doi: http://dx.doi.org/10.11606/issn.1679-9836.v101i2e-188655 Rev Med (São Paulo). 2022 March-April.;101(2):e-188655.

Original Article

Evaluation of knowledge about ionizing radiation in imaging methods in a non-medical population

Avaliação do conhecimento sobre radiação ionizante em métodos de imagem em uma população não médica

Ana Caroline Blanco Carreiro[1], Tiago Kojun Tibana[2], Daiana Lopez Conceição[3], Thaline Mairace das Neves Coutinho[4], Thiago Franchi Nunes[5]

Blanco Carreiro AC, Tibana TK, Conceição DL, Coutinho TMN, Nunes TF. Evaluation of knowledge about ionizing radiation in imaging methods in a non-medical population / *Avaliação do conhecimento sobre radiação ionizante em métodos de imagem em uma população não médica*. Rev Med (São Paulo). 2022 March-April; 101(2):e-188655.

ABSTRACT: *Objectives:* To describe the knowledge of ionizing radiation exposure in a non-medical population and evaluate the relationship between the understanding of these concepts and the subsequent risks. *Materials and Methods:* The survey consisted in eleven questions, and assessed knowledge about which tests use ionizing radiation, radiation exposure from medical imaging, and subsequent radiation-induced malignancies. Sociodemographic data were also collected. *Results:* 88 responses were obtained. 84% of patients had completed higher education and 98% had already undergone some type of imaging exam in their lifetime. About which methods they think use ionizing radiation: 73% responded MRI and 21% ultrasonography. When chest X-ray was compared with CT, only 11% indicated that CT had 100 times the amount of radiation and the majority (23%) responded that it had a little less. Regarding MRI, when asked the amount of radiation that an MRI of abdomen has compared to a CT of abdomen, most participants (28%) responded the same amount. About the knowledge of radiation induction of malignancy, 36% expressed disagreement, without certainty, with the true statement "person who undergoes 3-5 CTs has a higher risk of developing cancer throughout life" and 20% totally disagreed. *Conclusion:* Study participants did not demonstrate an understanding of which tests use ionizing radiation, the radiation dose, and the risk associated with CT imaging. In addition, they did not understand that MRI and ultrasonography does not expose them to ionizing radiation. The fact of having completed higher education has not been shown to improve understanding of radiation concepts.

Keywords: Computed tomography; Magnetic resonance; Ionizing radiation; Radiation-induced; Malignancy.

RESUMO: *Objetivos:* Descrever o conhecimento sobre exposição à radiação ionizante de uma população não-médica e avaliar as relações entre a compreensão sobre esses conceitos e os riscos subsequentes. *Material e Métodos:* A pesquisa se constituiu em onze perguntas, e avaliou o conhecimento sobre quais exames utilizam radiação ionizante, exposição à radiação a partir de imagens médicas e malignidades subsequentes

---

Study carried out at the University Hospital Maria Aparecida Pedrossian of the Federal University of Mato Grosso do SUL (HUMAP-UFMS), Campo Grande, MS, Brazil.

1. Resident Physician at the Department of Radiodiagnosis, University Hospital Maria Aparecida Pedrossian, Federal University of Mato Grosso do Sul (HUMAP-UFMS), Campo Grande, MS, Brazil. https://orcid.org/0000-0001-9401-4363. E mail: anacaroline_bc@hotmail.com.
2. Resident Physician at the Department of Interventional Radiology, University Hospital Maria Aparecida Pedrossian, Federal University of Mato Grosso do Sul (HUMAP-UFMS), Campo Grande, MS, Brazil. https://orcid.org/0000-0001-5930-1383. tiagotibana@hotmail.com.
3. Resident Physician at the Department of Radiodiagnosis, University Hospital Maria Aparecida Pedrossian, Federal University of Mato Grosso do Sul (HUMAP-UFMS), Campo Grande, MS, Brazil. https://orcid.org/0000-0002-6235-4723. dai_lopez_@hotmail.com.
4. Radiologist at the Department of Radiodiagnosis, University Hospital Maria Aparecida Pedrossian, Federal University of Mato Grosso do Sul (HUMAP-UFMS), Campo Grande, MS, Brazil. https://orcid.org/0000-0002-6172-5465 tha_neves@hotmail.com
5. Doctor, Interventional Radiologist Physician, University Hospital Maria Aparecida Pedrossian, Federal University of Mato Grosso do Sul (HUMAP-UFMS), Campo Grande, MS, Brazil. https://orcid.org/0000-0003-0006-3725 thiagofranchinunes@gmail.com.

Corresponding author: Ana Caroline Blanco Carreiro. Av. Senador Filinto Muller, 355 – Vila Ipiranga. 79008-190 – Campo Grande, MS – Brasil. E-mail: anacaroline_bc@hotmail.com

induzidas por radiação. Dados sociodemográficos também foram coletados. *Resultados:* 88 respostas foram obtidas. 84% dos pacientes possuíam curso superior completo e 98% já havia realizado algum tipo de exame de imagem na vida. Sobre quais métodos acham que utilizam radiação ionizante: 73% responderam ressonância magnética e 21% ultrassonografia. Quando foi comprado a TC com radiografia de tórax, apenas 11% indicaram que a TC tem 100 vezes a quantidade de radiação e maioria (23%) responderam que tem pouco menos. Em relação à ressonância magnética, quando questionados a quantidade de radiação que uma RM de abdome tem em comparação com uma TC de abdome, a maioria dos participantes (28%) respondeu a mesma quantidade. Sobre o conhecimento da indução de malignidade por radiação, 36% expressaram discordância, sem certeza, com a afirmação verdadeira "pessoa que faz 3-5 TCs tem um risco maior de desenvolver câncer ao longo da vida" e 20% discordaram totalmente. *Conclusão:* Os participantes do estudo não demonstraram uma compreensão sobre quais exames utilizam radiação ionizante, a dose de radiação e o risco associado às imagens de TC. Além disso, eles não entendiam que a ressonância magnética e a ultrassonografia não os expõem à radiação ionizante. O fato de possuírem ensino superior completo não demonstrou melhorar a compreensão dos conceitos sobre radiação.

Palavras-chave: Tomografia computadorizada; Ressonância magnética; Radiação ionizante; Malignidade.

INTRODUCTION

The advent of computed tomography (CT) revolutionized diagnostic radiology, and since the 1970s, its use has increased dramatically[1]. American data show that 80.6 million CT scans were performed in 2012, against 2 million in 1983[2]. The volume of CT scans of the cervical spine, chest, abdomen and skull of adult patients increased by 463%, 226%, 72% and 51% , respectively, from 2000 to 2005[3]. In children, it was observed that the use of CT doubled for children under 5 years and tripled for 5 to 14 years between 1996 and 2005, but there was a change in the trend after this period, remaining stable between 2006 and 2007 and then began to decline[4].

While CT helps make diagnoses faster and more accurate, clinicians are becoming increasingly aware of the associated radiation exposure. Such exposure poses the potential long-term risk of radiation-induced malignancies, particularly in children and young adults. Based on epidemiological data, the radiation exposure from an abdominopelvic CT, which is approximately 10 mSv, confers an estimated risk of 1:2000 of developing cancer[5]. Brenner and Hall estimated that approximately 2% of all cancer cases in 2007 in the United States were caused by medical imaging[1], while Berrington de González et al.[6] suggest that this trend will continue, totaling 29,000 cancers per year.

In 2010, growing concerns about the risks of ionizing radiation from medical imaging led the Food and Drug Administration (FDA) to call for an initiative to decrease the amount of radiation attributable to medical imaging. A key component of this initiative involves raising awareness of the risks that medical imaging poses[7]. However, patients' knowledge of the amount of radiation exposed to them in advanced medical imaging tests, as well as the downstream risks of such radiation exposure, have only begun to be characterized.

Recent studies suggest that patients underestimate the amount of radiation from CT compared to a chest radiography and do not understand the potential problem downstream of radiation-induced cancers[8,9]. Despite this, patients substantially increase confidence in the diagnostic assessment if medical imaging, especially CT, is performed[9]. Although critical, previous reports were limited in that, they did not assess whether patients understood the difference between sources of ionizing radiation, such as CT, and imaging tests that do not subject patients to such radiation, such as magnetic resonance imaging (MRI) and ultrasonography (US).

Our main objective was to characterize the knowledge of a non-medical population about the radiation exposure associated with CT and the risk of radiation-induced malignancies.

MATERIAL AND METHODS

This is a cross-sectional research study with adult patients older than 18 years, not hospitalized, lay people in the health field, who represented the general population. Patients unable to read in Portuguese, unable to answer the questionnaire and with altered mental status were excluded from the study.

A total of 150 electronic questionnaires were sent from December 2020 to February 2021, totaling 88 responses sent through an electronic application (Survey Monkey sent via WhatsApp). The survey consisted of eleven questions and assessed knowledge about which imaging tests use ionizing radiation, radiation exposure from medical imaging, and subsequent radiation-induced malignancies and was based on previously published research.

The first three questions were about sociodemographic data, such as age, sex and education level. The next two questions were whether the patient had already undergone an imaging exam and what the exam was, being possible to mark one or more answers. The last six survey questions confirmed the patients' understanding of: 1) which methods use ionizing radiation (being possible to mark more than one answer); 2) the relative amount of radiation exposed from the CT of the abdomen compared to a single chest radiography (x-ray); 3) the relative amount

of radiation exposed from MRI compared to CT; 4) the amount of radiation on an ultrasound compared to MR and 5) the possibility of radiation-induced malignancies on CT and MR.

A database was created using Microsoft Excel software, where the answers were entered and verified by the researcher.

RESULTS

Of the 150 questionnaires sent, 88 responses were obtained. Data are presented as percentages.

Characteristics of the study subjects

Regarding gender, 66% were female and 34% male. And finally, in relation to the level of education, 84% of respondents had completed higher education, 9% had completed high school and 7% had incomplete higher education, as shown in Figure 1.

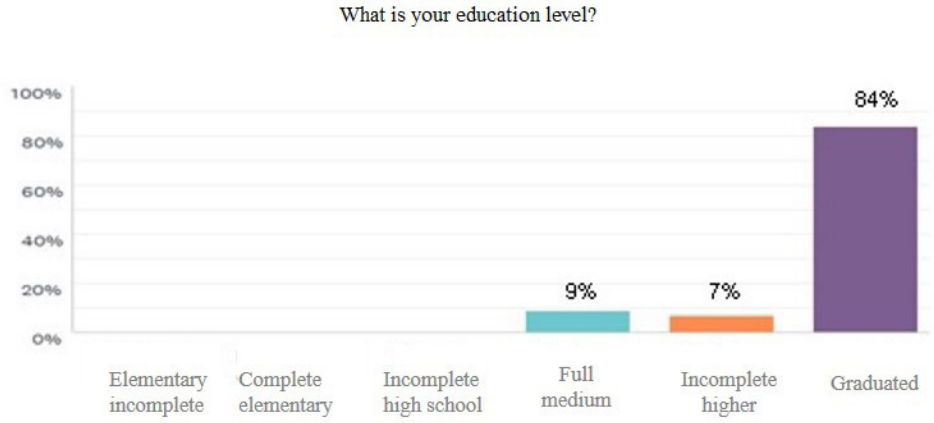

Figure 1. Participants' education level

Main results

When asked if they had already undergone an imaging test, 98% answered yes and only 2% said no, which confirms the degree of confidence that the population has in imaging tests for the correct diagnosis and the importance of knowing what type of radiation is used and poses a risk of malignancy. About which imaging exam they had already performed, (it being possible to mark more than one answer), as shown in figure 2, 84% answered x-ray, 84% ultrasonography, 63% magnetic resonance, 41% computed tomography and 30% mammography.

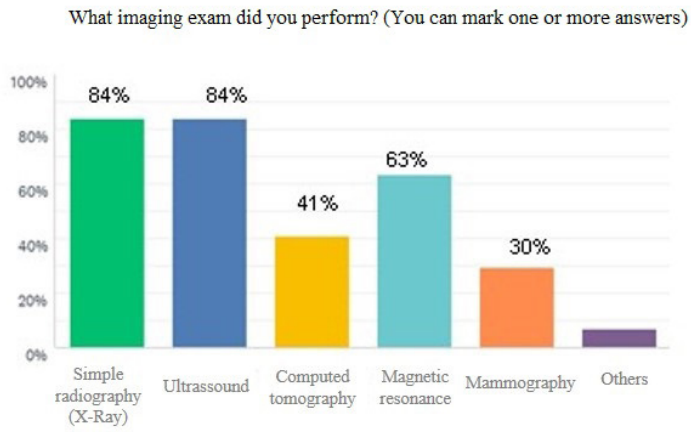

Figure 2. Which imaging exam was performed.

Figure 3 shows that participants showed a misunderstanding about which methods they think use ionizing radiation: 73% responded to MRI and 21% to ultrasound, and such methods are free of ionizing radiation. The other answers were: 52% plain radiography, 50% computed tomography and 27% mammography.

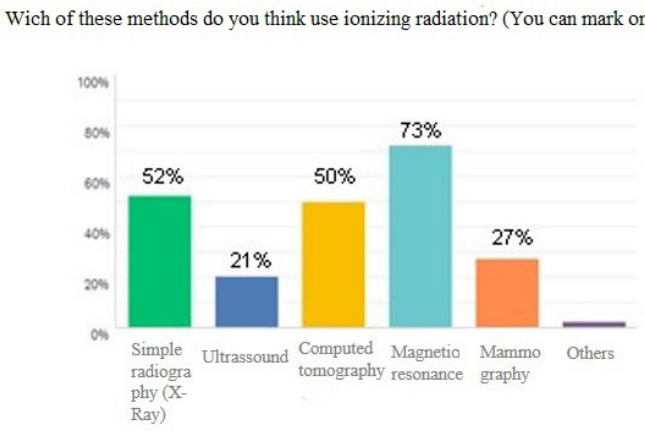

Figure 3. Which methods do you think uses ionizing radiation

Participants also had a limited understanding of the relative amount of ionizing radiation from CT of the abdomen compared to a plain chest x-ray, as shown in Figure 4: only 11% correctly indicated that CT has 100 times the amount of radiation. Mistakenly, 21% responded much less (virtually no radiation), 23% indicated slightly less, and 20% the same amount of radiation.

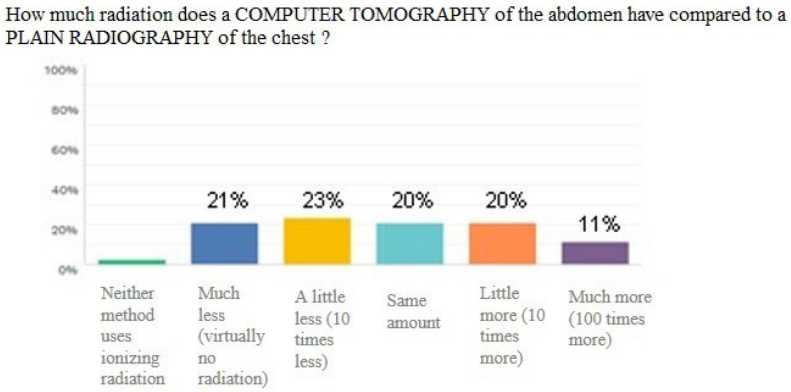

Figure 4. Comparison of the amount of radiation between CT and X-ray.

Regarding MRI, when asked the amount of radiation that an MRI of the abdomen has compared to a CT of the abdomen, again wrongly, most participants (28%) answered the same amount, as shown in Figure 5. The other responses were 23% much less (virtually no radiation), 23% a little more (10 times more), 14% a lot more (100 times more), and 9% a little less.

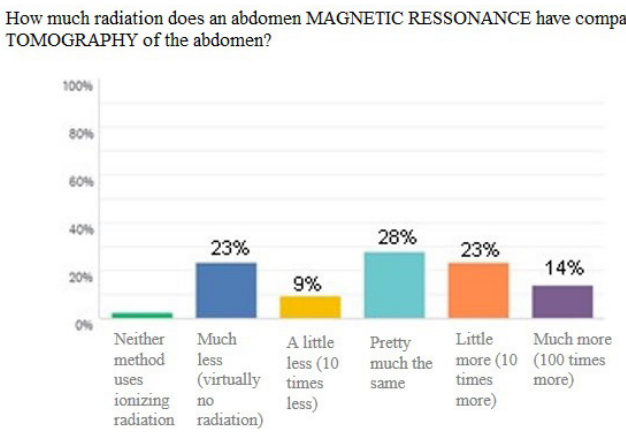

Figure 5. Comparison of the amount of ionizing radiation between MR and CT

Also on this topic, it was asked how much radiation an abdominal ultrasound has compared to an abdominal MRI, as shown in Figure 6: 32% answered the same amount, 23% much less (virtually no radiation), 20% correctly answered that none of the methods uses ionizing radiation, 11% a little less, 9% a little more (10 times more) and 3% a lot more (100 times more).

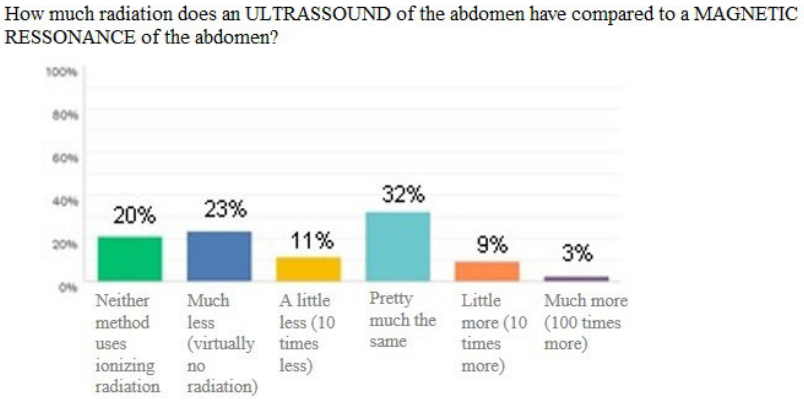

Figure 6. Comparison of the amount of ionizing radiation between ultrasound and MR

Such answers demonstrate that the population that is performing the exams does not have correct knowledge about which exams use or not ionizing radiation. About the knowledge of radiation induction of malignancy, 36% expressed disagreement, without certainty, with the true statement "person who undergoes 3-5 CTs has a higher risk of developing cancer throughout life" and 20% totally disagreed. The other answers were: 15% have no idea, 15% think so, but are not sure and the minority, only 11% correctly answered yes. The same question was asked in relation to MRI as follows: "do you think that a person who has had 3-5 MRIs has a higher risk of developing cancer throughout life?", 34% answered that they think not, but not sure and 25% correctly answered no. The other answers were: 16% have no idea, 16% think yes, but are not sure and 9% yes.

DISCUSSION

As previously reported, we found that the lay population in the health field, even the majority having completed higher education, did not understand which methods use or not ionizing radiation, the amount of radiation associated with CT and also did not understand that this radiation exposure placed them at an increased risk of developing cancer throughout life. Practically everyone in this population has already undergone some type of examination during their lifetime and did not have the knowledge that MRI and ultrasound do not use ionizing radiation.

Additional support for the liberal use of CT has come about as it has been shown to increase the certainty of the emergency physician's diagnosis, decrease the need for emergency surgery from 13% to 5%, and prevent up to 24% of hospital admissions[9]. Outside the hospital environment, the same scenario is observed: increased requests for imaging tests to help diagnoses and increased patient confidence in images as auxiliary methods. Despite these benefits, however, there is growing concern that CT are being overused, and it is estimated that 1.5% to 2.0% of all cancers in the United States can now be attributed to radiation from CT scans[9].

The same scenario is observed in pediatric patients: the use of ionizing radiation for diagnosis has become a common practice and its benefits are unquestionable. However, even if the use of such radiation in medical practice is justified, due to the benefit they will bring to the patient, the rules and techniques of radiological protection should not be forgotten. This means that all patients must receive the utmost attention, in order to minimize the possibility of biological effects, acute or late, resulting from exposure to radiation[10].

CT uses a higher radiation dose than conventional radiology. CT scanners with multiple rows of detectors, which allow increasingly thinner sections and multiple contrasted phases, further increase the radiation dose. The indiscriminate use of this diagnostic method has made a very important contribution to increasing the radiation dose given to patients at each exam. The radiologist should remind the requesting physician about the risks arising from radiation and suggest other imaging methods that can make the diagnosis, such as ultrasound and MRI. Studies on the risk of developing cancer from the effects of radiation come from data from survivors of nuclear attacks. Patients submitted to mean radiation doses of 40 mSv, which corresponds to a four-phase abdominal tomography, present an increased risk of developing different types of neoplasms. Children are especially susceptible to radiation,

due to the greater radiosensitivity and/or the greater number of years to be lived[11].

Since the 1980s, studies of workers in the nuclear industry have been conducted to provide direct information about these effects. The INWORKS epidemiological study of mortality among workers in the nuclear industry is an example and produced statistical information that allowed a relatively accurate estimate of the risk of cancer mortality in a population that tended to accumulate exposures at low dose rates (mean 25mSv) when over an extended period of time, with an average duration of employment of 15 years. These findings represent a substantial addition to the scientific basis for understanding the cancer risks of prolonged exposure to low dose rate ionizing radiation[12].

The International Atomic Energy Agency (IAEA) collected worldwide data in 2019 on cumulative radiation doses to assess the magnitude of patients above a defined level (>100mSv), and noted that the number of patients at this dose is much higher than previously known or anticipated and provided strong evidence of an increased risk of cancer mortality[13].

In Brazil, the National Nuclear Energy Commission (CNEN) establishes three basic principles of radioprotection: justification, optimization and limitation of individual doses. The principle of justification states that any activity involving radiation must be justified in relation to other alternatives and produce a net positive benefit to society. The optimization principle states that all exposures should be kept as low as reasonably achievable (ALARA). The last principle imposes that the individual doses of workers and individuals of the public must not exceed the annual dose limits established by CNEN[14].

As emphasized by the American College of Radiology, informed consent is a communication process that involves shared decision-making between a physician and a patient. While patients can show confidence in their physicians to do what is best for them, patients must be encouraged to take a more active role in their healthcare to improve quality, efficiency and healthcare outcomes. The patients' lack of knowledge about medical and imaging procedures, found in this study and many others, suggests that patients are not sufficiently involved in their own health care[15].

Given growing concerns about unnecessary radiation exposure from medical imaging, our results suggest that efforts to reduce unnecessary medical imaging will need to not only address the practices of healthcare professionals, but also include patient education and awareness.

In summary, providers should be aware that their patients do not have the knowledge base to properly weigh the potential harms against the potential benefits when considering the possibility of undergoing medical imaging, especially CT. This points to the need for better patient education so that they can make more informed decisions about their health care. Future directions in this field may focus on what minimal level of information would be sufficient for patients to really engage in shared decision-making regarding the choice of imaging test. As the science of medical imaging advances, particularly in the field of ultrasound and the use of MRI, this will be an even more critical part of meeting the patient. Clinical decision support will be of particular value when more information and diagnostic options are available.

CONCLUSIONS

Study participants did not demonstrate an understanding of which tests use ionizing radiation, the radiation dose, and the risk associated with CT imaging. Furthermore, they did not understand that MRI and ultrasound do not expose them to ionizing radiation and therefore do not increase their lifetime risk of developing cancer. The fact that they have completed higher education has not been shown to improve their understanding of radiation concepts. Future directions in this line of research may focus on effective means of shared decision-making regarding the use of medical imaging in diagnostic investigation and the conduct of campaigns by health authorities to disseminate knowledge about the risks of malignancy from exposure to ionizing radiation.

Appendix I. Radiation Knowledge

1. How old are you (in years)?

2. Gender FEMALE MALE

3. What is your education level?
a. Elementary incomplete
b. Complete Elementary
c. Incomplete high school
d. Full medium
e. Incomplete higher
f. Graduated.

4. Have you ever performed an imaging exam? YES NO
(If you answer no, skip to question 6)

5. What imaging exam did you perform? (You can mark one or more answers)
a. Simple radiography (X-Ray)
b. Ultrasound
c. Computed tomography
d. Magnetic resonance
e. Mammography
f. Others

6. Which of these methods do you think use ionizing radiation?
(You can mark one or more answers)
a. Simple radiography (X-Ray)
b. Ultrasound
c. Computed tomography
d. Magnetic resonance
e. Mammography
f. None

7. How much radiation does a COMPUTERIZED TOMOGRAPHY of the abdomen have compared to a PLAIN RADIOGRAPHY of the chest?
a. Neither method uses ionizing radiation.
b. Much less (virtually no radiation)
c. A little less (10 times less)
d. same amount
e. Little more (10 times more)
f. Much more (100 times more)

8. How much radiation does an abdomen MAGNETIC RESONANCE have compared to a COMPUTERIZED TOMOGRAPHY of the abdomen?
a. Neither method uses ionizing radiation.
b. Much less (virtually no radiation)
c. A little less (10 times less)
d. Pretty much the same
e. Little more (10 times more)
f. Much more (100 times more)

9. How much radiation does an ULTRASOUND from the abdomen have compared to a MAGNETIC RESONANCE from the abdomen?
a. Neither method uses ionizing radiation.
b. Much less (virtually no radiation)
c. A little less (10 times less)
d. Pretty much the same
e. Little more (10 times more)
f. Much more (100 times more)

10. Do you think that a person who has had 3 to 5 COMPUTERIZED TOMOGRAPHIES has a higher lifetime risk of developing cancer?
a. Not
b. I don't think so, but I'm not sure
c. I have no idea
d. I think so, but I'm not sure
e. Yes

11. Do you think that a person who has had 3 to 5 MAGNETIC RESONANCES has a higher lifetime risk of developing cancer?
a. Not
b. I don't think so, but I'm not sure
c. I have no idea
d. I think so, but I'm not sure
e. Yes

Authors' participation: *Ana Caroline Blanco Carreiro, Tiago Kojun Tibana, Daiana Lopez Conceição and Thaline Mairace das Neves Coutinho* - participated in data collection, analysis and interpretation and wrote the first version of the manuscript. *Thiago Franchi Nunes* - participated in the final review and approval of the manuscript.

REFERENCES

1. Brenner DJ, Hall EJ. Computed tomography-an increasing source of radiation exposure. Engl J Med. 2007;357(22):2277-84. doi: 10.1056/NEJMra072149.
2. Repplinger MD, Li AJ, Svenson JE, Ehlenbach WJ, Westergaard RP, Reeder SB, Jacobs EA. Emergency Department Patients' Perceptions of Radiation From Medical Imaging. WMJ. 2016;115(1):22-8. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4980072/
3. Broder J, Warshauer DM. Increasing utilization of computed tomography in the adult emergency department, 2000-2005. Emerg Radiol. 2006;13(1):25-30. doi: 10.1007/s10140-006-0493-9.
4. Miglioretti DL. The use of computed tomography in pediatrics and the associated radiation exposure and estimated cancer risk. JAMA Pediatr. 2013;167(8):700-7. doi: 10.1001/jamapediatrics.2013.311.
5. Dixon AK, Dendy P. Spiral CT: how much does radiation dose matter? Lancet. 1998;352(9134):1082-3. doi: 10.1016/S0140-6736(05)79751-8.
6. Berrington de González A, Mahesh M, Kim K-P, et al. Projected cancer risks from computed tomographic scans performed in the United States in 2007. Arch Intern Med. 2009;169(22):2071-7. doi: 10.1001/archinternmed.2009.440.
7. Research C for DE and. Initiative to Reduce Unnecessary Radiation Exposure from Medical Imaging - White Paper: Initiative to Reduce Unnecessary Radiation Exposure from Medical Imaging. Available from: http://www.fda.gov/Radiation-EmittingProducts/RadiationSafety/RadiationDoseReduction/ucm199994.htm.
8. Lee CI, Haims AH, Monico EP, Brink JA, Forman HP. Diagnostic CT scans: assessment of patient, physician, and radiologist awareness of radiation dose and possible risks. Radiology. 2004;231(2):393-8. doi: 10.1148/radiol.2312030767.
9. Baumann BM, Chen EH, Mills AM, Glaspey L, Thompson NM, Jones MK, Farner MC. Patient perceptions of computed tomographic imaging and their understanding of radiation risk and exposure. Ann Emerg Med. 2011;58(1):1-7.e2. doi: 10.1016/j.annemergmed.2010.10.018.
10. Travassos LV, Boechat MCB, Santos EN, Oliveira SR, Silva MO, Carvalho ACP. Avaliação das doses de radiação em uretrocistografia miccional de crianças. Radiol Bras. 2009;42(1):21-5. doi: 10.1590/S0100-39842009000100006
11. Parente, DB. O risco da radiação no uso indiscriminado da tomografia computadorizada. Radiol Bras. 2013;46(2):v-vi. doi: 10.1590/S0100-39842013000200001
12. Laurier D, Richardson DB, Cardis E, Daniels RD, Gillies M, O'Hagan J, Hamra GB, Haylock R, Leuraud K, Moissonnier M, Schubauer-Berigan MK, Thierry-Chef I, Kesminiene A. The International Nuclear Workers Study (Inworks): A Collaborative Epidemiological Study to Improve Knowledge About Health Effects of Protracted Low-Dose Exposure. Radiat Protect Dosimetry. 2017;173(1):21-5. doi: doi.org/10.1093/rpd/ncw314.
13. Brambilla M. Multinational data on cumulative radiation exposure of patients from recurrent radiological procedures: call for action. Eur Radiol. 2020;30(5):2493-501. doi:

10.1007/s00330-019-06528-7.

14. Madrigano RR, Abrão KC, Puchnick A, et al. Avaliação do conhecimento de médicos não radiologistas sobre aspectos relacionados à radiação ionizante em exames de imagem. Radiol Bras. 2014;47(4):210-16. doi: https://doi.org/10.1590/0100-3984.2013.1840

15. Hollada J, Speier W, Oshiro T, Marzan-McGill R, Ruehm SG, Bassett LW, Wells C. Patients' Perceptions of Radiation Exposure Associated With Mammography. AJR Am J Roentgenol. 2015;205(1):215-21. doi: 10.2214/AJR.14.13650.

Submeted: 2021, July 20
Accepted: 2021, November 11