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# Referral Physicians' Knowledge of Radiation Dose: A Cross-sectional Study

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**Abstract**

**AIM:** The purpose of the study was to evaluate the knowledge of referring physicians of general practitioners, residents, and medical specialists in Jordan and the Middle East on radiation dose and its impact on vulnerable patients.

**MATERIALS AND METHODS:** The Institutional Review Board approved this study before data collection. A cross-sectional study employed questionnaire that was distributed to respondents (n = 293) of general practitioners, residents, specialists, and therapists. The questionnaire consisted of 29 questions. Nine questions concerned with demographics and the remaining 20 questions were divided into five sections: Radiation dose, ionizing radiation, pediatric radiation, pregnant women radiation, and radiation risks. The mean score was computed out of 20. Chi-squared test of independence was utilized to analyze each question. To compare the responses between the demographic variables groups, Kruskal–Wallis and Mann–Whitney tests were used.

**RESULTS:** Out of the 293 respondents, 128 (43.7%) were aware of radiation. The average score of the questionnaire was 9.5 out of 20 (47.5%). Within each section, the level of knowledge varied. Physicians had the highest level of knowledge in radiation risk (85.7%) followed by ionizing radiation (62.1%). The questionnaire revealed lower levels of knowledge in the areas of pediatric radiation, pregnant women radiation, and radiation dose. The percentages of respondents, (with fair to good level of knowledge), were 47.1%, 34.5%, and 24.6%, respectively.

**CONCLUSION:** The results of this study were consistent with previous studies that demonstrated a poor level of general knowledge in referring physicians regarding radiation dose, ionizing radiation, pediatric radiation, pregnant women radiation, and radiation risks.

## Introduction

With the advent of imaging technology, ionizing radiation (IR) is considered one of the most valuable diagnostic tool in the detection and evaluation of disease and disorders [1]. Exposure of radiation workers and patients to IR is mainly evaluated on risk-benefit analysis [2]. Unnecessary exposure to IR should be avoided, as there is a dose-dependent increase in the risk of developing cancer [3]. The biological effects of IR are classified into either deterministic or stochastic effects [4], [5], [6]. Deterministic effects, which include cataracts or erythema, occur when IR exposure rises above a specific threshold dose. Certain cardiological interventional processes with multiple image acquisition and long screening times (e.g., radiofrequency ablation, percutaneous coronary intervention, etc.) increase the deterministic effects of IR exposure on patients and radiation workers [7]. On the other hand, the stochastic effect is considered a probabilistic event, as there is no recognized threshold dose. The probability of inducing the effect, but not the severity, will increase in relation to the dose and could be different between individuals. For example, a low dose of IR <50 mSv will not directly damage any organ in the body, but repeated exposures will increase cancer risk over the lifetime of the individual [8]. This risk can be mitigated by physicians ordering fewer unnecessary radiological examination procedures.

Both consultant and general physicians refer patients for radiological examinations and have a great responsibility to manage and moderate the IR dose patients will receive [9]. However, standardization and justification have emerged as a key concept in radiation protection and presents with challenges [10], [11]. Justification implies that the referring physician has determined the benefit toward the patient outweighs the risk of the radiation dose [12], however, both the medicolegal cloud and patient education have evolved over the last decade to which physicians are more inclined to request radiological examinations for patients to potentially prevent litigation.

Studies have reported a lack of acceptable knowledge among physicians regarding exposure to radiation: In one survey, physicians underestimated the dose of radiation received in an arteriogram by 16-fold (ref). The remainder of the survey demonstrated physicians was delivering an average dose of IR six times greater than they estimated [13]. It is also reported that referring physicians have limited knowledge of ionizing radiation and the carcinogenic potential of such radiation, and that referral guidelines are not widely used [12], [13]. Poor knowledge regarding radiation doses and its impact among physicians and health professionals is a well-reported concern with limited comparisons in the middle east [3], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27]. Nevertheless, to the best of our knowledge, this is the first study to investigate the knowledge of referral physicians in Jordan and the Middle East on radiation dose and its impact on vulnerable patients.

## Methodology

This prospective study obtained approval from the Institutional Review Board at 20190378. It was conducted in November 2018, consisting of an anonymous questionnaire applied and distributed online (Google survey) through social media networks to non-radiologist physicians with different specialties who are working in Jordanian hospitals.

### *Population demographics*

The participants were asked to estimate their knowledge about radiation doses, ionizing radiation, radiation in a pediatric population, radiation in pregnant women, and radiation risks. Adequate sample size was met by convenience and snowball sampling. Using Cohen's formula (1992) [28], a power analysis showed that a sample of 293 would provide an 80% chance of detecting correlations of ±0.223 at $p \leq 0.05$.

### *Questionnaire*

The questionnaire consisted of 29 mandatory questions; nine for demographic information that included gender, age, specialty, education (internship/resident/consultant), year of graduation, specific formal courses about radiology in their curriculum, self-reporting for their knowledge about radiology, any history of previous courses on radiation doses and their risk, and the most frequent radiological examination routinely requested. The second part of the questionnaire consisted of 20 questions divided into five sections: Radiation dose, ionizing radiation, pediatric radiation, pregnant women radiation, and radiation risks. All the questions were in English with formats, including multiple-choice and open-ended true/false questions.

### *Validation of the study tool*

The questions employed were consistent with the studies of [29], [30]. However, a few changes were made, which include adding and excluding some questions. To validate these changes, the updated questionnaire was presented to a panel of experienced radiographers, medical imaging residents, and an internal medicine physician who were not included in the study. Afterward, the study was again validated in a group of 10 physicians who assessed the questionnaire for clarity. These physicians were also excluded from the study results.

The reliability of the study tool was confirmed by the test-retest method, where the pilot study was resent with two weeks period on the same sample of (10) physicians.

### *Data analysis*

Data from completed surveys were manually transferred to Excel (Microsoft, Redmond, WA, USA) then transferred to SPSS, version 20 (SPSS, Chicago, IL, USA) for statistical analysis. Before analysis, missing values and accuracy of data entry were checked by reviewing all variables. The mean score was computed out of 20 for all the sample questions. The Chi-squared test of independence was used to analyze each question for determining if there is a significant relationship between the answers. Kruskal–Wallis and Mann–Whitney tests were used for comparing the responses between the demographic variables groups. Numbers, percentage, maximum, minimum, $5^{th}$ percentile, mean, and $95^{th}$ percentile for the correct answers of the whole exam were calculated. The Khan *et al*. (2014) scale (30) for knowledge, attitude, and practice scores were adopted. In this scale, ≤ 50% was considered as having poor knowledge, 51–69% is considered a fair level of knowledge, while 70% and above demonstrates a good level of knowledge. The total statistical significance value was $p < 0.05$.

## Results

A total of 293 respondents completed the questionnaire, 51.5% were males and 94.2% were within 20–30 years of age. General practitioners were 48.1% of the respondents, residents made up 46.1%, and the remainder was specialists (5.8%). Approximately, one-third (31.7%) of the respondents had previous courses on radiation doses of diagnostic imaging, and 73.7%

had not had any specific courses in radiation doses. As for the self-reporting of knowledge about radiation dose, respondents had a scale of five levels to choose from. Respondents assessed their knowledge as “moderate” 48.5% of the time. Chest examination was the most frequently ordered examination by doctors (82.9%), followed by ultrasound (59.0%) and CT examinations (55.3%). It was also noted that neither spine (10.2%) nor MRI examinations (12.3%) were as frequently ordered.

Less than half of the respondents (43.7%) were able to answer at least half of the questions correctly. The average number of correct answers was 9.5 out of 20, which indicates a general lack of knowledge (Table 1). The number of correct answers varied between sections. This questionnaire revealed that physicians knew the most regarding radiation risks, with the average of correctly answered questions instead (e.g., average of correctly answered questions of 184 [62.8%]). The section on ionizing radiation had the second-highest rate of the correct answer, with an average of 172 (58.8%). It was determined that the physicians possessed a low level of knowledge in the sections of pregnant women radiation, pediatric radiation, and radiation dose, with an average of correct answers of only 146 (49.7%), 139 (47.6%), and 96 (32.7%). 47.1%, 34.5%, and 24.6% of respondents had form fair to a good level of knowledge in these sections.

**Table 1: Descriptive analysis of correct answers of the whole exam**

| Measurements | n (%) |
|---|---|
| Maximum score | 18 (90) |
| Minimum score | 3 (15) |
| 5$^{th}$ percentile | 4.00 (20) |
| Mean of correct answers | 9.5 (47.5) |
| 95$^{th}$ percentile | 13.00 (65) |

Table 2 lists the number and percentage for the respondents’ answers on the five sections of the questionnaire. Two hundred twenty-seven physicians (77.5%) were able to correctly identify which examination produced the highest radiation dose. Fewer (58.3%) were able to identify the examination with a prolonged period of radiation emission. Only 31.4% of the participants correctly answered the equivalent radiation dose from chest X-ray compared to an annual dose of background radiation. While 20.8% of the participants knew patients absorbed dose from a chest X-ray, only 4.1% knew the radiation dose the public receives from medical imaging. Although 4.1% were able to specify that the annual dose limit for patients in mSv is unlimited, 49.1% of the respondents answered with (I don’t know). Within the ionizing radiation section, 66.2% of respondents were able to identify the examinations that ultrasound exam does not use ionizing radiation and 43.7% answered with MRI. Moreover, 43.7% of the respondents were aware of the acronym “ALARA”.

Less than half of participants (48.5%) were able to correctly identify the least radiosensitive organ, and 76.8% of them recognized that children are the

**Table 2: Participants’ answers to the five sections**

| Questions | Answer | n (%) |
|---|---|---|
| Radiation dose (Questions 1-6) | | |
| Which of the following modalities is responsible for most of radiation dose? | Ultrasound | 3 (1.0) |
| | Chest X-ray | 17 (5.8) |
| | CT | 227 (77.5) |
| | MRI | 34 (11.6) |
| | Lumbar spine X-ray | 2 (0.7) |
| | I don’t know | 10 (3.4) |
| Which of the following has a prolonged period of time of emitting radiation? | PET-CT | 171 (58.3) |
| | Abdomen CT | 40 (13.7) |
| | Abdomen MRI | 29 (9.9) |
| | Barium study | 12 (4.1) |
| | I don’t know | 41 (14.0) |
| How does the radiation dose from a chest X-ray compare to the annual dose of background radiation? | 1:100 | 92 (31.4) |
| | 1:10 | 44 (15.0) |
| | 1:1 | 9 (3.1) |
| | 10:1 | 27 (9.2) |
| | I don’t know | 121 (41.3) |
| What is the patients absorbed dose from a chest X-ray? | 0.02 mGy | 61 (20.8) |
| | 0.2 mGy | 56(19.1) |
| | 2 mGy | 34 (11.6) |
| | i don’t know | 142(48.5) |
| How much radiation does the public receive from medical imaging? | 1.5% | 40 (13.6) |
| | 5% | 75 (25.6) |
| | 15% | 36(12.3) |
| | 50% | 12 (4.1) |
| | I don’t know | 130(44.4) |
| What is the annual dose limit for patients in mSv? | 10 | 46 (15.7) |
| | 20 | 63 (21.5) |
| | 50 | 28 (9.6) |
| | Unlimited | 12 (4.1) |
| | I don’t know | 144 (49.1) |
| Ionizing radiation (Questions 7-10) | | |
| Which of the following does not use ionizing radiation? (Choose all that apply) | Ultrasound | 194 (66.2) |
| | Chest X-ray | 26 (8.9) |
| | CT | 13 (4.4) |
| | MRI | 128 (43.7) |
| | Nuclear medicine | 30 (10.2) |
| | I don’t know | 19 (6.5) |
| Do you know What does the acronym “ALARA” represent | Yes | 26 (8.8) |
| | No | 224 (76.5) |
| | I don’t know | 43 (14.7) |
| Which one of the following is less sensitive to radiation | Thyroid | 11 (3.7) |
| | Breast tissue | 55 (18.8) |
| | Gonads | 43(14.7) |
| | Kidney | 142 (48.5) |
| | I don’t know | 42 (14.3) |
| Which one of the following is most sensitive to radiation: | Children | 225 (76.8) |
| | Adolescents | 15 (5.1) |
| | Adults | 13(4.4) |
| | Elderly | 10 (3.4) |
| | I don’t know | 30 (10.2) |
| Pediatric radiation (Questions 11-13) | | |
| In pediatric population what are the most sensitive organs to radiation | Liver | 25 (8.5) |
| | Kidneys | 58(19.8) |
| | Gonads | 148 (50.5) |
| | Stomach | 5 (1.7) |
| | I don’t know | 57 (19.5) |
| Fetal tissue is susceptible to radiation, especially during: | Less than 20 weeks | 235 (80.2) |
| | Between 20 and 30 weeks | 19 (6.5) |
| | 30 weeks to term | 12 (4.1) |
| | I don’t know | 27 (9.2) |
| Estimate the radiosensitivity of 5-year-old patient in comparison to an adult? | The same | 21 (7.2) |
| | Less | 41(14.0) |
| | 5 times more | 93 (31.7) |
| | 10 times more | 35 (11.9) |
| | I don’t know | 103 (35.2) |
| Pregnant women radiation (Questions 14-16) | | |
| Can pregnant women be submitted to skull CT only? | Yes | 126 (43.0) |
| | No | 124 (42.3) |
| | I don’t know | 43 (14.7) |
| Can pregnant women be submitted to or screening mammography? | Yes | 119 (40.6) |
| | No | 139 (47.5) |
| | I don’t know | 35 (11.9) |
| Should every woman in childbearing age be submitted to a pregnancy test before being submitted to radiography of the pelvis | Yes | 181 (61.8) |
| | No | 82 (28.0) |
| | I don’t know | 30 (10.2) |
| Radiation risks (Questions 17-20) | | |
| Does the risk for developing cancer increase with the dose value and may be present even with a single exposure? | Yes | 177(60.4) |
| | No | 68 (23.2) |
| | I don’t know | 48(16.4) |
| Should any activity involving radiation be justified in relation to available alternatives | Yes | 210(71.7) |
| | No | 44 (15.0) |
| | I don’t know | 39 (13.3) |
| Should all exposures to radiation be maintained as low as reasonably achievable (ALARA)? | Yes | 165(56.3) |
| | No | 50 (17.1) |
| | I don’t know | 78 (26.6) |
| Should physicians and technicians who perform procedures utilizing ionizing radiation always be protected with shielding equipment and keep themselves as far as possible from the radiation source? | Yes | 256 (87.3) |
| | No | 26(8.9) |
| | I don’t know | 11 (3.8) |

*N is the number of respondents, %percentage in relation to total. In bold letter, the correct answers.

most sensitive age group to radiation. Similar results were observed in pediatric radiation section, where 50.5% of respondents knew the most sensitive organ to radiation in the pediatric population and only 11.9% of respondents correctly estimated the radiosensitivity of a 5-year-old child in comparison to an adult. However, most of the respondents (80.2%) correctly identified the age when fetal tissue is most radiosensitive. In the pregnant women radiation section, 43.0% were aware that pregnant women can undergo a skull CT, 47.5% knew pregnant women should not receive mammography, and 28.0% correctly reported that pregnancy testing is not mandatory for women of childbearing age before receiving a radiological examination of the pelvis.

Within radiation risks, the final section, 60.4% of the respondents correctly reported that the risk for developing cancer increases with dose, and there is a risk with a single exposure. Over half (56.3%) of the respondents knew that all exposures to radiation should be maintained As Low As Reasonably Achievable (ALARA). Moreover, 71.7% of the respondents were aware that any activity involving radiation should be justified in relation to available alternatives and 87.3% of them answered correctly when they were asked if physicians and technicians who perform procedures utilizing ionizing radiation should always be protected with shielding equipment and keep themselves as far as possible from the radiation source.

Table 3 illustrates the inter-group differences in the average number of correct answers. When comparing scores by gender, the Kruskal–Wallis test showed statistically significant differences in the pediatric radiation (p = 0.044) and pregnant women radiation sections (p = 0.018), with male respondents scoring higher than female respondents. However, in the radiation risks section, females scored higher than males (p = 0.009). Statistically significant differences were also found in the radiation risks section when analyzing scores by age (p = 0.001), with those over 30 years of age scoring the highest. Education significantly influenced score in the ionizing radiation and radiation risks sections, with specialists scoring highest in both categories (p = 0.045 for both). Finally, specialty significantly influenced the pregnant women's radiation section scores (p = 0.017) for both general surgery and specialty surgery. However, there were no statistically significant differences that are attributed to the variation in the year of graduation.

Most previous studies revealed an inadequate level of knowledge in radiation among physicians worldwide (Table 4). Radiation knowledge among doctors of all grades was described as lacking, poor, inadequate, unsatisfactory, and deficit.

## Discussion

A poor level of radiation knowledge was found overall among the respondents of this study, despite their self-reported "moderate" knowledge. This inconsistency between the reported and actual level of knowledge could indicate that doctors are not aware of their deficiencies. These findings are consistent with previous studies in other countries [13], [25], [29], [31], [32], [33], which also revealed a low level of radiation knowledge among referring physicians. This study found that only 31.7% of the respondents had previous courses on radiation doses in diagnostic imaging which may be a contributing factor in the overall poor knowledge base. Bosanquet *et al*. [3] also indicated that the poor level of knowledge could be related to insufficient education at the undergraduate level. Another explanation for the results may be due to the fact that physicians are mainly trained on image diagnostics and interpretation, rather than radiation dose [23]. However, different findings were reported by Quinn *et al.* [34] where it was claimed there was no difference in knowledge between physicians who attended radiation safety courses, and those who did not.

**Table 3: Knowledge score according to the physicians' characteristics**

| Variables | N | Radiation Dose (6 Questions) | | Ionizing Radiation (4 Questions) | | Pediatric Radiation (3 Questions) | | Pregnant Women Radiation (3 Questions) | | Radiation risks (4 Questions) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | p-value | Mean | p-value | Mean | p-value | Mean | p-value | Mean | p-value |
| Gender | | | | | | | | | | | |
| Male | 151 | 32.5% | 0.766 | 46.5% | 0.228 | **50.0%** | **0.044** | **41.0%** | **0.018** | 64.5% | **0.009** |
| Female | 142 | 33.0% | | 43.5% | | 44.3% | | 33.0% | | 73.5% | |
| Age | | | | | | | | | | | |
| 20-25 years | 147 | 32.8% | 0.664 | 43.2% | 0.373 | 46.0% | 0.303 | 34.0% | 0.187 | 72.2% | **0.001** |
| 25-30 years | 124 | 32.3% | | 46.0% | | 47.0% | | 39.3% | | 62.5% | |
| >30 years | 22 | 34.8% | | 47.5% | | 56.0% | | 45.3% | | **80.0%** | |
| Education | | | | | | | | | | | |
| Internship | 141 | 32.8% | 0.895 | 44.0% | **0.045** | 45.3% | 0.192 | 33.0% | 0.077 | 71.2% | **0.045** |
| Resident | 135 | 32.6% | | 44.2% | | 56.6% | | 40.0% | | 65.0% | |
| Specialist | 17 | 33.3% | | **58.7%** | | 56.6% | | 49.0% | | 77.7% | |
| Specialty | | | | | | | | | | | |
| Internal medicine | 75 | 34.1% | 0.303 | 45.2% | 0.336 | 48.0% | 0.508 | 39.3% | **0.017** | 69.2% | 0.435 |
| Emergency doctors | 24 | 27.6% | | 40.5% | | 48.3% | | 30.3% | | 62.5% | |
| General surgery | 31 | 32.6% | | 51.5% | | 54.6% | | **48.3%** | | 63.5% | |
| Special surgeries | 23 | 31.0% | | 48.7% | | 46.3% | | **47.6%** | | 86.2% | |
| Year of graduation | | | | | | | | | | | |
| < 1 year | 116 | 31.0% | 0.163 | 41.7% | 0.172 | 45.0% | 0.149 | 33.3% | 0.105 | 69.5% | 0.086 |
| 1-2 years | 53 | 34.8% | | 45.0% | | 44.0% | | 35.6% | | 69.2% | |
| > 2 years | 124 | 32.8% | | 48.7% | | 53.0% | | 43.0% | | 67.7% | |

Bold font indicates statistically significant values <0.050.

**Table 4: Comparison between the samples and results of the health professionals' knowledge about radiation studies in Jordan and other countries**

| Country | Reference | Year | Sample | Level of knowledge |
|---|---|---|---|---|
| Australia | (16) | 2010 | Doctors in the emergency departments | Poor |
| | (17) | 2010 | Student and intern | Lack of knowledge |
| | (3) | 2011 | Doctors from all grades | Poor |
| Hong Kong | (21) | 2012 | Local physicians, radiologists, and interns | Unsatisfactory |
| | (22) | 2012 | Radiologists and non-radiologists doctors | Inadequate among radiologists, and particularly poor in non-radiologists |
| India | (26) | 2014 | Physicians and junior residents | Deficit of knowledge |
| Italy | (31) | 2017 | Physicians | Good level |
| Jordan (This Study) | | 2018 | Internal medicine, emergency doctors, surgery internship, and minor surgeries | Poor |
| Malaysia | (25) | 2012 | Specialists, house officers, medical officers, trainee lecturers. | Poor |
| Morocco | (32) | 2017 | Medical specialists, surgeons, general practitioners, and residents | Poor |
| Nigeria | (24) | 2012 | Medical doctors apart from radiologists | Poor |
| Northern Ireland | (15) | 2008 | Consultants and junior doctors from a range of specialties | Poor |
| Norway | (23) | 2010 | General practitioners | Poor |
| Turkey | (14) | 2007 | Doctors and intern doctors | Inadequate |
| United Kingdom | (13) | 2003 | Senior house officers, specialist registrars, consultants, and consultant radiologists | Poor |
| | (19) | 2006 | Radiologists, nuclear physicians, dual-accredited radiologist–nuclear medicine physicians, medical physicists, and pulmonologists. | Lack of knowledge |
| | (18) | 2017 | Senior medical students | Poor |
| | (20) | 2002 | Doctors of all grades, including consultant radiologists | Lack of knowledge |

Despite the overall poor knowledge that was measured in this study, the respondents showed a fair knowledge about radiation risks (69.0%), which was higher than levels reported by other studies [9], [32], [35]. Furthermore, 77.5% of the respondents in this study had a good level of knowledge about the modalities for radiation dose, in the contrary to the studies of Keijzers and Britton [16] and Gervais *et al*. [36], which showed that the mean error of the physicians' estimates of the radiation dose of imaging modalities was high.

Alternatively, participants showed a poor level of knowledge about radiation doses (32.7%). This may be attributed to the precision of the questions; radiation specialists should be able to answer such questions, while the knowledge of physician is expected to be general. Unlike previous studies [13], [25], [29], [32], this study revealed a poor level of knowledge among physicians about ionizing radiation.

Other statistically significant differences were found between the age groups in the favor of the older age group (over 30 years of age) regarding the radiation risks section. This could be due to gaining experience with time. Bohl *et al*. [37] indicated that experienced physicians have greater knowledge regarding radiation and its effects. Furthermore, the results of this study revealed that specialists were significantly more knowledgeable in regards to ionizing radiation and radiation risks. When comparing the Jordanian case with cases from other countries, similarly, poor levels of knowledge were found [13], [17], [18], [25], [29], [32]. However, there were important differences in the demographics of the population, as some sampled students (17, 18) and some specialists [13], [25], [38].

Underestimation of the risk of radiation doses could expose patients to unnecessary radiological exams and increased risk of adverse events. Physicians must be made aware of the risks involved in receiving radiological examination [22]. Interventional training and courses on the effects of radiation exposure are recommended for physicians who regularly refer patients for such testing. Continuing medical education, quality controls, adherence to referral guidelines, and public campaigns can play a significant role in the quest for appropriate imaging for patients and dose reduction, in terms of collective and individual dose.

The limitations of this study include online distribution of the questionnaire that may lead to untrusted answers and possibility of selection bias. Moreover, the use of a self-reported questionnaire makes it difficult to validate the real knowledge about radiation dose of physicians.

## Conclusion

The results of this study were consistent with previous studies that showed a general poor level of knowledge about radiation dose among referral physicians. This poor knowledge was attributed to the lack of educational courses about radiation. The highest level of knowledge was on radiation risk, followed by ionizing radiation, pediatric radiation, pregnant women radiation, and radiation dose. The poor level of knowledge argues the need for effective tools to expand radiation education for doctors.

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