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ARTICLE

Radiographers' knowledge regarding patients' ionizing radiation doses during common radiological procedures in Saudi Arabia

F.M. Aldhafeeri*

College of Applied Medical Sciences, University of Hafr Albatin, P.O. Box 31991, Hafr Albatin, Saudi Arabia.

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Abstract – To evaluate the level of knowledge and awareness regarding radiation doses from common radiological examinations among 100 radiographers working in different hospitals across Saudi Arabia, a questionnaire comprising 21 multiple-choice questions was electronically distributed to 180 radiographers working in medical imaging departments in various hospitals in Saudi Arabia. Participants were instructed to estimate the radiation dose administrated to patients during common radiological procedures. I received 100 survey responses. Only 13% ($n = 13$) of the participants correctly identified the effective radiation dose from 1-view chest and abdominal X-ray, whereas 7% ($n = 7$) correctly identified the dose from 2-view chest X-ray. Approximately half of the participants underestimated the patient dose from head and abdominal computed tomography and 2-view unilateral mammogram. Moreover, 17–26% correctly estimated the patient's risk of fatal cancer from common radiological procedures. These results revealed a remarkably low level of knowledge among radiographers regarding radiation dose and risks. The vast majority of radiographers underestimated radiation doses and associated risks from common radiological examinations. The number of bachelor's programs in Saudi Arabia has been extremely limited in the past decade. Most radiographers hold a diploma degree, which does not include any courses on radiation dose or protection. Continuous professional development in radiation safety is required to practice radiography.

Keywords: radiation dose / x-ray / radiographer / computed tomography

1 Introduction

Radiological examinations are a critical element in modern medicine. Many diagnostic and interventional radiological procedures involve ionizing radiation exposure. While the overall benefits of imaging outweigh the associated risks of radiation, there is growing concern regarding the detrimental biological effects of ionizing radiation on living organisms. The demand for computed tomography (CT) has steadily increased, constituting 50% of the collective dose from radiological procedures (Hart and Wall, 2004; Hricak *et al.*, 2011). In the US, > 600,000 head and abdominal CT examinations are performed in children each year. The reported lifetime cancer risk of a single radiation exposure from abdominal CT in children is approximately 1 in 550 and is 1 in 1500 for a head CT examination (Brenner *et al.*, 2001). In the UK, it is estimated that medical radiation exposure is responsible for a total of 700 cancers each year (de González and Darby, 2004). Various studies have demonstrated the paucity of knowledge regarding radiation protection among radiographers (Paolicchi *et al.*, 2016), students and interns (Zhou *et al.*, 2010), and radiologists (Lee *et al.*, 2012). Guidelines on radiation protection education and training of medical professionals in the European Union (Radiation Protection no. 175) (Commission, 2014) recommend that undergraduate courses for all medical professionals include radiation protection training, followed by continuous professional development.

It is worth mentioning that Saudi universities are increasingly offering more bachelor's degree courses in radiography. Most radiographers currently working in diagnostic radiography hold diplomas, as there are few bachelor programs in radiography in Saudi Arabia. According to the Saudi Commission for Health Specialties, Saudi Arabia is expected to need 14,122 technologists based on the availability of 1 technologist per 3000 population over the next 10 years. This study aimed to examine radiographers' knowledge of radiation dose and risks of common radiological examinations in the Kingdom of Saudi Arabia.

2 Materials and methods

The Institutional Research Ethics Committee approved the present study. This prospective cross-sectional study was

*Corresponding author: fmaldhafeeri@uhb.edu.sa

performed across different hospitals in Saudi Arabia. A multiple-choice questionnaire comprising 21 questions on various aspects of radiation dose as well as demographical data. The questionnaire was based on a previously published study (Ramanathan and Ryan, 2015) and then electronically designed using online survey software "SoGoSurvey," and the link was emailed to all radiographers working in medical imaging departments in various hospitals across Saudi Arabia. A 2-week time limit was provided for participants to complete the questionnaire via the online survey tool, and a reminder email, including the survey link was sent 3 days before the deadline. Data were collected anonymously.

2.1 Questionnaire

The questionnaire consisted primarily of 2 parts with 21 questions regarding radiation dose from common radiological examinations (Ramanathan and Ryan, 2015). The first part of the questionnaire included four questions about demographic data such as age, sex, education level, and years of experience, and the second part comprised 17 multiple-choice questions regarding various aspects of radiation dose and risk (Tab. 1). The first couple of questions addressed basic awareness regarding average natural background radiation and effective dose from a chest radiograph. We assessed the effective dose that an adult patient would receive from a number of common diagnostic radiological examinations in terms of chest X-ray equivalents (assuming exposure from a single-view chest X-ray as 1 arbitrary unit). Next, participants were instructed to select the approximate estimated cancer risk from common radiological examinations based on 4 levels of risk (minimal, very low, low, and moderate). One question was on management of accidental radiation exposure during pregnancy. All questions were in a multiple-choice format, with 4 options and only 1 correct answer. The participants could only choose 1 answer per question.

2.2 Statistical analysis

Data were analyzed using SPSS Statistics software, version 14.0, to obtain frequencies, percentages, and descriptive statistical results.

3 Results

Of 180 questionnaires distributed, 100 were completed and returned. Approximately 43% ($n = 43$) of the radiographers participating in the study held a diploma degree, 55% ($n = 55$) held a bachelor's degree, and 2% ($n = 2$) held a master's degree or higher. Approximately 65% ($n = 65$) of the respondents had > 10 years of professional experience in radiography (Tab. 2).

The range of average natural background radiation is from 2 to 3 mSv, and only 22% of the participants answered correctly. The approximate effective dose from 1-view chest X-ray is 0.02 mSv and from 2-view chest X-ray is 5 times that of 1-view chest X-ray. The question pertaining to 1-view chest X-ray was answered correctly by 13% ($n = 13$) of respondents and by 7% for the question about 2-view chest X-ray. A small number (13%, $n = 13$) of participants identified correctly that the effective dose from 1-view abdominal X-ray is equivalent to that of 10–50 chest X-rays. Only 34% ($n = 34$) of the participants correctly identified that single-phase abdominal CT delivers a dose of 10 mSv. Approximately half (48%) of the participants underestimated the dose received during abdominal CT examinations, while 22% ($n = 22$) answered correctly that it is equivalent to 100–500 chest X-rays. The majority of the respondents (70%) either under- or overestimated the equivalent dose to head CT examination, and only 30% answered correctly that it is equivalent to 50–100 chest X-rays. More than half of the participants (53%) underestimated the radiation dose from head CT, 17% overestimated, and only 30% correctly identified the dose. Half of the participants (50%) underestimated the effective dose from 2-view unilateral mammogram, 19% correctly estimated, and 31% overestimated. Of participants, 68% correctly stated that MRI has no radiation risks. Moreover, only 26% ($n = 26$) correctly identified a minimal risk of fatal cancer from chest X-ray. The number of correct answers ranged between 14 and 25% for the remainder of the examinations including abdominal CT, coronary CT angiography, and positron emission tomography (PET)/CT of the head. The American College of Radiologists suggests that operators reassure pregnant women who have accidentally undergone abdominal CT that the risk to the fetus is negligible. Most of the respondents (83%) overestimated the required action in case of accidental radiation exposure to a pregnant woman, with only 17% identifying the correct action. The overestimation varied between suggesting medical termination of the pregnancy (15%), conducting genetic testing by amniocentesis (22%), and performing fetal MRI to look for central nervous system (CNS) anomalies (46%) (Figs. 1 and 2). The average number of correct answers of a total of the 17 questions was found to be greatest in the holders of Bachelor's degree ($p = 0.05$).

Correlation analysis between years of experience and the correct estimation of the effective dose equivalents of common radiology examinations and the knowledge of cancer risk from different radiology investigations was performed. No significant correlation was found between years of experience and either the correct estimation of the effective dose equivalents of common radiology examinations ($r = 0.02$, $p < 0.08$) or the knowledge about the level of cancer risk from different radiology investigations ($r = 0.06$, $p < 0.09$).

4 Discussion

Radiological examinations play a critical role in medical diagnostics, and the number of radiological investigations has dramatically increased over the past 2 decades. Reliance on radiological assessments is more common than ever before, and awareness regarding the damages and risks are well known and controversial. Disappointingly, the result of the present study revealed poor knowledge among the radiographers regarding the risks of radiation exposure to patients during diagnostic radiological procedures. Our results are consistent with the findings of Paolicchi *et al.* (2016), who reported a lack of radiation protection awareness among radiographers. Chest X-rays are among the most commonly performed radiological procedures; however, 87% ($n = 87$) of the respondents did not know the effective radiation dose from 1-view chest X-ray and

Table 1. Questionnaire on radiation doses and risk.

1. Sex	M	F			
2. What is your age range?	a. 25–30	b. 30–35	c. 35–40	d. 40–45	e. > 45
3. What are your qualifications?	a. Master's degree or higher	b. Bachelor's degree	c. Diploma		
4. How many years of professional experience do you have?	a. 1–5 years	b. 5–10 years	c. 10–15 years	d. 15–20 years	e. > 20 years
5. Average natural background radiation is in the range of	a. 20–30 mSv	b. 2–3 mSv	c. 0.2–0.3 mSv	d. 200–300 mSv	
6. The approximate effective dose received by a patient from a 1-view chest X-ray is	a. 0.5 mSv	b. 1 mSv	c. 0.02 mSv	d. 0.05 mSv	
7. The approximate effective dose received by a patient from a 2-view chest X-ray is	a. Almost equal to the amount 1-view chest X-ray	b. Twice the amount of 1-view chest X-ray	c. 5 times the amount of 1-view chest X-ray	d. 10 times the amount of 1-view chest X-ray	
8. The effective dose from 1-view abdominal X-ray is equivalent to	a. 0–1 chest X-rays	b. 1–10 chest X-rays	c. 10–50 chest X-rays	d. 50–100 chest X-rays	
9. Single-phase abdominal CT delivers a dose of	a. 10 mSv	b. 100 mSv	c. 1 mSv	d. None	
10. The dose from abdominal CT is equivalent to dosage from	a. 10–100 chest X-rays	b. 100–500 chest X-rays	c. > 1000 chest X-rays	d. 1 chest X-ray	
11. The dose from head CT is equivalent to dosage from	a. 10–50 chest X-rays	b. 50–100 chest X-rays	c. 100–500 chest X-rays	d. 10 chest X-rays	
12. The dose from 2-view unilateral mammogram is	a. Almost equal to the amount of 1-view chest X-ray	b. Twice the amount of 1-view chest X-ray	c. 10–20 times the amount of 1-view chest X-ray	d. 50–100 times the amount of 1-view chest X-ray	
13. Which of the following has no radiation risks?	a. Fluoroscopy	b. MRI	c. PET	d. Technetium bone scan	
14. Which of the following patient groups is most sensitive to radiation?	a. Children	b. Adolescent	c. Adults	d. Elderly	
15. The approximate estimated risk of fatal cancer from chest X-ray is	a. Minimal: 1 in 1,000,000 to 1 in 100,000	b. Very low: 1 in 100,000 to 1 in 10,000	c. Low: 1 in 10,000 to 1 in 1,000	d. Moderate: 1 in 1000 to 1 in 500	
16. The approximate estimated risk of fatal cancer from abdominal CT is	a. Minimal: 1 in 1,000,000 to 1 in 100,000	b. Very low: 1 in 100,000 to 1 in 10,000	c. Low: 1 in 10,000 to 1 in 1000	d. Moderate: 1 in 1000 to 1 in 500	
17. The approximate estimated risk of fatal cancer from coronary CT angiography is	a. Minimal: 1 in 1,000,000 to 1 in 100,000	b. Very low: 1 in 100,000 to 1 in 10,000	c. Low: 1 in 10,000 to 1 in 1000	d. Moderate: 1 in 1000 to 1 in 500	
18. The approximate estimated risk of fatal cancer from head CT is	a. Minimal: 1 in 1,000,000 to 1 in 100,000	b. Very low: 1 in 100,000 to 1 in 10,000	c. Low: 1 in 10,000 to 1 in 1000	d. Moderate: 1 in 1000 to 1 in 500	
19. The approximate estimated risk of fatal cancer from whole-body PET is	a. Minimal: 1 in 1,000,000 to 1 in 100,000	b. Very low: 1 in 100,000 to 1 in 10,000	c. Low: 1 in 10,000 to 1 in 1,000	d. Moderate: 1 in 1000 to 1 in 500	
20. The approximate estimated risk of fatal cancer from chest CT is	a. Minimal: 1 in 1,000,000 to 1 in 100,000	b. Very low: 1 in 100,000 to 1 in 10,000	c. Low: 1 in 10,000 to 1 in 1000	d. Moderate: 1 in 1000 to 1 in 500	
21. A pregnant woman underwent a contrast CT scan of her abdomen and pelvis, but the CT technologist did not inquire about her pregnancy status before performing the CT. According to ACR guidelines, what is the recommended course of action?	a. Reassure the mother that the risk to the fetus is negligible	b. Suggest medical termination of the pregnancy as an option	c. Perform genetic analysis by amniocentesis or chorionic villous biopsy	d. Perform fetal MRI to look for CNS anomalies	

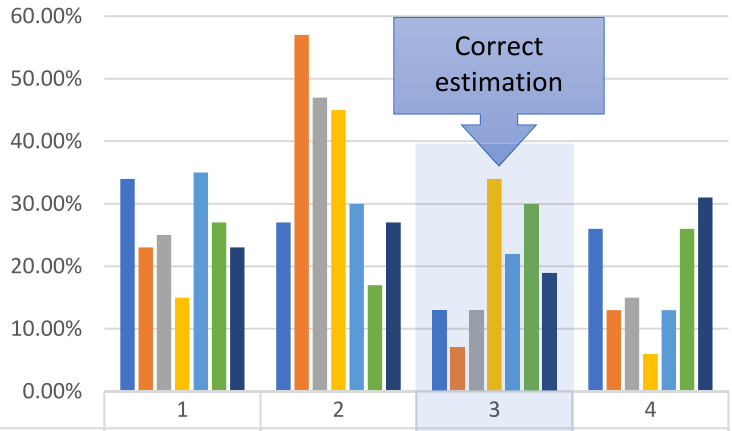
Table 2. Demographic characteristics of the participants.

Characteristic	*n* (%)
Age	
25–30 years	11 (11)
30–35 years	25 (25)
35–40 years	37 (37)
40–45 years	27 (27)
≥ 45 years	0 (0)
Sex	
M	67 (67)
F	33 (33)
Education level	
Diploma degree	43 (43)
Bachelor's degree	55 (55)
Master's degree or higher	2 (2)
Years of experience	
1–5 years	12 (12)
5–10 years	28 (28)
10–15 years	36 (36)
15–20 years	21 (21)
> 20 years	3 (3)

93% ($n = 93$) did not correctly identify the equivalent dose of 2-view chest X-ray. These findings are consistent with those from many previously published studies (Lee *et al.*, 2012; Ramanathan and Ryan, 2015). According to the current results, a serious knowledge deficit exists, as 80% of the respondents underestimated the effective dose from 2-view chest X-ray. Overall, 68 of the radiographers correctly identified that MRI has no ionizing radiation, and 78% correctly stated that children are more sensitive to radiation compared with other populations. In contrast to Ramanathan and Ryan (2015), who reported that 72% ($n = 72$) of the participants correctly identified radiation exposure from abdominal CT, only 22% ($n = 22$) correctly identified the dose in the current study. These findings correspond with previous studies among physicians and radiologists (Lee *et al.*, 2012; Azmoonfar *et al.*, 2016). Moreover, approximately 19% of the participants in the present study correctly identified the risks of fatal cancers from different radiological examinations. Our results are consistent with Marzouk Moussa and Kamoun (2016) who reported the lack of knowledge about the risks of ionising radiation. Generally, radiation exposure and its associated patient risks are underestimated, which is particularly concerning as it may reflect radiographers' unawareness regarding issues such as repeat radiological examinations. A consequence of this deficit in radiation dose knowledge will be increased radiation doses to patients due to the increasing number of radiological examinations. In agreement with Ramanathan and Ryan (2015), 17% ($n = 17$) of the participants would reassure an exposed pregnant woman that the radiation risk to the fetus is negligible. Forty-six of the participants would perform fetal MRI to look for CNS anomalies, 22% ($n = 22$) would recommend genetic testing, and 15% ($n = 15$) would suggest medical termination of the pregnancy. Radiographers' knowledge of radiation exposure during pregnancy is extremely important, as they are responsible for ensuring the absence of pregnancy in female patients before performing the exam. In some hospitals, appointments for certain radiological investigations are made far in advance (> 1 month), and patients might become pregnant in the interim; hence, it is the radiographers' responsibility to inquire whether the patient is pregnant, and they must know the right course of action in case a pregnant woman is accidentally exposed to radiation.

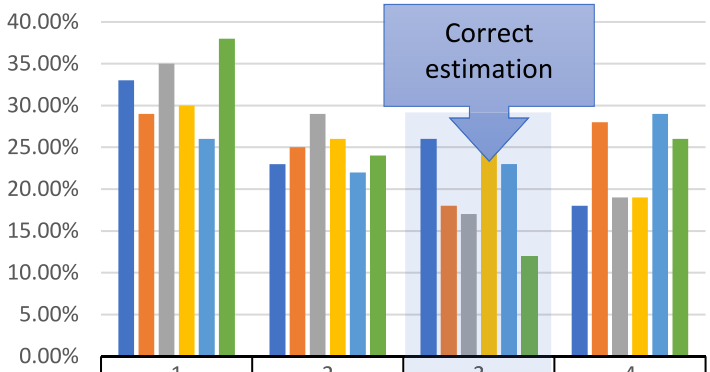
The results of the present study indicate that a large portion of the radiographers (43%) hold a diploma degree, often awarded after 2 years of study post-secondary school in Saudi Arabia. This period is certainly not long enough to become knowledgeable regarding all radiographic modalities in addition to radiation safety and protection and may be one reason we are seeing such results. Although more than half of the respondents (57%) had > 10 years of professional experience, this was not reflected in our results reporting a low level of awareness about radiation doses. The years of experience may only reflect the repetition of radiological examinations using the same concepts and repeating the same mistakes since image quality and radiographic positioning are the most important aspects in reporting.

Radiation protection is considered a professional principle of radiographers; therefore, lack of awareness of basic radiation protection reveals a defect in clinical practice. In addition to improved knowledge on radiation safety, an investigation into the reasons why radiographers are unaware of such a critical issue is needed. One of the possible reasons for the lack of knowledge might be because these courses are rarely offered in universities. Most universities in Saudi Arabia offer only 1 course in radiation protection (KS, 2018; PSBA University, 2018). National universities should improve their radiology curriculum and place more emphasis on radiation protection and dosimetry. Additionally, all radiographers in Saudi Arabia should be required to undergo continuous professional development in radiation protection and risks to renew their professional practice license, which is issued by the Saudi Commission for Health Specialties (Saudi Commission for Health Specialities, 2017). The lack of professional training has been reported to be associated with the decreased knowledge about radiation protection (Marzouk Moussa and Kamoun, 2016; Kouandongui Bangue Songrou *et al.*, 2019). It is well known that radiation dose delivery is the radiographers' responsibility; hence, they should be required to improve their knowledge on radiation dose levels. Education is the ultimate way to improve awareness of the potential risks of ionizing radiation. Although this study targets radiographers, *i.e.*, a homogeneous group, it has some limitations. First, compared with other studies, the sample size was not large (O'Sullivan *et al.*, 2010; Paolicchi *et al.*, 2016). Second, the participants' responses may be biased as they could use any source while answering the questionnaire; however, this would not be enough to alter the level of awareness among participants.In conclusion, the results of this study reveal the lack of awareness among radiographers regarding ionizing radiation doses from common radiological procedures. Educational courses on radiation protection should be required for all radiographers.



	1	2	3	4
Single-view CXR	34.00%	27.00%	13.00%	26.00%
Two-view CXR	23.00%	57.00%	**7.00%**	13.00%
Single-view AXR	25.00%	47.00%	**13.00%**	15.00%
CT abdomen single phase	15.00%	45.00%	**34.00%**	6.00%
CT abdomen	35.00%	30.00%	**22.00%**	13.00%
CT head	27.00%	17.00%	30.00%	26.00%
Two-view unilateral mammogram	23.00%	27.00%	19.00%	31.00%

Fig. 1. Percentage of participants' estimation of the effective dose equivalents of common radiology examinations (CXR: chest X-ray; AXR: abdominal X-ray).



	1	2	3	4
CXR	33.00%	23.00%	26.00%	18.00%
CT abdomen"	29.00%	25.00%	18.00%	28.00%
Coronary CT angiography	35.00%	29.00%	17.00%	19.00%
CT head	30.00%	26.00%	25.00%	19.00%
Whole-bodyPET	26.00%	22.00%	23.00%	29.00%
CT chest	38.00%	24.00%	12.00%	26.00%

Fig. 2. Percentage of participants' estimation of the level of cancer risk from different radiology investigations.

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