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ORIGINAL ARTICLE

Radiation exposure of health professionals in the emergency department from portable radiography machines: a prospective cohort study

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ABSTRACT

Background: Portable radiography machines are excellent diagnostic tools, but prolonged exposure to X-rays can damage tissue. The most severe concerns include increased cancer risk, cataract development, and fetal harm in pregnant workers. This study investigates whether healthcare personnel in the emergency department (ED) are exposed to X-ray ionizing radiation in excess of the National council on radiation protection and measurements limit.

Methods: A 5-month prospective cohort study was conducted. The sample population included healthcare professionals in the ED at King Abdulaziz Medical City, Saudi Arabia. All physicians and nurses were requested to wear thermoluminescent dosimeter (TLD) monitors while working in the ED. TLD monitors worn by consultants, residents, and nurses were assessed at the end of the study.

Results: Sixty-one participants met the inclusion criteria, and two TLDs served as controls to quantify natural background radiation levels. One of the 61 participants measured 0.1 mSv, and the rest measured lower, indicating that the average radiation dose to health professionals in the ED, such as consultants, residents, and charge nurses, is below 0.1 mSv. A total of 9,327 X-ray examinations were conducted by the participants, most commonly of the chest, followed by the pelvis.

Conclusion: Radiation exposure is not a major occupational concern, even during peak ED hours. The degree of radiation exposure measured in this study was far below the minimum permissible exposure level for ED staff. Therefore, additional protective equipment or individual surveillance with dosimeters appears unnecessary.

Keywords: Occupational health, health professionals, portable radiography, radiation exposure, environment and public health, accident and emergency department.

Background

Ionizing radiation is a type of electromagnetic penetrating radiation useful in illness diagnosis and therapy. The National council on radiation protection and measurements (NCRP) reports that X-rays are most frequently used in hospitals, clinics, and emergency rooms [1]. While X-ray machines are excellent diagnostic tools, prolonged exposure to X-ray radiation can cause tissue injury [2]. Furthermore, the repercussions of ionizing radiation exposure can be severe, including elevated cancer risk, cataract formation, and fetal damage in pregnant workers [3,4].

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The Saudi food and drug authority has issued guidance on radiation protection and safety requirements to outline the standards for using ionizing and nonionizing radiation-emitting medical equipment in healthcare facilities to mitigate the associated risks [5].

A cumulative whole-body effective dose equivalent limit of 5,000 mrem/y (50 mSv/y) has been established by the NRCP for healthcare workers to ensure safety and prevent the consequences of radiation exposure [6]. The 2020/2021 report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimated the annual number of medical radiological procedures to be 4.2 billion, corresponding to an annual collective effective dose of 4.2 million mSv [7]. The resulting yearly per capita effective dose from medical exposure has declined slightly as the global population has expanded (from 6.4 to 7.3 billion) from 0.65 mSv in the UNSCEAR 2008 Report [8] to 0.57 mSv in 2018.

Few studies have examined whether emergency department (ED) medical and health professionals are exposed to radiation levels exceeding the NCRP limit, with equivocal findings [9-11]. Some studies, for example, indicated that ED personnel received doses lower than the referenced occupational exposure limit. In contrast, others focused primarily on safety precautions and concluded that, in the absence of protection, ED health personnel might be exposed to considerable levels of ionizing radiation [12-15]. While the outcomes of these previous studies are valuable, the approaches had some drawbacks, including small sample size, the placement of monitors behind protective clothes [12], and the failure to document participant compliance. Few studies have examined the exposure of ED professionals to radiation from portable radiography machines (PRMs) [13]. One study revealed that emergency medical technologists (EMTs) receive the highest dose per hour of work (2.03 mSv), followed by nurses (0.83 mSv) and doctors (0.60 mSv). This study aimed to determine whether ED healthcare professionals at King Abdulaziz Medical City (KAMC), Riyadh, Saudi Arabia, are exposed to ionizing radiation from PRMs in excess of the NCRP limit.

Methods

A 5-month prospective cohort study was conducted from October 19, 2014 to March 31, 2015. This study aimed to determine whether KAMC ED healthcare workers are at risk for exceeding the NCRP recommended limits for occupational exposure to ionizing radiation from portable X-ray machines. The exposure level of occupationally exposed individuals at KAMC was measured, and the risk of ionizing radiation exposure among ED health professionals was assessed.

The sample population of KAMC ED healthcare professionals was recruited at the start of the study. All medical doctors and nurses working in the ED were eligible to participate. Non-ED physicians, interns, and medical students were excluded. In any particular month, 30 consultants, 22 rotating emergency medicine residents, and 55 nurses work in the ED trauma and critical care area; thus, we predicted that at least 60 health professionals across the three categories would participate. Those who expected to take a vacation or work outside the ED for more than 1 week during the 5-month study period were excluded. The study setting area was a 16-bed unit equipped with cutting-edge technologies used to resuscitate acutely and severely ill or injured patients.

Each participant wore a personal radiation thermoluminescent dosimeter (TLD) monitor on their collar during their shift. The TLD monitors were worn without protective lead gowns while treating critically ill patients in the trauma and critical care area. Nurses stored their TLD monitors in their lockers when not in use; attending health professionals passed their TLDs to the next team during a shift change. Two control TLD monitors were stored in different lockers in the department 24/7 during the study period to assess natural background radiation levels. Individual nurse exposure levels were calculated by subtracting the control monitor values from their TLD monitor readings. The TLD monitors were then delivered to King Faisal Specialized Hospital, a certified reading and dosage reporting facility. TLD monitors with high radiation exposure exceeding the permissible exposure limit would be referred to the KAMC occupational health and safety department for further investigation and reflection regarding the location to identify possible factors contributing to high radiation dose.

The mean exposure for each monitor was used to calculate the expected maximum exposure over5 months. The average cumulative individual effective dosages were calculated at the end of the study period. Consultant, resident, and charge nurse TLD monitors were assessed, reflecting 24/7 radiation exposure across the study period as opposed to individual exposure. Descriptive statistics were used for categorical variables, expressed as counts and percentages. Continuous variables are presented as means and SDs for normally distributed data and medians and interquartile ranges for nonnormally distributed data. Otherwise, all percentages were rounded to the nearest two decimal places. The significance level was set at a p-value of <0.05. The analysis was conducted using Statistical Package for the Social Sciences 24 (IBM-SPSS-24).

Results

Overview

Sixty-one participants met the inclusion criteria. The mean effective dose in the ED, including consultants, residents, charge nurses, and the 2 control monitors, was below 0.1 mSv; 60 participants measured below 0.1 mSv, with only one measuring ≥ 0.1 mSv (Table 1).

Table 1. *Effective dose received by the ED professionals from PRMs (n = 61).*

Number of samples	Deep dose	Shallow dose
60	M	M
1	0.1	0.1

Monitoring criteria

The International commission on radiological protection recommends individual monitoring devices (personnel monitoring devices) for external radiation dose monitoring. Additionally, external dose types must be monitored independently (i.e. deep dose and shallow dose equivalent to the skin, eye dosage equivalent, and shallow dose to the extremities at depths of 1 cm [(1,000 mg/cm^2) and 0.007 cm (7 mg/cm^2)].

Frequency of the use of PRMs and association of the type of device with the type of procedure, time of day, and month

Data on the use of the PRMs was collected between October 19, 2014 and March 31, 2015. The information includes the type of PRMs used, the procedure type, the time of the day, and the date. A total of 9,327 entries were obtained.

As shown in Table 2, the GE-Optima 1 portable device was used for 72.4% of the procedures, and the GE-AMX700 device was used for 27.6%. The devices were used to X-ray numerous body parts, most commonly the chest (89.4%), followed by the pelvis (2.5%) and the abdomen (1.9%). Most of the procedures were conducted in the morning (43.3%), followed by at night (23.9%), in the afternoon (19.3%), and in the evening (13.5%). PRMs were used most often in December 2014 (19.8%) and least often in October (5.9%); these findings correlate to the collection of data from the 14th of the month.

Regarding the type of device used according to the type of procedure, the GE Optima 1 was used more frequently than the GE-AMX700 for abdominal (53.4%), ankle (92.3%), calculus (100%), chest (71.7%), facial (100%), lumbar spine (100%), and tibia and fibula (77.1%) X-rays. The GE-AMX700 was used more frequently only for skeletal (100%) and upper GI (100%) X-rays. Both devices were used equally for diagnostic skull X-rays (Table 3).

Regarding the time of use of the different devices, the GE-Optima was used more frequently at all times; morning (64.3%), afternoon (72.7%), evening (78.9%), and night (83.2%) (Table 3). When the GE-AMX700 device was used, 56.09% of uses were in the morning, 19.02% in the afternoon, 10% in the evening, and 14.56% at night. GE-Optima use in the morning represented only 38.47% of its total use, significantly less than the 56.09% relative frequency of use of the GE-AMX700 in the morning. In contrast, 27.45% of GE-Optima use versus 14.56% of GE-AMX700 use occurred at night.

Regarding the frequency of usage of each device across different months, again, the GE-Optima was used more frequently each month (Table 3), ranging from 69.1% to 72.4%; however, the frequency relative to the total use of each device revealed that the GE-AMX700 was used relatively more often in November (21.12%) and December (24.92%) 2014, while the GE-Optima 1 was used significantly more often in January (19.61%) and February (19.73%) 2015 (Figure 1).

Table 2. *Frequency distribution of type of PRM, type of procedure, time, and month of use.*

		Frequency	Percent (%)
Type of PRM	GE-AMX700	2,576	27.6
	GE-Optima 1	6,751	72.4
Procedure	DX-ABDOMEN	178	1.9
	DX-ANKLE	39	0.4
	DX-CALCIS	1	0.0
	DX-CHEST	8,342	89.4
	DX-CLAVICLE	8	0.1
	DX-CSPINE	6	0.1
	DX-ELBOW	29	0.3
	DX-FACIAL	1	0.0
	DX-FEMUR	65	0.7
	DX-FINGER	1	0.0
	DX-FOOT	38	0.4
	DX-FOREARM	62	0.7
	DX-HAND	35	0.4
	DX-HIP	17	0.2
	DX-HUMERUS	35	0.4
	DX-KNEE	61	0.7
	DX-LSPINE	1	0.0
	DX-MANDIBLE	1	0.0
	DX-NECKST	4	0.0
	DX-PELVIS	230	2.5
	DX-SHOULDER	47	0.5
	DX-SKELETS	2	0.0
	DX-SKULL	2	0.0
	DX-TIBIFIB	70	0.8
	DX-TOE(S)	2	0.0
	DX-UPPER GI	1	0.0
	DX-WRIST	49	0.5
Time of day	Morning (5:00-11:59 a.m.)	4,042	43.3
	Afternoon (12:00-4:59 p.m.)	1,796	19.3
	Evening (5:00-8:59 p.m.)	1,261	13.5
	Night (9:00 p.m.-4:59 a.m.)	2,228	23.9
Month and year	October 2014	550	5.9
	November 2014	1,731	18.6
	December 2014	1,846	19.8
	January 2015	1,652	17.7
	February 2015	1,719	18.4
	March 2015	1,829	19.6
Total		9,327	100.0

A significant difference was found between the type of device used for the different types of procedures, time of day, and month/year ($p < 0.001$, Table 3). As already stated, the GE-AMX700 was used relatively more frequently in the morning (56.09%) and in November (21.12%) and December (24.92%), while the GE-Optima 1 was used significantly more often at night (27.45%) and in January (19.61%) and February (19.73%) (Figure 1; Table 3).

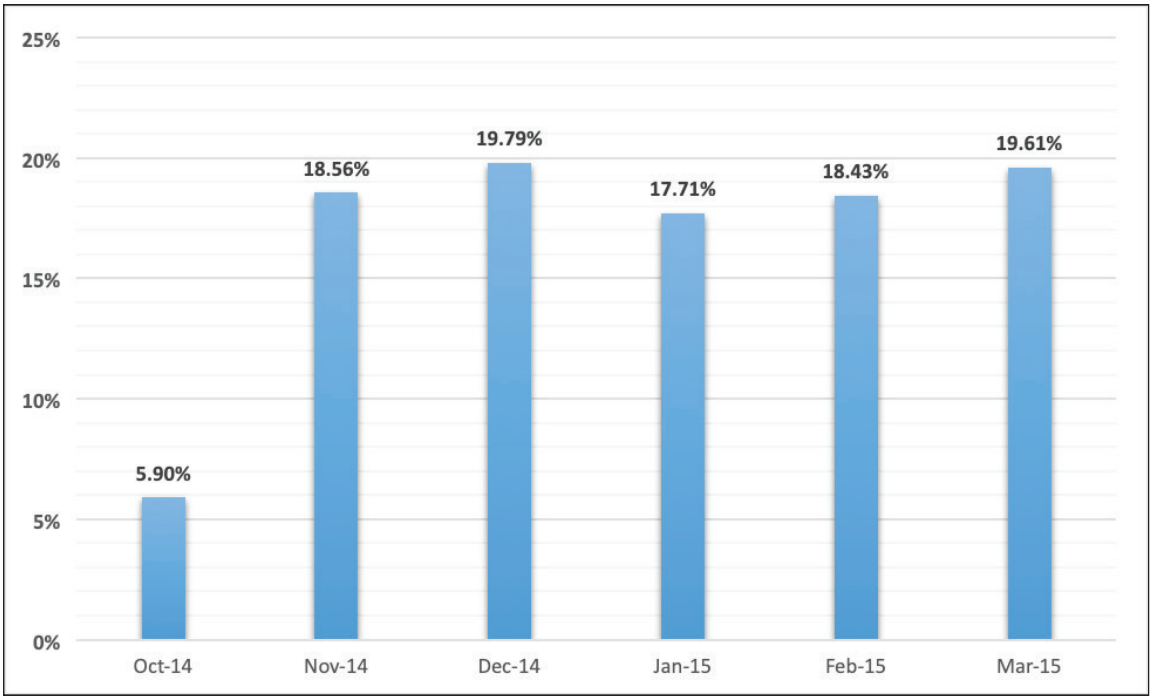

Figure 1. *Distribution of use of PRM according to months and years.*

Discussion

According to KAMC ED data, 5,248 registered patients required at least one diagnostic imaging procedure using PRM, and 61 health professionals cared for these individuals. Our investigation followed these health providers for 5 months. Considerable variation was observed in the types of radiographic devices utilized for the various procedures, the time of day, and the month. In our analysis, the GE-Optima was used more often than the GE-AMX700. The GE-Optima was used for 64.3% of diagnostic imaging procedures in the morning, 72.7% in the afternoon, 78.9% in the evening, and 83.2% at night. The GE-AMX700 equipment was used for 56.09% of procedures in the morning, 19.02% in the afternoon, 10% in the evening, and 14.56% at night, according to the relative frequency of use data.

Briggs et al. [16] conducted a 3-month study in which 1,464 mobile radiographs were taken in ED resuscitation units. Most were chest and pelvic radiographs. ED stationary dosimeter analysis revealed a mean of 0.18 mSv in the primary resuscitation room and 0 mSv in the other intensive care rooms. The evaluation of the health professional dosimeter indicated no significant exposure to radiation (0.00 mSv). No emergency room doctor breached the NCRP exposure limit for ionizing radiation for healthcare professionals in their active trauma center ED. This study was planned to include measures at several body regions along with specific participant and workplace (i.e. telephone area, attendance, and residential role) responses. Consistent with our findings, the detected ionizing radiation dose in the aforementioned investigation was considerably below the permissible limits; thus, their ED maintained their practice of not using TLD monitors or wearing lead aprons for regular ED radiography.

Lin [17] assessed emergency doctors' employment exposure to radiation and found conflicting results regarding the requirement for constant radiation surveillance for healthcare personnel. KIM et al. [16] conducted a prospective research study in the ED of an urban hospital from February 15, 2013 to May 15, 2013. Six doctors, 24 nurses, and 7 EMTs actively participated in this study and stayed at least 1.8 m away from the mobile X-ray machine during use. The overall average radiation exposure of these ED providers was -0.037 mSv, with the EMT group receiving the greatest dose (0.85 mSv). Thus, it was concluded that no significant association was present between the number of portable X-rays conducted and the radiation exposure dosage when providers maintain a 1.8 m distance from the portable X-ray system.

Yeung et al. [18] reported in 2021 that mobile X-ray scans have increased in Australia since the first reported coronavirus outbreak. Other preliminary data (January-March 2020) obtained in Australia indicated only a minor change in the number of chest X-rays conducted [19]. The prevalence of mobile chest X-rays in both research locations began to increase in April 2020. The highest demand for thoracic imaging was recorded between 2 and 10 p.m. for medical emergencies and 6 a.m. to 2 p.m. for hospitalized patients [20]. Due to the diversity of patient symptoms, bedside imaging was often required to obtain a rapid diagnosis. Another study indicated that using mobile radiography reduces health professionals' radiation exposure since the transfer of a patient to the diagnosing room is not required, and the potential for contamination is reduced [21]. Prior to the COVID-19 outbreak, mobile radiography of areas other than the chest was uncommon at the sampling sites. Only 6% of testing laboratories used mobile radiography. Furthermore, no statistically relevant spike in the proportion of workers

Table 3. Distribution of type of PRM used according to procedure, time, and month/year.

		PRM		*p*-value
		GE-AMX700	GE-Optima 1	
Procedure	DX-ABDOMEN	46.6%	53.4%	<0.001±
	DX-ANKLE	7.7%	92.3%	
	DX-CALCIS	0.0%	100.0%	
	DX-CHEST	28.3%	71.7%	
	DX-CLAVICL	37.5%	62.5%	
	DX-CSPINE	16.7%	83.3%	
	DX-ELBOW	10.3%	89.7%	
	DX-FACIAL	0.0%	100.0%	
	DX-FEMUR	26.2%	73.8%	
	DX-FINGER	0.0%	100.0%	
	DX-FOOT	18.4%	81.6%	
	DX-FOREARM	12.9%	87.1%	
	DX-HAND	11.4%	88.6%	
	DX-HIP	29.4%	70.6%	
	DX-HUMERUS	25.7%	74.3%	
	DX-KNEE	19.7%	80.3%	
	DX-LSPINE	0.0%	100.0%	
	DX-MANDIBL	0.0%	100.0%	
	DX-NECKST	0.0%	100.0%	
	DX-PELVIS	10.4%	89.6%	
	DX-SHOULDER	25.5%	74.5%	
	DX-SKELETS	100.0%	0.0%	
	DX-SKULL	50.0%	50.0%	
	DX-TIBIFIB	22.9%	77.1%	
	DX-TOE(S)	0.0%	100.0%	
	DX-UPPERGI	100.0%	0.0%	
	DX-WRIST	8.2%	91.8%	
Time of day	Morning	35.7%	64.3%	<0.001*
	Afternoon	27.3%	72.7%	
	Evening	21.1%	78.9%	
	Night	16.8%	83.2%	
Month and year	October 2014	30.9%	69.1%	<0.001*
	November 2014	31.4%	68.6%	
	December 2014	34.8%	65.2%	
	January 2015	19.9%	80.1%	
	February 2015	22.5%	77.5%	
	March 2015	27.6%	72.4%	

±Fischer's exact test (Monte-Carlo Simulation), $p < 0.05$, Significant.

*χ^2, $p < 0.05$, Significant.

exposed to doses larger than the lowest reportable level of 0.01 mSv each quarter was detected in mobile radiography units. As a result, this study found no substantial increase in radiation risk for radiographers.

Beyond accidental exposure, medical ionizing radiation exposure represents the highest anthropogenic per capita exposure, resulting in the highest overall organ exposure doses. This vulnerability for healthcare professionals has been shown in several research papers. Recent studies have estimated an overall yearly dosage of 0.0009 Sv/year among radiologists in the diagnostic department and 0.0019 Sv/year among radiologists in the therapeutic department. Physicians conducting fluoroscopy had prefrontal exposures ranging from 0.0005 to 0.0024 Sv/minute during fluoroscopy sessions [22]. The average ionization exposure of the eye during cardiac catheterization is roughly 0.2 Sv/minute. In recent studies by Braun et al. [10] on ED doctors' exposure (conducted inside an ED) from a satellite radiology unit (producing around 1,635 radiographs each month), ionization exposure to the lapel was determined to be 0.07 mSv/month. The most frequent origins of this radiation exposure are diagnostic portable radiographs performed in the ED and radiation absorbed while caring for patients in other departments of the hospital (i.e., angiography, radiology, and fluoroscopy) [23]. Nurses were exposed to more radiation than physicians, likely because nurses are much more likely to remain with patients in the ED and follow them to other sections of the hospital, especially locations where X-ray exposure is possible. Thus, it was concluded that health professionals exposed to occupational radiation should stand at least 6.5 feet (2 m) from patients during portable radiograph imaging to avoid radiation exposure and be properly attired when standing nearby [24].

Our research provides a more up-to-date evaluation of ED personnel's workplace exposure to ionizing radiation. However, our study has some limitations. Our findings were limited to specific types of radiological machines. Additionally, further research is necessary to monitor radiation exposure in healthcare professionals in more depth.

Conclusion

The degree of radiation exposure detected in this study was far below the minimum permissible occupational exposure of 50 mSv/year for ED staff. Radiation exposure is not a serious occupational concern during rush hour at KAMC ED. Existing safeguards should properly protect employees from ionizing radiation exposure, and additional protective equipment or individual surveillance with dosimeters appears unnecessary. The conclusions of this investigation will provide comfort to ED professionals performing key tasks during clinical shifts in that they are not at risk for ionizing radiation exposure exceeding that recommended in the NCRP guidelines. Nevertheless, doctors and other healthcare providers should be aware of occupational radiation and limit their exposure.

What is new?

Confirming the safety of using PRMs uses in ED.

Acknowledgment

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List of Abbreviations

ED	Emergency department
KAMC	King Abdulaziz Medical City
NCRP	The National Council on Radiation Protection and Measurements
PRM	Portable radiography machine
TLD	Thermoluminescent dosimeter

Conflicts of interest
The authors declare no conflicts of interest.

Funding
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Consent to participate
All study participants received written instructions about the study's purpose before participating and wearing TLDs.

Consent for publication
Not applicable.

Ethics approval
The study was approved by the IRB of National Guard Health Affairs, Riyadh, Saudi Arabia (Reference: IRBC/302/157), dated 6th July 2010.

Availability of data and materials
The data collected and used in this study are available from the corresponding author upon request.

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