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Knowledge and perceptions of ionising radiation among Croatian general practitioners: is there cause for concern?

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Recent data suggest that general practitioners (GPs) are insufficiently familiar with health risks associated with ionising radiation and radiation doses. The aim of our cross-sectional study was therefore to see if this holds true for Croatian GPs. To do that, we distributed a questionnaire about ionising radiation and doses used in various radiological procedures by email or by handing it out to participants at a national GP conference. We received responses from 120 participating GPs. Most were women (83.1 %), and the mean participant age was 44.2 years (range 26–65) with mean practice of 17.1 years (range 1–40). Most participants (97 %) believed patients should be informed about the procedures they were referred to. All respondents knew that radiological procedures irradiate the patient's body, but not everyone agreed that they could be harmful. Less than half (47 %) thought that exposure to a single irradiation dose was enough to increase cancer risk. Most participants (89.2 %) identified X-ray scans as the largest irradiation source, whereas three GPs replied that computed tomography (CT) and conventional X-ray procedures did not involve radiation. Some respondents did not know if ultrasound involved ionising radiation. Although most GPs were women, only 21.7 % correctly identified the radiation dose in mammography. Our findings confirm inadequate GPs' knowledge of radiation exposures and call for better training programmes as part of continuing professional development.

KEY WORDS: continuing professional development; CT; GP; irradiation doses; mammography; radiological procedures; ultrasound; X-ray

Recent decades have seen a high increase in the medical use of ionising radiation, of multi-slice computed tomography (CT) in particular (1–4). According to the 2006 report of the National Council on Radiation Protection and Measurements (NCRP) (5), exposure of the US general population to ionising radiation from diagnostic procedures had increased seven times since the early 1980s. Overall medical exposure, including treatment, accounted for 48 % of total exposure (background and medical), while CT alone accounted for 24 %. Between the 1980s and 2006, the estimated cumulative individual dose from all sources almost doubled (from 3.6 mSv to 6.2 mSv). Save for environmental exposure estimates (6), corresponding medical exposure data for Croatia are missing.

General practitioners (GPs) often refer patients to plain radiography, CT scans, and other forms of imaging to assist them in diagnosis and treatment. However, estimates are that half of these procedures are unnecessary and mainly owed to patient's wishes, defensive medicine, and media influence (7). Furthermore, previous systematic reviews have shown suboptimal radiation knowledge of referring physicians (1, 8), with many of them not knowing even the basic terms and principles regarding radiation safety, like the "as low as reasonably achievable" (ALARA) principle (9, 10). Our aim was therefore to see how Croatian GPs would fare in this respect by testing their knowledge of diagnostic radiological procedures and involved radiation doses.

PARTICIPANTS AND METHODS

This study is an extension of a study investigating patients' knowledge of radiation (11) and was approved by the Ethics Committee of the Merkur University Hospital, Zagreb (approval No. 0311–1347 of 14 February 2018).

We distributed a questionnaire to GPs from all over Croatia, most of whom worked in Zagreb, the nation's capital. Participants received the questionnaire either by email or as a handout at a national GP conference with an accompanying letter explaining the

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aim of the study. Participation was anonymous, voluntary, and implied consent of those who completed the questionnaire.

This questionnaire is based on similar, previously published surveys (12–14). The first part covers demographics, including gender, age, specialisation, years of medical practice, and whether the participants have ever taken a radiation protection course. The second part investigates general knowledge about radiation exposure in common radiological procedures and whether the participants inform their patients about medical imaging and associated risks. Eight items require yes or no answers and eight are multiple-choice. The last question investigates specific knowledge about the exposure doses of nine imaging methods. The participants are asked to assign to each method the equivalent number of units, assuming that 1 unit corresponds to the effective dose of standard chest X-ray (0.1 mSv) (15).

Replies were evaluated by an independent panel of radiology experts. Correct answers are available at the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) website (15). Multi-choice answers to the last question were analysed based on the article published by Wong et al. (16). Each answer was scored between 1 and 6, depending on the range corresponding to standard chest X-ray effective dose described above. If the answer was 0, the score was 1; if 1–49 (units), the score was 2, and so on. If the question was left blank or answered as „do not know", it was scored 0.

We then constructed a *radiation knowledge index* (RKI), a score based on respondents' correct answers to yes/no and multiple-choice questions. Each correct answer was awarded one point, while incorrect and missing answers received zero points.

Statistical analysis

The respondents were then divided into three groups according to their specialisation [family medicine specialists, family medicine residents, and other (no specialisation or any other specialist working as GP)], and group averages for each item compared with the right answer using the one-sample *t*-test. If the group average did not significantly differ from the answer, it was considered "correct". The difference between group average and correct answers, named right answer–mean answer difference (RMD), was applied to describe the extent of answer error. In total, there were nine RMD values for each group, and the mean RMD served to estimate how wrong the answers of the specific group were.

RMD means were compared between the three groups using a paired-sample *t*-test. All statistical analyses were run on STATISTICA for Windows (version 14.1.0, TIBCO, Palo Alto, CA, USA).

Table 1 Sociodemographic data of participating general practitioners from Croatia (N=120)

Mean age (and range) (years)		44.2 (26–65)
Gender* (%)	Female	83.1
	Male	16.9
Specialisation (%)	Family medicine	57.5
	Family medicine residents	23.3
	Others (no specialisation or any other specialisation working as GP)	19.2
Mean years of service (and range)		17.1 (1–40)
Have you ever taken any radiation protection course? (%)	yes	5.8
	no	94.2

*two respondents did not specify gender

Table 2 Replies of Croatian GPs (N=120) to the second set of yes/no questions establishing their referral practices and general knowledge of radiological procedures (preferable/correct answers are in boldface)

	Yes	No
	%	
Have you ever been asked by a patient to provide additional information about the radiological procedure to which you refer them?	**69.2**	30.8
Do you inform your patients sufficiently about radiological procedures to which you refer them?	**88.3**	11.7
Is informing patients necessary?	**97.5**	2.5
Can some radiological procedures irradiate patient's body?	**100.0**	
Can radiation harm patients' health?	**91.6**	8.4
Can single exposure to ionising radiation during a radiological procedure increase the risk of cancer?	**47.5**	43.3
Can repeated exposure to ionising radiation during radiological procedures increase the risk of cancer?	**94.2**	4.2
Is your knowledge of ionising radiation involved in radiological procedures sufficient for your daily work at the clinic?	**27.5**	72.5

Table 3 Replies of Croatian GPs (N=120) to the third set of multiple choice questions establishing their knowledge of radiation exposure through diagnostic imaging procedures (correct answers are in boldface)

Question	Reply (%)
Which of the selected imaging procedures do not expose patients to ionising radiation?	
Plain radiography	0.8
CT scan	1.7
MRI	**97.5**
Angiography	0
When selecting the appropriate radiologic procedure, what is the priority?	
To minimise radiation dose	27.5
To address the clinical issue	**69.2**
To reduce diagnostic expenses	0
To avoid radiation	2.5
Don't know	0.8
What age is most at cancer risk because of radiation exposure?	
10 years	**73.3**
30 years	5.8
50 years	5.8
70 years	3.3
Don't know	11.7
Which of the selected imaging procedures involves highest ionising radiation doses?	
Plain radiography	**89.2**
MRI	0
Mobile phone	7.5
Ultrasound	0
Don't know	3.3
Repeated brain CT can cause:	
Headaches	8.5
Cataract	**59.3**
Nothing	0.8
Don't know	31.4
The lowest lethal effective dose of radiation is:	
0.5 Sv	1.7
5 Sv	**15.8**
50 Sv	11.7
500 Sv	12.5
Don't know	58.3
The most sensitive organ to ionising radiation is:	
Skin	8.3
Bone marrow	**69.2**
Thyroid gland	15.8
Don't know	6.7
How important it is to know about ionising radiation in diagnostic imaging	
Very important	**59.2**
Important	37.5
Less important	3.3
Unimportant	0

RESULTS

A total of 120 GPs completed the questionnaire. Among those who received it by email (N=84), the response rate was nearly 100 %. The response rate of the rest (N=36) was 50 %.

Table 1 shows the respondents' demographic information. Most were women and family medicine specialists and most had never attended a radiation protection course.

Tables 2 and 3 show the prevalences of answers to the second set of questions regarding GPs' practice and general knowledge about radiological procedures to which they refer their patients.

Table 4 shows the prevalences of answers to the question about effective radiation doses involved in nine specific radiological procedures. Many GPs admitted that they did not know the answers and many provided incorrect answers, save for brain MRI. A glaring example is that as many as 20 % did not know if kidney ultrasound involved ionising radiation. In addition, although most respondents were women, only 21.7 % answered correctly about the radiation dose involved in mammography.

The radiation knowledge index of our respondents ranges between 4 and 16 (mean ± SD = 10.06±2.511) and is significantly higher in male GPs ($P<0.05$) (Table 5). Between family medicine specialists, residents, and others, however, it does not differ significantly (Table 6).

Table 7 shows that these groups showed poor knowledge about radiation doses involved in various diagnostic procedures as their mean scores mostly significantly differed from the right (correct answers). The exceptions are family medicine specialists answering correctly to questions about lumbar CT and kidney ultrasound, residents answering correctly about brain MRI and kidney ultrasound, and others answering correctly about lumbar CT, brain MRI, and kidney ultrasound.

The association between the RKI and years of service was not statistically significant (Spearman's rho=-1.065, $P=0.074$) for the entire sample or for each group (Kruskal-Wallis $H=6.539$, $P=0.478$).

Considering that the distribution of RMD values did not deviate significantly from normal (Table 8), we compared the arithmetic means of RMDs between the groups using a paired-sample *t*-test, which reveals significant differences between family medicine specialists and residents as well as between residents and others (Table 9).

DISCUSSION

Our study highlights a disconcerting lack of knowledge among GPs regarding radiation exposure from diagnostic imaging, a finding consistent with previous research. Most GPs had not attended radiation protection courses, mirroring the study by Willoughby et al. (7), where only 28 % of GPs had prior training. Research has shown that such training significantly improves physicians' ability to estimate radiation risks and doses (17, 18).

A key issue is the limited awareness of guidelines for radiological referrals. Many physicians are unfamiliar with the ALARA principle (3, 9, 10, 19–22), and studies indicate that adherence to referral guidelines can significantly reduce unnecessary imaging (21).

Even so, most of our GPs reported a higher rate of patient communication informing patients about radiographic procedures than other specialties reported by Lumbreras et al. (19), who also noted that prior education on radiation exposure increased the likelihood of discussing potential risks with patients. Lam et al. (1) reported that while patients preferred discussing risks with their referring physician, more than half of physicians felt this responsibility should fall on radiologists.

Considering the factors influencing referral decisions, most respondents reported the clinical issue as the key factor in selecting imaging modalities, with only a minority prioritising minimal exposure. This is in line with the report by Borgen et al. (3), who found that GPs and hospital physicians valued radiation dose less than the diagnostic benefit of imaging. In fact, 88.3 % of GPs in

Table 4 Replies of Croatian GPs (N=120) to the question: "If the single chest X-ray is taken as a dose unit, how much radiation does a person receives during the following procedures?" (correct answers are in boldface)

	Chest X-ray unit* (score)						
Procedure	**0 (1)**	**1–49 (2)**	**50–99 (3)**	**100–199 (4)**	**200–499 (5)**	**≥500 (6)**	**Do not know/blank (0)**
Abdominal CT	1.7	15.8	17.5	10.8	14.2	**21.7**	18.3
Intravenous urography	6.7	20.8	15.8	**15.8**	15.0	3.3	22.5
Barium meal	11.7	20.8	14.2	13.3	**12.5**	2.5	25.0
Lumbar spine CT	2.5	15.0	18.3	**14.2**	22.5	3.3	24.2
Brain MRI	**73.3**	1.7	2.5	0.8	0.0	0.8	20.8
Brain MRI with contrast	**58.3**	10.8	2.5	1.7	3.3	0.0	23.3
Lumbar spine X-ray	47.5	20.0	**6.7**	3.3	0.8	0.0	21.7
Mammography	50.8	**21.7**	6.7	2.5	0.0	0.0	18.3
Renal US	**80.0**	0.0	0.0	0.0	0.0	0.0	20.0

* 1 unit = 0.1 mSv

Table 5 Differences in the radiation knowledge index (RKI) between male and female respondents (N=120)

Gender	N	Mean rank	Sum of ranks	P*
Male	20	75.25	1505.00	665.000; 0.023
Female	98	56.29	5516.00	
Total**	118			

*Mann-Whitney *U* test; ** two respondents did not specify their gender and were excluded from analysis

Table 6 Differences in the radiation knowledge index between specialisations (N=120)

Specialisation	N	Mean rank	P*
Family medicine specialists	69	57.33	1.602; 0.449
Family medicine residents	28	62.68	
Others	23	67.35	
Total	120		

*Kruskal-Wallis (H) test; Others – physicians with no specialisation or other specialisation working as GPs

this study referred patients for imaging that was unlikely to alter treatment, largely due to patient expectations. In some settings, overuse of imaging was owed to considerations such as workload pressure and wish to "avoid a lawsuit" (20).

Gaps in knowledge about radiation risks and biological effects

Although all participants acknowledged that some radiological procedures involve radiation exposure, 8.4 % disagreed that radiation could be harmful. Some even believed that mobile phones posed greater risks than plain (X-ray) radiography. Previous studies have reported a similar lack of awareness, with many physicians unable to tell the difference between deterministic and stochastic biological effects of radiation (3, 4).

Another critical gap was in recognising which imaging modalities use ionising radiation. While MRI was correctly identified as non-ionising by 97.5 % of respondents, some mistakenly believed CT (1.7 %) and X-ray (0.8 %) were non-ionising. Previous studies have found that 1–35 % of physicians misclassified MRI, and 0.5–24 % misidentified ultrasound as a radiation source (1–3, 7, 8, 10, 17, 23).

In response to the last question, our GPs struggled to correctly estimate radiation doses of various imaging procedures; many did not know the answer, and a great majority answered incorrectly, save for brain MRI, which most correctly recognised as non-irradiating procedure. In fact, an overwhelming majority underestimated the effective doses of the imaging procedures involving ionising radiation. This is probably the key finding of our study, and it confirms earlier findings that underestimation of effective doses is widespread among physicians regardless of specialisation (3, 7, 8, 17, 23–26).

The pairwise comparison of mean RMDs shows that residents performed worse in radiation dose estimation than family medicine specialists and other physicians (Table 9; $P<0.015$ and $P<0.004$, respectively), yet did not differ from these two groups significantly in the radiation knowledge index, most likely because RKI includes not only the last question on specific doses for each imaging procedure. We find this finding somewhat surprising, considering that residents had finished their medical school more recently than those with completed specialisations and should be better acquainted with updated information. However, this finding confirms previous research indicating that medical students have substantial knowledge deficits in this area (27–29). In contrast, greater clinical experience appears to contribute to improved understanding over time.

Study limitations

This study has limitations, particularly regarding the sampling methods. The initial snowball sampling may have introduced selection bias, and the 50 % response rate in the second phase could reflect nonresponse bias. Additionally, while a gender-based difference in radiation knowledge was observed, the study design was not suited to explore the underlying reasons. Future research should investigate factors contributing to these disparities and evaluate the effectiveness of targeted educational interventions for improving physicians' radiation knowledge and referral practices.

Table 7 Group mean scores in the answers to the last question by specialisation among Croatian GPs (N=120)

	Abdominal CT	Intravenous urography	Barium meal	Lumbar spine CT	Brain MRI	Brain MRI with contrast	Lumbar spine X-ray	Mammography	Renal ultrasound
Correct answer	6	4	5	4	1	1	3	1	1
Family medicine specialists	**3.95***	**3.5***	**3.1***	3.76	**1.17***	**1.49***	**1.73***	**1.51***	1
Family medicine residents	**3.77***	**2.77***	**2.68***	**3.32***	1.21	**1.5***	**1.3***	**1.61***	1
Others	**4.57***	**3.26***	**3.21***	3.75	1.11	1.26	**1.6***	**1.45***	1

*Significant right answer – mean answer difference (RMD), i.e., significant difference between mean score and correct answer maximum score ($P<0.05$); Others – physicians with no specialisation or other specialisation working as GPs; CT – computed tomography; MRI – magnetic resonance imaging

Table 8 Test of distribution normality for RMD values for the three specialisations

RMD	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Significance	Statistic	df	Significance
Family medicine specialists	0.312	9	0.012	0.844	9	0.065
Family medicine residents	0.224	9	0.200	0.910	9	0.317
Others*	0.211	9	0.200	0.878	9	0.151

*physicians with no specialisation or other specialisation working as GPs; [a]Lilliefors significance correction; RMD – Right answer - mean answer difference

Table 9 Pairwise comparison of RMD scores between specialisation groups

		Paired differences					t	df	Significance (two-tailed)
		Mean	SD	SE	95 % Confidence interval of the difference				
					Lower	Upper			
Pair 1	Family medicine specialists vs residents	-0.261	0.255	0.085	-0.457	-0.065	-3.078	8	**0.015**
Pair 2	Family medicine specialists vs others	0.078	0.244	0.081	-0.109	0.265	0.956	8	0.367
Pair 3	Residents vs others	0.339	0.249	0.083	0.148	0.530	4.085	8	**0.004**

Values in boldface denote significant difference between pairs (P<0.05); Others – physicians with no specialisation or other specialisation working as GPs; RMD – Right answer - mean answer difference; SD – standard deviation; SE – standard error of the mean

CONCLUSION

This cross-sectional study clearly reveals major gaps in knowledge about radiological procedures among Croatian general practitioners, which seems to be consistent with other countries. One of the reasons is the lack of continuing professional development in this respect, that is, a lack of radiation courses that would fill these gaps and refresh their memories. We therefore urge for additional pre- and post-graduate radiological training and utilising tools such as referring guidelines to improve the current situation. Furthermore, more nuanced studies are needed to identify specific gaps that need addressing.

Conflict of interests

None to declare.

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Znanje i percepcija liječnika obiteljske medicine u Hrvatskoj o ionizirajućem zračenju – ima li razloga za zabrinutost?

Dosadašnja su istraživanja pokazala kako liječnici obiteljske medicine (LOM) nisu dovoljno upoznati sa zdravstvenim rizicima koji su povezani s ionizirajućim zračenjem i dozama zračenja. Cilj ovoga presječnog istraživanja bio je provjeriti jesu li spomenute tvrdnje istinite i za LOM u Hrvatskoj. Istraživanje je provedeno na temelju anonimiziranih upitnika koji su podijeljeni LOM-u putem elektroničke pošte i tijekom nacionalnoga kongresa LOM-a. Ukupno je njih 120 ispunilo upitnike. Sudionici su većinom bile žene (83,1 %) i srednja dob bila je 44,2 godine (raspon 26 – 65) s prosjekom rada u struci od 17,1 godina (raspon 1 – 40). Stav većine sudionika (97 %) bio je da pacijenti trebaju biti informirani o radiološkim postupcima na koje se šalju. Svi su sudionici znali da se nekim radiološkim postupcima ozračuje tijelo pacijenata, međutim nisu se svi složili da to može imati štetne učinke. Manje od polovice sudionika (47 %) smatralo je da je samo jedno izlaganje ionizirajućem zračenju dovoljno da se poveća rizik od maligne bolesti. U većini slučajeva (89,2 %) RTG snimanje smatrano je najvećim izvorom zračenja, a troje sudionika pogrešno je zaključilo da se tijekom CT i konvencionalnog RTG snimanja ne primjenjuje ionizirajuće zračenje. Neki sudionici nisu znali je li ultrazvuk ionizirajući postupak. Iako su većina sudionika bile žene, samo je 21,7 % njih točno procijenilo dozu zračenja kod mamografije. Ova je studija pokazala neadekvatno znanje LOM-a o izlaganju zračenju te potrebu za unaprjeđenjem edukacije u sklopu trajnog medicinskog usavršavanja.

KLJUČNE RIJEČI: CT; doze zračenja; liječnici obiteljske medicine; mamografija; radiološki postupci; RTG; trajno medicinsko usavršavanje; ultrazvuk