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Assessment of Knowledge and Practice on Radiation Protection in Radiological Imaging Among Healthcare Professionals at HPUniSZA

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Abstract
Ionizing radiation aids in diagnosing and treating diseases. However, without proper knowledge and practice of radiation protection, it can be harmful, especially among healthcare professionals. This study aims to examine the knowledge and practice of radiation protection among healthcare workers at the HPUniSZA. A cross-sectional study was conducted in the HPUniSZA from March 2022 to June 2023 for healthcare professionals in HPUniSZA. The questionnaire was distributed online and through face-to-face interviews. Descriptive statistics were used to analyze sociodemographic, knowledge, and practice of radiation protection while Pearson's correlation was used to determine the relationship between knowledge and practice of radiation protection among the respondents. A total of 60 healthcare professionals in HPUniSZA participated in this study. The mean knowledge level was found to be 6.2 (SD, 2.9) indicating a range of medium-good level of knowledge of radiation protection while for practice was found to be 8.2 (SD, 2.3) indicating a good practice of radiation protection among healthcare professionals. A significant positive and fair correlation ($r = 0.48$, $p < 0.001$) was demonstrated between knowledge and practice levels on radiation protection in radiological imaging. The knowledge level and the practice of radiation protection among healthcare professionals are in the range of medium-good level and good levels respectively. There is a correlation between knowledge and practice of radiation protection among healthcare professionals in HPUniSZA. Assessing the knowledge and practice of radiation protection among healthcare professionals is of utmost importance to ensure patient safety, minimize radiation risks, and facilitate effective and efficient healthcare delivery both now and in the future.

Keywords
Knowledge, Practice, Radiation Protection, Healthcare Professionals

Introduction
Health technology is the application of organized knowledge that takes the form of devices, medicines, vaccines, procedures, and systems to help address health problems and improve the quality of life. A subset of health technology is a medical technology that uses a wide range of devices to diagnose, monitor, or cure medical problems in humans. Such medical technology applications aim to improve the quality of healthcare by enabling earlier diagnosis, less invasive treatment alternatives, and shorter hospital stays

and rehabilitation times. With the advancement of medical science and rapidly changing health technologies, diagnostic imaging techniques and interventional radiological procedures are increasingly used to accurately diagnose a variety of diseases and injuries and provide life-saving treatments in this modern era [1].

Several medical procedures use ionizing radiation, including angiography, fluoroscopy, computed tomography (CT), and radiographic imaging. Although radiological imaging is excellent in diagnosis and therapy, it uses radiation exposure that has potential effects on the patient's health. In some cases, dose limits approved by international authorities may be exceeded for some interventional uses [2]. Therefore, according to the basic principles of radiation protection, exposure to ionizing radiation must be kept within the as low as reasonably achievable (ALARA) principle [3]. This is because the use of ionizing radiation, such as X-rays in particular, is associated with potentially harmful biological effects. High doses of radiation tend to kill cells, while low doses tend to damage or alter the deoxyribonucleic acid (DNA) of irradiated cells [4].

Furthermore, there has been a growing worry about the insufficient understanding among physicians regarding the radiation doses employed in diagnostic radiological procedures [5]. Consequently, this issue could affect the staff and, due to the lack of information on radiation protection, will lead to unsafe actions and adverse health effects pathways [6]. Furthermore, other healthcare professionals also require a thorough understanding of radiation protection. This includes nurses assigned to the radiology department and those participating in radiological procedures, providing professional care to patients throughout the entire radiologic process. This knowledge is essential to guarantee the safety of themselves, the patients, and the public by minimizing unnecessary radiation exposure [7].

The researchers in previous studies also observed that nurses rarely adhered to radiation-protection measures, especially during mobile radiography [8]. In the ward, nurses would withdraw assistance during the radiological examination and stand behind a curtain for protection. Therefore, the aim of this was to investigate the level of knowledge of the healthcare professionals at HPUniSZA.

Materials and Methods

Study design

This is a cross-sectional study involving all healthcare professionals at HPUniSZA with a study period from March 2022 to June 2023.

Ethical statement

Ethical approval was obtained from the Human Research Ethics Committee (UHREC) [UniSZA/UHREC/2022/421 (1)]. The procedures followed were in accordance with the study protocol amendment form, application form, and UniSZA Ethics Approval.

Study population

This study employed non-probability sampling, specifically purposive sampling because data was collected from all healthcare professionals via a questionnaire-based survey. Healthcare professionals of all genders and races were included in this study. The sample size was calculated using the single mean formula involving numerical data analysis. Thus, according to the calculation, 111 respondents were required for this study.

Data collection

The data was collected through a Google form-based questionnaire from all healthcare professionals which was adapted from an article titled "Radiation Protection Literacy and its Associated Factors among Healthcare Workers in Negeri Sembilan" [9]. It is a self-administered questionnaire that was divided into three sections which were section A: demographic information, section B: knowledge of radiation protection, and section C: practice on radiation protection.

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Data collection process

This study was conducted at UniSZA's Teaching Hospital (HPUniSZA). The questionnaires were distributed in the form of QR codes via online and also face-to-face to all the healthcare professionals.

Data and statistical analysis

The data were analyzed using IBM SPSS Statistics 21. A descriptive analysis was performed for the knowledge level and practice of healthcare professionals respectively. The number of respondents (n) and percentages (%) were reported for each question. In addition, the overall mean, median, standard deviation, and interquartile range were also reported for both knowledge and practice. However, only the mean was used for the interpretation of knowledge level and practice according to the mean score interpretation table [10]. A Pearson's correlation test analysis was conducted to determine the correlation between the knowledge level and practice of radiation protection among healthcare professionals in HPUniSZA.

Results

Socio-demographic Characteristic Data

A total of 66 respondents from HPUniSZA answered the questionnaire. Table 1 illustrates the socio-demographic characteristics of the respondents. The mean age of the respondents is 31.9, with a standard deviation of 4.2. Furthermore, there were more female (n = 47) respondents than male (n = 19). Most of the respondents were diploma qualifiers (n=33, 50%) followed by degree qualifiers (n=31, 47%), while no respondents had a PhD qualification. Additionally, the nurses responded the most while only one medical assistant responded. Moreover, majority of respondents had less than 10 years of employment duration.

Table 1: The socio-demographic data

Socio-demographic Characteristics	Mean	SD	n	%
Age (years)	31.9	4.2		
Gender				
Male			19	28.8
Female			47	71.2
Race				
Malay			66	100
Chinese			0	0
Indian			0	0
Others			0	0
Educational Level				
Diploma			33	50
Degree			31	47
Master			1	1.5
PhD			0	0
Others			1	1.5
Occupation				
Medical Officer			14	21.2
Medical Assistant			1	1.5
Radiographer			12	18.2
Nurse			21	31.8
Dietitian			2	3.0
Pharmacist			10	15.2
Medical Laboratory Technologists			3	4.5
Others			3	4.5
Duration of current employment				

<10 years		49	74.2
10-20 years		16	24.2
20-30 years		1	1.5
>30 years		0	0

(SD = Standard Deviation, n = number of respondents, % = percentage)

Table 2 presents the frequencies and percentages of responses regarding various aspects of radiation protection knowledge. The first question revealed that only 50% of healthcare professionals were aware of acute radiation syndrome. Only two respondents correctly identified the diseases caused by radiation hazards and acute radiation symptoms. Approximately 16.7%, 15.2%, 10.6%, and 30.3% of respondents provided correct answers to the questions related to maximum dose limits and periodic medical examinations for radiation workers. However, a significant number of respondents provided incorrect answers to critical questions. For instance, none of the respondents correctly identified the maximum dose limit per year averaged over five consecutive years, only six respondents correctly answered the maximum dose limit for pregnant workers, and only three respondents provided the correct frequency for periodic medical examinations.

Approximately 72.7% of respondents knew that a dosimeter measures radiation exposure and only 15 correctly identified all the personal protective devices (PPDs). Furthermore, less than half of the respondents correctly identified the SI unit for measurement of equivalent dose and absorbed dose as Sievert and Gray, respectively. Additionally, by the cardinal principle, 72.7% of respondents correctly identified "use shielding effectively" as the true statement. Only 15 respondents accurately identified the imaging modalities that involve ionizing radiation. The mean score for knowledge of radiation protection was 6.2.

Table 2: The responses to the knowledge of radiation protection

Questions	n	%
I know about Acute Radiation Syndrome.		
No	15	22.7
Not sure	18	27.3
Yes	33	50.0
Diseases that occur by radiation hazards (can choose more than 1 answer).		
Skin injuries	45	68.2
Cataract	26	39.4
Bone marrow depression	21	31.8
Infertility	50	75.8
Congenital Malformations	43	65.2
Gastritis	7	10.6
Diabetes Mellitus	1	1.5
Thyroid Cancer	33	50.0
Leukaemia	22	33.3
Anaemia	9	13.6
Symptoms of acute radiation syndrome (can choose more than 1 answer).		
Nausea	58	87.9
Vomiting	57	86.4
Headache	51	77.3
Diarrhoea	14	21.2
Flu	5	7.6

Sore throat	11	16.7
Itchiness	30	45.5
I know the limit of effective whole-body dose that I must not exceed in a calendar year for radiation workers (dose per year averaged over 5 consecutive years).		
No	25	37.9
Not sure	30	45.5
Yes	11	16.7
I know the maximum limit of effective whole-body dose that I must not exceed in a calendar year for radiation workers (maximum dose per year).		
No	26	39.4
Not sure	30	45.5
Yes	10	15.2
I know the maximum dose limit of radiation exposure for pregnant workers recommended by the Atomic Energy Licensing (Basic Safety Radiation Protection) Regulation 2010.		
No	29	43.9
Not sure	30	45.5
Yes	7	10.6
I know being exposed to radiation during work warrants periodic medical examination and the frequency of periodic examination is based on Atomic Energy Licensing (Basic Safety Radiation Protection) Regulation 2010.		
No	21	31.8
Not sure	25	37.9
Yes	20	30.3
I know the device used to measure exposure to radiation while on duty.		
Luxmeter	7	10.6
Dosimeter	48	72.7
Sonometer	11	16.7
I know of any personal protective devices that I can wear to reduce exposure to radiation while on duty.		
No	4	6.1
Not sure	10	15.2
Yes	52	78.8
I know some of the personal protective devices that I can wear to reduce exposure to radiation while on duty.		
Lead goggles	36	54.5
Lead apron	57	86.4
Lead gloves	30	45.5
Thyroid shield	41	62.1
Gonad shield	35	53.0
The International System of Units (SI) for radiation measurement of "equivalent dose".		
Rem	11	16.7
Rad	17	25.8
Sievert	30	45.5
Gray	8	12.1

The International System of Units (SI) for radiation measurement of "absorbed dose".		
Rem	16	24.2
Rad	14	21.2
Sievert	18	27.3
Gray	18	27.3
The cardinal principles of radiation protection for complying with the "as low as reasonably achievable" (ALARA) principle. (Select all true statements).		
Use shielding effectively	48	72.7
Use magnification as often as possible	10	15.2
Collimate the beam	21	31.8
Maximize the distance to the source of radiation	42	63.6
Minimize exposure time	47	71.2
The radiological procedures below contain ionizing radiation. (Can choose more than one answer).		
X-ray	56	84.8
Computed Tomography Scan	49	74.2
Magnetic Resonance Scan	28	42.2
Fluoroscopy	36	54.5
Mobile x-ray	42	63.6
Ultrasound	11	16.7
Mammography	28	42.4

(n = number of respondents, % = percentage, rad = Radiation Absorbed Dose, rem = Roentgen Equivalent Man)

Practice of Radiation Protection

Table 3 describes the responses to the practice of radiation protection in terms of frequencies and percentages. The majority of respondents experienced all radiological procedures except for mammography (0%). A significant percentage (77.3%) demonstrated good practice by wearing proper PPD while on duty and 75.8% implemented the good practice of closing the door during radiological procedures. However, only six healthcare professionals reported "rarely" using a dosimeter while on duty.

Regarding a question reflecting good practice, 9.1% and 37.9% of participants incorrectly answered, "share a dosimeter" and "keep the dosimeter where it is safe during work hours" as the answer, respectively. Notably, 57 respondents reported experiencing no injury or illness related to radiation exposure. Additionally, 7.6% of respondents were uncertain about reporting work-related injuries or accidents to the officer in charge, and 21.2% of respondents were unsure about reporting injuries to the occupational and environmental health unit in their district and state levels, and the Department Occupational Safety and Health (DOSH) in their state. The mean score for the practice of radiation protection was 8.2.

Table 3: The responses to the practice of radiation protection

Questions	n	%
I have experience working with these radiological procedures.		
X-ray	41	71.2
Computerized Tomography Scan	31	47.0
Magnetic Resonance Imaging scan	29	43.9
Fluoroscopy	23	34.8
Mobile X-ray	38	57.6

Ultrasound	33	50.0
Mammography	0	0
None	17	25.8
I wear a proper personal protective device to reduce radiation exposure while on duty.		
No	8	12.2
Not sure	7	10.6
Yes	51	77.3
I close the radiation-shielded door in the monitor cubicle properly while performing the radiological procedures.		
No	7	10.6
Not sure	9	13.6
Yes	50	75.8
I wear a device that measures exposure to radiation while on duty.		
Never	19	28.8
Rarely	6	9.1
Sometimes	14	21.2
Often	10	15.2
Always	17	25.8
True statements that reflect good practice.		
Return the dosimeter at the end of the wearing period	52	78.8
Share a dosimeter	6	9.1
Report a lost dosimeter	45	68.2
Hand the dosimeter in before taking leave	34	51.5
Keep the dosimeter in the locker where it is safe during work hours	25	37.9
Wear the dosimeter during work hours	47	71.2
I have experienced injury/accident or illness related to radiation exposure.		
No	57	86.4
Not sure	6	9.1
Yes	3	4.5
I should report any work-related injuries/ accidents to the officer in charge at that time.		
No	8	12.2
Not sure	5	7.6
Yes	53	80.3
Any incident/ accident in my workplace should be reported to the occupational and environmental health unit at my district and state levels.		
No	8	12.1
Not sure	14	21.2
Yes	44	66.7
Any incident/accident in my workplace should be reported to the Department of Occupational Safety and Health (DOSH) in my state.		
No	10	15.2
Not sure	14	21.2
Yes	42	63.6

(n – number of respondents, % - percentage)

Table 4 provides insights into various responses across the different personal protective equipment (PPE) to reduce radiation exposure while on duty. Lead goggles were the least frequently used protective devices, with the highest percentage of responses falling under the "rarely" category at 22.7%. Regarding lead aprons, a small percentage of respondents reported either not provided (4.5%), never wearing them (4.5%), or rarely wearing them (4.5%). Similarly, for lead goggles, a considerable number of respondents indicated that they were either not provided (18.2%) or, often wearing them (18.2%). As for thyroid shields, the majority of respondents indicated a consistent usage with the highest response being "always" at 17 (25.8%). Finally, regarding gonad shields, respondents reported wearing them with varying frequencies, with the majority indicating that they wear them sometimes (21.2%) or always (24.2%).

Table 4: The percentage of personal protective equipment (PPE)

Protective Devices	Not provided	Never	Rarely	Sometimes	Often	Always
Lead goggles (n)	9	9	15	12	8	13
(%)	(13.6%)	(13.6%)	(22.7%)	(18.2%)	(12.1%)	(19.7%)
Lead apron (n)	3	3	3	6	18	33
(%)	(4.5%)	(4.5%)	(4.5%)	(9.1%)	(27.3%)	(50.0%)
Lead gloves (n)	12	10	19	4	12	9
(%)	(18.2%)	(15.2%)	(28.8%)	(6.1%)	(18.2%)	(13.6%)
Thyroid shield (n)	3	7	10	13	16	17
(%)	(4.5%)	(10.6%)	(15.2%)	(19.7%)	(24.2%)	(25.8%)

(n – number of respondents, % - percentage)

Relationship between Knowledge and Practice of Radiation Protection

In this study, the knowledge was normally distributed, while the practice was not normally distributed. The correlation coefficient (r) was reported as 0.481 with p < 0.001 and the positive direction of the scatter plot graph (Figure 1) indicates a significant, positive, and fair correlation between knowledge and practice.

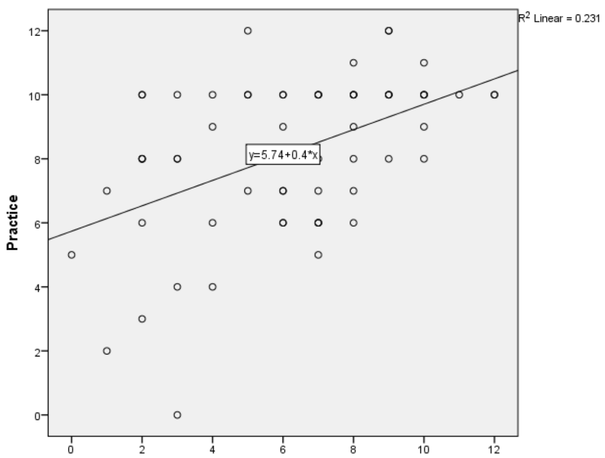

Figure 1: A scatter plot graph with a positive direction.

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Discussion

Knowledge of Radiation Protection

It was observed that only half of the participants demonstrated awareness of acute radiation syndrome. Furthermore, the inability of 64 participants to correctly identify diseases caused by radiation hazards and acute radiation syndrome may be attributed to a lack of knowledge and inadequate education. Identifying diseases related to radiation hazards requires specialized understanding. Therefore, without proper education in this area, expertise in accurate diagnosis is impossible.

Another area of concern was the comprehension of dose limits and radiation exposure. The low percentage of correct responses regarding maximum dose limits indicated a lack of understanding, particularly with none of the respondents accurately identifying the maximum dose limit per year averaged over five consecutive years. These results are consistent with the research conducted by Bolbol S et al., which revealed that fewer than 30.0% of participants had a basic understanding of the threshold of effective dose for a radiation worker [6]. On the other hand, other healthcare professionals, including dietitians, pharmacists, physiotherapists, and medical laboratory technologists who participated in this study, also possessed familiarity with radiology procedures. Consequently, it's imperative that they are also provided with information regarding radiation dose limits.

The knowledge of PPDs was relatively better, with a majority acknowledging their use for measuring radiation exposure. A similar study also shows a high level of awareness among participants regarding the usage of dosimeters as radiation monitoring devices [11]. However, participants exhibited limited ability to identify all the PPEs, possibly due to infrequent utilization and varying usage based on specific situations and protocols in healthcare settings. Factors such as the type of procedure, the level of radiation involved, and the availability of alternative radiation protection measures can influence the decision to use PPEs like lead goggles, lead gloves, and gonad shields. Therefore, healthcare professionals may tend to underestimate the usage of these devices during radiological procedures due to their infrequent utilization.

Regrettably, healthcare professionals at HPUniSZA have not demonstrated a satisfactory level of proficiency in the understanding of SI units for equivalent and absorbed doses. This is mainly because most healthcare professionals come from non-radiology backgrounds, in contrast to the limited number of radiographers in the radiology department. More than half of the respondents successfully identified all the cardinal principles of radiation protection as they are likely to have a solid understanding of the fundamental principles and the guidelines governing the safe use of radiation. This understanding aids in reducing radiation exposure to staff, patients and the public.

Additionally, the deficit in the participants' knowledge of basic scientific principles has contributed to the lack of recognition of ionized-based modalities. These results are consistent with a previous study, which found that some medical practitioners fail to recognize MRI and ultrasound as radiation-free modalities [12]. Similarly, a study also reported that 5% and 8% of participants associated ultrasound and MRI, respectively, with radiation [13]. Therefore, healthcare professionals overlook this fact and opt for ionizing-based modalities that could increase the risks of radiation exposure by disregarding the safer alternatives available. In summary, the mean score fell within the range of medium-good level of knowledge in radiation protection, according to the mean score interpretation table.

Practice of Radiation Protection

This study revealed Healthcare Professionals at HPUniSZA had good practices towards radiation protection in Radiological Imaging. The respondents demonstrated a fundamental understanding and adherence to the ALARA principle by consistently wearing PPD and closing the radiation-shielded door. These practices reflect their commitment to minimizing radiation exposure and ensuring safety. Additionally, the participants had experience in various radiological procedures, except for mammography, which is due to unavailability, and due to male radiographers are generally not allowed to perform mammographic procedures in any healthcare setting.

Wearing PPE is a fundamental preventive measure during radiographic procedures to enhance radiation protection. Consistently utilizing lead aprons can provide approximately 75% to 80% protection for the bone marrow. In addition, employing lead shielding is an important precautionary measure to minimize avoidable exposure [6]. Consequently, the study's findings reveal that the majority of respondents consistently wear PPEs while on duty. This demonstrates healthcare professionals' awareness of and concern for the risks associated with radiological procedures involving ionizing radiation. However, a minority of the participants may not have worn PPE while on duty due to reasons such as not working in the radiology department or shortages of PPE in the hospital.

Moreover, most respondents recognized that a dosimeter was used to measure radiation exposure and, some were not aware of the implications of sharing a dosimeter or keeping it in the locker during work hours. This could lead to difficulty in tracking their exposure levels individually and leads to inaccurate monitoring of radiation exposure and can shield it from direct radiation exposure, potentially resulting in an underestimation of the actual radiation dose received by an individual. Moreover, the workplace was generally safe, as most respondents had not experienced work-related injuries or accidents during their working hours.

The uncertainty among respondents regarding reporting work-related injuries or accidents to other authorities is possibly due to inadequate information about proper reporting channels. Therefore, healthcare professionals are unsure to whom to report such incidents. As a result, there could be a lack of awareness of the importance of reporting work-related injuries.

Relationship between Knowledge and Practice of Radiation Protection

A positive and fair correlation was shown between knowledge and practice of radiation protection at HPUniSZA. These outcomes were in line with a study that also reported a positive correlation between adherence and knowledge scores [14]. The diverse application of knowledge in different healthcare settings and the hospital being newly established with various backgrounds and experiences of the staff may have contributed to this fair correlation. The positive correlation between knowledge and practice suggests that as the knowledge level increases, so does the practice. In summary, the level of knowledge has a significant impact on the practices observed. An excellent knowledge base typically leads to good practice. However, the correlation might differ across different healthcare settings.

Conclusion

In conclusion, HPUniSZA's healthcare professionals have exhibited a medium-good level of knowledge of radiation protection and a good level of practice in radiation protection among healthcare professionals at HPUniSZA. Apart from that, there was still a significant fair and positive correlation between knowledge and practice among healthcare professionals in HPUniSZA suggesting that the practice increases as the knowledge level increases. Therefore, this study has highlighted the importance of assessing the knowledge and practice of radiation protection to ensure patient safety, minimize radiation risks, and promote effective and efficient patient care in the present and future.

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Conflict of Interest Disclosure
None to declare

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