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Original article

Evaluation of Adherence to Radiation Protection Measures among C-arm Fluoroscopy Users in the Operating Room

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Abstract
Occupational exposure to IR may have detrimental health effects. Longer and more complicated fluoroscopic procedures have placed interventionalists at elevated occupational health hazards. Measures of radiation protection are necessary for all healthcare workers who work in the interventional fluoroscopy room. The purpose of this study was to assess adherence to radiation protection measures among C-arm fluoroscopy users in the operating room. A questionnaire was developed to conduct a cross-sectional study. The questionnaire comprised multiple sections, each evaluating knowledge of radiation protection, use of personal protective equipment, procedures for reducing radiation exposure, and monitoring of personal radiation dose, respectively. The participants included physicians and radiographers who use C-arm fluoroscopy in the operating room. The results of the current study showed several important observations about knowledge and adherence of C-arm users to radiation protection measures. The results showed that there was a significant deficiency in some key aspects of radiation protection, both at the level of knowledge and at the level of actual practice. In conclusion, there was a significant deficiency among the majority of participants in regularly use of some key aspects of radiation protection, particularly at the level of actual practice of PPE, pulsed fluoroscopy, and personal dosimetry. Implementation of radiation safety training programs is thus recommended.
Keywords. Radiation Protection, C-arm Fluoroscopy, Operating Room.

Introduction

C-arm fluoroscopy is an important medical imaging machine. It is used to guide a lot of surgical and interventional procedures. C-arm fluoroscopy is utilized in many areas of medicine, including neurosurgery, orthopedics, urology, gastroenterology, cardiology, and pain management. Less invasive treatments that reduce reliance on open surgeries and the hazards associated with them are made possible by the C-arm's adaptability, portable, and functional design. Due to its ability to provide high-quality X-ray images in real time, its usage in minimally invasive surgery has rapidly expanded [1].
Ionizing radiation (IR) is essential and integral in modern medical prognostic, diagnostic, and interventional procedures. Globally, over the past few decades, the number of interventional procedures has significantly increased [2]. Interventional physicians are, however, performing longer and more complicated procedures, they are occupationally exposed to IR for a longer time [3].
Radiation exposure is a major risk for interventional physicians and radiographers [4]. According to the ALARA principle, the radiation dose received during fluoroscopy should be kept to a minimum [5]. The ICRP has established occupational radiation dose limits to be 20 mSv per year, averaged over 5 years. However, the annual permissible occupational dose should not exceed 50 mSv. The NRC likewise recommended that cumulative fetal dose throughout the pregnancy period be less than 5 mSv [6]. Reducing the radiation exposure dose is known to depend on a number of parameters, including distance from the radiation source, time of radiation exposure, and barriers against exposure to radiation [7].
Radiation effects are classified as stochastic effects or deterministic effects. Stochastic effects are dose-independent and include DNA damage and radiation-induced cancer. X-rays used in medical imaging can lead to Stochastic effects. Deterministic effects are dose-dependent, such as skin reddening and burns, with causing more severe outcomes as the dose increases [8]. Therefore, occupational radiation protection is a necessity whenever radiation is used in the practice of medicine. It is especially important for image-guided medical procedures. These procedures may involve high radiation dose rates [9].
Occupational radiation protection requires both the appropriate training and education for the fluoroscopy users and the availability of appropriate protection equipment. Occupational radiation protection measures must also comply with local and national regulations [10]. Therefore, it is important to conduct assessment studies to evaluate the knowledge and practices related to radiation protection among those who utilize C-arm fluoroscopy. This assessment is a primary step in identifying limitations and developing training and corrective strategies that contribute to ensuring the protection of C-arm fluoroscopy users from the potential hazards of IR. Accordingly, this study aimed to assess the adherence of C-arm fluoroscopy users to radiation protection measures in the operating room.

Methods

Study Design

This study was a cross-sectional study conducted via questionnaire. The questionnaire was distributed for responses between December 11, 2025, and February 10, 2026.

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Participants

Its scope was limited to a random sample of radiographers and physicians who use the C-arm in the operating room. This study was conducted in a healthcare facility in Misrata, Libya. The questionnaire was manually distributed to a random sample. A total of 162 questionnaires were returned, of which 23 were excluded for failing to meet the criteria, and thus 139 questionnaires were included in the statistical analysis. Consent was implicitly obtained prior to survey completion from all participants. Participants were informed about the voluntary nature of their participation and the objective of the study. To adhere to ethical standards for a study of this nature, the survey was completely anonymous and collected no personally identifiable information to ensure full confidentiality.

Study Tool

To achieve the objectives of this study, a questionnaire was developed as a primary tool for data collection. In its final form, the questionnaire comprised five main sections: Section 1 gathered the demographic characteristics of the participants. Section 2: knowledge of radiation protection. Section 3: use of personal protective equipment (PPE). Section 4: procedures for reducing radiation exposure. Section 5: monitoring of personal radiation dose. The questionnaire was reviewed by a panel of experts and specialists for their feedback and finalization. Cronbach's alpha coefficient was calculated to ensure the internal consistency and reliability of the questionnaire. The overall Cronbach's alpha coefficient value was 0.78, which exceeds the universally accepted threshold of 0.70. This indicates a high level of internal consistency, demonstrating that the study tool was reliable for the main study deployment.

Data Analysis

Descriptive analysis was conducted using frequency distributions and the arithmetic mean. The degree of agreement was categorized according to the mean values. When the mean ranged from 1 to less than 1.50, the response was classified as “Yes,” indicating a high degree of agreement. A mean between 1.50 and 2 corresponded to the response “No,” reflecting a low degree of agreement.

In another categorization, when the mean ranged from 1 to less than 1.67, the response was “Yes,” denoting a high degree of agreement. A mean between 1.67 and less than 2.34 corresponded to the response “Sometimes,” which indicated a moderate degree of agreement. Finally, a mean between 2.34 and 3 was associated with the response “No,” signifying a low degree of agreement.

To assess the overall statistical trend of the main hypothesis in the study questionnaire, a one-sample t-test was applied. If the p-value exceeded 0.05, this suggested that the overall statistical trend for the statement was moderate. Conversely, if the p-value was less than 0.05, the overall trend was either low or high, and in such cases, the mean value was examined to determine the precise direction of agreement.

Results

Section 1: Demographic characteristics of participants

(Table 1) illustrates the distribution and characteristics of the study sample by gender, age, and job, demonstrating its diversity and suitability for the study.

Table1. The distribution of participants within different subgroups

Subgroups	Labeling	Frequency (Fr)	Percent (%)
Gender	Male	109	78.4%
	Female	30	21.6%
	Total	139	100.0%
Age	21 – 30	54	38.8%
	31 – 40	58	41.7%
	41 – 50	20	14.4%
	51 – 60	7	5.0%
	Total	139	100.0%
Gob	Radiographer	76	54.7%
	Physician	63	45.3%
	Total	139	100.0%

Section 2: Knowledge of Radiation Protection

This section was investigated to determine whether "there is knowledge of radiation protection principles among C-arm fluoroscopy users." This hypothesis was evaluated for every item of this Section. The results in (Table 2) indicate a high level of agreement with the majority of the statements in this section. The statement with the most agreement was, " Realization that reducing exposure time decreases the radiation dose." The statement with the lowest agreement was, " Knowledge of the ALARA principle ". From (Table 3), our results show that the P-value was less than 0.05. Additionally, the arithmetic mean was less than 1.5, indicating a high degree of agreement in this section. Therefore, it can be concluded that there was knowledge of radiation protection.

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Table 2. The results of the statistical analysis for Section 2

Item		Yes	No	Mean	Std. Deviation	Degree of agreement
Knowledge of ALARA principle	Fr	62	77	1.55	0.50	Low
	%	44.6	55.4			
Knowledge of the annual permissible occupational dose	Fr	79	60	1.43	0.50	High
	%	56.8	43.2			
Realization that reducing exposure time decreases the radiation dose	Fr	132	7	1.05	0.22	High
	%	95	5			
Realization that doubling the distance from the radiation source reduces the dose fourfold	Fr	121	18	1.13	0.34	High
	%	87.1	12.9			
Total	-	-	-	1.29	0.25	High

Table 3. The results of the one-sample t-test for Section 2

N	Mean	Std. Deviation	P-value
139	1.2914	0.251080	0.000

Section 3: Use of Personal Protective Equipment (PPE)

This section was studied to determine whether "personal protective equipment is used when using the C-arm fluoroscopy." This hypothesis was evaluated for each item in the questionnaire. Based on the results in (Table 4), there is a low level of agreement with the majority of the statements in this section. The statement with the highest agreement was "Utilization of a lead apron during procedure," while the statement with the lowest agreement was "Utilization of protective gloves during procedure". According to (Table 5), our results showed that the P-value was less than 0.05. Additionally, the arithmetic mean was greater than 2, indicating a low degree of agreement in this section. Thus, it can be concluded that there was no use of PPE when using the C-arm fluoroscopy.

Table 4. The results of the statistical analysis for Section 3.

Phrase		Yes	Sometimes	No	Mean	Std. Deviation	Degree of agreement
Utilization of a lead apron during procedure	Fr	70	58	11	1.58	0.64	High
	%	50.4	41.7	7.9			
Utilization of a thyroid shield during procedure	Fr	32	39	68	2.26	0.81	Low
	%	23	28.1	48.9			
Utilization of protective goggles during the procedure	Fr	18	18	103	2.61	0.71	Low
	%	12.9	12.9	74.1			
Utilization of protective gloves during procedure	Fr	16	22	101	2.61	0.69	Low
	%	11.5	15.8	72.7			
PPE regularly inspected	Fr	19	41	79	2.43	0.72	Low
	%	13.7	29.5	56.8			
Total	-	-	-	-	2.30	0.52	Moderate

***Table 5. The results of the one-sample t-test for Section* 3**

N	Mean	Std. Deviation	P-value
139	2.2978	0.519960	0.000

Section 4: Procedures for Reducing Radiation Exposure

This section was investigated to determine whether "procedures are followed to reduce radiation exposure when using the C-arm fluoroscopy". This hypothesis was evaluated for each item in the questionnaire. The results in (Table 6) indicate different degrees of agreement for most statements in this section. The statement with the highest agreement was " non-essential personnel are kept away from the radiation area," while the statement with the lowest agreement was "Utilization of pulsed fluoroscopy whenever possible". From (Table 7), our results showed that the P-value was less than 0.05. Additionally, the arithmetic mean was less than 2, indicating a high degree of agreement in this section. Therefore, it can be concluded that there was adherence to procedures for reducing radiation exposure when using the C-arm fluoroscopy.

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Table 6. The results of the statistical analysis for section 4

Phrase		Yes	Sometimes	No	Mean	Std. Deviation	Degree of agreement
Utilization of pulsed fluoroscopy whenever possible	Fr	31	39	69	2.27	0.81	Moderate
	%	22.3	28.1	49.6			
X-ray tube is positioned beneath the patient whenever possible	Fr	57	53	29	1.80	0.76	Moderate
	%	41	38.1	20.9			
Hands are kept out of the radiation field during the procedure	Fr	85	35	19	1.53	0.73	High
	%	61.2	25.2	13.7			
Non-essential personnel are kept away from the radiation area	Fr	94	35	10	1.40	0.62	High
	%	67.6	25.2	7.2			
Total	-	-	-	-	1.75	0.46	Moderate

Table 7. The results of the one-sample t-test for the section 4

N	Mean	Std. Deviation	P-value
139	1.7482	0.460880	0.000

Section 5: personal radiation dose monitoring

This section was investigated to determine whether "The adherence to monitoring of the personal radiation dose varies among C-arm fluoroscopy users." This hypothesis was evaluated for each item in the questionnaire. The results in (Table 8), indicate low degrees of agreement for all statements in this section. The statement with the highest agreement was "Regular use of a personal dosimeter," while the statement with the lowest agreement was " Regular analysis of a personal dose". From the results in the (Table 9), the P-value was less than 0.05. Additionally, the arithmetic mean was greater than 2, indicating a low degree of agreement in this section. Therefore, it can be concluded that there was no adherence to monitoring of the personal radiation dose among C-arm fluoroscopy users.

Table 8. The results of the statistical analysis for section 5

Phrase		Yes	Sometimes	No	Mean	Std. Deviation	Degree of agreement
Regular use of a personal dosimeter	Fr	24	26	89	2.47	0.77	Low
	%	17.3	18.7	64			
Regular analysis of a personal dose	Fr	10	31	98	2.63	0.62	Low
	%	7.2	22.3	70.5			
Implementation and periodic review of permissible occupational dose by the workplace	Fr	5	39	95	2.65	0.55	Low
	%	3.6	28.1	68.3			
Total	-	-	-	-	2.58	0.53	Low

Table 9. The results of the one-sample t-test for Section 5

N	Mean	Std. Deviation	P-value
139	2.5827	0.526420	0.000

Discussion

In recent years, there has been a significant development in the use of ionizing radiation in diagnostic imaging, which has resulted in increasing radiation exposure among healthcare workers [11]. Occupational exposure to IR may have detrimental health effects. Longer and more complicated fluoroscopic procedures have placed interventionalists at elevated occupational health hazards [12]. Measures of radiation protection are necessary for all healthcare workers who work in the interventional fluoroscopy room. This includes not only radiographers, who spend a long time in a radiation environment, but also individuals such as anesthesiologists who may be in a radiation environment only occasionally. All of these healthcare workers may be considered radiation workers, according to their level of exposure to radiation and national regulations. All radiation workers require appropriate monitoring, as well as protection tools and equipment. They must also receive education and training programs appropriate to their jobs [10]. The results of the current study showed important observations about knowledge and adherence of C-arm users to radiation protection measures.

In terms of knowledge of radiation protection, our results showed a significant majority of the sample were cognizant that

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reducing the exposure time reduces the radiation dose. Similarly, 87.1% recognized the effect of doubling the distance from the source on the radiation dose, and although the general trend of the results of this section indicated adequate knowledge regarding radiation protection, 43.2% of participants indicated a lack of awareness concerning the limits of the annual permissible occupational dose. Indeed, 55.4% of the study respondents lacked awareness of the ALARA principle. Thus, these results reported the need for the implementation of training programs and continuous information updates in radiation protection.

Healthcare workers should utilize proper PPE to reduce radiation exposure. This may include lead aprons, eye shields, thyroid shields, protective gloves, protective goggles, and other shielding tools that provide adequate safety for the specific radiation procedures being performed [13]. In regarding to use of proper PPE Our data showed that PPE, particularly in regarding to use of eye shield, thyroid shield, protective gloves, and protective goggles were not used consistently. This trend reflects a significant deficiency in adherence to using PPE, potentially due to a lack of PPE. Moreover, our results also showed that there was no adherence to the protocols for regular screening of PPE. The deficiency in regular adherence to using PPE contradicts the basic principles of radiation protection, which state that a protective shield is one of the three fundamental pillars alongside time and distance that play a vital role in radiation protection [13]. This deficiency may lead to the risk of accumulating radiation dose to personnel over time, particularly within high-throughput operational environments such as major hospitals. This result is consistent with the findings of Hashem et al., 2021, which showed that there was no adherence among orthopedic surgeons to utilize PPE, particularly regarding the use of thyroid shields, eye shields, and protective gloves. However, there was marked adherence to the utilization of lead aprons [14].

To minimize radiation exposure during fluoroscopic procedures, there are techniques have to be used, particularly regarding the use of pulsed fluoroscopy, positioning of the C-arm, and collimation. Surgeons should consider using these techniques to protect patients and themselves from radiation [15,16]. In terms of procedures for reducing radiation exposure, the results showed that most study respondents avoid placing their hands in the radiation field. Similarly, 67,6% of study respondents demonstrated that non-essential personnel are kept away from the radiation area. Although the overall statistical trend for this section indicated that there was adherence to procedures for reducing radiation exposure, there was a weakness in compliance with the use of Pulsed fluoroscopy and the under-table position of the X-ray tube, which may cause an undue increase in occupational exposure to radiation.

Radiation exposure for healthcare workers has to be evaluated carefully due to its repetitive character and potential stochastic effects. the medical staff who work in the radiation environment should be aware of the radiation dose they may receive during a particular procedure and which factors determine the level of these doses. Knowledge of personal radiation dose allows for optimal use of the ALARA principles [17]. As such, dose monitoring systems could be recommended as an integral part of the clinical workflow [18]. Regarding personal radiation dose monitoring, our results showed that there was no recording of occupational personal radiation periodically. Furthermore, the facility where respondents were employed lacked adherence to the implementation and periodic review of occupational dose limits, which is contrary to the recommendations of the ICRP. ICRP emphasizes the need to monitor occupational radiation exposure and record personal radiation dose through dosimeters. This neglect appears to be partly due to the lack of personal protective equipment, reflecting a weakness in occupational safety infrastructure. Our result in agreement with the results of Hayashi et al., 2021, which reported that there was a disparity in the use of radiation protection measures among workers and revealed a significant decrease in the rate of using personal dosimeters among gastroenterologists [19].

Conclusion

There was a significant deficiency in the majority of participants in regularly use of some of the key aspects of radiation protection, in particular at the level of actual practice of PPE, pulsed fluoroscopy, and personal dosimetry. Implementation of radiation safety training programs is thus recommended.

Data Availability Statement

The questionnaire used in this study is available from the corresponding author upon reasonable request.

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Conflicts of Interest

The authors declare no conflicts of interest.

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