Published online: 2021-07-19

A study to assess the knowledge and practice of medical professionals on radiation protection in interventional radiology

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Abstract

Objective: Ionizing radiation has been extensively used in medical procedures throughout the world. Such interventional radiological procedures could result in occupational exposure that needs urgent control. Therefore, MPs (medical professionals) should receive education and appropriate training on occupational radiation protection. In this context, the present study is aimed to investigate the MPs' knowledge and practice regarding radiation protection principles during interventional radiological procedures. **Material and Methods:** A descriptive questionnaire-based study was carried out among 215 MPs involved in interventional fluoroscopy procedures. The practice of 31 MPs was studied using a checklist based on ALARA principles and ICRP guidelines. **Results:** A total of 43.3% and 45.1% answered correctly for knowledge and practice. However, the difference between radiation protection knowledge and practice between the physicians and nurses was statistically significant. The knowledge and practice survey of MPs demonstrated that nurses rarely adhered to radiation-protection measures. **Conclusion:** The present study reflects the lack of knowledge and practice concerning radiation protection concepts among the nurses. This deficiency needs to be resolved by periodic practical radiation protection courses in the curriculum of medicine.

Key words: Education; knowledge; medical professionals; practice, radiation protection

Introduction

The use of interventional X-ray procedures has been continuously increasing since 1950; the investigators reported a dramatic increase in the number and frequency of medical-related exposures.[1] Medical professionals (MPs) are exposed to both primary and scattered radiation during

Access this article online	
Quick Response Code:	Website: www.ijri.org
	DOI: 10.4103/ijri.IJRI_333_19

Cite this article as: Shafiee M, Rashidfar R, Abdolmohammadi J, Borzoueisileh S, Salehi Z, Dashtian K. A study to assess the knowledge and practice of medical professionals on radiation protection in interventional radiology. Indian J Radiol Imaging 2020;30:64-9.

Received: 06-Aug-2019 **Revised:** 31-Aug-2019
Accepted: 28-Jan-2020 **Published:** 30-Mar-2020

various radiological procedures.[1] Particularly, there is a concern regarding the occupational exposure of MPs involved in the interventional radiological procedures, especially when the presence of MPs is mandatory in the radiation area during radiation exposure. Although interventional radiology is associated with low-dose radiation,[2] however, the potential damages of radiation during fluoroscopically guided and CT-guided procedures in the interventional laboratory are significant on the MPs,[3] and, particularly, the nurses.[4]

Numerous interventional medical imaging procedures can potentially expose the workers to the low-energy radiation which may cause biological stochastic effects on the MPs.[5,6] Stochastic effects refer to the mutations which can potentially lead to cancers or genetic disorders. The primary basis for estimating the cancer risks due to the ionizing radiation exposures are the epidemiological studies on the Japanese atomic bomb survivors who were primarily exposed to high dose rates. The risks of radiation associated with low-dose exposures of MPs through radiological procedures should be also evaluated. Some studies report an excess risk of cancer among MPs due to low-dose exposures.[7,8]

Some studies have addressed the occupational exposure-induced cancer rate and mortality among radiation workers.[9] The National Council on Radiation Protection and Measurement (NCRP) reported a decrease of occupational exposure in an effective dose per individual in the United States, while the number and frequency of medical exposures were increased.[10] Most of the obtained occupational effective dose values are well below the International Commission on Radiological Protection (ICRP) dose limits; however, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reported that only a few countries have provided the data on interventional occupational exposures. Moreover, several studies have observed the annual effective dose and the percentage of measurable exposures on radiation workers.[11] According to the UNSCEAR report, during the interventional procedures, the average annual effective doses are 1.6 mSv and 3.1 mSv for MPs and radiation workers, respectively.[11]This report demonstrates the necessity to consider the safety of MPs involved in the interventional radiological procedures.

In ICRP Report No 118, the equivalent dose limit for the eye lens for occupational exposure of radiation workers was reduced from 150 mSv year^{-1} to 20 mSv year^{-1}.[12] Some of the earlier retrospective cohort studies reported the excess risk of cataract among the radiologic technologists assisting in interventional radiological procedures.[13,14]

It is recommended that healthcare workers can reduce the risks of radiation using various standard principles such as ALARA, which consist of three important parts: time, distance, and shielding. According to the ICRP recommendation, occupational radiation protection can be achieved by applying three main principles: justification, optimization, and dose limitation.[15] MPs are continuously exposed to the ionizing radiation; therefore, they must receive proper education and training to minimize their occupational dose.This study is aimed to survey the knowledge, practice, and the factors affecting the practices of MPs concerning the radiation protection regulations during the interventional fluoroscopy procedures.

Material and Methods

The main purpose of this descriptive questionnaire-based study was to evaluate the knowledge and practice of MPs. The knowledge of 215 medical professionals (MPs) participating in the C-Arm (Technix, TCA 6) fluoroscopically-guided procedures including 174 nurses, and 41 physicians (urologist, orthopedics, surgery, neurologists, and radiologist) was evaluated by a questionnaire [Tables 1 and 2]. The questionnaire encompassed two major parts including various questions on radiation protection principles. The first part was related to demographic information such as the participant's age, sex, and work experience [Table 1]. The second section consisted of 17 questions [Table 2] testing their knowledge on radiation protection principles. Furthermore, the practice of 31 MPs (24 nurses and 7 physicians) involved in the interventional fluoroscopy procedures was studied by a checklist of questions [Table 3]. The checklist included ten questions on radiation protection practice provided based on the ICRP guidelines and the ALARA principles.

Statistical analysis

The validity of the questionnaire was assessed by three radiologists and medical physicists, and its reliability was determined by the test-retest (Cronbach's alpha = 0.88). After collecting the data, statistical analyses were carried out using SPSS 16 software through the parametric (Student's *t*-test) and nonparametric (Mann–Whitney U and Kruskal–Wallis) tests. All the values are rounded by two decimal places. Each participant signed a consent form, and the study was reviewed and approved by the ethical committee of Yasuj University of Medical Sciences.

Results

The correct answer rates (CAR) of the knowledge and practice parts of MPs were separately determined for each question [Tables 2 and 3]. Our findings indicated that CAR of the practice and knowledge of the nurses was significantly lower than those of the physicians ($P = 0/007$, $P = 0/001$, respectively). The CAR of the knowledge in terms of the operator distance and time was 50.6% and 52%, respectively. Concerning the place of the personal

Table 1: Demographic characteristics of participants in current study

Characteristic	*n* (*P*)*
Years of professional experience	
1-4 years	32 (15%)
5-9 years	84 (39%)
10-14 years	56 (26%)
15-19 years	26 (12%)
More than 20 years	17 (8%)
Level of education	
Undergraduate	143 (67%)
Postgraduate	31 (14%)
Doctorate degree	41 (19%)
Gender	
Male	79 (27.5%)
Female	136 (63.5%)
Age	
19-25 years	41 (19%)
26-35 years	82 (38%)
36-45 years	74 (34%)
45 and more	18 (9%)
Profession	
Specialists	41 (19.06%)
Nurses	174 (80.93%)
Radiophobia	
Specialists	0 (0%)
Nurses	17 (9.7%)
Training courses of radiation safety	
Specialists	27 (65.85%)
Nurses	40 (22.98%)

**n* (*P*): *n*: Number of participants, P: Percentage of participants

dosimeter, the CAR of knowledge was 87.4%. Surprisingly, while MPs were familiar with the right place of the personal dosimeter, 12.9% of them chose to not use it, 16% wore it inappropiratly, and 9.6% of them forgot to wear their dosimeters during the interventional fluoroscopy procedures [Figure 1].

Considering shielding (personal protective devices and equipment-mounted shields), the CAR of knowledge about shielding (personal protective devices and equipment mounted shields) was 40.4%. Concerning the personal protective devices, the lowest and highest CAR of the knowledge was observed for eyewear and gloves (23.7% and 58%), respectively.

66.1% of the MPs did not wear personal protective devices led by eyewear, 77.4%, thyroid shields, 64.5%, and aprons, 58%. Moreover, 74.1% of the MPs did not know how to appropriately use the mounted shielding equipment during the interventional fluoroscopy procedures. Furthermore, a significant disparity was observed between physicians and nurses concerning the use of the shielding ($P < 0.001$).

The results showed that only 25.5% of the physicians and nurses were familiar with the staff positioning to alleviate their occupational exposure to the radiation scattered from

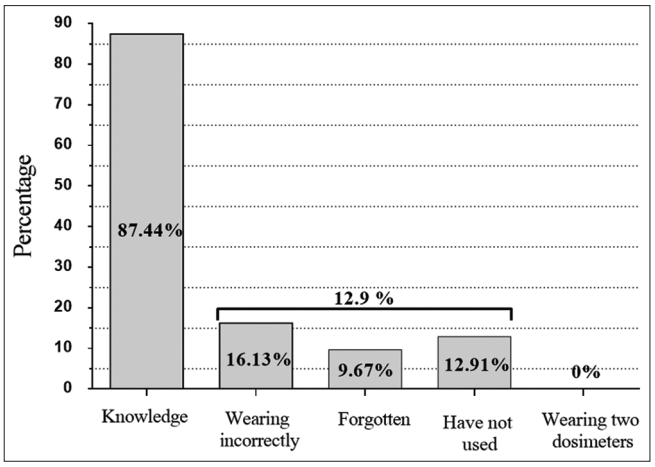

Figure 1: The knowledge and practice of MPs of personal dosimeter usage

the patient. Less than one-third of the participants knew about the leakage radiation from the tube X-ray (25.5%) and 17.2% of them were aware of the radiation scattered from the patient's body. The lack of knowledge on the radiological questions about the stochastic and nonstochastic effects was clear (28.3%). The results also indicated that the participants with a low level of work experience (1–4 years) had less knowledge about the radiation-induced stochastic and non-stochastic effects as compared with the more experienced participants (>20 years) ($P = 0.043$).

The majority (88.3%) of MPs were aware that fetuses or pregnant mothers are more sensitive to radiation compared to the other patients. Nearly 16% of the MPs were familiar with the organ radiosensitivity during interventional radiology. Furthermore, only 19 respondents knew about the occupational dose limits for MPs according to ICRP recommendations.

According to the first part of the questionnaire, 134 nurses (77%) did not pass a radiation protection course during their undergraduate and postgraduate studies or at their workplace. In the case of the physicians, the condition was better although 34% did not receive such education during their studies. Moreover, none of the MPs had any practical training in their workplace or during their education on radiation safety. Our findings showed that the highest rate of proficiency about radiation protection was found among the MPs that received a radiation protection course in the workplace or their educational curriculum ($P = 0.041$). Among the physicians, the radiologists and surgical specialists had the highest and lowest correct answers rates, respectively ($P = 0.03$).

According to the first part of the questionnaire, one of our most considerable findings was that 17 nurses had radiophobia and four female nurses withdrew to participate in fluoroscopically-guided procedures.

Table 2: The questionnaire applied to assess the knowledge of 215 medical professionals, CAR%(N): CAR%: Correct Answers rate, N: Number of Correct Answers, The percent and number of physicians and nurses who answered the questions correctly are shown in the third column seperately

Subject	Questions	CAR%(N)	P: Physicians Nu: Nurse
Distance (ALARA)	1. What is the most important factor in radiation protection that radiation workers should consider according to ALARA?	50.69 (109)	P: 60.97 (25) Nu: 48.27 (84)
Time (ALARA)	2. What does the "time principle" mean in ALARA?	52.09 (112)	P: 56.09 (23) Nu: 51.14 (89)
Shielding (ALARA)	3. Where the personal dosimeter must be placed?	87.44 (188)	P: 73.17 (30) Nu: 90.8 (158)
	4. On what conditions should you use lead glasses?	23.72 (51)	P: 36.58 (15) Nu: 20.68 (36)
	5. On what conditions the lead gloves must be used?	58.13 (125)	P: 85.36 (35) Nu: 51.72 (90)
	6. On what conditions the thyroid shields must be used?	24.18 (52)	P: 39.02 (16) Nu: 20.68 (36)
	7. On what conditions the leaded aprons need to be used?	25.11 (54)	P: 36.58 (15) Nu: 22.41 (39)
	8. On what conditions the mounted shield must be used?	24.18 (52)	P: 65.85 (27) N: 14.36 (25)
Dose limitation	9.What is the maximum permissible absorbed dose for occupational exposure based on ICRP recommendations?	8.83 (19)	P: 19.51 (8) Nu: 6.32 (11)
Justification	10. What is the meaning of Justification in radiation protection, in accordance with ICRP recommendations?	88.37 (190)	P: 87.80 (36) Nu: 88.5 (154)
Optimization	11. What is the implication of optimization in radiation protection according to ICRP recommendations?	92.09 (198)	P: 92.68 (38) Nu: 91.95 (160)
Leakage radiation	12. What is the source of leakage ionizing radiation in interventional radiology procedures?	25.58 (55)	P: 41.46 (17) Nu: 21.83 (38)
Scatter radiation	13. Which beam has the highest contribution in the occupational exposure of medical professionals?	17.2 (37)	P: 29.26 (12) Nu: 14.36 (25)
Stochastic and non-stochastic effects	14.What are the stochastic and deterministic effects of ionizing radiation?	28.37 (61)	P: 70.73 (29) Nu: 18.39 (32)
Organs radiosensitivity	15. Which organs are more sensitive to ionizing radiation?	16.27 (35)	P: 43.90 (18) Nu: 9.77 (17)
Fetus or pregnancy	16.Which group of patients is the most radiosensitive to ionizing radiation?	88.37 (190)	P: 100 (41) Nu: 85.63 (149)
Position	17. What is the best place for medical staff to stay (close to the patient) in order to reduce the scattered rays?	25.58 (55)	P: 43.90 (18) Nu: 21.26 (37)

Discussion

The results of this study showed that only 47.7% of the participants were able to comprehend the concept of ALARA, although it is the basic principle of radiation protection. Nearly 88% of the physicians were familiar with the basic concepts of radiological procedures as a primary principle of the patients' radiation protection.[15] This finding confirms the ICRP reports expressing that some radiological procedures are prescribed without sufficient justification.[15] Moreover, 8.8% of the MPs knew about the ICRP dose limit (a fundamental part of most radiation protection programs) and the fact that the purpose of individual radiation monitoring is to ensure that the dose limits are not exceeded.

The significance of radiation-sensitive organ shielding in reducing the equivalent and effective dose has been already approved.[16] According to the basic principles of radiation protection, the protective leaded aprons and thyroid shields must be periodically applied during the interventional procedures; however, most of the MPs ignored the role of the personal protective devices in controlling the occupational radiation exposure. Flôr and colleagues[17] showed that technicians did not even use these personal protective devicesas they found that such equipment heavy and uncomfortable (particularly leaded aprons). Among the personal protective devices, MPs exhibited the lowest knowledge and the weakest practice for the leaded eyewear, while the risk of exceeding the annual lens dose limit can be dramatically reduced upon using leaded eyewear shields during the interventional radiological procedures.[18] It should be mentioned that ICRP recommended 20 mSv year^{-1}as a dose limit for the eyes lens, averaged over defined periods of 5 years, with no annual dose in a single year exceeding 50 mSv.[12]

The participant's awareness of the right place of personal dosimeter (87.4%) was appropriate, but the MPs' practice

Table 3: The checklist applied to evaluate the practice of 31 medical professionals, P%: Percentage of Participants, N: Number of Participants

Practice	P%(N)	P: Physicians Nu: Nurses
1. The radiation worker has participated in a practical training course on radiation protection?	0	P: 0 N: 0
2. The radiation worker is in a safe place?	29.03 (9)	P: 42.85 (3) Nu: 25 (6)
3. Do the radiation workers use the leaded eyewear if necessary?	22.58 (7)	P: 71.42 (5) Nu: 8.33 (2)
4. Do the radiation workers use the lead gloves if necessary?	35.48 (11)	P: 85.71 (6) Nu: 20.83 (5)
5. Do the radiation workers use the Lead Apron?	41.93 (13)	P: 71.42 (5) Nu: 33.33 (8)
6. Do the radiation workers use the Thyroid shields?	35.48 (11)	P: 42.85 (3) Nu: 33.33 (8)
7. Do the radiation workers use the mounted Shield?	25.80 (8)	P:85.71 (6) Nu: 8.33 (2)
8. The personal dosimeter is used in correct place by the radiation worker?	83.87 (26)	P: 71.42 (5) Nu: 87.5 (21)
9. How many of the radiation workers do not forget to apply the personal dosimeter?	90.33 (28)	P: 71.42 (5) Nu: 95.83 (23)
10. Do the radiation workers use personal dosimeters?	87.09 (27)	P: 71.42 (5) Nu: 91.66 (22)
11. Do the radiation workers apply two personal dosimeters simultaneously?	0	P: 0 Nu: 0

demonstrated that 12.8% of them did not use the personal dosimeters appropriately [Figure 1]. Similarly, working with the ionizing radiation without personal dosimeters has been reported in the other studies as well.[19,20] This may affect the accurate and precise determination of the equivalent and effective doses in order to compare it with the dose limits. It was observed that the MPs' physical dosimetry values are lower than the dose limits between 2014 and 2016.[21]

All of the MPs only applied one personal dosimeter during the interventional fluoroscopy procedures, whereas the ICRP publication 117 recommends a double-dosimetry method, one under the leaded apron and the other at the collar level above the lead apron.[22] Furthermore, an additional dosimeter was recommended to estimate the dose absorbed by hand during the interventional radiological procedures.[23] The hands of the physicians may be highly exposed to the radiation, however, only a few countries have reported data on the equivalent doses in hands.[11] It seems that particular attention should be paid to extremity doses received during the interventional radiology.

It is generally known that significant amount of radiation is scattered when the radiation flows through the patient body; although, in interventional radiology, the MPs spend a substantial amount of time inside the X-ray rooms with significant radiation intensity.[1] Only 37 (17.2%) of the MPs knew that radiation scattering from the patients' bodies is one of the prominent sources of radiation exposure. Another important findingis that 17 (54.8%) of the nurses suffered from radiophobia and some of the female nurses preferred to avoid participating in the interventional fluoroscopy procedures, which might be due to the rumors or lack of precise knowledge on the radiobiological effects of radiation. A similar finding has been observed among the nurses investigated in the work of Dianati *et al*.[24-26] It seems that the main reason for their reluctance to assist in the radiological examinations was the lack of practical radiation protection education and training. Our results also indicated that the MPs are not entirely aware of the radiobiological effects of radiation, which is in agreement with a previous study carried out by Alotaibi *et al*.[26]

Several studies have indicated the poor radiation protection awareness of the MPs.[27-30] There are also some other researchers that reported proper awareness of the MPs.[31,32] Such discrepancies could be due to the participants and the research methodology. According to the results of the current study, the CAR of knowledge toward radiation protection was 57.81%, 39.88%, 43.30% among the physicians, nurses, and all MPs, respectively. This value was 40% and 39% in the studies carried out by Keijzers *et al*.[29] and Soya *et al*.,[33] respectively. The lack of effective radiation protection practice was also observed among the nurses, which can be attributed to the insufficient training in the field of radiation protection.[20] In summary, our research indicates that the lack of knowledge and practice among the nurses makes them unable to protect the patients and themselves against ionizing radiation. It may indicate a deficiency in the educational training of nurses since this study, in addition to many others,[20,34,35] showed that most of the nurses had not passed any theoretical course or practical trainingon radiation protection at the universities or hospitals.

Conclusion

The current study showed that many medical professionals (MPs) are not aware of the necessary scientific information about the radiation protection concepts and practices which may lead to serious radiation-related errors. The potential benefits of MPs, as active players in radiation protection, need to be emphasized in universities and hospitals, where the curriculum contents in radiation sciences are insufficient. Additional training is also recommended in medical schools or hospitals.

Financial support and sponsorship

The study was supported by Yasuj University of Medical Sciences, Yasuj, Iran.

Conflicts of interest

There are no conflicts of interest.

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