Radiology

ORIGINAL RESEARCH • COMPUTER APPLICATIONS

ChatGPT versus Radiology Institutional Websites: Comparative Analysis of Radiation Protection Information Provided to Patients

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Conflicts of interest are listed at the end of this article.

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Despite the public recognizing the benefits of medical imaging, the level of public knowledge of associated risks lags behind (1–3). In this context, patients increasingly seek answers on the internet. The advent of easily accessible artificial intelligence (AI) has revolutionized the way the public interacts with the internet, particularly with language models such as OpenAI's ChatGPT (4,5). However, the accuracy and reliability of AI-based information about radiation protection, or radioprotection, have not been evaluated. Therefore, the aim of this study was to assess if ChatGPT generates comprehensive and scientifically adequate information to frequently asked questions about radiation protection compared with human answers published on institutional websites.

Materials and Methods

One medical physicist, one radiologist, and one radiology fellow, in consensus, retrieved 12 radiation protection–related questions posed by patients from institutional websites and entered them into ChatGPT (version 3.5; OpenAI [4]) (Table 1). Twelve expert participants from the United States and Europe (four radiologists, four medical physicists, and four radiographers), who were blinded to the source of the answer, randomly evaluated the institutional website responses and ChatGPT responses (Table 2) in terms of three outcomes, which were scientific adequacy, public comprehension, and overall satisfaction (Likert scale: 1 = No, 7 = Yes). For the fourth outcome, the raters assessed if, in their opinion, the text was AI-generated or not (Likert scale: 1 = No, 7 = Yes). The Wilcoxon test with Bonferroni correction was used to compare the distributions of human and ChatGPT-generated response scores across the four outcomes. The χ^2 test was used to compare the proportion of accurately identified, with a high degree of certainty (ratings 1 and 2 or 6 and 7), human and ChatGPT responses. The mean word count difference between human and ChatGPT answers was compared using the *t* test. As supplementary qualitative feedback, raters could provide comments on the questions if they deemed it necessary. Further details are provided in Appendix S1.

Results

The overall median values for human and ChatGPT-generated responses were 5.4 and 5.6, respectively, for scientific adequacy, 5.6 and 5.1 for general public comprehension, and 5.1 and 4.7 for overall satisfaction (Table 2, Figure). No statistically significant differences in the three parameters between human and ChatGPT-generated answers were found ($P > .999$, $P = .92$, $P > .999$, respectively). However, scores were different between human and ChatGPT-generated texts regarding participant perception of whether AI had generated the response ($P = .02$). Raters correctly identified the source with high confidence in 43% (62 of 144) and 61% (88 of 144) of human and ChatGPT responses, respectively ($P < .001$) (Appendix S1). The mean word count was 173 words for human responses and 268 words for ChatGPT-generated responses ($P = .08$). Six participants also provided free-text comments.

Discussion

In this study, ChatGPT performed comparably to official institutional websites in terms of scientific adequacy, public comprehension, and overall satisfaction, suggesting that ChatGPT has the potential to be a valuable tool in providing information on radiation protection topics to the general public. Although experts correctly identified ChatGPT responses more frequently than human responses, awareness of the source of responses was weak, indicating that distinguishing between human and AI-generated answers is not straightforward. Nevertheless, the AI responses had characteristics, such as wordiness, that led to better identification. Lastly, rater comments highlighted three areas of criticism in ChatGPT-generated texts: response format and language, relevance, and misleading

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Table 1: Patient Questions with Human and ChatGPT-generated Responses

Question	URL Source of Question and Human Response	Human Response	ChatGPT Response
1. Is the radiation from CT harmful?	*https://www.cancer.gov/about-cancer/diagnosis-staging/ct-scans-fact-sheet#:~:text=Individuals%20who%20have%20had%20multiple,decade%20following%20their%20first%20scan*	Some people may be concerned about the amount of radiation they receive during CT. CT imaging involves the use of x-rays, which are a form of ionizing radiation. Exposure to ionizing radiation is known to increase the risk of cancer. Standard x-ray procedures, such as routine chest x-rays and mammography, use relatively low levels of ionizing radiation. The radiation exposure from CT is higher than that from standard x-ray procedures, but the increase in cancer risk from one CT scan is still small. Not having the procedure can be much more risky than having it, especially if CT is being used to diagnose cancer or another serious condition in someone who has signs or symptoms of disease. It is also important to note that everyone is exposed to some background level of naturally occurring ionizing radiation every day. The average person in the United States receives an estimated effective dose of about 3 millisieverts (mSv) per year from naturally occurring radioactive materials, such as radon and radiation from outer space. By comparison, the radiation exposure from one low-dose CT scan of the chest (1.5 mSv) is comparable to 6 months of natural background radiation, and a regular-dose CT scan of the chest (7 mSv) is comparable to 2 years of natural background radiation. The widespread use of CT and other procedures that use ionizing radiation to create images of the body has raised concerns that even small increases in cancer risk could lead to large numbers of future cancers. People who have CT procedures as children may be at higher risk because children are more sensitive to radiation and have a longer life expectancy than adults. Women are at a somewhat higher risk than men of developing cancer after receiving the same radiation exposures at the same ages.	The potential harm from radiation exposure, including that from CT scans, depends on various factors, including the dosage, the number of scans performed, and the individual's health condition. CT scans use x-rays to create detailed cross-sectional images of the body. X-rays are a form of ionizing radiation, which means they have enough energy to remove electrons from atoms and can potentially damage cells and DNA. However, it's essential to understand that the radiation dose from a single CT scan is relatively low and usually considered safe for most individuals. For the majority of patients, the benefits of obtaining crucial diagnostic information through a CT scan outweigh the potential risks associated with radiation exposure. CT scans are often necessary for diagnosing and monitoring various medical conditions, such as detecting tumors, assessing injuries, or evaluating the severity of diseases. However, in certain situations, repeated or excessive exposure to radiation from CT scans could become a concern, especially for young children, pregnant women, or individuals with certain health conditions. In such cases, doctors will carefully consider the risk-benefit balance and may explore alternative imaging techniques with lower or no radiation, such as MRI or ultrasound, if possible. Your health care provider can provide you with personalized advice based on your specific medical history and needs. (211 words)

(Table 1 continues)

Table 1 *(continued)*: Patient Questions with Human and ChatGPT-generated Responses

Question	URL Source of Question and Human Response	Human Response	ChatGPT Response
		People considering CT should talk with their doctors about whether the procedure is necessary for them and about its risks and benefits. Some organizations recommend that people keep a record of the imaging examinations they have received in case their doctors don't have access to all of their health records. (348 words)	
2. What are the risks of CT scans for children?	*https://www.cancer.gov/about-cancer/diagnosis-staging/ct-scans-fact-sheet#:~:text=Individuals%20who%20have%20had%20multiple,decade%20following%20their%20first%20scan*	Radiation exposure from CT scans affects adults and children differently. Children are considerably more sensitive to radiation than adults because of their growing bodies and the rapid pace at which the cells in their bodies divide. In addition, children have a longer life expectancy than adults, providing a larger window of opportunity for radiation-related cancers to develop. Individuals who have had multiple CT scans before the age of 15 were found to have an increased risk of developing leukemia, brain tumors, and other cancers in the decade following their first scan. However, the lifetime risk of cancer from a single CT scan was small—about one case of cancer for every 10 000 scans performed on children. In talking with health care providers, three key questions that the parents can ask are: Why is the test needed? Will the results change the treatment decisions? Is there an alternative test that doesn't involve radiation? If the test is clinically justified, then the parents can be reassured that the benefits will outweigh the small long-term risks. (172 words)	While CT scans are valuable diagnostic tools and can provide critical medical information, they do involve exposure to ionizing radiation, which carries certain risks. Here are some key considerations: Ionizing radiation: CT scans use x-rays to create detailed cross-sectional images of the body. Unlike nonionizing radiation (eg, from cell phones or microwaves), ionizing radiation has enough energy to remove tightly bound electrons from atoms, potentially damaging cells and DNA. Children are generally more sensitive to radiation than adults because their bodies are still developing, and their cells divide at a faster rate. Increased cancer risk: The main concern with CT scans for children is the potential long-term risk of developing cancer due to radiation exposure. While the absolute risk of CT-induced cancer is relatively small, the cumulative effects of multiple scans throughout childhood can increase this risk. Developing organs: In children, certain organs and tissues are more susceptible to radiation damage because they are still growing and developing. These include the brain, thyroid gland, bone marrow, and gonads (reproductive organs). Unnecessary examinations: Another risk lies in overusing CT scans when other imaging modalities with lower or no radiation exposure (such as ultrasound or MRI) could be sufficient. Unnecessary exposure to radiation should be avoided whenever possible. Sedation risks: Some children may require sedation to remain still during the CT scan, particularly for young children or those with special needs. While sedation is generally safe, there are inherent risks associated with administering anesthesia or sedative medications. To mitigate the risks associated with CT scans for children, here are some important steps you can take:

(Table 1 continues)

Table 1 *(continued)*: Patient Questions with Human and ChatGPT-generated Responses

Question	URL Source of Question and Human Response	Human Response	ChatGPT Response
			Discuss necessity: Before proceeding with a CT scan, talk to your child's health care provider about the necessity of the procedure and whether alternative imaging options are available. Dose optimization: Ask about dose optimization techniques that can help reduce radiation exposure while maintaining image quality. Pediatric facilities: If possible, choose a medical facility with expertise in pediatric imaging and equipment calibrated for children to minimize radiation exposure. Radiology protocols: Ensure that the medical staff follows appropriate pediatric radiology protocols to limit unnecessary exposure. Share medical history: Inform the medical team about any previous imaging studies your child has undergone to avoid duplicate scans. Follow-up care: After the CT scan, discuss the results and any potential follow-up procedures or treatments with your child's health care provider. Remember that in many cases, the benefits of a CT scan in diagnosing and treating medical conditions outweigh the risks. The decision to proceed with a CT scan should be made with the input of your child's health care provider, who can weigh the risks and benefits based on your child's specific medical situation. (439 words)
3. What are the risks related to mammograms?	*https://www.mayoclinic.org/tests-procedures/mammogram/about/pac-20384806*	Mammograms expose you to low-dose radiation. The dose is very low, though, and for most people the benefits of regular mammograms outweigh the risks posed by this amount of radiation. Having a mammogram may lead to additional testing. If something unexpected is detected on your mammogram, you may need other tests. These might include additional imaging tests such as ultrasound, and a procedure (biopsy) to remove a sample of breast tissue for laboratory testing. However, most findings detected on mammograms aren't cancer. If your mammogram detects something unusual, the doctor who interprets the images (radiologist) will want to compare it with previous mammograms. If you have had mammograms performed elsewhere, your radiologist will ask for your permission to request them from your previous health care providers.	Mammograms are widely used for breast cancer screening and early detection. While they are generally considered safe and effective, there are some potential risks associated with the procedure: Radiation exposure: Mammograms use low-dose x-rays to create images of the breast tissue. Although the amount of radiation used in modern mammography machines is considered safe, repeated exposure over time may slightly increase the risk of developing cancer. The benefits of early cancer detection generally outweigh the small risk of radiation exposure. False positives: Mammograms can sometimes produce false-positive results, indicating an abnormality when no cancer is present. This can lead to additional tests, stress, and anxiety for the patient. False negatives: In some cases, mammograms may miss detecting cancerous lesions, leading to a false-negative result. This can give a false sense of security and delay diagnosis.

(Table 1 continues)

Table 1 *(continued)*: Patient Questions with Human and ChatGPT-generated Responses

Question	URL Source of Question and Human Response	Human Response	ChatGPT Response
		Screening mammography can't detect all cancers. Some cancers detected by physical examination may not be seen on the mammogram. A cancer may be missed if it's too small or is located in an area that is difficult to view by mammography, such as your armpit. Not all of the cancers found by mammography can be cured. Some breast cancers are aggressive, grow rapidly and quickly spread to other parts of the body. (198 words)	Overdiagnosis: Mammograms can also detect very early-stage or slow-growing cancers that may not pose a significant threat to the patient's health. Overdiagnosis may lead to unnecessary treatment and potential side effects. Compression discomfort: During a mammogram, the breast is compressed between two plates to obtain clear images. This compression can cause temporary discomfort or pain for some patients. Anxiety and emotional impact: Waiting for the results of a mammogram and facing the possibility of a breast cancer diagnosis can cause emotional stress and anxiety in patients. It's important to remember that while mammograms have some risks, they are still a crucial tool in breast cancer screening and early detection. The benefits of detecting breast cancer early, when it is most treatable, generally outweigh the potential risks. (261 words)
4. What are the possible effects of radiation exposure from interventional procedures?	*https://www.iaea.org/resources/rpop/patients-and-public/interventional-procedures#3*	The typical dose of an interventional procedure brings a one in 10 000 risk of skin injury and a small increased probability of cancer in future years. In most situations, skin injuries can be prevented by using the proper technique. An interventional procedure performed under x-ray fluoroscopy guidance often replaces a more invasive surgical procedure. (56 words)	While these procedures can be highly beneficial in diagnosing and treating various conditions, they also expose patients to ionizing radiation, which can have both short-term and long-term effects. Some possible effects of radiation exposure from interventional procedures include: Skin reactions: In some cases, radiation exposure can lead to skin reactions, such as redness, swelling, and, in severe cases, skin burns. Radiation sickness: High doses of radiation exposure can cause radiation sickness, leading to symptoms like nausea, vomiting, fatigue, and diarrhea. Cataracts: Repeated exposure to radiation may increase the risk of developing cataracts, clouding of the eye's lens, leading to vision impairment. Infertility: Radiation exposure to the reproductive organs can potentially cause temporary or permanent infertility Increased risk of cancer: Ionizing radiation is known to increase the risk of developing certain types of cancer, especially when received in high doses or over prolonged periods. However, the risk is generally considered to be low with standard medical imaging procedures. Radiation-induced tumors: Extremely high doses of radiation can, in rare cases, lead to the development of radiation-induced tumors in the area exposed to radiation.

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Table 1 *(continued)*: Patient Questions with Human and ChatGPT-generated Responses

Question	URL Source of Question and Human Response	Human Response	ChatGPT Response
			It's important to note that the risk of experiencing adverse effects from radiation exposure during interventional procedures is typically outweighed by the potential benefits of accurate diagnosis and treatment. Health care professionals take precautions to minimize radiation exposure during procedures, such as using the lowest possible radiation dose necessary and employing shielding techniques to protect surrounding tissues and organs. If you are scheduled for an interventional procedure that involves radiation, it's essential to discuss any concerns you may have with your health care provider. They can explain the specific risks and benefits of the procedure and address any questions you might have. Additionally, make sure to inform your health care provider of any existing medical conditions, allergies, or previous radiation exposures to ensure your safety during the procedure. (306 words)
5. Is MRI safer than CT?	*https://stanfordhealthcare.org/medical-tests/m/mri/risk-factors.html*	Risks of MRI: Because radiation is not used, there is no risk of exposure to radiation during an MRI procedure. However, due to the use of the strong magnet, MRI cannot be performed on patients with implanted pacemakers, intracranial aneurysm clips, cochlear implants, certain prosthetic devices, implanted drug infusion pumps, neurostimulators, bone-growth stimulators, certain intrauterine contraceptive devices, or any other type of iron-based metal implants. MRI is also contraindicated in the presence of internal metallic objects such as bullets or shrapnel, as well as surgical clips, pins, plates, screws, metal sutures, or wire mesh. If you are pregnant or suspect that you may be pregnant, you should notify your physician. Due to the potential for a harmful increase in the temperature of the amniotic fluid, MRI is not advised for pregnant patients. If contrast dye is used, there is a risk for allergic reaction to the dye. Patients who are allergic to or sensitive to medications, contrast dye, iodine, or shellfish should notify the radiologist or technologist. MRI contrast may also have an effect on other conditions such as allergies, asthma, anemia, hypotension (low blood pressure), and sickle cell disease.	Both MRI and CT are valuable imaging techniques used in medical settings to diagnose and monitor various conditions. They have their own advantages and disadvantages, and whether one is safer than the other depends on several factors. Safety considerations for MRI: No ionizing radiation: MRI does not use ionizing radiation, which is a potential health risk associated with CT scans. Noninvasive: MRI is a noninvasive procedure and generally does not require the use of contrast agents. Allergy concerns: Some people may be allergic to the contrast agents used in MRI, but this is relatively rare. Safety considerations for CT: Ionizing radiation: CT scans use x-rays, which expose patients to small amounts of ionizing radiation. Repeated exposure to ionizing radiation may carry some long-term risks. Contrast agents: In some cases, CT scans may require the use of contrast agents, which can carry a small risk of allergic reactions or kidney problems in some individuals.

(Table 1 continues)

Table 1 *(continued)*: Patient Questions with Human and ChatGPT-generated Responses

Question	URL Source of Question and Human Response	Human Response	ChatGPT Response
		There may be other risks depending upon your specific medical condition. Be sure to discuss any concerns with your physician prior to the procedure. Risks of CT scan: The amount of radiation used during a CT scan is considered minimal; therefore, the risk for radiation exposure is low. If you are pregnant or suspect that you may be pregnant, you should notify your physician. Radiation exposure during pregnancy may lead to birth defects. If contrast dye is used, there is a risk for allergic reaction to the dye. Patients who are allergic to or sensitive to medications, contrast dye, iodine, or shellfish should notify their physician. Patients with kidney failure or other kidney problems should notify their physician. In some cases, the contrast dye can cause kidney failure, especially if the person is taking Glucophage (a diabetic medication). There may be other risks depending upon your specific medical condition. Be sure to discuss any concerns with your physician prior to the procedure. Certain factors or conditions may interfere with the accuracy of a CT scan of the chest. These factors include, but are not limited to, the following: metallic objects within the chest, such as surgical clips or a pacemaker; body piercings on the chest; barium in the esophagus from a recent barium study. (404 words)	In summary, MRI is generally considered safer than CT because it does not involve ionizing radiation. However, both imaging techniques have their unique advantages and may be more appropriate for specific medical conditions. (186 words)
6. What are the risks of prenatal ultrasounds?	*https://my.clevelandclinic.org/health/diagnostics/9704-ultrasound-in-pregnancy*	Studies have shown ultrasounds are safe during pregnancy. There are no harmful side effects to you or your baby. (19 words).	The potential risks of prenatal ultrasounds were believed to be minimal. Here are some key points to consider: Heating effects: Ultrasound machines emit sound waves that bounce off tissues and create an image. There was some concern that the energy from ultrasound waves could cause heating of tissues, but modern ultrasound machines use low-intensity waves to minimize this risk. Potential biologic effects: There has been ongoing research to explore the potential long-term effects of ultrasound exposure on developing fetuses. While most studies have not shown any harmful effects, it's important to use ultrasound only when medically necessary and to avoid excessive or unnecessary exposure.

(Table 1 continues)

Table 1 *(continued)*: Patient Questions with Human and ChatGPT-generated Responses

Question	URL Source of Question and Human Response	Human Response	ChatGPT Response
			Overdiagnosis and anxiety: Prenatal ultrasounds can sometimes detect minor variations or abnormalities that may not have any significant impact on the baby's health. However, this could lead to unnecessary anxiety for parents and might prompt further testing or interventions that may not be required. Operator skill and interpretation: The quality and accuracy of the ultrasound largely depend on the skill of the operator. A less-experienced sonographer may miss important details or misinterpret images, potentially leading to incorrect conclusions. It's important to remember that prenatal ultrasounds are typically performed by skilled professionals, and they are essential for monitoring the development of the fetus, assessing potential complications, and guiding medical decision-making when necessary. The benefits of ultrasound in diagnosing and managing certain conditions often outweigh the potential risks. As technology and medical knowledge continue to advance, it is possible that additional research may provide new insights into the safety of prenatal ultrasounds. (255 words)
7. Hello. I am 36 years old now and have had undiagnosed illness for years. I have had a few CT scans, 3 nuclear stress tests, a few x-rays, ultrasounds, MRIs, and a combined CT abdomen/pelvis/chest (300 mGy·cm). I'm worried about radiation exposure. Does this sound a lot to you and can you please break the exposure levels down to me in layperson's terms?	*https://www.medicalradiationinfo.org/ask-the-experts/all-questions/*	Not all imaging procedures use "ionizing" radiation, which is the type of radiation that has the potential to cause harm when received in high amounts. The ultrasound and MRI procedures you've had are examples of nonionizing procedures, so there is no concern about radiation effects. Your CT scans, nuclear scans, and radiographs (x-rays) used fairly small amounts of ionizing radiation to produce images. The radiation dose level that you provided for your CT scan of the chest/abdomen/pelvis (300 mGy·cm) is extremely low compared with national averages for that (very common) imaging examination. The information obtained from medically necessary imaging like CT scanning, nuclear imaging, and x-rays is often very beneficial to medical diagnosis and patient outcomes. The small amount of ionizing radiation used in medical imaging has not been scientifically proven to cause any harm, and if there is any long-term risk, then	I understand your concerns about radiation exposure. Let me break down the types of medical imaging you've had and provide some context on radiation levels in layperson's terms: X-rays: X-rays are a type of electromagnetic radiation used for imaging bones and some soft tissues. They are relatively low-dose radiation examinations, and the exposure from each x-ray is generally considered safe. The risk associated with a single x-ray is minimal. CT scans: CT scans involve a series of x-ray images taken from different angles to create cross-sectional images of the body. CT scans do expose you to a higher dose of radiation compared with conventional x-rays, but they are still considered safe for medical purposes. The exposure from a single CT scan is generally not harmful, but repeated CT scans can accumulate radiation exposure over time.

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Table 1 *(continued)*: Patient Questions with Human and ChatGPT-generated Responses

Question	URL Source of Question and Human Response	Human Response	ChatGPT Response
		it is believed to be extremely small. If radiation exposures are separated by weeks or months, then the body's innate ability to repair DNA damage will go into action, further reducing the small theoretical risk. There is no limit on the amount of medical imaging a patient can receive. Each imaging examination is ordered based on the patient's situation at that particular time, without regard to their radiation exposure history. This is good, because it means that a patient should not be denied a potentially life-preserving imaging examination just because they may have had prior imaging. With modern imaging equipment, the amount of radiation used to produce images is customized for the patient's body size and for the purpose of the examination. (264 words)	MRIs: MRIs use strong magnetic fields and radio waves to create detailed images of the body's internal structures. Unlike x-rays and CT scans, MRIs do not use ionizing radiation, so there is no radiation exposure associated with this imaging method. Nuclear stress tests: Nuclear stress tests involve injecting a small amount of radioactive tracer into your bloodstream to evaluate blood flow to the heart. The radiation dose from nuclear stress tests is higher than conventional x-rays, but it is still considered safe for diagnostic purposes. Radiation exposure is typically measured in units called "milligray" (mGy) or "millisievert" (mSv). The effective dose of radiation takes into account the type of radiation and the sensitivity of different organs to radiation exposure. For example: A typical chest x-ray exposes you to about 0.1 mSv. A CT scan of the abdomen and pelvis may expose you to around 10 mSv. A nuclear stress test can expose you to between 5 to 15 mSv. It's essential to note that the risk of developing radiation-induced health effects increases with higher doses and cumulative exposure over time. However, the doses you receive during medical imaging are generally kept within safe limits, and the benefits of these tests in diagnosing and managing medical conditions often outweigh the risks. (345 words)
8. How long should I wait to try to become pregnant after x-ray examinations that have exposed my ovaries or my husband's testes?	*https://www.radiationanswers.org/radiation-questions-answers/radiation-and-pregnancy.html*	There is no evidence of effects on the ovaries or sperm at radiation doses used in diagnostic x-ray procedures. Radiation doses from routine medical x-rays are too small to affect sterility or have an effect on a future pregnancy. Therefore, you do not need to wait after diagnostic x-ray examinations before trying to become pregnant. (56 words)	The waiting period before attempting to become pregnant after x-ray examinations that exposed the ovaries or testes can vary depending on the type of examination, the radiation dose received, and individual factors. It is best to consult with a health care professional, such as a radiologist or a reproductive specialist, who can provide personalized advice based on your specific situation. They can review your medical history, the details of the x-ray examinations, and any other relevant factors to provide you with appropriate guidance on when it is safe to try to conceive after the exposure. They may also recommend follow-up tests or monitoring to ensure your reproductive health is not adversely affected.

(Table 1 continues)

Table 1 *(continued)*: Patient Questions with Human and ChatGPT-generated Responses

Question	URL Source of Question and Human Response	Human Response	ChatGPT Response
			In general, the International Commission on Radiological Protection (ICRP) recommends that women avoid becoming pregnant for a period of time after exposure to significant radiation doses. This period is typically around one to three months for women and about two to three months for men. (156 words)
9. Can I undergo a CT scan while I am pregnant?	*https://www.iaea.org/resources/rpop/patients-and-public/pregnant-women*	Yes, if medically justified and with certain precautions. The aim is to minimize the unborn child's radiation exposure. An unborn child is considered to be more sensitive than adults or children to potential adverse radiation effects. For many examinations such as CT of the head (including dental CT scans), chest and limbs, where the pelvic region is not in the direct beam, the dose to the unborn child can be very low. Doctors may consider delaying procedures that would put the pelvic region and the unborn child in the direct path of the beam. If the procedure is essential to the mother's health, the doctors take special actions to keep the dose to the unborn child as low as possible. For example, lower exposure factors can be chosen and pregnant patients can have their pelvic regions shielded during the procedure. (140 words)	CT scans involve the use of x-rays to create detailed cross-sectional images of the body. X-rays do expose the body to ionizing radiation, which carries potential risks, especially for a developing fetus. The decision to perform a CT scan during pregnancy will depend on the specific medical condition being investigated and the urgency of the procedure. In some cases, the potential benefits of the CT scan in diagnosing and managing a medical issue may outweigh the risks of radiation exposure. If the health care provider believes that the information obtained from the CT scan is crucial for the health of the pregnant individual or the baby, they might recommend proceeding with the scan. However, there are precautions that can be taken to minimize radiation exposure during a CT scan, such as shielding the abdomen and using the lowest possible radiation dose that still allows for accurate imaging. Ultimately, the decision to undergo a CT scan while pregnant should be a collaborative effort between you and your health care provider, carefully considering the risks and benefits involved. (174 words)
10. Do patients need to cease breastfeeding after CT with iodine contrast?	*https://medicine.yale.edu/diagnosticradiology/patientcare/policies/breastfeeding/*	For all IV iodinated contrast and gadolinium, American College of Radiology (ACR) guidelines state that contrast administration to the mother is considered safe for both the baby and nursing mother. Mothers who are breastfeeding should be given the opportunity to make an informed decision as to whether to continue or temporarily abstain from breastfeeding after receiving IV contrast. If the mother remains concerned about any potential ill effects to the infant, she may abstain from breast-feeding for 24 hours with active expression and discarding of breast milk from both breasts during that period. (93 words)	In general, after receiving iodine contrast for a CT scan, the recommendation is typically to temporarily suspend breastfeeding for a short period. Iodine contrast agents used in medical imaging can pass into breast milk, and there may be potential risks to the infant. The specific guidelines for how long to stop breastfeeding after a CT with iodine contrast can vary depending on the type of contrast used and the recommendations of the radiologist or health care provider. Generally, breastfeeding can be resumed after a certain waiting period, during which the iodine contrast is cleared from the body.

(Table 1 continues)

Table 1 *(continued)*: Patient Questions with Human and ChatGPT-generated Responses

Question	URL Source of Question and Human Response	Human Response	ChatGPT Response
			If you are a breastfeeding parent and have been scheduled for a CT with iodine contrast, it is crucial to discuss your specific situation with your health care provider. They will be able to provide you with the most accurate and up-to-date information and guidance regarding breastfeeding and medical imaging procedures. (146 words)
11. Why is reproductive organ shielding no longer recommended?	*https://ncrponline.org/wp-content/themes/ncrp/PDFs/NCRP_Gonadal_Shielding_Trifold.pdf*	You may notice that we no longer shield patients' reproductive organs during imaging examinations. Based on over 70 years of research, medical experts now know that the best way to keep patients safe during imaging examinations is to not use shields. This is true at any age, including for those who plan to have children in the future. We know this is different from how things have been done for a long time. In the 1950s, medical experts had less knowledge about how the x-ray radiation used in medical imaging affected our bodies. One concern was that the radiation might damage cells that could be passed along to future generations. Because of this concern, lead shields were often placed over patients' reproductive organs during medical imaging examinations. We now know that the best way to safely image you is to not use shields. The amount of radiation used in medical imaging has decreased over 95% since the 1950s. Better technology means that today's medical imaging equipment can make high quality images using only very small amounts of radiation. Scientists found that the gonads are much less sensitive to radiation previously thought. This is true for everyone, including children and adults who plan to have children in the future. Shields can cover up parts of the body that your doctor needs to see. If this happens, then the examination may need to be repeated. Shields can interfere with other dose-saving features. X-ray equipment includes technology that makes sure just the right amount of radiation is used for the examination. Sometimes a shield can interfere with this technology, which can actually increase the amount of radiation from the examination. (278 words)	Historically, reproductive organ shielding was used during x-ray and other medical imaging procedures to protect the gonads (testicles in males and ovaries in females) from radiation exposure. The concern was that radiation exposure to these sensitive organs could potentially lead to genetic mutations or an increased risk of developing certain cancers. However, over time, advancements in imaging technology and changes in medical understanding have led to a shift in the approach to radiation protection. Here are some reasons why reproductive organ shielding is no longer universally recommended: Focus on image quality: Shielding the reproductive organs can sometimes interfere with obtaining high-quality diagnostic images. In some cases, the shield itself could obscure the area of interest, making it more difficult for the radiologist to make an accurate diagnosis. Negligible risk: Modern imaging equipment is designed to minimize radiation exposure to patients. The amount of radiation delivered during imaging procedures has significantly reduced compared with older practices, making the risk to reproductive organs quite low. Scatter radiation: Placing a shield over the gonads can cause additional scatter radiation, potentially affecting adjacent tissues and increasing the overall radiation exposure. Gender and Age Considerations: Shielding for reproductive organs might be more relevant for pediatric patients due to their longer life expectancy and potential for radiation-induced long-term effects. However, even for pediatric patients, the risk of exposure needs to be carefully balanced with the diagnostic benefits of the imaging study.

(Table 1 continues)

Table 1 *(continued)*: Patient Questions with Human and ChatGPT-generated Responses

Question	URL Source of Question and Human Response	Human Response	ChatGPT Response
			Awareness and Consent: In some cases, patients might be asked about their preference for shielding. For instance, in situations where reproductive organs are not directly in the imaging field, patients may choose not to use shields to avoid potential interference with image quality. It's important to note that while reproductive organ shielding might not be universally recommended, medical professionals always consider individual patient factors and tailor the approach to each patient's specific needs and concerns. (310 words)
12. If radiation is harmful to humans, how can it also be used to treat cancer?	*https://www.medicalradiationinfo.org/ask-the-experts/all-questions/*	Radiation can damage cells in the body. Healthy, normal cells are capable of repairing themselves following exposure to radiation. However, cancerous cells have lost this ability. When radiation is delivered to a part of the body containing a tumor, the cancerous cells are killed but the noncancerous cells survive. (49 words)	Radiation can indeed be harmful to humans, but it can also be used as an effective treatment for cancer. The key to its successful use lies in carefully controlling the dose and targeting the radiation to specific areas of the body where cancer cells are present. Radiation therapy, also known as radiotherapy, is a medical treatment that uses high doses of radiation to kill or damage cancer cells. It works by damaging the DNA inside the cancer cells, preventing them from growing and dividing further. While radiation can also affect normal healthy cells, the goal of radiation therapy is to maximize the damage to cancer cells while minimizing harm to healthy tissues. Here's how radiation therapy achieves this balance: Precise targeting: Modern radiation therapy techniques, such as intensity-modulated radiation therapy (IMRT) and image-guided radiation therapy (IGRT), allow for highly accurate and precise targeting of the tumor. This reduces exposure to surrounding healthy tissues, which helps minimize damage to noncancerous cells. Fractionation: Radiation treatment is usually delivered in multiple sessions or fractions over several days or weeks. By dividing the total radiation dose into fractions, the healthy cells have time to repair themselves between treatments, while cancer cells are less likely to recover. Shielding and blocking: Special shields and blocks may be used during radiation therapy to protect nearby organs and tissues that are sensitive to radiation.

(Table 1 continues)

Table 1 *(continued)*: Patient Questions with Human and ChatGPT-generated Responses

Question	URL Source of Question and Human Response	Human Response	ChatGPT Response
			Advanced planning and imaging: Prior to treatment, detailed planning is done using advanced imaging techniques to determine the exact location and size of the tumor, as well as nearby critical structures. This enables the medical team to design a treatment plan that delivers the radiation precisely to the tumor while sparing healthy tissues. Radiosensitivity of cancer cells: Cancer cells are generally more sensitive to radiation than normal cells, making them more susceptible to damage and death at the same radiation dose that may only cause temporary effects on healthy cells. While radiation therapy is a valuable tool in cancer treatment, it does have potential side effects, which can vary depending on the area being treated and the overall health of the patient. Common side effects include fatigue, skin changes, and mild inflammation of the treated area. However, most side effects are temporary and resolve after treatment is completed. It's crucial for patients considering radiation therapy to discuss the potential risks and benefits with their oncologist to make informed decisions about their cancer treatment plan. Every patient's situation is unique, and the decision to use radiation therapy will depend on factors such as cancer type, stage, location, and the patient's overall health. (427 words)

Note.—ChatGPT (version 3.5; OpenAI) was used to generate textual responses to patient questions. The word count for each response is provided in parentheses. IV = intravenous.

or missing critical information. This contrasts with a previous study where evaluators significantly preferred the ChatGPT responses for both quality and empathy over physician exchanges in the r/AskDocs forum on Reddit *(https://www.reddit.com)* (6). Further data interpretation, as well as study limitations, are provided in Appendix S1.

As revealed in a recent survey, patients recognize their limited understanding of radiation protection and have expressed a desire for more information to make informed decisions (3). Although communication about radiation protection is indispensable, it often remains shrouded in complex language that health care professionals cannot easily simplify, thus leading to inadequate information (7). Implementing ChatGPT may address the need for clear and accessible information about radiation protection. A practical application could involve making ChatGPT or other AI chatbots available in radiology waiting rooms to allow patients access to information while waiting for their examinations. It is important to note that this should complement, not replace, the communication between health care providers and patients (7).

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Table 2: Mean Scores Obtained by Human and ChatGPT-generated Responses to Patient Questions for Each Outcome

	Human Response				ChatGPT Response			
Question	Mean Score for "The Answer is Scientifically Adequate"	Mean Score for "The General Public Can Understand the Text"	Mean Score for "I am Satisfied with the Answer"	Mean Score for "This Answer Seems to be Generated by an AI"	Mean Score for "The Answer is Scientifically Adequate"	Mean Score for "The General Public Can Understand the Text"	Mean Score for "I am Satisfied with the Answer"	Mean Score for "This Answer Seems to be Generated by an AI"
1. Is the radiation from CT harmful?	6.2	5.1	5.8	4.0	5.8	4.8	5.0	4.8
2. What are the risks of CT scans for children?	5.8	5.8	5.0	4.1	6.2	5.6	5.6	5.0
3. What are the risks related to mammograms?	5.0	5.6	4.7	3.7	6.2	5.7	5.3	5.3
4. What are the possible effects of radiation exposure from interventional procedures?	3.9	4.4	3.3	3.4	5.3	4.9	4.5	5.9
5. Is MRI safer than CT?	5.1	4.9	4.1	4.8	4.8	5.5	3.9	3.7
6. What are the risks of prenatal ultrasounds?	5.2	6.9	5.3	2.8	5.4	4.8	4.5	5.8
7. Hello. I am 36 years old now and have had undiagnosed illness for years. I have had a few CT scans, 3 nuclear stress tests, a few x-rays, ultrasounds, MRIs, and a combined CT abdomen/pelvis/chest (300 mGy·cm). I'm worried about radiation exposure. Does this sound a lot to you and can you please break the exposure levels down to me in layperson's terms?	5.3	5.5	5.3	3.6	5.5	4.2	4.3	5.8
8. How long should I wait to try to become pregnant after x-ray examinations that have exposed my ovaries or my husband's testes?	5.5	6.1	5.8	2.7	4.0	5.1	3.2	6.3
9. Can I undergo a CT scan while I am pregnant?	5.8	5.9	4.8	2.9	6.1	5.9	5.3	5.7
10. Do patients need to cease breastfeeding after CT with iodine contrast?	5.5	5.3	5.2	3.8	4.7	6.0	4.3	4.0
11. Why is reproductive organ shielding no longer recommended?	5.8	5.6	5.7	3.0	5.8	5.2	5.2	6.0
12. If radiation is harmful to humans, how can it also be used to treat cancer?	3.9	5.8	3.7	2.8	5.8	4.3	4.8	5.9
Overall score								
Mean	5.3	5.6	4.9	3.5	5.4	5.2	4.7	5.3
Median	5.4	5.6	5.1	3.5	5.6	5.1	4.7	5.7

Note.—Medical experts evaluated human and ChatGPT (version 3.5; OpenAI) responses to 12 patient questions in terms of four outcomes, which were scientific adequacy, public comprehension, overall satisfaction, and whether the response was AI-generated or not, according to a Likert scale (1 = No, 7 = Yes). AI = artificial intelligence.

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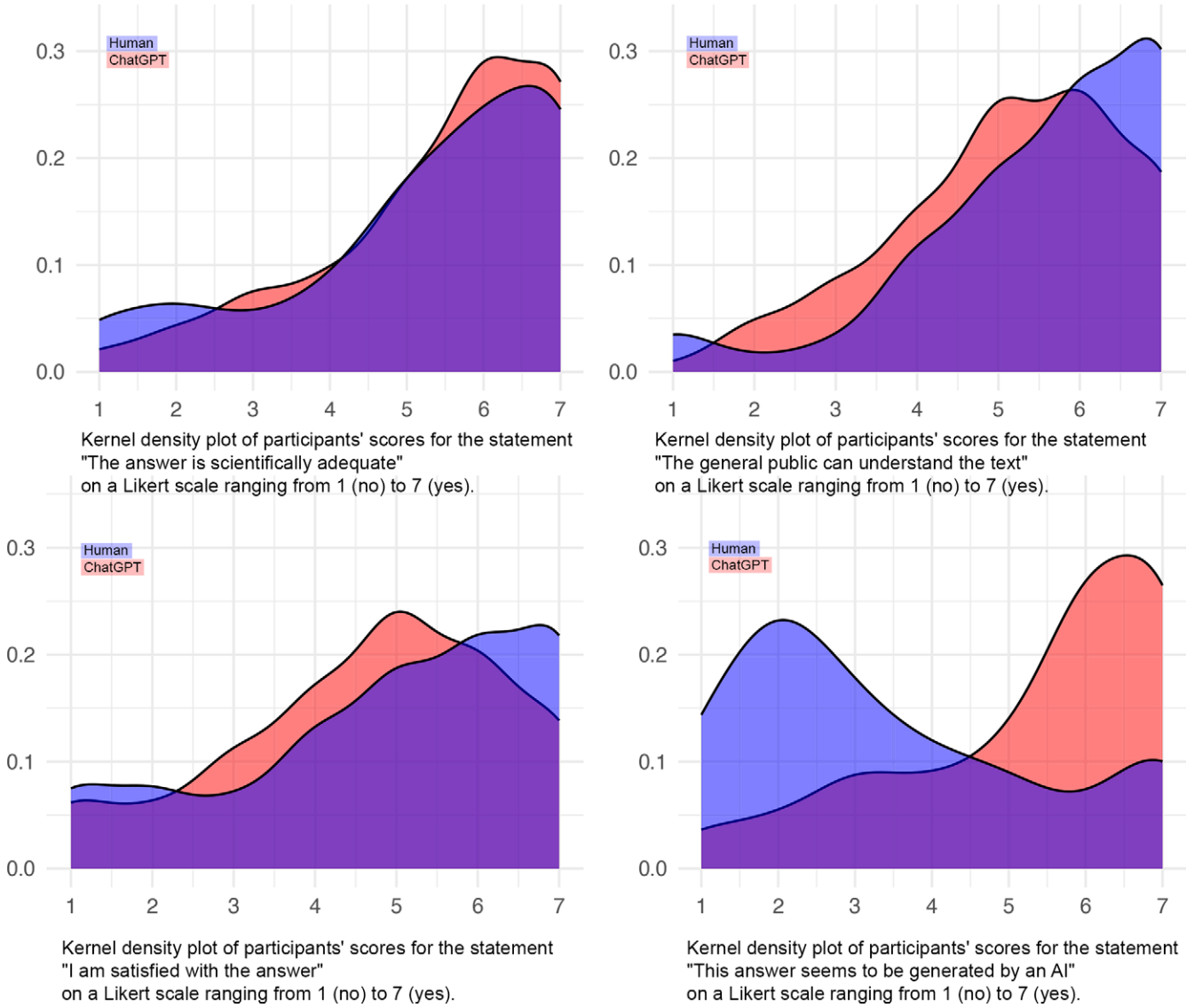

Kernel density plots show all participant scores (Likert scale: 1 = No, 7 = Yes) obtained after reviewing each of the human and ChatGPT-generated (version 3.5; OpenAI) responses to 12 patient questions. Participants assessed the four outcomes reported in the x-axis statements. The density plots serve as an illustration, providing an approximate representation of overall distribution of the discrete data.

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