DOSIMETRY OF CHEST X-RAYS IN ADULTS IN BENIN

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Abstract. Chest radiography is one of the sources of X-ray exposure in the medical setting. The objective of this study was to evaluate the entry dose of X-rays during chest radiography examinations in adults in Benin. This was a cross-sectional study conducted over eleven months, from January to November 2025. It took place in 30 healthcare facilities across the country equipped with functional conventional radiology equipment. Diagnostic reference levels (*DRL*s) were defined as the 75th percentile of entry dose (*ED*) and dose area product (*DAP*) values for chest radiography examinations. Lung disease was the most frequently investigated type of pathology in adult patients, with 966 patients seen, representing 27.52 % of the reasons for examination. The national 75th percentile (*DRL*s) value for *ED* (mGy) was 0.70. The national 75th percentile (*DRL*s) values for *DAP* (mGy·cm²) were 1120. These values were higher than the expected reference values. The doses delivered to patients during chest X-ray examinations in Benin were significantly higher than the international standards. Therefore, a process for standardizing procedures and optimizing them based on these DNRs is necessary.

Key words: Chest X-ray, dosimetry, diagnostic reference levels, Benin.

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INTRODUCTION

Chest radiography is one of the most frequently performed diagnostic imaging examinations worldwide and remains a cornerstone in the clinical evaluation of thoracic pathology in adult patients due to its wide availability, speed, and relatively low cost. Despite its diagnostic utility, chest radiography exposes patients to ionizing radiation, which carries a potential stochastic risk that must be carefully managed and optimized. Accurate dosimetry assessment and comparison to established *DRL*s are essential for ensuring patient safety and radiation protection, particularly in low- and middle-income countries where practices and equipment may vary significantly. Radiation doses from chest X-rays have been shown to vary widely between institutions and among equipment types, underscoring the need for local dose evaluation and optimization strategies to minimize unnecessary radiation exposure while maintaining diagnostic image quality [1, 4, 5].

In several studies conducted across African healthcare settings, patient entrance surface doses and other dosimetric quantities for adult chest radiography have often been found to exceed international guideline values, highlighting inconsistencies in radiographic technique and dose management [2, 17]. To date, however, there is a lack of published data on adult chest radiography dose levels in Benin, which limits the establishment of national benchmarks and the implementation of dose optimization measures. The present study aims to fill this gap by measuring and analyzing dosimetric parameters for standard posteroanterior (PA) chest radiographs in adult patients across selected healthcare facilities in Benin, and by comparing these values to international reference standards.

MATERIALS AND METHODS

This was a descriptive cross-sectional study with both retrospective and prospective data collection, conducted over eleven-month period from January to November 2025. The study was carried out in the radiology departments of healthcare facilities in Benin, including public institutions (university teaching hospitals, regional hospitals, district hospitals) as well as private healthcare facilities equipped with functional conventional radiography units.

The study population consisted of conventional radiography equipment and patients examined in radiology units. An exhaustive sampling approach was adopted, including all patients aged over 15 years who underwent chest X-ray in medical imaging departments, as well as all functional radiography units with a dosimetry accuracy of less than 10 %.

The variables studied included patients' socio-clinical data, acquisition parameters, and dosimetry data for each examination, namely *ED* and *DAP*. These two dosimetry quantities were calculated using the acquisition parameters (kV, mAs, focus-to-patient distance, and irradiation field area) according to the following formulas:

$$ED = 0.15 \times \left[\left(\frac{U}{100}\right)^2 \times Q \times \left(\frac{100}{FPD}\right)^2 \right] \quad (1)$$

ED = X-ray entrance dose, expressed in mGy; *U* = tube voltage, expressed in kV; *Q* = X-ray tube charge, expressed in mAs; *FPD* = focus-to-patient distance, expressed in cm.

$$DAP = ED \times \frac{S}{BSF} \quad (2)$$

DAP = dose–area product, expressed in mGy·cm²; *ED* = X-ray entrance dose, expressed in mGy; *BSF* = backscatter factor (1.35 for tube voltages between 60-80 kV; 1.5 for tube voltages ≥120 kV); *S* = irradiation field area

Data were collected using Google Forms and subsequently exported to SPSS version 2020 for statistical analysis. Analyses were performed by examination type, defined according to the anatomical region or organ examined, and by healthcare facility. Acquisition parameters and dosimetry data were considered only for commonly performed examinations. These examinations were identified in accordance with the criteria specified in the Safety Standards Guide (SSG-46) published by the International Atomic Energy Agency (IAEA) [8], which requires a minimum of 20 examinations per radiological examination type within each healthcare facility.

For comparative purposes, only examinations that met these criteria in at least two centers were included [10, 11]. These included skull (anteroposterior view), chest (posteroanterior view), cervical spine (anteroposterior and lateral views), and lumbar spine (anteroposterior and lateral views) radiographic examinations. The 75th percentiles of entrance dose (*ED*) and dose-area product (*DAP*) were calculated for each examination type, both at the facility level and at the national level. The calculated 75th percentiles of *ED* and *DAP*, representing the national diagnostic reference levels (*DRL*s), were subsequently compared with *DRL*s reported in the literature.

The mean of the variables considered (*ED* and *DAP*) was calculated using the following formula:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_{\mathrm{i}} \quad (3)$$

$\bar{x}$ represents the mean; x_i is the i-th value in the data set; n is the total number of values; $\sum$ denotes summation.

The research project was submitted for approval to the Local Ethics Committee for Biomedical Research of the University of Parakou (CLERB-UP) and received ethical approval under the reference number 694/2024/CLERB-UP/P/SP/R/SA.

RESULTS

A total of 30 conventional radiology units were included based on the study criteria. To ensure confidentiality, these units were labeled from C1 to C35. Each unit was equipped with a radiology device.

CHARACTERISTICS OF CONVENTIONAL RADIOLOGY DEVICES

The conventional radiology devices used for examinations in the included healthcare facilities were manufactured between 1993 and 2023 and installed in these facilities between 1994 and 2023, mostly as new equipment. The devices varied in brand and type. They consisted of analog devices (12 units), indirect digital devices (12 units), and direct digital devices (4 units). Preventive maintenance was not systematically performed in almost all conventional radiology devices (24 out of 30 units). Calibration was carried out at the start of each device's commissioning. Subsequent calibration was performed in case of malfunction for twelve devices and annually for eight devices.

DEMOGRAPHIC CHARACTERISTICS OF PATIENTS UNDERGOING CHEST X-RAYS

A total of 1,438 adult patients who underwent conventional radiology examinations were included in this study, originating from the 30 surveyed radiology units. The mean age was 48.80 ± 16.51 years, ranging from 16 to 90 years. The age group of 35 to 55 years was the most represented, accounting for 49.38 % of the adult patients. In this series, 826 patients (57.44 %) were male, corresponding to a sex ratio of 1.35.

Types of pathologies investigated

Lung disease was the most frequently investigated type of pathology in adult patients, with 811 patients seen, representing 56.4 % of the reasons for examination. Fig. 1 illustrates the distribution of patients according to the pathology groups that prompted chest X-rays in adult patients.

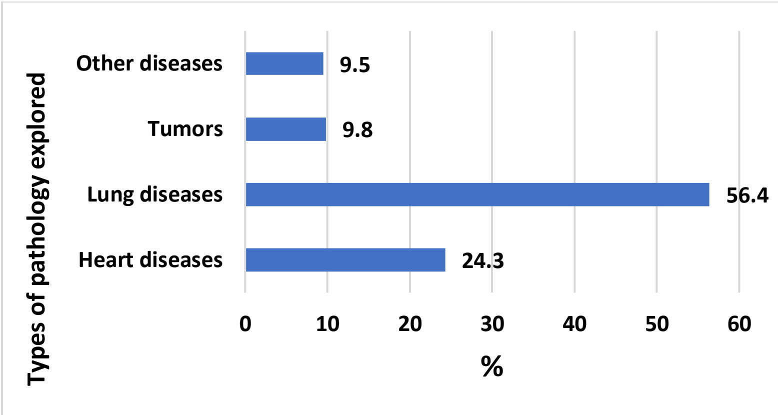

Fig. 1. Distribution of adult patients received according to the pathology groups that motivated the performance of chest X-rays examinations in health facilities in Benin.

DOSIMETRY DATA FOR CHEST X-RAYS

The dosimetry parameters studied were the X-ray entry dose (*ED*) and the dose-area product (*DAP*).

Thirty standard radiology units met the number and frequency criteria for dosimetry calculations of chest X-rays. Table 1 presents the dosimetry statistics for chest X-rays by radiology unit.

Table 1

Description of *ED* and *DAP* for chest X-rays by radiology unit (Pc = percentile)

Radiology unit	***ED* (mGy)**				***DAP* (mGy.cm^2)**			
	Mean	**25th Pc**	**50th Pc**	**75th Pc**	**Mean**	**25th Pc**	**50th Pc**	**75th Pc**
C3a	0.69	0.56	0.70	0.70	1,371	1,120	1,400	1,400
C1	0.69	0.56	0.70	0.73	1,382	1,120	1,400	1,460
C10	0.33	0.23	0.32	0.32	489	336	478	478
C12a	0.58	0.27	0.56	0.70	912	312	1,120	1,400
C12b	0.58	0.43	0.56	0.70	979	505	765	1,400
C13	0.45	0.36	0.43	0.50	529	421	505	585
C15	0.69	0.46	0.63	0.71	1,126	686	1,120	1,400
C16	0.65	0.51	0.70	0.70	1,259	1,020	1,122	1,400
C18	0.48	0.36	0.43	0.56	722	417	505	1,095
C19	0.40	0 .36	0.41	0.45	481	417	482	523
C2	0.70	0.56	0.70	0.92	1,404	1,120	1,400	1,840
C20	0.45	0.36	0.46	0.51	671	425	686	757
C22	0.35	0.19	0.24	0.27	275	231	286	312
C23	0.43	0.37	0.46	0.49	590	433	686	686
C24	0.41	0.24	0.37	0.46	458	286	425	686

C25	0.51	0.46	0.46	0.56	828	569	686	918
C26	0.43	0.32	0.46	0.50	571	425	585	686
C27	0.44	0.36	0.43	0.50	595	417	505	612
C28	0.44	0.36	0.43	0.55	634	417	505	654
C29	0.37	0.28	0.32	0.46	542	420	478	686
C31	0.47	0.32	0.56	0.56	691	478	830	830
C32	0.44	0.32	0.56	0.56	647	478	830	830
C33	0.34	0.26	0.32	0.46	500	384	478	686
C34	0.37	0.29	0.32	0.46	541	433	478	686
C35	0.37	0.29	0.32	0.46	551	425	478	686
C4	0.38	0.20	0.24	0.27	276	239	286	312
C5	0.45	0.46	0.46	0.47	836	686	686	704
C6	0.40	0.36	0.39	0.43	464	417	459	505
C7	0.73	0.70	0.75	0.75	1,227	1,112	1,112	1,120
C8	0.73	0.56	0.83	0.83	1,196	1,120	1,235	1,235

Note: Pc = percentile

The mean, 25th and 75th national percentile values for *ED* and *DAP* of chest X-rays are presented in Table 2.

Table 2

Mean, 25th, and 75th (representing the *DRL*s) national percentile values for *ED* and *DAP* of chest X-rays

X-rays exams	***ED* (mGy) national**				***DAP* (mGy.cm²) national**			
	Mean	**25th Pc**	**50th Pc**	**75th Pc (DRLs)**	**Mean**	**25th Pc**	**50th Pc**	**75th Pc (DRLs)**
Chest X-rays	0.52	0.32	0.46	0.70	1,438	442	686	1,120

Note: The 75th percentile represents the *DRL*s; Pc = percentile

DISCUSSION

This study provides the first multicenter evaluation of patient radiation doses from adult posteroanterior (PA) chest radiography in Benin, based on entrance dose (*ED*) and dose-area product (*DAP*) measurements across 30 conventional radiology units. The findings highlight substantial inter-facility variability in patient doses, reflecting heterogeneity in equipment type, technical parameters, and quality assurance practices.

The inclusion of 30 conventional radiology units reflects a representative overview of radiographic practices in healthcare facilities in Benin. The wide manufacturing period of the X-ray equipment (1993–2023) highlights the coexistence of old and relatively modern technologies within the same national healthcare system. Similar heterogeneity in radiology equipment age and technology has been reported in several low- and middle-income countries, where limited resources often delay equipment renewal and standardization [14, 16].

The inclusion of 1,438 adult patients provides a robust sample size for dosimetric analysis and comparison with international data. The mean age of approximately 49 years, with a predominance of patients between 35 and 55 years, reflects the age group most commonly affected by respiratory and occupational lung diseases, as reported in previous epidemiological studies [19].

The male predominance observed in this study, with a sex ratio of 1.35, is consistent with findings from other African and international studies on chest radiography utilization [7, 13]. This trend may be explained by higher exposure of men to occupational and environmental risk factors, such as smoking, dust inhalation, and industrial pollutants, which increase the likelihood of respiratory symptoms requiring radiological investigation [3].

Lung diseases accounted for more than half of the indications for chest radiography in adult patients, confirming the central role of chest X-rays in the diagnostic workup of respiratory conditions in Benin. This finding is in line with previous studies conducted in sub-Saharan Africa, where chest radiography remains a first-line imaging modality for the evaluation of tuberculosis, pneumonia, chronic obstructive pulmonary disease, and other pulmonary disorders [6, 15].

The national median *ED* and *DAP* values for chest X-rays were 0.46 mGy and 686 mGy·cm², respectively, with corresponding 75th percentile values (proposed diagnostic reference levels, *DRL*s) of 0.70 mGy and 1120 mGy·cm². These values are higher than those reported in several international studies conducted in Europe and parts of Asia, where median *ED* values for adult PA chest radiography typically range between 0.10 and 0.30 mGy and *DAP* values between 100 and 400 mGy·cm² [12]. However, they remain comparable to or slightly lower than values reported in some African settings with similar technological constraints [17].

The wide dispersion of *ED* and *DAP* values between radiology units, with *ED* averages ranging from 0.33 to 0.73 mGy and *DAP* averages from 275 to 1,404 mGy·cm², suggests inconsistent optimization of exposure parameters. This variability can be explained by several factors observed in the present study, including the coexistence of analog, indirect digital, and direct digital systems, as well as the absence of systematic preventive maintenance in most units. Previous studies have demonstrated that analog and computed radiography systems often require higher exposure levels than direct digital radiography to achieve acceptable image quality, particularly when exposure parameters are not adequately optimized [18].

Additionally, the lack of routine equipment calibration and structured quality control programs likely contributed to elevated doses in some facilities. Although all units were calibrated at commissioning, subsequent recalibration was mostly performed only in the event of equipment failure rather than on a regular basis. International guidelines emphasize the importance of periodic quality assurance testing to maintain dose consistency and prevent gradual dose escalation over time [9].

The predominance of lung diseases as the main indication for chest radiography (56.4 %) underscores the clinical importance of this examination in Benin. Given the high frequency of chest X-ray use, even moderate dose elevations may have significant cumulative implications at the population level. This reinforces the need for dose optimization strategies, including standardized protocols, appropriate filtration, optimal kilovoltage selection, and regular training of radiographers.

CONCLUSION

This multicenter dosimetry evaluation of adult PA chest radiography in Benin demonstrates significant variability in patient radiation doses across healthcare facilities. The proposed national diagnostic reference levels of 0.70 mGy for entrance dose and 1,120 mGy.cm² for dose-area product are higher than those reported in many high-income settings but remain consistent with values observed in comparable low-resource contexts. These results highlight the urgent need for standardized protocols, enhanced quality assurance, and continuous professional training to optimize patient doses while preserving diagnostic image quality. The data generated by this study provide a robust baseline for national radiation protection initiatives and future dose optimization programs in Benin.

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Conflicts of interest. The authors declare that there are no conflicts of interest related to this research and this article.

Data availability statement. The data are available in Excel and Google Forms databases through a link that can be shared upon reasonable request.

Authors' contributions. O.H. Fachinan: conceptualization, methodology, data collection and analysis, interpretation of results, writing, and revision; A. Avocefohoun: methodology, revision, and supervision; T.A. Zohizalan: data analysis and revision; E.H.L. Bathily: methodology, revision, and supervision; K.M. Savi de Tove: methodology, revision, and supervision.

Ethical approval. The research project was submitted to the Local Committee for Biomedical Research Ethics of the University of Parakou (CLERB-UP) and received ethical approval under reference No. 694/2024/CLERB-UP/P/SP/R/SA.

Informed consent statement. Free and informed consent was obtained from the patients and, where applicable, from their parents prior to inclusion in the study. Data anonymity was ensured. All collected data were analyzed and presented anonymously.

Declaration of generative AI and AI-assisted technologies in the writing process. Since we are in a French-speaking country (Benin), we used AI to translate certain parts into English so that the written English would be much more understandable.

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