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Review Article

Daily sources of radiation in our environment: Potential Exposure beyond hospitals

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Abstract

Radiology examinations play a vital role in healthcare worldwide, but patient safety, particularly radiation protection, remains a key concern for all stakeholders. Despite this, some patients and their families still express concerns about the impact of radiation from radiology exams. Healthcare workers, including radiographers, radiologists, interventional surgeons, interventional cardiologists, and others, often find themselves explaining these concerns repeatedly before procedures. Misconceptions about the effects of radiation from medical examinations may stem from misinformation encountered by patients in the past. In reality, people are exposed to various environmental radiation sources daily, often without being aware of it, although the doses are typically low. The goal of this study was to explore the radiation sources that individuals are potentially exposed to on a daily basis. By integrating the ALARA (As Low As Reasonably Achievable) principle into radiological practice, the public should feel more reassured and less anxious about the risks. Thus, it is important for people to understand the sources of radiation in their everyday environment.

Keywords: Radiology examinations, radiation protection, patient safety, ALARA concept, environmental radiation source

Introduction

Radiology plays a critical role in modern medical diagnosis and treatment, using imaging techniques like X-rays, CT scans, and MRIs (Bárdyová et al. 2021; Tomà et al. 2017). However, one concern frequently raised by patients undergoing these examinations is the potential negative effects of radiation exposure (Dauer et al. 2011; Larson et al. 2007; Oakley and Harrison 2020). In practice, doctors will usually explain the purpose of radiological examinations that use X-ray ionization radiation to their patients, but they may not explain the details of the side effects that may appear in the future for these patients (Bastiani et al. 2021; Naderi et al. 2021). Some argue that health facilities should reduce the exposure of patients to ionizing radiation during examinations (Maleachi and Tjakraatmadja 2018; Vano 2020). This is due to the indoctrination of fear of radiation (radiophobia) that arises from many events (Dauer et al. 2011). The negative public stigma arises because many believe that the use of radiation in hospitals carries risks similar to those associated with such events as nuclear accidents (Bastiani et al. 2021; Dauer et al. 2011; Naderi et al. 2021). In fact, most of the general public does not have adequate knowledge about the relationship between radiation and cancer, so some people refuse to have medical imaging if it involves radiation (e.g. X-ray and CT scan) (Bastiani et al. 2021; Oakley and Harrison 2020). Radiation's adverse effects are postulated effects that are unexpected and relatively avoidable if they do not lead to accumulated exposure above the safety limits recommended by radiation regulatory agencies (BAPETEN 2007; Goverment of Indonesia 2023; National Council on Radiation Protection and Measurement 1990). In the use of radiation exposure doses above the threshold, side effects that can appear immediately include nausea, vomiting, and dizziness, while negative impacts can appear later such as hair loss, cancer, genetic mutations, and can even cause death

(Bandunggawa et al., 2009; Brenner et al., 2001; Matsuya et al., 2023). Therefore, it is imperative for policymakers, hospital management and clinical practitioners to take patient safety seriously (BAPETEN 2013; National Council on Radiation Protection and Measurement 1990; Tsapaki et al. 2021). Additionally, the public should also receive sufficient information and explanations regarding the dangers of radiation if undergoing examination and treatment with radiation (Bárdyová et al. 2021; Rahman et al. 2020).

In many countries, three categories of sources are reported to be responsible for almost 100% of the radiation dose received by the population, namely: (1) medical diagnostics; (2) uncontrolled natural sources, such as cosmic radiation and Potassium-40 (K-40); and (3) soil or soil-based building materials (Hasegawa et al. 2021; Hendry et al. 2009; Tomà et al. 2017). All other sources of ionizing radiation, such as the nuclear industry, processing industry, consumer products with radioactive content, and impacts from previous accidents) are reported to account for only 1-2% of the total dose received by the population (Smetsers and Tomas 2019). While in everyday life, there are man-made radiation sources that are often found. Medical device radiation sources are the most significant, whether from diagnostic X-rays, which generally use radiation from electrical sources, or nuclear medicine procedures (iodine-131, cesium-137, and others) which are artificial radioisotopes (Ravikanth 2017; Tomà et al. 2017). In addition, everyday consumer products can contribute to radiation exposure, such as building and road construction materials, combustible fuels (gas and coal), security screening systems using X-rays such as at airports, televisions, fluorescent lamp starters, smoke detectors (using americium materials), luminous watches (tritium materials), lantern coats (thorium materials), tobacco (polonium-210 materials), eyeglasses, and even some types of floor tiles. All of the materials mentioned above are sources of radiation that people often receive on a daily basis (Matsuya and Saga 2023; Smetsers and Tomas 2019).

Daily natural radiation dose obtained from the surrounding environment

The human body is naturally exposed to low levels of ionizing radiation from natural sources, such as cosmic rays and terrestrial radon gas (Abdullahi et al. 2019; Smetsers and Tomas 2019). These natural sources even account for about 85% of the total radiation exposure that individuals experience daily (Smetsers and Tomas 2019). The magnitude of radiation exposure received annually from natural sources is comparable to the radiation dose associated with computed tomography scans (Ferrero et al. 2019). However, despite these levels of natural radiation, no evidence of increased cancer incidence has been observed in different regions of the world, including whether regions characterized by high or very high levels of naturally occurring ionizing radiation (Ferrero et al. 2019; Rehani et al. 2020; Tsapaki et al. 2021). According to current estimates, the average person in the United States receives an effective dose of about 3 mSv per year from natural radiation, which includes cosmic radiation from outer space (Smetsers and Tomas 2019). Additionally, different places or regions can have different doses of natural radiation (Matsuya and Saga 2023; US Department of Energy 2000). The human body's exposure to radiation is naturally categorized into several sources, they are as follows (EPA US 2015; US Department of Energy 2000). First, cosmic radiation. Cosmic radiation is natural radiation that comes from outer space, mainly from the sun and distant stars. People will be exposed to more cosmic radiation when they are in a higher altitude. People in the mountains will be exposed to more cosmic radiation than people who live on the coast. Likewise, people who often fly will increase their exposure to cosmic radiation. For example, pilots or airplane passengers who travel frequently will get more cosmic radiation than people who live in cities or at sea level. Second, terrestrial radiation. Terrestrial radiation is natural radiation that comes from naturally occurring radioactive materials in the Earth's crust, such as uranium, thorium, and radon. Exposure to this radiation can come from soil, rocks, and water. Another example is radon gas, which is a by-product of the decay of uranium in the ground. This gas can then seep into buildings and cause radiation exposure. This gas is one of the most significant natural sources of radiation. Third, internal radiation. Internal Radiation is natural radiation that comes from some naturally occurring radioactive materials found in our bodies, such as potassium-40, carbon-14, and radium. Exposure to these natural sources of radiation can enter our bodies through food, water, and air, where they continue to emit small amounts of radiation. Even foods such as bananas, which contain potassium-40, can also emit small amounts of radiation. Lastly, background radiation from everyday life. Natural Radiation from Everyday Life is radiation that comes from building materials (such as bricks and stones) and household items (such as smoke detectors).

The use of floor or wall tiles in homes, mosques and other buildings also has radiation impacts. The overall total effective dose (TED) received by occupants from floor tiles based on room size and direction is 0.75 mSv/y (Abdullahi et al. 2019). In the Netherlands, doses from medical diagnostics and doses received from indoors contribute 40% and 38%, respectively, to the total dose of 2.7 mSv in the Netherlands. Uncontrollable natural sources are responsible for 21% and all other sources contribute only 1% of the total annual dose (Smetsers and Tomas 2019).

The daily dose of radiation from these environments may vary depending on the respective locations (National Council on Radiation Protection and Measurement 1990). In comparison, the amount of radiation from a single chest X-ray of an adult (0.1 mSv) is estimated to be equivalent to 10 days of natural background radiation that we encounter as part of our daily lives. Thus, a good understanding of the daily sources of radiation from the environment can help in understanding radiation exposure in hospitals. This may improve some people or patients who are sometimes apprehensive when offered an X-ray or CT scan at the hospital (Bárdyová et al. 2021; Hasegawa et al., 2021).

Daily radiation dose sources from electronic devices

Daily radiation doses can also come from electronic devices. However, the doses from these sources are generally very low and are believed to be within the safe limits set by authorized regulatory agencies. Most everyday electronic devices, such as smartphones, laptops and televisions, emit non-ionizing radiation, mainly in the form of radio frequency waves and electromagnetic fields. These forms of radiation do not have enough energy to ionize atoms or molecules, which means they are not capable of causing cancer-causing cell damage. This makes radiation from electronic equipment sources different from ionizing radiation from the other sources described above (Batubara et al., 2023; Hendry et al., 2009; Imansyah et al., 2023).

Types of radiation from electronic devices include: radio frequency radiation, which is emitted by devices that use wireless communication, such as mobile phones, Wi-Fi routers and Bluetooth devices (Batubara et al., 2023; EPA US 2015; Imansyah et al., 2023). Exposure levels are usually minimal and decrease with distance (EPA US 2015). Electromagnetic fields are produced by the power supplies in devices such as computers, microwaves and televisions (Hendry et al., 2009). Again, exposure levels are low and are not considered harmful in general use. Infrared Radiation is another type produced by remote controls and infrared sensors, and does not pose a significant health risk. These radiation exposure limits are regulated by agencies such as the Federal Communications Commission (FCC) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) which set exposure limits to ensure that devices are safe to use. These limits are based on extensive research and are designed to keep radiation levels well below dangerous thresholds (Hasegawa et al., 2021; US Department of Energy 2000).

For most users of electronic devices, exposure to radiation from everyday electronic devices may be negligible and believed not to pose a significant health risk. However, this does not mean that the accumulation of all the natural and environmental radiation that the body receives does not have the potential to become a health problem in the future, so further research is needed on this matter (Batubara et al., 2023; Imansyah et al., 2023).

Radiation sources from radiological examinations in hospitals

Applications of medical radiology imaging with ionizing and non-ionizing radiation-based modalities continue to increase in the world of medical practice. It is undeniable that the role of these modalities is very significant in supporting more precise and accurate diagnoses, even for treatment (Ferrero et al., 2019; Matsuya and Saga 2023; Smetsers and Tomas 2019). The use of ionizing radiation beams in cancer treatment is also very important and is growing very rapidly (Chen et al., 2024; Hasegawa et al., 2021). In addition to the positive impacts, there are also negative impacts that should be watched out for. The impact of medical imaging radiation raises concerns about patient radiation exposure. Relevant regulatory bodies such as the International Atomic Energy Agency (IAEA) which is a world-class regulator, the Nuclear Regulatory Commission (NRC) in the US, the Health Security Agency (HSA) in the UK (EPA US 2015; National Council on Radiation Protection and Measurement 1990), the Nuclear Security Regulatory Framework (BAPETEN) in Indonesia (BAPETEN 2013; Goverment of Indonesia 2023), and others, are the authorities related to the regulation of the use of radiation for civil, health, and educational research purposes (National Council on Radiation Protection and Measurement 1990). They set annual cumulative effective dose (CED) limits for the use of patient radiation in hospitals. The CED refers to the total amount of ionizing radiation a person has been exposed to over a period, often from various diagnostic or therapeutic medical imaging procedures. The CED is measured in millisieverts (mSv) and accounts for the long-term risk associated with multiple exposures. This metric is critical for ensuring radiation safety in medical settings, particularly for patients who undergo repeated radiological exams, as cumulative exposure increases the potential risk of adverse health effects, such as cancer (Chen et al., 2024; EPA US 2015; National Council on Radiation Protection and Measurement 1990; Vano 2020).

Medical imaging techniques such as X-rays, CT scans, and nuclear medicine procedures involve ionizing radiation, which can damage living tissues if exposure is too high (Ferrero et al., 2019; Tomà et al., 2017). Each type of diagnostic test exposes the patient to varying doses of radiation: (1) X-rays generally expose patients to small amounts of radiation, typically between 0.01 to 1 mSv per procedure (Oakley and Harrison 2020); (2) CT scans expose patients to higher doses, ranging from 2 to 20 mSv depending on the type of scan (e.g., a head CT might be 2 mSv, while a full-body scan could be up to 20 mSv) (Journy et al., 2015; Larson et al., 2007); (3) Nuclear medicine procedures like PET scans can expose patients to anywhere between 3 and 20 mSv depending on the injected radioactive material (Chen et al., 2024).

The practice of using ionizing radiation in hospitals for diagnostics or treatment has recently been increasingly reported to reach or exceed 100 mSv (da Silva Moura et al. 2019). Although 100 mSv is not a threshold for a single radiation effect, the CED for patients ≥100 mSv may result from repeated imaging procedures. Recently published data on the number of patients with CED ≥100 mSv are 0.6-3.4% from the use of CT modalities and approximately 4% during interventional radiology procedures (Vano 2020).

When the reported CED exceeds 100 millisieverts (mSv) per year, it can be dangerous. Therefore, doses below this threshold are believed to be safe and do not cause dangerous side effects for patients (Rehani et al. 2020). Radiation doses from hospital radiological examinations vary depending on the modality used. For comparison, the amount of radiation from a single adult chest X-ray (0.1 mSv) is considered equivalent to 10 days of the natural background radiation that we all encounter as part of our daily lives.

ALARA

ALARA is an acronym used in radiation safety use to set the radiation dose "As Low As Reasonably Achievable". The ALARA radiation safety principle is based on minimizing the radiation dose used for reasonable, image-generating examinations and limiting the release of radioactive material into the environment using all "reasonable methods." ALARA is not only a good radiation safety principle but also a regulatory requirement for all "radiation protection programs" (Bastiani et al. 2021; Rahman et al. 2020; Tsapaki et al. 2021). The ALARA concept is an integral part of all activities involving the use of radiation or radioactive materials and can help prevent unnecessary exposure as well as overexposure. The three key principles to help maintain "As Low As Reasonably Achievable" doses are time, distance, and shielding (Hiswara 2023; National Council on Radiation Protection and Measurement 1990).

ALARA principle was introduced in 1977 by the International Commission on Radiological Protection (ICRP), with the aim of balancing the risks and benefits of the use of radiation for diagnostic and therapeutic purposes in health care. Ionizing radiation has a versatile role in diagnostic imaging. From traditional radiography to three-dimensional imaging with CT, and real-time video with fluoroscopy, the discovery of X-rays by Wilhelm Röntgen has benefited countless patients and health care practitioners and is used every day today (National Council on Radiation Protection and Measurement 1990; Tsapaki et al. 2021; US Department of Energy 2000). However, concerns about its safety have occasionally arisen, and there is a need to discuss and continue to elaborate on radiation protection, as knowledge of the biological effects of radiation continues to grow (Hall 2009; National Council on Radiation Protection and Measurement 1990)

The three principles of radiation protection that have been adopted globally for years including in Indonesia are regulated in the regulation of the Head of BAPETEN Number 8 of 2011 concerning radiation safety in the use of diagnostic and interventional radiology X-ray machines in the chapter on protection requirements (BAPETEN 2007). Thus, in the implementation of radiology services in hospitals, these provisions are absolutely implemented and checked periodically. If there is a violation of these provisions, the permit to operate radiology services can be revoked. Although hospitals have complex operational permit procedures, the permit for radiology services is separate and regulated separately with regulations managed by the national BAPETEN (BAPETEN 2007; Goverment of Indonesia 2023).

Importance of patient education efforts on radiation in order to improve the quality of hospital services

Given the low understanding and awareness of patients about the impact of radiation on imaging modalities, hospitals can make various efforts such as preparing brochures and guides on radiation exposure and absorbed doses in each radiology modality (Chen et al., 2024; Naderi et al., 2021). In addition, providing multimedia in the form of educational videos may be very helpful for patients with low health literacy skills (Bastiani et al., 2021). As is known, the public is more likely to get information related to radiation safety from mass media and even social media which tend to provide irrelevant or sometimes incorrect information (Naderi et al., 2021). Several research reports state that patients are quite satisfied and their knowledge increases regarding radiation in radiotherapy services after watching educational videos on radiation oncology (Chen et al., 2024). Another report states that patients become more confident with their knowledge of the radiotherapy process after watching educational videos compared to patients who do not receive educational videos (Bárdyová et al., 2021; Chen et al., 2024; Dauer et al., 2011). Increased adoption of multimedia materials and partnerships with patients to customize patient education resources across hospitals are needed to promote the delivery of high-quality, patient-centered radiation education (Chen et al., 2024).

Conclusion

The use of ionizing radiation beams in hospital healthcare is growing and plays a significantly important role. Sometimes, patients or their families worry about the negative impact of radiation from radiology examinations. This can be due to their lack of knowledge, or because they get misinformation from mass media or social media. If the patient or their family feels worried, especially if the patient refuses the planned examination, it will certainly be very detrimental to the optimization of the implementation of their medical services. Therefore, patients' understanding of radiation should be taken seriously by the hospital, including doctors, radiographers, and hospital management. Hospitals need to develop effective and careful education strategies related to this matter. The information provided in education is not only limited to radiology examinations at the hospital but also includes everyday sources of radiation from their environment that they need to be aware of. Electronic devices such as smartphones and televisions also emit radiation even though they are not ionizing radiation, so patients can be aware of the benefits as well as the potential side effects of radiation properly. The use of brochures and video media has been reported to be very effective and meaningful. Other educational methods, such as short lectures in the ward or waiting room can also be considered. A good understanding of the impact of radiation on patients can increase their comfort in undergoing radiological examination procedures and treatment with ionizing radiation rays in hospitals so that the results of treatment outcomes can be better and optimal.

Authors’ contributions

Study concept and design: TMY, AW, DS, KR and MDA; Acquisition of data: TMY, AW, DS, KR and MDA; Analysis and interpretation of data: TMY, AW, DS, KR and MDA; Drafting of the manuscript: TMY, AW, DS, KR and MDA; Critical revision of the manuscript for important intellectual content: TMY, AW, DS, KR and MDA; Statistical analysis: TMY, AW, DS, KR and MDA; Study supervision: TMY, AW, DS, KR and MDA.

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Ethical approval

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Conflict of interest

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References

Abdullahi S, et al. Assessment of the long-term possible radiological risk from the use of ceramic tiles in Malaysia. Nucl Sci Technol 2019;30(2):19.

Bandunggawa P, et al. Bahaya Radiasi dan Cara Proteksinya. Medicina 2009;40:4-7.

BAPETEN. Peraturan Pemerintah Republik Indonesia Nomor 33 Tahun 2007 Tentang Keselamatan Radiasi Pengion dan Keamanan Sumber Radioaktif: 2007.

BAPETEN. Peraturan Kepala Badan Pengawas Tenaga Nuklir Nomor 4 Tahun 2013 tentang Proteksi dan Keselamatan Radiasi dalam Pemanfaatan Tenaga Nuklir: 2013.

Bárdyová Z, et al. The importance of public health in radiology and radiation protection. J Public Health Res 2021;10(3).

Bastiani L, et al. Patient perceptions and knowledge of ionizing radiation from medical imaging. JAMA Netw Open 2021;4(10):e2128561.

Batubara D, et al. Pengaruh radiasi elektromagnetik yang ditimbulkan oleh telepon seluler. J Phys Educ 2023;2:76-85.

Brenner DJ, et al. Estimated risks of radiation-induced fatal cancer from pediatric CT. Am J Roentgenol 2001;176(2):289-296.

Chen J, et al. Patient education practices and preferences of radiation oncologists and interprofessional radiation therapy care teams: A mixed-methods study exploring strategies for effective patient education delivery. Int J Radiat Oncol 2024;119(5);1357-1367.

da Silva Moura W, et al. Factors influencing the effective dose associated with CBCT: A systematic review. Clin Oral Investig 2019;23(3):1319-1330.

Dauer L T, et al. Fears, feelings, and facts: Interactively communicating benefits and risks of medical radiation with patients. Am J Roentgenol 2011;196(4):756-761.

EPA US. Radiation sources and doses. Retrieved from https://www.epa.gov/sites/default/files/2015-06/relative-doses-radiation.jpg. Accessed: 7 June 2023.

Ferrero A, et al. Understanding, justifying, and optimizing radiation exposure for CT imaging in nephrourology. Nat Rev Urol 2019;16(4):231-244.

Government of Indonesia. Peraturan Pemerintah Republik Indonesia Nomor 45 Tahun 2023 tentang Keselamatan Radiasi Pengion dan Keamanan Zat Radioaktif (177034): 2023.

Hall E J. Radiation biology for pediatric radiologists. Pediatr Radiol (2009);39(1): 57-64.

Hasegawa K, et al. Meeting Report on The 6th Educational Symposium on Radiation and Health by Young Scientists (ESRAH2019). Radiat Environ Med 2021;10(2):108-114.

Hendry JH, et al. Human exposure to high natural background radiation: What can it teach us about radiation risks? J Radiol Prot 2009;29(2).

Hiswara E. Buku pintar proteksi dan keselamatan radiasi ebook. Jakarta: BRIN; 2023.

Imansyah F, et al. Sosialisasi permasalahan dampak radiasi gelombang elektromagnetik menara telekomunikasi di permukiman masyarakat. J Abdi Insani 2023;10(3):1436-1452.

Journy N, et al. Are the studies on cancer risk from CT scans biased by indication? Elements of answer from a large-scale cohort study in France. Br J Cancer 2015;112(1):185-193.

Larson DB, et al. Informing parents about CT radiation exposure in children: It's OK to tell them. Am J Roentgenol 2007;189(2):271-275.

Maleachi R, et al. Pencegahan efek radiasi pada pencitraan radiologi. Cermin Dunia Kedokteran 2018;45(7):537-539.

Matsuya Y, et al. Biophysical simulations for estimating biological effects after exposure to ionizing radiation: Current state and future prospects. Radiat Environ Med 2023;12(2):81-90.

Naderi M, et al. The need to increase patient awareness of radiation exposure in imaging modalities: A study on the awareness and attitude of patients. J Med Imaging Radiat Sci 2021;52(3):450-455.

National Council on Radiation Protection and Measurement. NCRP Report No. 107: Implementation of the Principle of as Low as Reasonably Achievable (ALARA) for Medical and Dental Personnel: 1990.

Oakley PA, et al. X-ray hesitancy: Patients' radiophobic concerns over medical X-rays. J Radiol Technol 2020;18(3):1-11.

Rahman FUA, et al. Paradigma baru konsep proteksi radiasi dalam pemeriksaan radiologi kedokteran gigi: dari ALARA menjadi ALADAIP. J Radiol Dentomaxillofac Indonesia 2020;4(2):27.

Ravikanth R. Effective radiological imaging for the good of patients: Weighing benefits and risks. World J Nucl Med 2017;16(02):85-87.

Rehani MM, et al. Patients undergoing recurrent CT scans: Assessing the magnitude. Eur Radiol 2020;30(4):1828-1836.

Smetsers RCGM, et al. A practical approach to limit the radiation dose from building materials applied in dwellings, in compliance with the Euratom Basic Safety Standards. J Environ Radioact 2019;196(10):40-49.

Tomà P, et al. Radiation exposure in diagnostic imaging: Wisdom and prudence, but still a lot to understand. La Radiol Med 2017;122(3):215-220.

Tsapaki V, et al. Annals of the ICRP. In Radiation Phys Chem 2021;188.

US Department of Energy. Ionizing radiation dose ranges. Available from: https://www.nrc.gov/docs/ml1209/ML120970113.pdf. Accesed: 18 June 2023.

Vano E. Challenges for managing the cumulative effective dose for patients. Br J Radiol 2020;93(1116):20200814.