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Assessment of Patient Skin Dose During Routine X-ray Procedures in Selected Libyan Healthcare Facilities

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تقييم جرعة الجلد للمريض اثناء إجراءات الاشعة السينية الروتينية في مرافق رعاية صحية ليبية مختارة

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Abstract:

Background: Medical use of X-rays is one of the largest sources of human radiation exposure today, with an equivalent dose of 3 mSv, compared to 2.4 mSv from natural background radiation. The risk of cancer induction exists within these dose levels, necessitating the avoidance of excessive radiation exposure and the use of doses higher than required for specific examinations. Therefore, estimating the Entrance Surface Dose (ESD) for patients undergoing X-ray examinations is crucial for radiation protection.

Materials and Methods: This study aimed to assess patients' skin exposure to radiation during routine radiographic examinations for five selected procedures in four healthcare facilities in Libya. The examinations included chest (PA, LAT), lumbar spine (AP, LAT), foot (AP, LAT), hand (AP, LAT), and knee (AP, PA, LAT). The study involved 169 patients, with a mean age of 42 ± 15 years, a mean weight of 74 ± 12 kg, and a mean height of 1.68 ± 0.08 m. The radiation dose for participants was estimated by determining the X-ray tube output (kVp) and imaging factors, such as patient weight, height, exposure time, and tube current.

Results: The mean ESD (mGy) for each examination was as follows: Chest: 1.58 ± 0.30, Lumbar spine: 13.8 ± 7.5, Foot: 1.65 ± 0.28, Hand: 1.58 ± 0.19, Knee: 3.58 ± 0.59.

Conclusion: The study concluded that patient exposure to radiation during routine radiographic examinations is inevitable. Therefore, it is essential to regularly review patient doses to achieve the ALARA (As Low as Reasonably Achievable) principle, ensuring that doses remain as low as possible without compromising diagnostic quality. This study provided essential baseline information on patient radiation dose levels in the assessed healthcare facilities. A significant variation in dose values for the same examination was observed, attributed to differences in examination techniques, radiographers' proficiency, and patient weight. The study also emphasizes the importance of radiation protection programs in diagnostic radiology, effective quality control, and establishing reference dose levels in these healthcare facilities.

Keywords: Entrance Surface Dose, ALARA Principle, Exposure Factors, Radiation Protection.

الملخص

الخلفية : يعد الاستخدام الطبي للأشعة السينية أحد أكبر مصادر التعرض الإشعاعي للبشر حاليًا، حيث تبلغ الجرعة المكافئة 3 ملي سيفرت، مقارنة بـ 2.4 ملي سيفرت من الإشعاع الطبيعي الخلفي. توجد مخاطر لإحداث السرطان ضمن هذه المستويات من الجرعات، مما يستلزم تجنب التعرض المفرط للإشعاع واستخدام جرعات أعلى من المطلوبة للفحوصات المحددة. لذلك، فإن تقدير جرعة السطح الداخلة *(ESD)* للمرضى الخاضعين لفحوصات الأشعة السينية يُعد أمرًا بالغ الأهمية لحماية المريض من الإشعاع.

المواد والطرق : هدفت هذه الدراسة إلى تقييم تعرض جلد المرضى للإشعاع أثناء الفحوصات الشعاعية الروتينية لخمس إجراءات مختارة في أربعة مرافق رعاية صحية في ليبيا. شملت الفحوصات: الصدر أمامي خلفي*PA*، جانبي *LAT* ،العمود الفقري القَطَني أمامي خلفي*AP* ، جانبي *LAT* القدم أمامي خلفي*AP* ، جانبي(*LAT* ، اليد) أمامي خلفي*AP* ، جانبي(*LAT* ، والركبة) أمامي خلفي*AP* ، أمامي خلفي بزاوية *PA* ، جانبي *LAT* . شارك في الدراسة 169 مريضًا بمتوسط عمر 42 ± *15* سنة، ومتوسط وزن 74 ± *12* كجم، ومتوسط طول *0.08 ± 1.68* متر. تم تقدير جرعة الإشعاع للمشاركين من خلال تحديد ناتج أنبوب الأشعة السينية (kVp) وعوامل التصوير مثل وزن المريض، طوله، زمن التعرض، وتيار الأنبوب.

النتائج :كان متوسط جرعة السطح الداخلة لكل فحص كما يلي: الصدر: 1.58 ± 0.30، العمود الفقري القَطَني: 13.8 ± 7.5، القدم: 1.65 ± 0.28، اليد: 1.58 ± 0.19، الركبة: 3.58 ± 0.59.

الخلاصة : خلصت الدراسة إلى أن تعرض المرضى للإشعاع أثناء الفحوصات الشعاعية الروتينية أمر لا مفر منه، لذلك من الضروري مراجعة جرعات المرضى بانتظام لتحقيق مبدأ ALARA (أقل ما يمكن تحقيقه بشكل معقول)، لضمان بقاء الجرعات منخفضة قدر الإمكان دون التأثير على جودة التشخيص. قدمت هذه الدراسة معلومات أساسية مهمة عن مستويات جرعات الإشعاع للمرضى في المرافق الصحية التي تم تقييمها. كما لوحظ اختلاف كبير في قيم الجرعات لنفس الفحص، ويُعزى ذلك إلى اختلاف تقنيات الفحص، وكفاءة فنيي الأشعة، ووزن المريض. وتؤكد الدراسة كذلك على أهمية برامج الحماية من الإشعاع في الأشعة التشخيصية، وضبط الجودة الفعال، وتحديد مستويات جرعات مرجعية في هذه المرافق الصحية.

الكلمات المفتاحية: جرعة السطح الداخلة، مبدأ ALARA ، عوامل التعرض، الحماية من الإشعاع.

Introduction

In the 20th century, the use of various ionizing radiations became widespread in the field of diagnosing all pathological phenomena in the human body, as well as in various biological and medical applications. Since the discovery of X-rays at the end of the 19th century, they began to be used for imaging all organs and tissues of the human body, thereby diagnosing the vast majority of physical defects and deformities in living organisms. These rays are capable of producing clear images of the internal details of any human organ or tissue, revealing all its internal structures, which provides physicians with tremendous capabilities to diagnose diseases or deformities in specific organs or tissues. However, as is the case with all imaging devices that use X-rays, there are always minor harms associated with this imaging. To determine this harm, it is necessary to quantify the radiation dose the patient is exposed to during the imaging process. On the other hand, efforts must be made to keep the dose as low as possible and within the limits of the ALARA principle (As Low As Reasonably Achievable). The ALARA principle states that for practical protection from the effects of radiation, exposure should be kept at the lowest possible levels. This has led to an increased interest in studying the calculation of the dose delivered to the patient's skin surface and determining the minimum possible values of the parameters used in this field, through which image quality can be achieved with the lowest possible dose. The first to propose ideas for calculating skin dose was the scientist Britch in 1974 [5]. Later, in 1984, the scientist Edmonds introduced modifications to Britch's proposals [7], taking into account in his relationship the values of the tube voltage (kVp), exposure (mAs), which is the product of the tube current and exposure time in seconds the thickness of the filter used (T), and the distance between the X-ray tube and the skin surface. The relationship was as follows:

$$ESD(\mu Gy) = \frac{836\ \times (KV) \times (mAs)}{(d_{FSD})^2} \times \left(\frac{1}{T} + 0.114\right) \rightarrow (1)$$

Until the scientist Shripton came along, and through his experimental results, he noted that Britch's relationship was merely a formula for calculating air kerma. In 1999, the scientists Tung and Tsai derived a relationship that allows us to calculate the dose delivered to the skin surface. During the same period, McParland also established a relationship that enables us to calculate the skin dose value. The relationship is as follows:

$$ESD = OP \times (\frac{KV}{80})^2 \times mAs \times (\frac{100}{FSD})^2 \times BSF \quad \rightarrow (2)$$

In practical applications, the Entrance Skin Dose (ESD) can be calculated by knowing the tube output (OP). The relationship was established between the exposure of the X-ray unit (mAs) and the air kerma in air at a reference point in the X-ray field at a tube potential of 80 kV. Subsequent estimates of ESD can be made by recording relevant information (tube potential, filtration, mAs, FSD) and correcting for distances and backscatter radiation according to the following equation [6]:

$$ESD(mGy) = C(\frac{KV_p}{FSD})^2 . (\frac{mAs}{mm.Al}) \quad \rightarrow (3)$$

Where (kVp) represents the applied tube voltage, (mAs) is the exposure, which is the tube current in mA multiplied by the exposure time in seconds (s), (FSD) is the distance between the X-ray tube and the patient, (mmAl) represents the thickness of the filter used, which is the sum of the filters present in the X-ray tube and any additional filters. In this study, the filter thickness for the four devices ranged from 1.5 to 2 mm, (C) is a constant equal to 0.2775 [6].

Material and methods

This study aims to evaluate radiation protection in diagnostic radiology departments at some healthcare facilities in Libya. The data used in this study were collected from four radiology departments in four healthcare facilities in Libya. Initially, questionnaires were distributed to the radiographers responsible for the diagnostic facilities. Each radiographer was asked to provide information regarding their X-ray unit, including the manufacturer, model, date of manufacture, and exposure factors for the devices. To calculate the ESD (Entrance Skin Dose), the radiographers were also requested to provide the exposure factors used for 169 patients across all the facilities. These factors included: tube voltage (kVp), exposure quantity (mAs), and focus-to-skin distance (FSD). The dose values were obtained using the mathematical formula (3), which calculates the ESD value. Calculating ESD from output measurements and exposure.

Study Participants

The primary study was conducted on a random sample of 169 participants (89 females and 80 males) across the four healthcare facilities. The mean age, weight, height, and their standard deviations of the participants were 42 ± 15 years, 74 ± 12 kg, and 1.68 ± 0.08 m, respectively. The study included five different examinations: chest, spine, foot, hand, and knee. The data presentation did not reveal the identity of individual participants in any way. Informed consent was obtained from each participant involved in this study. Ethical approval was also obtained from the four healthcare facilities. Data were collected using a sheet for each patient to ensure consistency of information: weight, height, tube voltage, exposure quantity, tube-to-skin distance, and body mass index (BMI). All data were recorded.

Conventional X-ray Systems Used in the Study

In this study, four types of X-ray devices were used across the four healthcare facilities, as shown in the following table:

Table (1): Table showing the type and main characteristics of the X-ray devices used in the study

Center	Manufacturer	Manufacturing Date	Type	Focal Spot (mm)	Total Filtration (mm Al)	Max kVp	Max mA
HP1	Toshiba	September 2012	Fixed	1.2 / 0.6	1.5	150	200
HP2	Toshiba	March 2005	Fixed	1.2 / 0.6	1.5	125	200
HP3	Toshiba	March 2010	Fixed	1.2 / 0.6	1.5	150	630
HP4	Toshiba	June 2012	Fixed	1.2 / 0.6	2.0	150	500

Figure (1): X-ray machine in the Diagnostic Radiology Department at HP1

Figure (2): X-ray machine in the Radiology Department at HP2

Figure (3): X-ray machine in the Radiology Department at HP3

Figure (4): X-ray machine in the Radiology Department at HP4

Imaging Technique

Routine X-ray examinations consist of imaging positions: PA (Posterior-Anterior), AP (Anterior-In X-ray imaging, the exposure factors used are chosen based on the patient's weight and the size of the bod

Dose Evaluation Measurements:

To estimate the ESD for these examinations, patient habits (age, w No prior preparation is necessary for routine X-rays. The hospital gown is used to replace all upper body clothing, and all jewelry must be removed from the part to be examined. The patient is then prepared by taking measurements such as weight and height to calculate the body mass index. Weight was measured using a scale, while height was measured using a five-meter tape measure. The distance between the skin surface and the X-ray tube (BSF), focus-to-detector distance (FDD), and placing the patient in the appropriate imaging position were also recorded. Available values such as tube current (mA), tube voltage (kVp), and exposure time (s) were noted. This study conducted four examinations: chest, back, foot, hand, and knee, according to the imaging technique used in each healthcare facility.

Results and discussion

Distribution of Patients by Healthcare Facility

Table (2): Table showing the type and main characteristics of the X-ray devices used in the study.

Hospital Name	Sample Size	Percentage
HP1	39	23%
HP2	45	26%
HP3	47	28%
HP4	38	23%
Total	169	100%

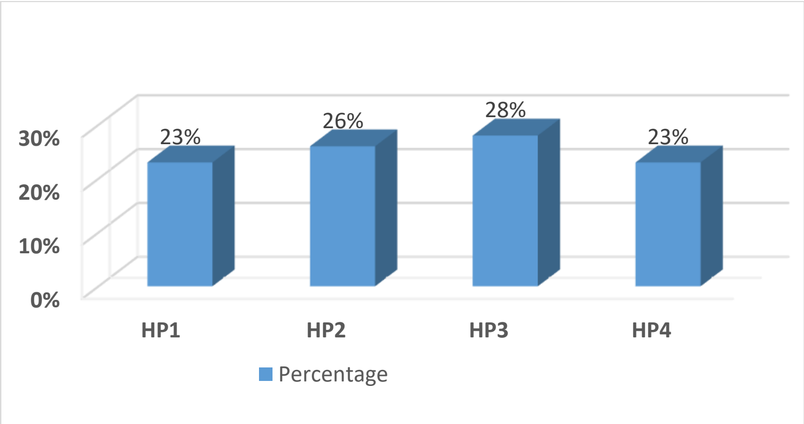

Figure (5): Distribution of the sample across the four healthcare facilities.

From Table (2) and Figure (5), it is clear that the total number of study participants is 169, distributed across the four healthcare facilities as follows: in HP1 39 (23%), in HP2 45 (26%), in HP3 47 (28%), and in HP4 38 (23%). The distribution is quite balanced across the healthcare centers.

2- Distribution of Patients by Gender

Table (3): Distribution of patients by gender.

Hospital Name	Number of Males	Percentage
HP1	14	17.5%
HP2	29	36.25%
HP3	18	22.5%
HP4	19	23.75%
Total	80	100%

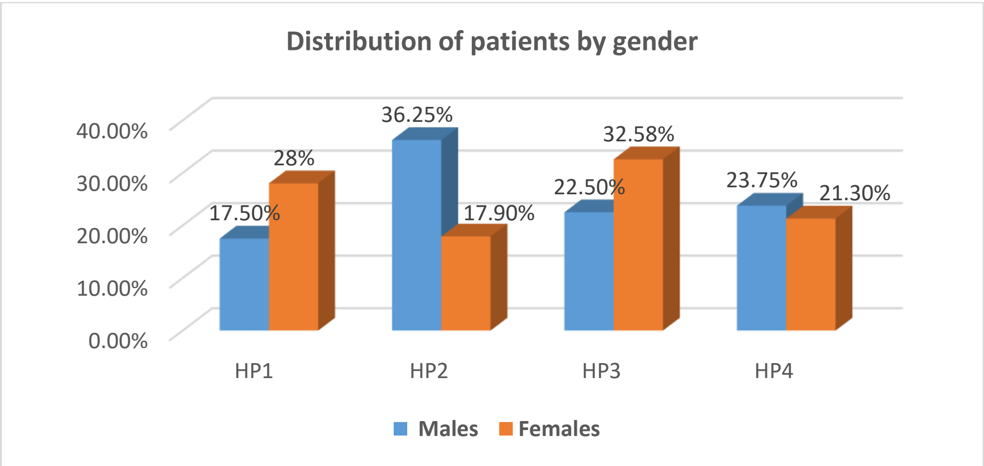

Figure (6): Distribution of patients by gender.

From Table:(3) and Figure:(6), it is clear that the total number of males in the study sample is 80, distributed across the four healthcare facilities as follows: in HP1 14 (17.5%), in HP2 29 (36.25%), in HP3 18 (22.5%), and in HP4 19 (23.75%). The total number of females in the study sample is 89, distributed as follows: in HP1

25 (28%), in HP2 16 (17.9%), in HP3 29 (32.58%), and in HP4 19 (21.3%). This shows that the sample includes both genders, and the distribution between males and females is almost equal.

Distribution of Patients by Age

Table (4): Distribution of the study sample by age.

Age Range	Number	Percentage
1.5 to 20 years	39	23%
21 to 40 years	38	22.5%
41 to 60 years	54	32%

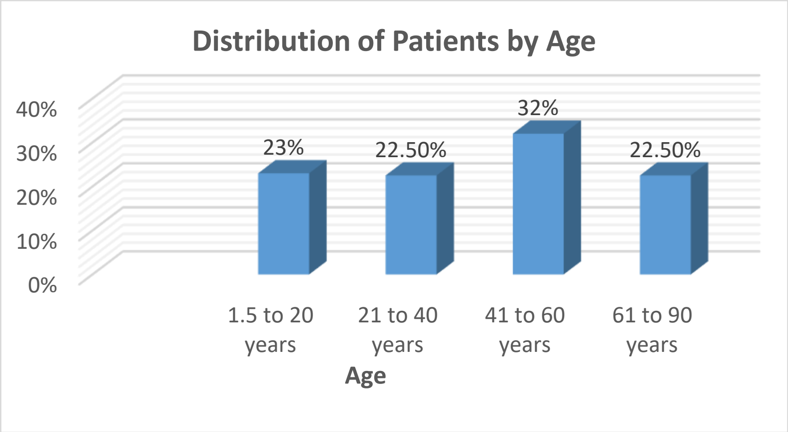

Figure (7): Distribution of the study sample by age**.**

From Table (4) and Figure (7), it is clear that the number of individuals aged 1.5 to 20 years is 39 (23%), those aged 21 to 40 years is 38 (22.5%), those aged 41 to 60 years is 54 (32%), and those aged 61 to 90 years is 38 (22.5%). This shows a wide age range among the study participants, with the largest percentage (32%) being in the age group of 41 to 60 years.

4- Distribution of Patients by Examination

Table (5): Distribution of patients by examination type.

Examination Type	Chest Exam	Lumbar spine Exam	Foot Exam	Hand Exam	Knee Exam
HP1	48%	8.5%	26%	24%	19%
HP2	15%	36%	34%	16%	22%
HP3	18.5%	33%	21.5%	36%	49%
HP4	18.5%	22.5%	18.5%	24%	11%
Total	100%	100%	100%	100%	100%

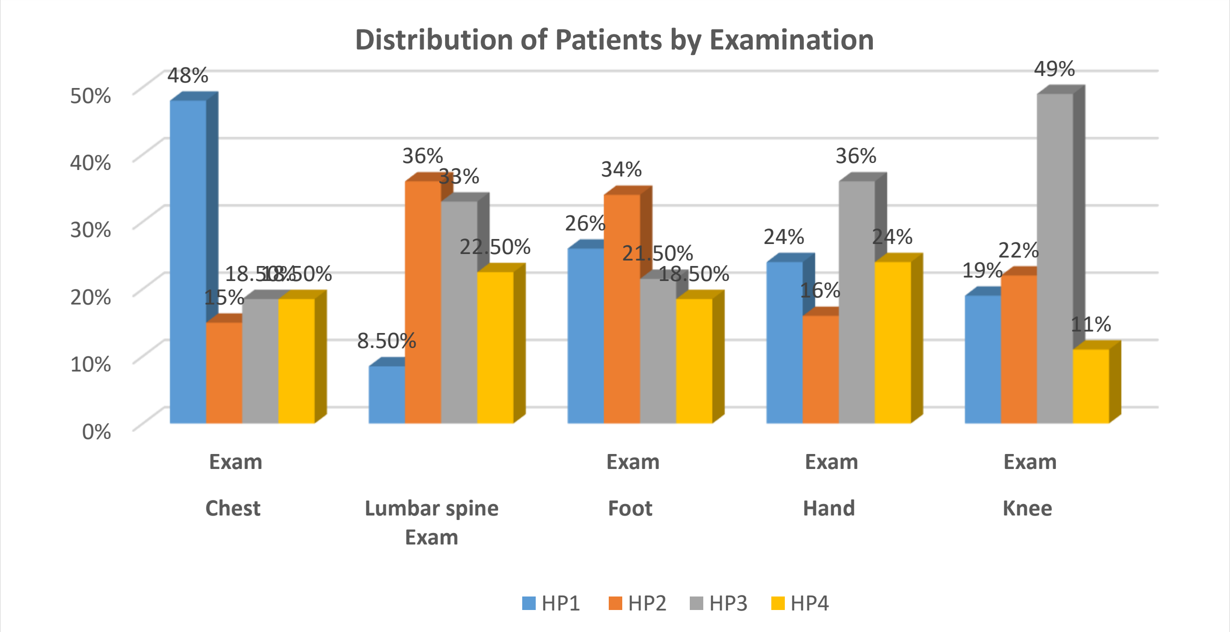

Figure (8): Distribution of the study sample by examination type.

From Table (5) and Figure (8), it is clear that there were four types of examinations in this study: chest, back, foot, hand, and knee, distributed across the four healthcare facilities as shown in the graph.

5- Surface Dose (ESD) for Chest Examination in Each Healthcare Facility

Table (6): Average Surface Dose (ESD) for chest examination in each healthcare facility.

Reference Value	HP1 ESD	HP2 ESD	HP3 ESD	HP4 ESD
Mean ESD	0.30	0.92	1.44	1.58
Standard Deviation (SD)	0.12	0.23	0.44	1.55

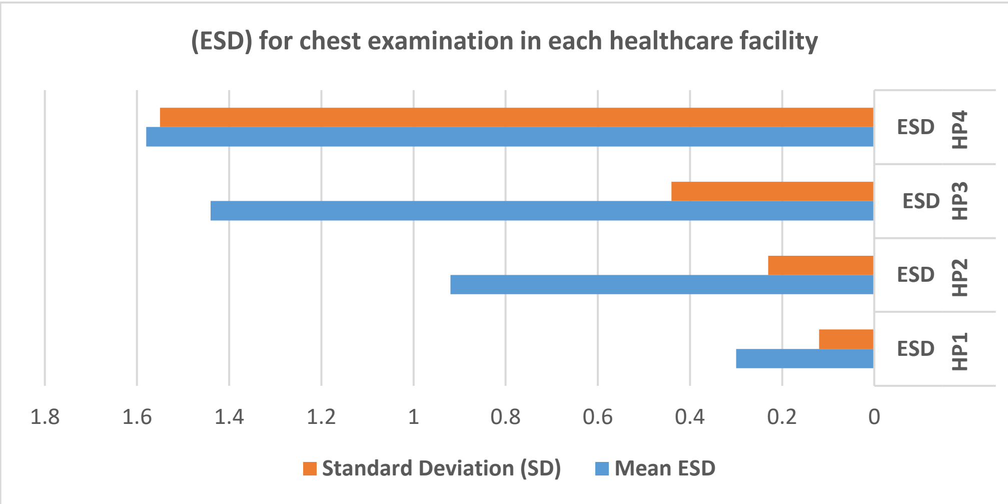

Figure (9): Surface Dose (ESD) for chest examination in each healthcare facility.

From Table:(6) and Figure:(9), it is clear that the highest surface dose (ESD) was recorded in HP4 (1.58), followed by HP3 (1.44), and HP2 (0.92). These values were higher than the internationally accepted reference value of approximately 0.4, as noted in several studies referenced. HP1 had the lowest dose (0.30), which is closer to the internationally acceptable value and considered the best among the healthcare facilities for this examination.

Surface Dose (ESD) for Back Examination in Each Healthcare Facility

Table (7): Surface Dose (ESD) for back examination in each healthcare facility.

Reference Value	HP1 ESD	HP2 ESD	HP3 ESD	HP4 ESD
Mean ESD	13.54	11	10.06	9.85
Standard Deviation (SD)	7.449	9.38	5.95	5.58

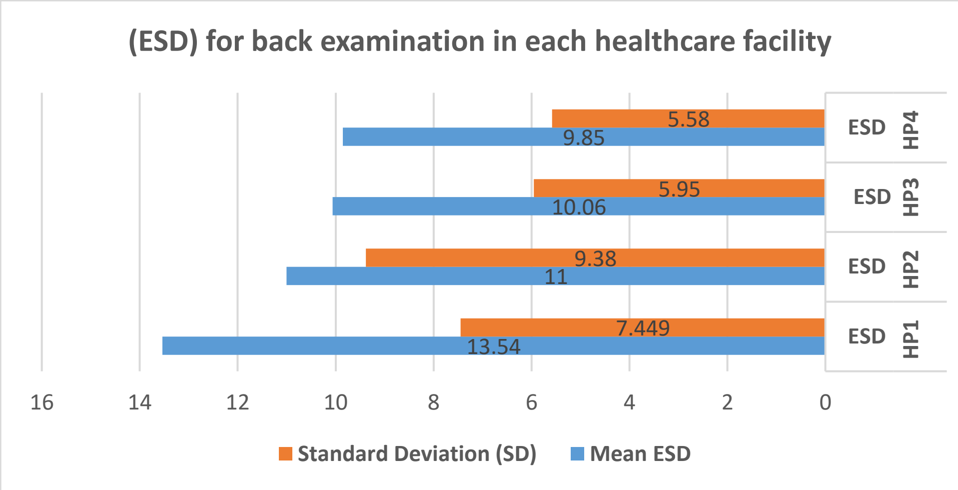

Figure (10): (ESD) for back examination in each healthcare facility.

From Table (7) and Figure (10), it is clear that the highest surface dose (ESD) was in HP1 (13.54), followed by HP2 (11), which is above the international reference value of 7.5mGy, as noted in several studies.

7-Surface Dose for Foot Examination in Each Facility

Table (8): (ESD) for foot examination in each healthcare facility.

Reference Value	HP1 ESD	HP2 ESD	HP3 ESD	HP4 ESD
Mean ESD	0.61	0.28	1.65	0.36
Standard Deviation (SD)	0.84	0.14	0.47	0.064

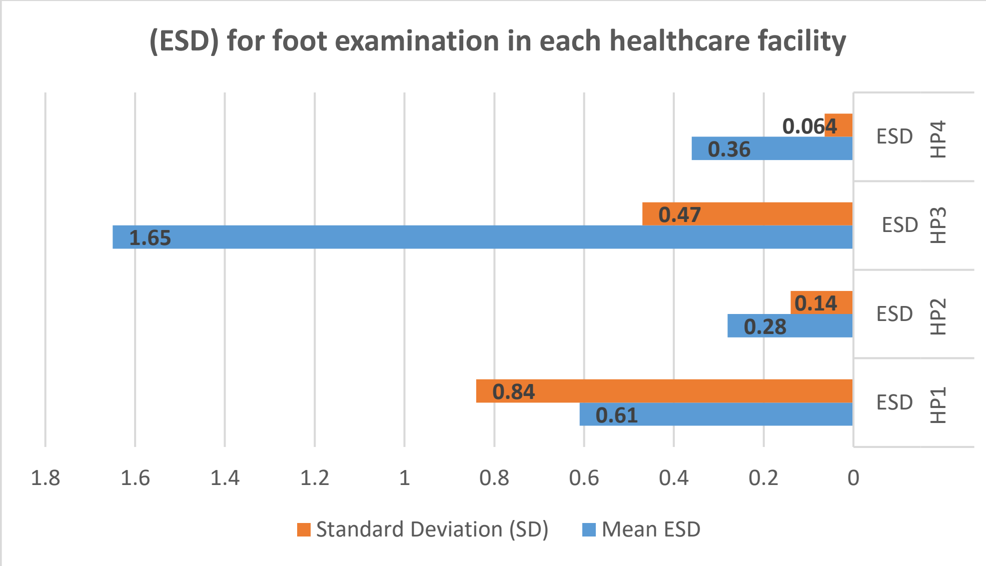

Figure (11): ESD for foot examination in each healthcare facility.

From Table (8) and Figure (11), it is clear that the highest surface dose (ESD) for foot examination was in HP3 (1.65), which is above the international reference value of approximately 0.45mGy. The remaining facilities had lower doses and were closer to the internationally accepted value.

Surface Dose for Hand Examination in Each Facility

Table (9): Surface Dose (ESD) for hand examination in each healthcare facility.

Reference Value	HP1 ESD	HP2 ESD	HP3 ESD	HP4 ESD
Mean ESD	0.19	0.37	1.58	0.48
Standard Deviation (SD)	0.116	0.14	0.53	0.079

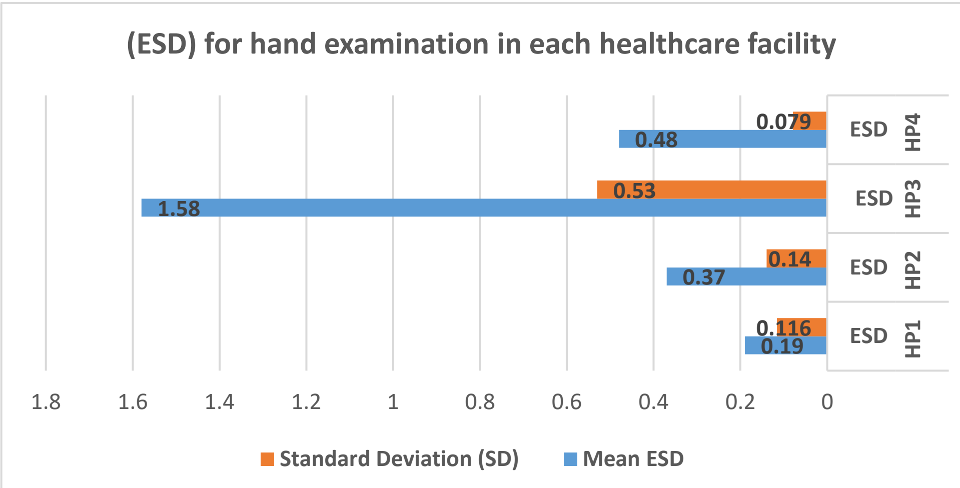

Figure (12): Surface Dose (ESD) for hand examination in each healthcare facility**.**

From Table (9) and Figure (12), it is clear that the highest surface dose (ESD) for hand examination was also in HP3 (1.58), above the international reference value of approximately 0.45mGy. The other healthcare facilities had lower doses and were closer to the internationally accepted value.

Surface Dose for Knee Examination in Each Facility

Table (10): Surface Dose (ESD) for knee examination in each healthcare facility.

Reference Value	HP1 ESD	HP2 ESD	HP3 ESD	HP4 ESD
Mean ESD	1.33	0.59	3.58	1.93
Standard Deviation (SD)	1.65	0.22	3.38	2.03

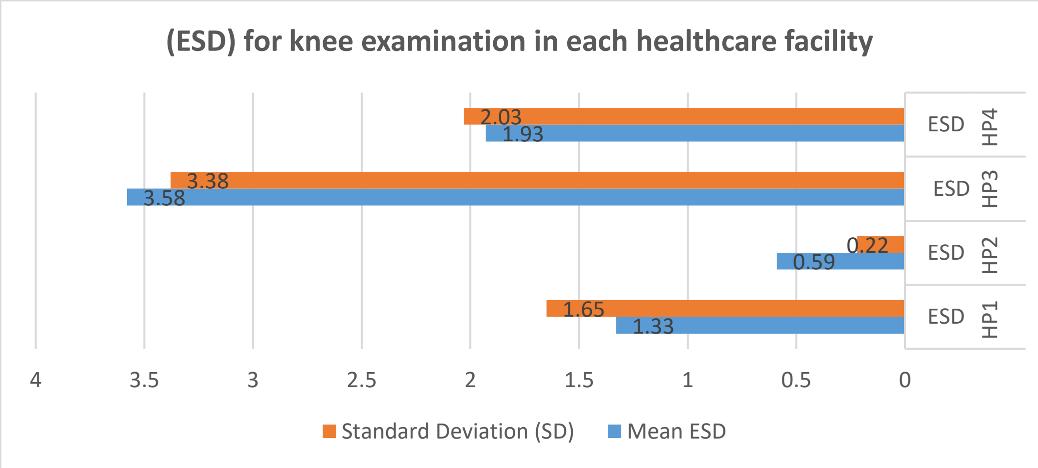

Figure (13): Surface Dose (ESD) for knee examination in each healthcare facility.

From Table:(10) and Figure:(13), it is clear that the highest surface dose (ESD) for knee examination was also in HP3 (3.58), exceeding

Discussion

Based on the results and the study, we conclude that there is a significant variation in radiation doses across the four healthcare facilities, even for the same examination within the same facility. This is due to the substantial differences in the exposure factors (KVp-mAs) used for each examination and even for the same examination. There is also a noticeable difference in the values of the distance between the source and the skin surface (BSF), even though all the equipment used was similar and had almost the same specifications. This could be attributed to the efficiency of the radiology technicians, their lack of knowledge about permissible values, or failure to implement quality standards within the radiology departments. Moreover, the increase in exposure time for some examinations was a clear factor in the increase in the entrance surface dose (ESD), as we observed repeated imaging in some examinations and facilities due to scattering and lack of focus from the radiology technician, which is unacceptable. Also, the lack of monitoring, evaluation, and quality control of the radiation equipment, as well as non-compliance with safety protocols in all four healthcare facilities, such as wearing protective clothing and using personal dosimeters, is a significant issue. Additionally, improper placement of equipment and allowing companions to accompany patients during imaging are safety violations in radiology.

Conclusion

This study revealed significant variations in patient radiation doses during routine radiographic examinations across the four investigated healthcare facilities, despite the use of X-ray machines with similar specifications. These discrepancies were mainly attributed to differences in exposure parameters (kVp, mAs, source-to-skin distance), as well as the lack of experience among some radiologic technologists and the absence of regular quality control measures. Based on these findings, the study recommends several practical actions to improve radiation protection practices. These include continuous training for radiologic technologists on safe and effective imaging techniques that minimize patient dose without compromising image quality, adopting national Diagnostic Reference Levels (DRLs) as a benchmark for performance evaluation, and enforcing routine quality control of radiographic equipment through regular testing and maintenance programs. The study also highlights the importance of establishing a national patient dose database and implementing quality assurance systems within radiology departments to enable continuous assessment and ensure adherence to the ALARA (As Low As Reasonably Achievable) principle. These measures would significantly enhance patient safety and improve the overall quality of radiological services in Libya.

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