RESEARCH PAPER

Radiation Dose Assessment In Diagnostic Radiography: A Case Study From A Medical Center In Qalqilya City, Palestine

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Abstract

Background: Diagnostic radiography using x-rays is widely used in modern medicine for its important diagnostic benefits. However, careful monitoring of patient radiation dose is essential to ensure radiation safety and minimize unnecessary exposure.

Aim: To measure and evaluate the x-ray radiation dose received during diagnostic radiographic examinations in a medical center in palestine, and to determine whether these doses fall within internationally accepted radiation safety limits.

Methods: This study evaluated radiation dose levels during diagnostic x-ray examinations at a medical center in qalqilya, palestine. A total of 31 measurements were obtained using an at6130 radiation survey meter with a geiger–müller detector, and the results were analyzed and compared with international radiation safety standards.

Results: The measured radiation doses varied according to the examined body region and exposure parameters such as kvp and mas. The maximum recorded dose was 580 nsv, and even with a hypothetical scenario of five examinations per month, the estimated annual exposure would be 0.034 msv, representing only about 3% of the recommended annual public dose limit (1 msv).

Conclusion: The results show that radiation doses from diagnostic x-ray procedures at the studied medical center are well below international safety limits. Continuous dose monitoring and adherence to the alara (as low as reasonably achievable) principle are recommended to further improve patient safety and optimize radiological practices.

Keywords: X-Ray Radiation Dose, Diagnostic Radiology, Radiation Measurement (Geiger–Müller Detector), Patient Radiation Exposure, Radiation Protection And Safety (Alara Principle).

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Introduction

Medical imaging has become one of the most important tools in modern healthcare for diagnosing and monitoring diseases (1)(2). Among the different imaging techniques, X-ray radiography is considered one of the most widely used diagnostic methods because it provides fast, accurate, and non-invasive visualization of internal body structures (3)(1). Since the discovery of X-rays by Wilhelm Conrad Röntgen in 1895, the use of X-ray radiation in medicine has expanded rapidly and has become an essential component of diagnostic radiology (4)(5).

X-rays belong to the electromagnetic spectrum and are classified as ionizing radiation because they carry enough energy to remove electrons from atoms and molecules (6). This ionization process allows X-rays to penetrate biological tissues and produce diagnostic images that reveal bones, organs, and other anatomical structures (7). However, the same ionization process may also cause biological effects in human tissues, which makes radiation protection and dose monitoring extremely important in medical imaging procedures (8).

In medical radiography, X-rays are generated when high-speed electrons collide with a metal target inside an X-ray tube, producing electromagnetic radiation with wavelengths typically ranging from approximately 0.01 to 10 nanometers (9). These X-rays pass through the patient's body and are absorbed in varying degrees depending on tissue density and composition (10). Dense structures such as bones absorb more radiation than soft tissues, which results in the contrast that forms the diagnostic image (11).

Although diagnostic radiology provides significant benefits for patient care, exposure to ionizing radiation carries potential risks (12). When X-ray photons interact with biological tissues, they can cause ionization that may damage cellular components such as DNA molecules (13). In most cases, cells are capable of repairing this damage; however, in rare situations incorrect repair may lead to long-term biological effects such as mutations or cancer development (13). For this reason, international health organizations emphasize the importance of minimizing radiation exposure while maintaining diagnostic image quality (14).

Radiation dose in medical imaging is usually expressed in units such as the Gray (Gy), which measures absorbed energy, and the Sievert (Sv), which represents the biological effect of radiation on human tissues. The effective dose is often used to estimate the overall risk of radiation exposure because it considers the varying sensitivity of different organs and tissues in the human body (15). According to international radiation protection guidelines, the recommended annual effective dose limit for members of the public is approximately 1 mSv, while higher limits may apply to occupationally exposed radiation workers under controlled conditions (16).

Monitoring radiation exposure in healthcare facilities is therefore an essential aspect of radiation safety and quality assurance (15). Various radiation detection devices are used to measure radiation levels in medical environments (17). One of the most widely used instruments is the Geiger-Müller counter, which detects ionizing radiation by measuring the ionization produced in a gas-filled tube (17). These devices allow researchers and radiation protection specialists to evaluate radiation levels and ensure that diagnostic procedures remain within safe limits (18).

Medical centers that perform radiographic examinations must carefully monitor radiation doses delivered to patients and staff to ensure compliance with international radiation protection standards (19). Therefore, the purpose of this study is measure and evaluate the X-ray radiation dose received during diagnostic radiographic examinations in a medical center in Palestine, and to determine whether these doses fall within internationally accepted radiation safety limits.

Methodology

Study Design

This study was conducted using a descriptive experimental approach to measure the radiation dose received by patients during diagnostic X-ray examinations. The research aimed to evaluate whether the radiation doses used in the medical center comply with internationally accepted radiation safety limits.

Study Location

The measurements were carried out in a medical imaging center located in Qalqilya city, Palestine. The radiology department performs routine diagnostic X-ray examinations for different body organs including the chest, skull, spine, limbs, and abdomen as shown in the Figure 1.

Figure 1: The image show the X-ray devices used in the evaluation of radiation dose during patient examinations. A) showed Carestream DRX-Ascend; DRX Plus detector, B) JPI Healthcare – DR system.

Study Period

The data were collected during April and May 2018, through several visits to the medical center.

Determination of sample size

The sample size of 31 patients was selected based on practical availability, study design, and the exploratory nature of the research. The study aimed to measure radiation doses during routine diagnostic radiographic procedures within a limited data-collection period. Data were collected during April–May 2018, and only patients undergoing radiographic examinations during the measurement sessions were included.

From a methodological perspective, a sample size greater than 30 observations is commonly considered adequate for preliminary experimental and descriptive studies (20). According to the Central Limit Theorem in statistics, when the sample size is $n \geq 30$, the sampling distribution of the mean approximates a normal distribution, allowing the use of standard statistical analysis methods for estimating averages and variability of measured radiation doses (21).

Additionally, the study focused on direct physical dose measurements rather than population-based epidemiological analysis. Therefore, the primary objective was to evaluate radiation exposure levels and compare them with international radiation protection limits, rather than estimate population parameters with high statistical power.

Furthermore, the 31 measurements included different anatomical regions, patient ages, body masses, and exposure parameters (kVp and mAs), which allowed the study to capture representative variability in clinical radiographic practice within the investigated medical center.

Pro-forma and Data Collection Procedure

A structured data collection pro-forma was developed to systematically record all variables related to the radiographic examinations and the measured radiation doses. The pro-forma served as a standardized tool to ensure consistency and accuracy during the data collection process. Each examination was assigned a coded identification number to maintain patient confidentiality while allowing proper organization of the collected data.

The pro-forma included several categories of information. Patient-related variables consisted of age (years) and body mass (kg). Examination-related variables included the anatomical region examined, the type of radiographic projection (such as anterior–posterior (AP), posterior–anterior (PA), or lateral view), and the exposure parameters, including tube voltage (kVp) and tube current–time product (mAs). In addition, the measured radiation dose expressed in nano-Sievert (nSv), the date of examination, and the measurement sequence number were recorded for each radiographic procedure.

Data collection was conducted in the radiology department of the medical center in Qalqilya, Palestine, during the study period from April to May 2018. Prior to the measurements, the radiation monitoring instrument (AT6130 radiation survey meter) equipped with a Geiger–Müller detector was checked and prepared according to the manufacturer's operational instructions to ensure reliable measurements as shown in figure 2.

Figure 2: Radiation monitor AT6130.

Patients undergoing routine diagnostic radiographic examinations during the study period were included in the study. For each radiographic procedure, the relevant patient characteristics and exposure parameters were first recorded in the prepared pro-forma. The radiation monitoring device was then positioned near the examination area to measure the radiation dose generated during the X-ray exposure.

During each examination, the radiation survey meter detected the ionizing radiation produced by the X-ray system and automatically converted the detected signal into measurable dose values. The measured radiation dose corresponding to each exposure was recorded in the pro-forma in nano-Sievert (nSv). In total, 31 radiation dose measurements were collected from different radiographic examinations involving various anatomical regions.

Following each measurement session, the recorded data were carefully reviewed to verify completeness and accuracy before being transferred to the dataset for further analysis. The use of the standardized pro-forma ensured uniform data recording and facilitated the comparison of radiation doses across different radiographic procedures and exposure conditions.

Radiation Dose Evaluation

Assessment of patient radiation exposure is a critical component of diagnostic radiology to ensure compliance with international safety standards (22). In this study, the measured radiation doses from various X-ray procedures were systematically analyzed and compared with the dose limits recommended by the International Commission on Radiological Protection (ICRP). According to these guidelines, the annual dose limit for the general public is 1 mSv, while for occupational exposure among radiation workers it is 20 mSv.

Data Analysis

The collected radiation dose data were analyzed using descriptive statistical methods to provide a comprehensive assessment of patient exposure. Key parameters calculated included the maximum dose, minimum dose, and average dose for each type of radiographic procedure. These values were subsequently compared with internationally recommended dose limits to evaluate compliance with established safety standards.

Additionally, the study examined the relationship between technical exposure parameters, specifically kilovoltage peak (kVp) and tube current-time product (mAs), and the measured radiation doses. This analysis aimed to identify potential correlations between procedural settings and patient dose, providing insights for optimizing radiographic techniques while maintaining image quality and minimizing radiation exposure.

Ethical Considerations

Ethical considerations were taken into account throughout the study to ensure the protection of patient privacy and the integrity of the research process. The study involved only the measurement of radiation doses during routine diagnostic radiographic examinations and did not introduce any additional procedures or radiation exposure beyond standard clinical practice. Patient confidentiality was strictly maintained during the data collection process.

Results

Radiation dose measurements were conducted for 31 patients undergoing various diagnostic X-ray examinations at a medical center in Qalqilya. The measurements were obtained using an AT6130 radiation monitor equipped with a Geiger–Müller detector**.** The recorded parameters included patient age, body mass, exposure factors (kVp and mAs), and the corresponding measured radiation dose.

Table 1: **Patient Characteristics of the Study Population (n = 31)**

Characteristic	Value
Number of patients	31
Age (years)	Range: 1 – 57
Mean age (years)	≈ 30
Body mass (kg)	Range: 12 – 130
Mean body mass (kg)	≈ 73
Type of examinations	Hand, Foot, Skull, Chest, Leg, Wrist, Elbow, Spine, Sinus, Pelvis, Abdomen, Shoulder
Exposure parameters (kVp)	Range: 42 – 81 kVp
Exposure parameters (mAs)	Range: 2 – 63 mAs
Measured dose (nSv)	Range: 6 – 580 nSv

The patients' ages ranged from 1 to 57 years, with an average age of approximately 30 years, while body mass ranged from 12 to 130 kg, with a mean value of about 73 kg. A wide range of anatomical regions was examined, including the extremities, chest, skull, spine, and abdomen. The exposure parameters varied across examinations, with tube voltage ranging from 42 to 81 kVp and tube current–time product ranging from 2 to 63 mAs. The measured radiation doses ranged from 6 nSv to 580 nSv, reflecting differences in patient characteristics and imaging requirements. These variations provide a representative dataset for evaluating radiation dose distribution across different diagnostic radiographic procedures.

Table 2: **Typical Exposure Parameters by Examination Type**

Examination	kVp (Range)	mAs (Range)	Dose (nSv Range)
Hand / Wrist	42 – 52	2 – 6	6 – 25
Foot / Elbow	45 – 55	4 – 10	10 – 45
Chest	60 – 70	8 – 20	30 – 70
Skull / Sinus	65 – 75	10 – 25	50 – 110
Spine	70 – 80	20 – 40	150 – 200
Pelvis / Abdomen	75 – 81	25 – 63	90 – 580
Shoulder / Leg	60 – 75	15 – 40	100 – 220

The measured radiation doses varied according to the examined anatomical region and the applied exposure parameters. In this study, the recorded dose values ranged from 6 nSv to 580 nSv, depending on the type of radiographic examination. The lowest doses were observed during extremity imaging such as the hand and wrist, where the measured values ranged between 6 and 45 nSv. Moderate radiation doses were recorded for chest and skull examinations, typically ranging from 34 to 109 nSv. In contrast, higher radiation doses were associated with examinations of thicker anatomical regions such as the spine, pelvis, and abdomen due to the higher exposure factors required for adequate image penetration. The results also showed a clear relationship between radiation dose and technical exposure parameters. Increasing the tube voltage (kVp) enhances X-ray beam penetration, while increasing the tube current–time product (mAs) increases the number of emitted photons, both of which contribute to higher radiation dose levels. The maximum measured dose in this study was 580 nSv (0.00058 mSv) per examination. Even under a hypothetical worst-case scenario in which a patient undergoes five radiographic examinations per month, the estimated annual exposure would be approximately 0.034 mSv, which represents only 3.4% of the recommended annual public dose limit of 1 mSv. These findings indicate that all measured radiation doses in the studied medical center remain well below internationally accepted safety limits, confirming that the radiographic procedures are performed within appropriate radiation protection standards.

Table 3: **Measured X-ray Dose for Different Radiographic Examinations**

Examination Type	Minimum Dose (nSv)	Maximum Dose (nSv)	Mean Dose (nSv)
Hand	6	18	≈ 10.7
Wrist	15	27	≈ 21
Foot	9	18	≈ 13.5
Elbow	25	61	≈ 43
Chest	29	65	≈ 47
Skull	34	109	≈ 61
Sinus	47	84	≈ 65
Shoulder	75	141	≈ 108
Pelvis	71	118	≈ 94
Spine (Cervical)	156	219	≈ 187.5
Abdomen	112	580	≈ 198
Leg	121	322	≈ 222

The statistical analysis of the measured radiation doses shows clear variation depending on the examined anatomical region. The lowest radiation doses were recorded in extremity examinations such as the hand and wrist, where the mean doses were approximately 10.7 nSv and 21 nSv, respectively. Slightly higher doses were observed for the foot and elbow, with average values of 13.5 nSv and 43 nSv**.** Moderate radiation levels were measured in examinations of the chest and skull**,** where the mean doses reached 29 nSv and 61 nSv, respectively. In contrast, examinations involving thicker body regions resulted in higher radiation doses, including the cervical spine (187.5 nSv)**,** pelvis (94 nSv)**,** and abdomen (198 nSv). The maximum recorded dose in the dataset occurred during leg imaging, reaching approximately 222 nSv. These findings demonstrate that radiation exposure increases with the thickness and density of the examined anatomical region, which requires higher exposure parameters to achieve adequate diagnostic image quality. Nevertheless, all recorded values remain well below internationally recommended radiation safety limits, confirming that the radiographic procedures performed in the studied medical center operate within acceptable radiation protection standards.

Discussion

The present study evaluated radiation doses associated with diagnostic X-ray examinations performed at a medical center in Qalqilya. Measurements were obtained from 31 patients using an AT6130 radiation monitor equipped with a Geiger–Müller detector, allowing precise assessment of radiation exposure during various radiographic procedures. The collected data included patient characteristics and exposure parameters such as tube voltage (kVp) and tube current–time product (mAs), which are well-known determinants of radiation dose during imaging.

The results demonstrated clear variations in radiation dose depending on the anatomical region examined. The lowest doses were recorded during extremity imaging, including examinations of the hand, wrist, and foot. These procedures typically require lower exposure parameters, as the bones and tissues in these regions are thin and allow sufficient X-ray penetration. Consequently, the measured doses were generally below 25 nSv, reflecting the reduced radiation requirement for peripheral body parts. Moderately higher doses were observed during chest and skull imaging, ranging from approximately 34 nSv to 109 nSv. These regions contain thicker and more complex anatomical structures, necessitating slightly higher exposure settings to achieve adequate image quality and diagnostic visibility.

The highest radiation doses occurred during imaging of larger and denser anatomical regions, such as the spine, pelvis, abdomen, and leg. Examinations of the cervical spine and abdomen, in particular, required higher tube voltage and current to ensure sufficient X-ray penetration. This pattern aligns with established radiographic principles, which indicate that radiation dose increases with tissue thickness and higher exposure parameters (23). Analysis confirmed a direct relationship between radiation dose and exposure parameters. Increasing the tube voltage enhances X-ray beam penetration, while increasing the tube current–

time product increases the number of emitted photons (24). Both factors contribute directly to the radiation dose received during imaging (24).

Comparison with international radiation protection standards revealed that all measured doses were significantly below the recommended annual public dose limit of 1 mSv**.** The maximum recorded dose was 580 nSv (0.00058 mSv) per examination**.** Even if a patient were to undergo multiple radiographic procedures each month, the estimated annual exposure would remain only a small fraction of the safety limit. These findings indicate that radiographic procedures at the studied medical center operate within acceptable radiation safety limits, suggesting that both the imaging equipment and clinical practices adhere to recommended protection protocols. Adherence to the ALARA (As Low As Reasonably Achievable) principle remains essential to minimize exposure while maintaining diagnostic quality.

When compared with previous studies, the radiation doses measured in this study are consistent with those reported in similar clinical settings. Extremity imaging doses in other regional hospitals were reported between 20–30 nSv**,** chest examinations ranged from 30–120 nSv, and spinal or abdominal imaging showed higher doses, reflecting the increased tissue thickness and exposure requirements (25)(26). The maximum dose per examination in our study **(**580 nSv**)** aligns with these previously published values, confirming that patient exposure during routine diagnostic radiography remains well below international safety limits (27). These comparisons underscore the reliability and safety of standard radiographic protocols and demonstrate that the findings of this study are in line with established evidence in the field. Overall, the results demonstrate that diagnostic radiography at the investigated medical center provides effective imaging with minimal radiation risk, supporting the continued safe use of X-ray technology in clinical practice.

Conclusion

This study evaluated radiation doses from diagnostic X-ray examinations in a medical center in Qalqilya using measurements from 31 patients. The results showed that all recorded doses, including the maximum value of 580 nSv, were well below international safety limits. Even under repeated exposure scenarios, the estimated annual dose remained significantly lower than the recommended 1 mSv/year limit for the public. These findings indicate that radiographic practices in the studied center are safe and comply with radiation protection standards. Continuous dose monitoring and adherence to the ALARA principle are recommended to maintain and further improve patient safety.

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