Saudi Pharmaceutical Journal 31 (2023) 101820

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Saudi Pharmaceutical Journal

journal homepage: www.sciencedirect.com

Original article

Assessment of radiographers' knowledge about radiation doses and DRLs in computed tomography departments in Jeddah, Saudi Arabia: A cross-sectional study

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ARTICLE INFO

Article history:
Received 13 August 2023
Accepted 8 October 2023
Available online 12 October 2023

Keywords:
Computed Tomography
Exposure factors
ALARA
Radiation dose
Image quality

ABSTRACT

Objective: To assess radiographers' understanding of radiation safety considering the newly approved national diagnostic reference levels (DRLs) as an optimization tool for radiation dose.
Methods: A cross-sectional study was conducted in Saudi Arabia among radiographers working at local hospitals in Jeddah city from February to March 2022. The survey comprised of 22 questions involving demographic information; and general information related to radiation dose; $CTDI_{vol}$ and DRLs. Data were analyzed using IBM SPSS Statistics version 26. Chi-square test was used to compare demographic groups regarding their distribution of responses with 0.05 as the level of significance.
Results: A total of 169 radiographers participated in the study (39 % females, 60 % males). Most of the participants (91 %) were aware of the description of the ALARA principle. It was noted that (47 %) of the participants indicated that the routine scanning protocols are designed by the radiologists. The majority of them (78 %) were confident to manipulate the CT scanning parameters properly. In addition, half of the participants (53 %) were aware of the $CTDI_{vol}$ and DLP. Unexpectedly, none of the demographic variables were significantly associated with the radiographers' knowledge about radiation dose, p-values are > 0.05.
Conclusion: Although radiographers demonstrated good knowledge of radiation protection, limited awareness of DRLs was noted among radiographers and lack of implementing and optimizing the local dose of the DRLs in this study. Therefore, education and training for healthcare professionals including radiographers are necessary to enhance clinical practical performance in radiology departments.

1. Introduction

The number of medical procedures that involve exposure to ionizing radiation has been increasing worldwide (Aldhafeeri, 2020; Al-Mallah et al., 2017). These procedures are performed routinely in daily medical practice owing to their usefulness in diagnosis and treatment planning. Among these procedures, computed tomography (CT) and radiography are the radiological imaging modalities of choice for a host of medical indications (Bukhary et al., 2021). Although the advantages of radiological imaging outweigh the hazards of radiation exposure, concern has been increasing over the potential detriment from the improper use of radiation doses, which increases patients' and healthcare professionals' risks of radiation exposure (Frane et al., 2023). The literature has shown massive differences in the radiation dose delivered across sites and countries, even for similar-sized patients. This may be attributed to the differences in the equipment and scan protocols used for

Abbreviations: ALARA, *As Low as Reasonably Achievable*; CT, Computed Tomography; $CTDI_{vol}$, CT Dose Index-Volume; DLP, Dose Length Product; DRL, Diagnostic Reference Levels; ICRP, The International Commission on Radiation Protection; kVp, Kilovoltage Peak; mAs, Milliampere-seconds; MRI, Magnetic Resonance Imaging; PET, Positron Emission Tomography.

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Peer review under responsibility of King Saud University.

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https://doi.org/10.1016/j.jsps.2023.101820
1319-0164/

modalities that use ionizing radiation (Smith-Bindman et al., 2019).

The variation in radiation dose might indicate a lack of knowledge or skills to manipulate imaging protocols; therefore, it is important for radiographers to have adequate knowledge about radiation dose optimization during examinations (Fiagbedzi et al., 2022). Radiation safety precautions are required, especially with the increasing use of CT technology in clinical diagnosis. To ensure that the advantages of CT imaging do not outweigh its radiation dose risks, the International Commission on Radiation Protection (ICRP 103) proposed recommendations for dose optimization, justification, and limitation principles (Bawazeer, 2022). Repeated radiation exposure increases the risk of cancer; therefore, protecting patients against unjustified radiation exposure has been suggested (Lukoff et al., 2017). According to the ICRP, as low as reasonably achievable (ALARA) describes the concept of dose reduction in radiation protection by minimizing radiation exposure without compromising the image quality (Nagayama et al., 2018; Najjar et al., 2022). Wide variations in patient dose levels were noted up to the factor of 100 for the same examination (Afifi et al., 2020; Jibiri et al., 2016), which could be driven by different factors such as the institutional decisions regarding the technical parameters that are used, patient characteristics, machine factors or, region of interest choices. Smith-Bindman et al., 2019, found that standardizing radiation dose is important and possible by providing training courses to the protocols' decision-makers, recalibrating the standards of image quality to better answer the clinical questions, and frequent sharing of the protocols across institutions.

The ICRP introduced diagnostic reference levels (DRLs) in 1996 and then expanded the concept of providing reference levels to radiation doses under defined guidelines (Vañó et al., 2017). As the use of DRLs is newly established in Saudi Arabia by the Saudi Food and Drug Authority to establish national diagnostic reference levels (NDRL) in 2021 (National Diagnostic Reference Levels (NDRL), 2021), it is assumed that radiographers might have acquired their knowledge about DRLs from their routine-based practices in radiology departments (Bawazeer, 2022). Therefore, the awareness of NDRL among radiology staff might be limited. Assessing the level of knowledge is an important aspect in recognizing and resolving deficiencies for an optimal reduction of radiation hazards to all persons involved in the radiological examination (Awad, 2021; Maharjan et al., 2020). Several studies assessed radiology staff's level of knowledge about radiation doses have reported a significant inadequacy in the knowledge of DRLs optimization, which could lead to unwarranted procedures (Abdulkadir et al., 2021; Alotaibi et al., 2017; Alshammari et al., 2019; Bawazeer, 2022; Zaid et al., 2019). Expert radiographers with high knowledge levels about radiation protection and DRLs are required, which would help in enhancing the clinical practice at radiology departments (Bárdyová et al., 2021; Saeed et al., 2018; Zekioğlu et al., 2021). Therefore, the aim of this study was to assess the current knowledge of radiation doses and DRLs among radiographers in the radiology department of Saudi hospitals.

2. Methods

2.1. Study design and settings

A cross-sectional survey was developed to assess radiographers' knowledge and understanding of radiation dose and DRLs optimization at CT departments in Jeddah, Saudi Arabia. A web-based questionnaire was designed and created using Google Forms and distributed electronically between February and March 2022 to participants working at local hospitals in Jeddah by using a non-probability convenient sampling technique (Bornstein et al., 2013). The questionnaire used in this study was adopted from previous studies (Almohiy et al., 2020; Bawazeer, 2022). The survey contained 22 multiple-choice questions in three sections. The first section included demographic information: gender, qualification level, years of clinical experience, and place of experience. The second section of the survey obtained general information on radiation doses, while the third section involved questions about the DRLs. To verify the clarity and applicability of the questions, the survey was first validated by three academic faculty members specialized in radiography with experiences ranging from 6 to 10 years. In accordance with the academic faculty members' comments generated from the pilot study, the survey questions were modified and adapted. The data generated by the pilot study were not involved in the main study dataset. The data was validated by the study researcher as she is a radiologic technologist consultant by documenting any data inconsistencies, and checking all datasets for duplicates and errors by using Excel software. Validity testing was followed by piloting the questionnaire using a web-based Microsoft Forms between January, to February 2022. The keywords "diagnostic reference levels (DRL)," "radiation protection," "computed tomography," "volume computed tomography dose index ($CTDI_{vol}$) measured in mGy," "patient's confidentiality," and "image interpretation" were used in the MeSH Advanced Search Builder of PubMed.

2.2. Data collection

A web-based questionnaire was sent to the head of the radiology departments and radiographers across eight hospitals. Before the start of the survey, the participants were required to read a brief introduction of the study, the goals of the study, who would be conducting the study, the consent form, and the agreement to complete the survey. Anonymity was assured to all participants. The inclusion criteria were radiographers working at local hospitals in Jeddah, Saudi Arabia.

2.3. Statistical analysis

Data were analyzed using the SPSS statistical package (IBM SPSS Statistics version 26, PASW, Chicago, IL). The radiographers' overall understanding of radiation doses was evaluated on the basis of their scores in the questionnaire. Each participant's score was calculated separately for the first section, which was on the general information about radiation doses, and the second section, which was about $CTDI_{vol}$ and dose length product (DLP) measured in mGy*cm, to compare the demographic groups in terms of the two scores. Knowledge level was measured through 5 and 4 questions under the two sections, respectively. The score was calculated as the number of correct answers. Therefore, it ranged from 0 to 5 for the first section. Any participant with a score of ≥ 4 was considered to have good knowledge. For the second section, the score ranged from 0 to 4, and any participant with a score of ≥ 3 was considered to have good knowledge. Frequency distribution was the main descriptive statistics used in the analysis. A chi-square test was used to assess the level of associations of the demographic groups in terms of the distributions of their responses to the questions, with 0.05 as the level of significance.

2.4. Ethical approval

Ethical approval was received from the Bioethics Committee for Scientific and Medical Research of the University of Jeddah under registration No. HAP-02-J-094, with application No. UJ-REC-046. It includes an understanding of the research by presenting the aims of the research and a multidisciplinary review of its ethical acceptability to ensure the dignity, rights, safety, and well-being of the research participants.

3. Results

A total of 169 radiographers completed the questionnaire (60 % male and 39 % female), of whom 10 % had more than 20 years of clinical experience and 75 % had less than 5 years of experience. The participants' demographic characteristics such as their departments, qualifications, and trainings and who designed the scanning protocols are shown in Table 1.

With regard to the general information about radiation doses, the results show that most participants were confident in manipulating the CT scanning parameters properly (78 %) while considering the image quality and radiation dose. In addition, most participants believed that choosing the appropriate scanning protocol might affect CT dose optimization (88 %).

The general knowledge of the participants regarding radiation doses was assessed through 5 questions (Table 2). The results show that most participants understood the ALARA principle (91 %). Of the participants, 73 % manipulated the CT scanning parameters according to age, anatomical area, and clinical indication, and 57 % understood the dose optimization concept for CT scans. In addition, less than half (42 %) of the participants reported that radiological examinations can be performed in female patients of childbearing age. Only 37 % of the participants selected all the correct modalities that use radiation doses, namely positron emission tomography (PET), fluoroscopy, and technetium bone scan.

In terms of the radiographers' knowledge of $CTDI_{vol}$ and DRLs, the results show that more than half (53 %) of the participants were familiar with the terminologies of $CTDI_{vol}$ and DLP that were introduced by the ICRP. Most participants (80 %) believed that the $CTDI_{vol}$ and DLP applications are useful for evaluating scanners' radiation dose exposures. In addition, most participants (61 %) reported that the monitoring practice for $CTDI_{vol}$ and DLP values had been implemented in their workplaces. In addition, the participants' knowledge of $CTDI_{vol}$ and DRLs was assessed through 4 questions (Table 3). Most participants (62 %) demonstrated awareness of the functions of DRLs, which are organ dose evaluation, justification of medical exposure, and optimization of radiation protection. However, most study participants (82 %) were not aware of the concepts of DRL, $CTDI_{vol}$, and DLP.

None of the participant characteristic variables (e.g., experience, education, and gender) was significantly associated with the general knowledge about radiation dose, as all the chi-square p values were > 0.05 (Table 4).

Table 5 shows that most characteristic variables are non-significantly associated with knowledge about $CTDI_{vol}$ and DRLs ($p > 0.05$). However, a significant association was found between the participants working in Magnetic Resonance Imaging (MRI) departments and knowledge about $CTDI_{vol}$ and DRLs. A relatively less chance of having knowledge about $CTDI_{vol}$ and DRLs ($p < 0.05$) was found among MRI radiographers, as only 6 % of them had good knowledge compared with 23 % of non-MRI radiographers. In addition, a significant association was found between those who had previously participated in surveys about CT radiation doses and knowledge about $CTDI_{vol}$ and DRLs. A relatively less chance of having good knowledge about $CTDI_{vol}$ and DRLs ($p < 0.05$) was found among the participants who previously participated in surveys about CT radiation doses, as only 8 % of them had good knowledge compared with 26 % of those who previously did not participate in such surveys.

Table 1
Demographic characteristics of radiographers:

Variable	Categories	Freq.	% (N = 169)
Experience	< 5 years	127	75.1
	6–10 years	14	8.3
	11–20 years	12	7.1
	> 20 years	16	9.5
Education*	Diploma	4	2.4
	Bachelor	103	61.3
	Radiography intern student	48	28.6
	Master	7	4.2
	PhD	6	3.6
Gender	Male	103	60.9
	Female	66	39.1
Departments**	CT	62	36.7
	X-ray	75	44.4
	Ultrasound	35	20.7
	MRI	50	29.6
	Other	46	27.2
Participated in survey (about CT radiation dose)	Yes	75	44.4
	No	94	55.6
Had training course about ionizing radiation	Yes	118	69.8
	No	51	30.2
Person who decides the routine scan protocols in the department*	Radiologist	79	47.0
	Radiography technologists	43	25.6
	Physicists	30	17.9
	Application specialists	15	8.9
	Other	1	0.6
Thinking that education of optimization of CT scan protocols would be beneficial for radiography technologists	Yes	158	93.5
	No	11	6.5

* 1 participant did not provide information.
** Percentages add up to more than 100% because one participant may be applicable in more than one category.

4. Discussion

The current study has assessed the radiographers' awareness and level of knowledge about radiation doses and DRL working at Computed Tomography Departments in Jeddah, Saudi Arabia. The participants in this study were radiographers with diverse educational qualifications and years of experience. The study demonstrated that the radiographers exhibited an understanding of radiation dose optimisation, as most of them (78 %) appeared to be confident in manipulating CT parameters properly, considering image quality and radiation dose, 73 % believed that patient's characteristics is one of the factors to decide the proper CT protocol, and 91 % have a clear understanding of ALARA principle (Table 2). This may be due to the involvement of younger radiographers (75 %), who had less than 5 years of experience, and the fact that more than half of the study participants (61 %) had bachelor's degrees in radiography. However, 74 % of the participants were unaware of the concept of the DRL, and 71 % of them were unknowledgeable about the concept of DLP (Table 3). Radiological procedures involving ionizing radiation are commonly used as diagnostic imaging tools that require the awareness of radiology staff about patient safety (Bastiani et al., 2021). The use of DRLs in radiology departments have been demonstrated to be useful in monitoring suboptimal practices and enhancing staff knowledge of the optimal use of radiation doses (Tonkopi et al., 2017).

The findings of this study show that the radiographers lacked understanding of radiation doses, and $CTDI_{vol}$ and DRL. Radiographers are at the forefront of examinations using radiation-based imaging modalities, and their proficiency in scanning reflects their

Table 2
General knowledge questions about radiation dose optimization:

Questions	Answers (%)
Are you confident to manipulate the CT parameters properly, considering image quality and radiation dose?	
Yes	78.11
No	21.89
Do you think that choosing a proper scanning protocol might impact on CT dose optimization?	
Yes	11.83
No	88.17
Do you think that radiological examination can be performed in female patients in childbearing age?	
Yes, in urgent cases	24.3
Yes, by doctor consultation	22.5
Yes, if the patient is required	11.2
Yes, only during the 10 days following the onset of menstruation.	42
Which of the following situation you might decide to manipulate CT scanning parameters?	
Age.	21.4
Anatomical area.	7.7
Clinical indication.	6.5
All of the above.	73.4
Which of the following best describes the concept of ALARA principle?	
As low as reasonably achievable.	91.1
As large as reasonably achievable.	3.6
As huge as reasonably achievable.	3
As great as reasonably achievable.	2.4
Which of the following uses radiation dose?*	
PET	8.9
MRI	3.6
Fluoroscopy	43.2
Technetium bone scan	6.5
MRI, and Fluoroscopy	0.5
PET, and Fluoroscopy	5.3
PET, Fluoroscopy, and Technetium bone scan	29.6
PET, MRI, Fluoroscopy, and Technetium bone scan	0.6
PET, and Technetium bone scan	1.8
Which of the following best describes the concept of dose optimization?	
Practicing optimization to obtain proper contrast to be able to identify the smallest details as possible.	2.4
To provide the maximum diagnostic information with the least radiation dose as possible.	21.3
To obtain as low as reasonably achievable to meet clinical objectives.	19.5
All of the above	56.8

*The question provides respondents with multiple answer options.

Table 3
Information about DRLs questions that used in the knowledge score:

Questions	Answers (%)
Are you familiar with $CTDI_{vol}$ and DLP those are introduced by the International Commission on Radiological Protection?	
Yes	53.25
No	46.75
Do you think that the $CTDI_{vol}$ and DRLs applications are useful to compare scanners' radiation dose?	
Yes	79.88
No	20.12
Is there a department that monitors the values of $CTDI_{vol}$ and DLP in your workplace?	
Yes	62.13
No	37.87
Which of the following best describes the concept of the DRL?	
It is a measure of CT tube radiation output/exposure.	45.6
It is a relative measure of the risk of stochastic effects.	17.2
It is a maximum high voltage applied across an x-ray tube.	11.2
It is an indicative dose that is not expected to be exceeded under normal imaging conditions.	26
Which of the following best describes the function of DRLs?	
Optimization of radiation protection.	10.7
Justification of medical exposure.	11.2
Organ dose evaluation.	16
All of the above	62.1
Which of the following best describes the concept of the $CTDI_{vol}$?	
It is a dimensionally-equivalent to one joule per kilogram	20.1
It is the length of radiation output along the long axis of the patient.	23.7
It is the radiation dose for a single volume of anatomy imaged per slice.	33.7
It allows the different relative biological effects of different types of ionizing radiation.	22.5
Which of the following best describes the concept of dose length product (DLP)?	
It is the CTDI volume divided by the pitch	32.5
It is the CTDI volume multiplied by the pitch	16
It is the CTDI volume divided by the length of the scan	22.5
It is the CTDI volume multiplied by the length of the scan	29

understanding of radiation exposure. Furthermore, reporting on this lack of knowledge can lead to the provision of suitable training courses for standardized measurements of radiation dose outputs (Maharjan et al., 2020; Partap et al., 2019). Therefore, more efforts are required to enhance radiographers' knowledge and understanding of the beneficial use of DRLs (Abdulkadir et al., 2021; Bornstein et al., 2013).

Approximately half of the radiographers included in this study reported that scanning protocols were designed by radiologists. Subsequently, they determined the radiation doses resulting from the radiological examinations. A study was conducted by Saeed et al., 2018 aimed to estimate the physicians' understanding and awareness of the radiological examinations' risks to both their health and that of their patients. It was found that there is poor knowledge about the radiation protection and the hazards of radiological examinations among physicians on the healthy patients and staff in Saudi Arabia. In addition, a study was conducted in Saudi Arabia found that a high percentage of orthopedic surgeons had rarely or never attended such training courses, which makes it a compelling reason for the inadequate knowledge of radiation safety (Bukhary et al., 2021). However, Borgen et al., 2014 reported that radiologists and radiographers have better understanding than the referral physicians regarding radiation protection and safety. Therefore, following radiologists' instructions to select the appropriate scanning protocols in advance requires radiographers to have the appropriate knowledge of radiation protection issues and to be aware of the unnecessary radiation doses delivered to the patient during an imaging examination (Chilanga et al., 2020).

The results showed that none of the characteristic variables, including years of experience and educational qualification, were significantly associated with the general knowledge about radiation doses of radiographers ($p > 0.05$). Most study participants believed that educating radiographers on how to optimize scanning protocols would be beneficial. Although more than half of the radiographers had attended specific training courses related to ionizing radiation safety and protection, the results still demonstrate an insufficient understanding about radiation protection issues among them. Therefore, working as a team of radiographers, medical physicists, and radiologists is important to provide vital reviews in designing scanning protocols that would yield better-quality diagnostic images using the available imaging modalities that are safe to use clinically and fit the clinical needs of the radiology department (Mahesh, 2018). Cody et al., 2021 reported that such decisions are made by a combination of radiologists, radiographers, and medical physicists. Therefore, for patient safety and enhancing the quality of imaging procedures, requiring representa-

Table 4
Association between the knowledge of general radiation dose and the characteristic variable:

Characteristic Variable	Categories	N of the Category	% with Good Knowledge	Chi-square P-value
Experience	< 5 years	127	40.2 %	0.178
	6–10 years	14	50.0 %	
	11–20 years	12	16.7 %	
	> 20 years	16	25.0 %	
Education	Bachelor	103	40.8 %	0.279
	Radiography intern student	48	31.3 %	
	Higher education	13	53.8 %	
Gender	Male	103	34.0 %	0.199
	Female	66	43.9 %	
Working in CT	No	107	33.6 %	0.143
	Yes	62	45.2 %	
Working in X-ray	No	94	35.1 %	0.429
	Yes	75	41.3 %	
Working in ultrasound	No	134	37.3 %	0.845
	Yes	35	40.0 %	
Working in MRI	No	119	34.5 %	0.169
	Yes	50	46.0 %	
Working in other departments	No	123	36.6 %	0.596
	Yes	46	41.3 %	
Participated in survey (about CT radiation dose)	Yes	75	33.3 %	0.339
	No	94	41.5 %	
Had training course about ionizing radiation	Yes	118	40.7 %	0.301
	No	51	31.4 %	
Person who decides the routine scan protocols in the department	Radiologist	79	36.7 %	0.837
	Radiography technologists	43	39.5 %	
	Physicists	30	33.3 %	
	Application specialists	15	46.7 %	
Thinking that education of optimization of CT scan protocols would be beneficial for radiography technologists	Yes	158	39.2 %	0.210
	No	11	18.2 %	

Table 5
Association between the knowledge of DRLs and the characteristic variable:

Characteristic Variable	Categories	N of the Category	% with Good Knowledge	Chi-square P-value
Experience	< 5 years	127	17.3 %	0.385
	6–10 years	14	7.1 %	
	11–20 years	12	33.3 %	
	> 20 years	16	18.8 %	
Education	Bachelor	103	14.6 %	0.242
	Radiography intern student	48	22.9 %	
	Higher education	13	30.8 %	
Gender	Male	103	16.5 %	0.681
	Female	66	19.7 %	
Working in CT	No	107	19.6 %	0.532
	Yes	62	14.5 %	
Working in X-ray	No	94	20.2 %	0.420
	Yes	75	14.7 %	
Working in ultrasound	No	134	18.7 %	0.628
	Yes	35	14.3 %	
Working in MRI	No	119	22.7 %	**0.008**
	Yes	50	6.0 %	
Working in other departments	No	123	15.4 %	0.257
	Yes	46	23.9 %	
Participated in survey (about CT radiation dose)	Yes	75	8.0 %	**0.004**
	No	94	25.5 %	
Had training course about ionizing radiation	Yes	118	18.6 %	0.827
	No	51	15.7 %	
Person who decides the routine scan protocols in the department	Radiologist	79	17.7 %	0.954
	Radiography technologists	43	18.6 %	
	Physicists	30	20.0 %	
	Application specialists	15	13.3 %	
Thinking that education of optimization of CT scan protocols would be beneficial for radiography technologists	Yes	158	19.0 %	0.216
	No	11	0.0 %	

tives from each of the three professions (radiologists, medical physicists, and radiological technologists) to participate in radiation safety training courses would be beneficial.

The study results showed that there is no statistically significant difference between the knowledge of DRLs and the radiographers working with ionizing radiation modalities. However, approximately 5 % of the participants claimed that ionizing radiation is used in MRI, which is actually a non-ionizing imaging modality. They are unaware of the type of radiation from at least one of the three modalities, namely PET, fluoroscopy, and technetium bone scan. This result is consistent with those of previous studies that reported that study participants attributed radiation exposure to ultrasonography and MRI (Alelyani et al., 2021). Another recent survey found that the majority (85 %) of healthcare professional participants in Saudi Arabia provided incorrect answers when asked whether brain MRI examinations used more ionizing radiation than thorax X-rays (Alghamdi et al., 2020). However, in this study most participants (91 %) have a clear understanding of the ALARA principle, which could be due to the regular use of lead aprons and the awareness of the continuous monitoring practice using dosimeters imposed by the Nuclear and Radiological Regulatory Commission. In the current study, 73 % of the participants had sufficient knowledge about the situations that require decisions to manipulate CT scanning parameters, which was comparable to the results of Kazemi et al., 2023 who evaluated the CT technologists' (59.4) knowledge concerning CT parameters to optimize image quality and patient dose in Iran. However, as mentioned earlier, half of the radiographers claimed that scanning protocols were designed by radiologists without their involvement. Altering scanning parameters depending on the situation such as the clinical indication has been shown to be associated with a considerable dose reduction, particularly for high-contrast scans, which do not require high image quality, such as those used in renal stone examinations (Joyce et al., 2020).

Therefore, applying an appropriate scanning parameter with the least radiation dose possible while maintaining the image quality depends on the patient's case. According to Alchallah et al., 2020, in their study conducted in Syria, 39 % of undergraduate medical students correctly identified CT scans as the procedure that confers the greatest radiation exposure and its effect to fetuses owing to its high radiation dose. In this study, less than half (42 %) of the participants believed that radiological examinations can be performed for female patients of childbearing age only during the 10 days following the onset of menstruation, which demonstrates their awareness of the hazards of radiation exposure to pregnant women. This result nearly agrees with a previous study conducted in Egypt that aimed to assess the awareness and practices in ionizing radiation protection procedures and reported low awareness concerning the 10-day rule (33 %). In addition, a pregnancy blood test to exclude pregnancy is a mandatory test performed before any procedure in nuclear medicine and radiotherapy departments (Ng et al., 2020). Therefore, the study results demonstrated a good knowledge of radiation protection and dose optimisation. These results are comparable with some studies have indicated that healthcare professionals in radiology departments have a good understanding of general radiation protection (Almohiy et al., 2020; Rawashdeh et al., 2018).

This study also assessed the awareness level of DRL and $CTDI_{vol}$, which showed that the radiographers' long years of experience, high educational level, and attendance in training courses on ionizing radiation were found to have no impact on their knowledge and awareness of DRLs. Thus, the need for additional training to improve radiographers' knowledge is obvious. The findings showed that only 18 % of the radiographers correctly answered all questions. This result is consistent with that of a study conducted in Italy that revealed no association between radiographers' years of experience and knowledge (Paolicchi et al., 2016). Conversely, Chilanga et al., 2020 reported that years of experience can be positively related to radiologists' and clinical specialist radiographers' knowledge of CT exposure parameters. This discrepancy could be largely caused by the fact that educational programs vary between countries and by the small sample size of this study. It is interesting that more than half of the study participants were aware that $CTDI_{vol}$ and DLP introduced by the ICRP and that most of them (53.2 %) agreed that these parameters are useful tools for comparing scanner radiation doses. In addition, most radiographers (62.13 %) reported their departments record the $CTDI_{vol}$ and DLP in applied radiation dose monitoring practices. It is well documented that monitoring patients' radiation doses and comparing them with the national standards is often advised but not required (Rehani, 2017). In addition, it is anticipated that incorporating healthcare professionals in radiology departments in dose management will help to promote radiation safety by raising staff awareness (Inoue, 2023). Therefore, obligatory reporting of radiation doses in the diagnostic report could encourage the use of the DRL optimization tool.

Previous studies have shown variations in radiographers' understanding of radiation safety and dose optimization (Abdulkadir et al., 2021; Lewis et al., 2022). The results of this study showed that most participants identified the best description of the function of DRLs, demonstrating their awareness that the national DRLs had been implemented recently in data collections to effectively reduce the radiation dose to patients (Bawazeer, 2022). However, although most of the participants showed high knowledge of radiation protection, a high percentage of the participants failed to provide the best description of the concept of DRL. The obvious limited awareness might be related to the lack of knowledge of the recently published national DRLs and the apparent lack of participation in radiation dose awareness surveys, as previously reported by Mahmoudi et al., 2019. A study conducted among CT radiographers in Saudi Arabia by Bawazeer, 2022 revealed that most of their participants were unable to correctly identify DRLs' concept and function. This outcome was anticipated, and it may be explained by the fact that the DRL concept is relatively new in Saudi Arabia. Therefore, it might be possible to improve the radiographer education plans by recognizing gaps in the participants' knowledge of DRLs (Bawazeer, 2022).

The dosimetric quantities used to establish DRLs are $CTDI_{vol}$ and DLP (AlNaemi et al., 2020). Several national studies have proven that an occasional review of DRLs enables effective reductions in dose levels (Aberle et al., 2020; Faggioni et al., 2017). The results in this study demonstrate a weak understanding of the concepts of $CTDI_{vol}$ and DRLs among radiographers. However, the finding does not represent the entire population of all radiographers in Saudi Arabia due to its particular local design. A significant association was found between MRI radiographers and the knowledge of $CTDI_{vol}$ and DRLs, as they presented relatively less awareness of these dosimetric quantities than radiographers working at different radiology departments, although both groups of radiographers had generally weak knowledge similar to that reported in previous studies (Kada, 2017). This significance indicated that the awareness of $CTDI_{vol}$ and DRLs is not limited to radiographers working with ionizing radiation, as all radiographers work in radiology departments and might be rotated to work on ionizing radiation modalities in the future. This might also highlight that radiographers rely on the automatic collection of dose surveys implemented for imaging modalities by some manufacturers. However, this finding emphasizes the critical necessity of prioritizing training radiographers as healthcare professionals in charge of patient safety from radiation overdose. The radiation of CT examinations must be kept according to ALARA principle to achieve the lowest doses possible. This can be achieved by justifying the scanning protocols, recording DRL values, scanning only the region of interest, and applying the lowest radiation dose possible without reducing image quality (Abuzaid et al., 2022).

The study has several limitations, including its small sample size. Therefore, further research based on a national level is needed with a larger sample to represent the understanding of both radiographers and radiologists. In addition, using a larger sample can validate the results of the comparison that revealed a knowledge discrepancy based on different variables and categories (Table 2). The participants were urged to avoid a deliberate search from information sources such as books and the Internet while answering the survey questions. However, because the survey was online, this could not be ensured. Furthermore, the perspectives regarding other radiation protective measures such as the use of a lead apron have not been surveyed. Finally, this study involved randomly selected radiographers from different specialties. In the future, with larger samples, studies focusing on professionals working on ionizing radiation modalities might report superior knowledge scores.

5. Conclusion

The assessment of radiation doses and comparison of local practices with DRLs have become critical, especially in the light of reported overexposures to radiation, as they can effectively assist in reducing patient radiation doses. This study provides good knowledge on the general information about radiation doses, while there exhibited a lack of awareness and knowledge of DRLs. There was no significant relationship between the radiographers' years of clinical experience and knowledge of radiation protection. Radiographers must have knowledge and understanding of the relationship between scanning parameters and their practical applications to continually optimize radiation doses. Therefore, healthcare professionals, particularly those who work with ionizing radiation modalities, must be encouraged to attend educational and training courses to enhance the practical performance of radiology departments. In addition, further research is needed from a higher-level administrative perspective to provide a deeper understanding of the newly established guidelines on DRLs in Saudi Arabia in the future.

Funding

None.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The author would like to thank SCRIBENDI for editing and proofreading the manuscript. The author also extends her appreciation to Shahad Nawawi, Fatemah Alamri, and Samaher Alyanbaawi for their support in conducting this study.

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