ACADEMIC: ORIGINAL RESEARCH

Assessment of resident doctors' knowledge levels regarding radiation doses during routine radiological investigations

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Abstract

Background

The biological effects of radiation, its applications, and safety measures are crucial in medical education, yet knowledge varies widely among doctors in different specialties. This study investigates the awareness of resident doctors regarding commonly used radiation doses in medical practices, aiming to identify knowledge gaps across specialties.

Materials and Methods

This descriptive study, conducted from April to June 2023, surveyed 235 resident doctors at a state university hospital in Istanbul, Türkiye to assess their knowledge of the ionising radiation dose received by patients during various radiological imaging procedures. Participants, selected through a non-random convenience sampling method, compared radiation exposure from commonly used radiological exams to that of a standard chest X-ray. Data were analysed using the Chi-Square Test and Fisher's Exact Test.

Results

Among 235 resident doctors surveyed, radiology, and related specialty (nuclear medicine and radiation oncology) residents demonstrated superior accuracy in estimating radiation doses for various radiological tests compared to their counterparts in other departments. Notably, 98.3% of participants accurately estimated pelvic magnetic resonance imaging doses and 99.1% for ultrasound, with no significant differences across departments. Overall, factors such as age, gender, graduation year, and general practice experience did not significantly affect the accuracy of dose estimations.

Conclusion

The study found that resident doctors in radiology and related fields were generally more accurate in estimating radiation doses for various procedures compared to their peers in other specialties. Notably, all residents demonstrated a high level of knowledge regarding the radiation doses in magnetic resonance imaging and ultrasound, and this result was consistent across hospital departments. Despite this, substantial knowledge gaps were observed, especially in departments outside radiology, where residents from medical and surgical specialties more frequently underestimated the radiation doses of computed tomography scans. This knowledge deficit underscores the need for enhanced radiation safety education, emphasising targeted training sessions and expanded curriculum content, particularly in medical and surgical specialties. Addressing these gaps could reduce unnecessary exams, limit patient exposure to ionising radiation, and optimise healthcare costs.

Keywords

Ionising Radiation, Medical Education, Radiation Dose, Radiological Investigation, Resident Doctor

Introduction

Radiation is defined as the transfer and transport of energy through electromagnetic waves or particles. When the energy transported induces ionisation of atoms, it is classified as "ionising radiation".[1]

Radiation is known to induce adverse biological effects in living organisms, varying according to the radiation dose and exposure duration.[2] While individual responses to ionising radiation differ, awareness of its effects emerged at the end of the 19th century. Initial observations highlighted the reversible side effects of radiation on cells, followed by research confirming its carcinogenic effects.[3]

The use of radiological investigation in disease diagnosis has rapidly increased due to technological advancements. As a result, there has been a significant rise in the radiation dose to which patients are exposed in recent years.[4] A study covering the period from 1996 to 2010 reveals that per capita radiation exposure doubled during this time. Moreover, the incidence of high (20-50 mSv) and very high (>50 mSv) annual radiation doses has also doubled.[5]

Estimates suggest that annually, 100-250 deaths in the United Kingdom result from diagnostic radiation exposure.[4] The biological effects of ionising radiation, particularly cancer induction, even at the low doses encountered during diagnostic tests, are well-documented.[5] Studies on post-atomic bomb survivors have further demonstrated the carcinogenic potential of low-dose radiation.[6] The recent Chornobyl disaster has once again underscored the profound effects of radiation on living organisms. Individuals exposed suddenly to high doses experience acute symptoms such as burns, nausea, vomiting, dizziness, and fatigue. Over the long term, consequences include congenital anomalies in pregnancies, increased incidences of cancers, particularly thyroid cancer, cardiovascular diseases, and abortions.[7] This tragedy reaffirmed that the severity of radiation exposure outcomes varies with factors such as dose, duration, and individual susceptibility.[7]

It is of paramount importance that procedures with potential side effects, yet valuable for diagnostic purposes, be conducted judiciously and in adherence to the ALARA (As Low As Reasonably Achievable) principle, considering the cost-benefit ratio. In 1954, the National Council on Radiation Protection and Measurements (NCRP) published recommendations that emphasised the ALARA principle, advocating for the maintenance of radiation doses at the lowest feasible levels.[8]

Numerous studies indicate that doctors working outside radiology and related departments often lack sufficient knowledge in this domain.[5] A systematic review of 3091 studies concluded that, on average, doctors' knowledge about this subject remains at a moderate level, and in certain cases, it is even considered low.[9]

The aim of this study was to assess resident doctors' knowledge of the radiation doses associated with commonly utilised radiological imaging methods.

Materials And Methods

This descriptive study was conducted with volunteer resident doctors from a state university hospital in Istanbul, Türkiye, between April and June 2023.

The study population consisted of 600 resident doctors working at the hospital. We determined that a sample of 235 participants would give us a reasonable sample size to run our analysis. 235 resident doctors were selected via a non-random convenience sampling method.

A survey questionnaire, divided into two sections, was administered to participants through face-to-face data collection techniques. The first section contained seven questions aimed at gathering sociodemographic data, including age, gender, year of graduation, current hospital department, experience as a general practitioner, and years spent in the healthcare field as a doctor. Possible hospital departments included Plastic Surgery, Orthopaedics, Ear, Nose, and Throat (ENT), Obstetrics and Gynaecology, Thoracic Surgery, Cardiovascular Surgery, Ophthalmology, General Surgery, Paediatric Surgery, Neurosurgery, Anaesthesia, Radiology, Radiation Oncology, Nuclear Medicine, Neurology, Cardiology, Infectious Diseases, Internal Medicine, Public Health, Respiratory Medicine, Physical Medicine and Rehabilitation, Clinical Pharmacology, Dermatology, Paediatrics, Family Medicine, and Emergency Medicine. The second section comprised nine multiple-choice questions designed to assess participants' knowledge of the radiation doses associated with commonly used radiological investigations when compared to a standard chest X-ray. For instance, participants were asked how many chest X-rays' worth of radiation a brain computed tomography (CT) scan, or a Magnetic Resonance Imaging (MRI) would correspond to. In evaluating the radiation doses for routine medical investigations, data from the "United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2020/2021" report were utilised.[10]

In our study, we used the methodology outlined by Paolicchi and colleagues[2] as a reference to define acceptable ranges of responses. This methodology provides benchmark values for typical radiation doses associated with different imaging procedures.

Using chest X-rays as the standardised reference, if the doctors' estimation of the radiation dose fell within the accepted range, it was considered an 'accurate estimate'. If the guess was above the accepted range, it was labelled as a 'high estimate'. If the guess was below the accepted range, it was labelled as a 'low estimate'. This approach simplified the comparison and helped respondents relate complex radiation dose information to a familiar and comprehensible reference point. The acceptable ranges were as follows:

1. 0 or No radiation
2. (>0) – 20
3. 21 – 100
4. 101 – 500
5. >500

The data collected through a written survey during face-to-face interactions were transferred to Microsoft Excel and subsequently analysed using statistical software. All information was de-identified. Descriptive statistics were used to present categorical variables, reporting counts, and percentages. Binary categorical variables were compared using Chi-Square and Fisher's Exact tests, with statistical significance defined as $p < 0.05$.

We obtained the necessary permissions from the Clinical Research Ethics Committee of the university's medical faculty under protocol number 09.2023.572, dated April 7, 2023. Our research was conducted in accordance with the principles outlined in the Helsinki Declaration. Prior to conducting the face-to-face survey, informed consent was obtained from all participants. Additionally, we received permission via email from Dr. Fabio Paolicchi[2] to utilise the questions in the second part of the survey, which assesses the knowledge levels of resident doctors regarding radiation doses.

Results

Among the 235 resident doctors who participated in the study, 46.8% (n=110) were female, while 53.2% (n=125) were male. The average age of the participants was 28.5 ± 2.22 years (Table 1). These results are representative of the wider hospital population, as the sample size was calculated at the beginning of the research to ensure statistical sufficiency and representativeness.

Table 1 also summarises additional sociodemographic characteristics of the participants, including their graduation period, department of work, and experience as a general practitioner.

The approximate radiation doses from commonly used radiologi-

Table 1: Distribution of participants based on sociodemographic characteristics.

Socio-demographic characteristics	*n*	*%*
Gender (n=235)		
Female	110	46.8
Male	125	53.2
Graduation period (n=235)		
2021-2022	20	8.5
2020-2021	46	9.6
2019-2020	78	33.2
2018-2019	46	19.6
Before 2018	45	19.1
Department of work (n=235)		
Medical Specialties	111	59.4
Surgical Specialties	46	24.6
Radiology and Related Specialties	30	16.0
Experience as a general practitioner (n=235)		
Yes	187	79.6
No	48	20.4
Age (28.5 ± 2.22)	Mean+SD [a]	Min. and Max.
Female (n=110)	28.63 ± 1.99	25-36
Male (n=125)	28.38 ± 2.41	25-41

[a] SD: Standard Deviation (SD)

Table 2: Comparative radiation doses (mSv) of radiological imaging methods compared to chest X-rays.

Radiological imaging methods	Radiation dose (mSv)	Approximate equivalent in terms of chest X-ray
Chest X-ray	0.08	1
Head X-ray	0.08	1
Head CT [a]	1.7	21
Chest CT [a]	6.4	80
Extremity X-ray	0.02	0.25
Abdomen X-ray	0.61	7
Abdomen CT [a]	11	137
Cardiac Angiography	7	87
Pelvis MRI [b]	0	0
Ultrasound	0	0

[a] CT: Computed Tomography

[b] MRI: Magnetic Resonance Imaging.

Table 3: Distribution of low/accurate/high estimates of radiation doses by hospital department.

		Department of work				
		Medical specialties	Surgical specialties	Radiology and related specialties	Total	P value
	Estimates	n (%)	n (%)	n (%)	n (%)	
Head X-ray (n=235)	Low	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	<0.001[a]
	Accurate	95 (67.9%)	34 (56.7%)	35 (100.0%)	164 (69.8%)	
	High	45 (32.1%)	26 (43.3%)	0 (0.0%)	71 (30.2%)	
Head CT (n=235)	Low	38 (27.1%)	19 (31.7%)	1 (2.9%)	58 (24.7%)	<0.001[a]
	Accurate	58 (41.4%)	24 (40.0%)	34 (97.1%)	116 (49.4%)	
	High	44 (31.4%)	17 (28.3%)	0 (0.0%)	61 (26.0%)	
Chest CT (n=235)	Low	50 (35.7%)	24 (40.0%)	6 (17.1%)	80 (34.0%)	<0.001[a]
	Accurate	51 (36.4%)	18 (30.0%)	29 (82.9%)	98 (41.7%)	
	High	39 (27.9%)	18 (30.0%)	0 (0.0%)	57 (24.3%)	
Extremity X-ray (n=235)	Low	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	<0.001[a]
	Accurate	72 (51.4%)	28 (46.7%)	35 (100.0%)	135 (57.4%)	
	High	68 (48.6%)	32 (53.3%)	0 (0.0%)	100 (42.6%)	
Abdomen X-ray (n=235)	Low	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	<0.001[a]
	Accurate	80 (57.1%)	29 (48.3%)	32 (91.4%)	141 (60.0%)	
	High	60 (42.9%)	31 (51.7%)	3 (8.6%)	94 (40.0%)	
Abdomen CT (n=235)	Low	108 (77.1%)	45 (75.0%)	7 (20.0%)	160 (68.1%)	<0.001[a]
	Accurate	25 (17.9%)	12 (20.0%)	28 (80.0%)	65 (27.7%)	
	High	7 (5.0%)	3 (5.0%)	0 (0.0%)	10 (4.3%)	
Cardiac angiography (n=235)	Low	14 (10.0%)	7 (11.7%)	1 (2.9%)	22 (9.4%)	<0.001[a]
	Accurate	60 (42.9%)	27 (45.0%)	30 (85.7%)	117 (49.8%)	
	High	66 (47.1%)	26 (43.3%)	4 (11.4%)	96 (40.9%)	
Pelvis MRI (n=235)	Low	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1.000[b]
	Accurate	137 (97.9%)	59 (98.3%)	34 (100.0%)	230 (98.3%)	
	High	3 (2.1%)	1 (1.7%)	0 (0.0%)	4 (1.7%)	
Ultrasound (n=235)	Low	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.646[b]
	Accurate	139 (99.3%)	59 (98.3%)	35 (100.0%)	233 (99.1%)	
	High	1 (0.7%)	1 (1.7%)	0 (0.0%)	2 (0.9%)	

[a] *Chi-Square test*
[b] *Fisher's Exact Test*

Table 4: Distribution of low/accurate/high estimates of radiation doses among doctors in medical and surgical specialties.

		Department of work			
		Medical specialties	Surgical specialties	Total	P value
	Estimates	n (%)	n (%)	n (%)	
Head X-ray (n=200)	Low	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.130[a]
	Accurate	95 (67.9%)	34 (56.7%)	129 (64.5%)	
	High	45 (32.1%)	26 (43.3%)	71 (35.5%)	
Head CT (n=200)	Low	38 (27.1%)	19 (31.7%)	57 (28.5%)	0.797[a]
	Accurate	58 (41.4%)	24 (40.0%)	82 (41.0%)	
	High	44 (31.4%)	17 (28.3%)	61 (30.5%)	
Chest CT (n=200)	Low	50 (35.7%)	24 (40.0%)	74 (37.0%)	0.677[a]
	Accurate	51 (36.4%)	18 (30.0%)	69 (34.5%)	
	High	39 (27.9%)	18 (30.0%)	57 (28.5%)	
Extremity X-ray (n=200)	Low	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.537[a]
	Accurate	72 (51.4%)	28 (46.7%)	100 (50.0%)	
	High	68 (48.6%)	32 (53.3%)	100 (50.0%)	
Abdomen X-ray (n=200)	Low	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.252[a]
	Accurate	80 (57.1%)	29 (48.3%)	109 (54.5%)	
	High	60 (42.9%)	31 (51.7%)	91 (45.5%)	
Abdomen CT (n=200)	Low	108 (77.1%)	45 (75.0%)	153 (76.5%)	0.937[a]
	Accurate	25 (17.9%)	12 (20.0%)	37 (18.5%)	
	High	7 (5.0%)	3 (5.0%)	10 (5.0%)	
Cardiac angiography (n=200)	Low	14 (10.0%)	7 (11.7%)	21 (10.5%)	0.866[a]
	Accurate	60 (42.9%)	27 (45.0%)	87 (43.5%)	
	High	66 (47.1%)	26 (43.3%)	92 (46.0%)	
Pelvis MRI (n=200)	Low	0 (0.0%)	0 (0.0%)	0 (0.0%)	1.000[b]
	Accurate	137 (97.9%)	59 (98.3%)	196 (98.0%)	
	High	3 (2.1%)	1 (1.7%)	4 (2.0%)	
Ultrasound (n=200)	Low	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.511[b]
	Accurate	139 (99.3%)	59 (98.3%)	198 (99.0%)	
	High	1 (0.7%)	1 (1.7%)	2 (1.0%)	

[a] *Chi-Square test*
[b] *Fisher's Exact Test*

cal tests are expressed in terms of equivalent chest X-ray exposures (Table 2). These assessments were then stratified by participant age group, gender, graduation year, department, and experience as a general practitioner.

Table 3 illustrates the distribution of resident doctors' estimates of radiation doses, categorised as lower, accurate, or higher than the actual values, and organised by department.

When analysing responses to dose estimation questions for head X-rays, head CTs, chest CTs, extremity X-rays, abdomen X-rays, abdomen CTs, and cardiac angiography, a significantly higher rate of correct answers was observed among residents in radiology and related specialties (Table 3). However, upon excluding residents from the radiology and related departments from the analysis, no significant difference was observed in the rate of correct responses to these initial seven questions among residents in medical and surgical specialties (Table 4).

In the assessment of dose estimation, doctors demonstrated high accuracy, with 98.3% correctly answering the question on pelvic MRI dose estimation and 99.1% providing accurate responses for an ultrasound scan (USS) dose estimation. Notably, the hospital department a doctor belongs to did not significantly influence the residents' ability to estimate the doses accurately for pelvic MRI and USS (Table 3). Further analysis revealed that participant factors such as age group, gender, years of graduation, and experience as a general practitioner did not significantly influence the accuracy of responses to the dose estimation questions.

Residents in surgical specialties tended to underestimate the true values for head CT, chest CT, and cardiac angiography questions more frequently than doctors from specialties related to radiology or medicine. Conversely, they were more likely to overestimate values for head X-rays, chest CTs, extremity X-rays, and abdomen X-rays, again at a higher rate than residents from other departments. However, it is important to note that these differences were not found to be statistically significant (Table 4).

Residents in medical specialties tended to provide lower estimations than the actual values for the abdomen CT question at a higher rate compared to other residents. Similarly, for the head CT and cardiac angiography questions, they tended to overestimate the radiation dose at a greater rate than doctors from other departments. Notably, these differences were not statistically significant (Table 4).

In evaluating the last two questions concerning pelvic MRI and USS dose estimation relative to the department of work, significant differences were not found (Table 4).

No significant differences were observed in the distribution of overestimations or underestimations of dose estimates with respect to gender, age, graduation period, or experience as a general practitioner.

Discussion

Currently, the global utilisation of radiological examinations for diagnostic purposes is on the rise.[11] Despite their widespread use, healthcare professionals do not adequately understand both the radiation doses involved in these examinations and their potential effects. Accordingly, our study aimed to investigate the accuracy of resident doctors' estimates of radiation doses in commonly utilised radiological investigations, considering variables such as age, gender, year of graduation, and experience as general practitioners.

A systematic review emphasised that misconceptions about radiation often manifest as underestimations of the actual radiation dose.[12] This gap in knowledge is particularly evident in queries about CT scans, which involve higher radiation doses.[13]

Our study found that a quarter of resident doctors underestimated the radiation dose of brain CT scans, a third did so for lung CT scans, and two-thirds for abdominal CT scans. Among all surveyed questions, the radiation doses of CT scans were the least accurately estimated. Similar research conducted in Türkiye reported that 46.3% of resident doctors underestimated radiation doses.[14] In contrast, in Australia, only 17.3% of doctors accurately estimated the radiation dose of CT scans.[15] Another study highlighted that 93.1% of doctors and interns (6th-year medical students) underestimated patient radiation exposure during radiological investigations.[16] These findings indicate a global trend among doctors to underestimate the radiation doses of routinely used radiological investigations, especially CT scans.[15,17] The importance of accurately assessing CT scan radiation doses has grown, particularly given the twelvefold increase in CT scan use in emergency departments during the COVID-19 pandemic, most notably among younger patients.[18] Moreover, this underestimation could lead to a reduced perception of risk and consequently an increase in the demand for radiological investigations, highlighting the importance of addressing this issue.[16]

Our study found that nearly all resident doctors were aware that MRI and USS investigations do not involve ionising radiation. This finding aligns with a study where 100% of radiology residents recognised the absence of radiation in MRI procedures.[19] Contrastingly, a cross-sectional study in Malaysia reported that 4% of doctors in non-radiology departments were unaware that USS does not emit radiation, and 34% were similarly uninformed about MRI.[20] The higher awareness of MRI and USS among our study's participants could be attributed to the emphasis placed on these radiological investigations in the medical education curriculum in Türkiye.

In our study, when categorising and analysing resident doctors by department, it was observed that, as anticipated, residents in radiology and related fields were more adept at accurately estimating the radiation doses of radiological examinations in comparison to their peers in other disciplines. This finding aligns with similar research in the literature, which consistently shows that radiologists have greater knowledge of radiation doses than doctors in non-radiological departments.[5,21-23] It underscores a significant knowledge gap among doctors in medical and surgical specialties.

In our analysis, the correlation between the accuracy of questionnaire responses provided by resident doctors and their graduation years was statistically insignificant. That is, an increase in the duration and experience within the profession did not correspond to an improvement in knowledge level. This observation is in line with a study carried out in a paediatric department, which also reported no significant enhancement in residents' knowledge with greater seniority.[24] These outcomes challenge the prevalent assumption in the existing literature, that knowledge accumulation increases proportionally with experience.[15,25] A potential explanation for the absence of a discernible relationship between experience level and knowledge could be the relatively young average age of our study participants, coupled with the fact that nearly three-quarters of them had graduated post-2018. Future research might explore these dynamics further by including a broader participant base, such as specialist doctors and academics, to better understand variations in knowledge acquisition over time.

This research highlights areas for quality improvement. Residents in non-radiological specialties still fall short of the necessary knowledge level. To improve the accuracy of risk-benefit assessments for radiological investigations, targeted educational initiatives, such as training sessions and seminars, are needed, particularly within medical and surgical specialties. Arguably, non-radiology doctors should know the most about the dose of radiation exposure, given that they most often counsel patients about the potential risks/benefits of radiological investigations. Incorporating additional coursework on this topic into the medical curriculum could serve as an effective intervention. Currently, many medical schools allocate insufficient time to radiology internships, underscoring a significant gap in medical education.[26] A comprehensive review of the existing curriculum, along with the promotion of radiological safety courses and the development of quick reference tools on radiation doses, could help address this discrepancy effectively. A more informed approach across all specialties would support safer, more cost-effective care and foster a culture of conscientious imaging practices in healthcare.

Our study has several limitations. Firstly, the selection of only resident doctors as participants resulted in a homogeneous group in terms of professional experience, limiting the ability to discern differences across varying levels of expertise. Expanding the sample size could potentially mitigate this. Additionally, the study's conduct within a single hospital setting restricts the generalisability of our findings to the broader population. Furthermore, grouping multiple subspecialties into a single category may have influenced the analysis, as it fails to account for potential differences in radiation knowledge across various fields of specialisation.

Conversely, the strengths of our study are noteworthy. It tackles a significant issue within the realm of medical diagnostics and radiation awareness. The achievement of the calculated sample size ensures that our sample is representative of the hospital population from which it was drawn, lending credibility to our findings within this context.

Conclusion

In this study, we assessed resident doctors' knowledge of radiation doses in radiological imaging across various specialty areas, gender, graduation years, and age groups. The findings highlight a significant gap in their understanding of radiation doses, particularly concerning radiological procedures other than MRI and USS. A significant underestimation of CT scan radiation doses was observed among residents from medicine and surgical departments. This underestimation underscores a profound knowledge gap, potentially leading to the ordering of unnecessary radiological investigations, increased patient exposure to ionizing radiation, and higher healthcare costs. As imaging demands continue to grow globally, addressing this knowledge gap becomes even more critical.

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Ethical approval/patient consent

Necessary permissions to conduct this research were obtained from the Clinical Research Ethics Committee of Marmara University Medical Faculty, protocol number 09.2023.572, dated 07/04/2023. The research was conducted in accordance with the principles outlined in the Helsinki Declaration. Prior to conducting the face-to-face survey, informed consent was obtained from all participants.

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