelled stochastic risk; optimisation requires the lowest practicable dose compatible with adequate image quality, not minimisation without regard to diagnosis (IAEA, 2018). No occupational or public monitoring data were collected, so patient ESD cannot establish the safety of radiographers or people near the X-ray unit.

Implications of comparisons with previous investigations

Taken together, the comparisons with Obed et al. (2007) and Suliman et al. (2007) suggest that the recorded Gombe entrance doses, particularly for skull imaging, should be examined through an independent quality-assurance audit. The earlier Nigerian study involved 766 patients across nine hospitals, while the present study covers only 30 examinations in one hospital. The smaller dataset is valuable as an initial local assessment but cannot establish how common such doses are across the state. The practical priority is to confirm the measurements and then determine whether exposure settings can be optimised without compromising diagnostic image quality, in keeping with ICRP (2017) and IAEA (2018) guidance.

CONCLUSION

This study provides an initial assessment of radiation exposure during adult skull and chest radiography at Federal Teaching Hospital, Gombe, based on 30 examinations. The individual records showed mean entrance skin doses of 41.59 ± 7.78 mGy for skull examinations and 3.85 ± 1.17 mGy for chest examinations, with higher mean values in the older age groups. The difference between skull and chest doses is consistent with their distinct imaging requirements, but the size of the difference and particularly the high skull measurements—requires confirmation through a

documented dosimetry and equipment-quality-assurance review. The observed age-group pattern cannot establish an effect of age because of the small sample and the absence of information on patient size and other relevant exposure factors. Effective doses and nominal cancer-risk indices were calculated using assumed conversion and risk coefficients; they are not direct measurements or predictions of an individual patient's lifetime cancer probability. Comparison with earlier Nigerian and Sudanese investigations suggests a need to examine local radiographic practice, although differences in projection and dosimetry prevent a direct judgement of compliance. The principal limitations are the small single-centre sample, incomplete calibration and exposure-geometry records, unverified conversion factors and lack of image-quality assessment. Future work should include a larger, representative patient-dose survey, traceably calibrated TLD or air-kerma measurements, examination-specific dose modelling and comparison with appropriately matched diagnostic reference levels. Where consistently elevated doses are confirmed, radiographers and medical physicists should jointly review exposure protocols, equipment performance and image quality to reduce avoidable exposure while preserving the clinical value of the examinations.

REFERENCES

International Atomic Energy Agency. (2002). Radiological protection for medical exposure to ionizing radiation (Safety Standards Series No. RS-G-1.5). IAEA. https://www.iaea.org/publications/6291/radiological-protection-for-medical-exposure-to-ionizing-radiation

International Atomic Energy Agency. (2018). Radiation protection and safety in medical uses of ionizing radiation (IAEA Safety Standards Series No. SSG-46). IAEA. https://www.iaea.org/publications/11102/radiation-protection-and-safety-in-medical-uses-of-ionizing-radiation

International Commission on Radiological Protection. (2007). The 2007 recommendations of the International Commission on Radiological Protection (ICRP Publication 103). Annals of the ICRP, 37(2–4). https://doi.org/10.1016/j.icrp.2007.10.003

International Commission on Radiological Protection. (2017). Diagnostic reference levels in medical imaging (ICRP Publication 135). Annals of the ICRP, 46(1). https://doi.org/10.1177/0146645317717209

Obed, R. I., Ademola, A. K., Adewoyin, K. A., & Okunade, O. A. (2007). Doses to patients in routine X-ray examinations of chest, skull, abdomen and pelvis in nine selected hospitals in Nigeria. Research Journal of Medical Sciences, 1(4), 209–214.

United Nations Scientific Committee on the Effects of Atomic Radiation. (2022). Sources, effects and risks of ionizing radiation: UNSCEAR 2020/2021 report, volume I, scientific annex A: Evaluation of medical exposure to ionizing radiation. United Nations. https://www.unscear.org/unscear/en/publications/2020_2021_1.html

Suliman, I. I., Abbas, N., & Habbani, F. I. (2007). Entrance surface doses to patients undergoing selected diagnostic X-ray examinations in Sudan. Radiation Protection Dosimetry, 123(2), 209–214. https://doi.org/10.1093/rpd/ncl137