KARYA ILHAM PUBLISHING
CONNECTING MINDS, BRIDGING IDEAS, INSPIRING READERS

Journal of Advanced Research in Computing and Applications

Journal homepage:
https://karyailham.com.my/index.php/arca/index
ISSN: 2462-1927

Strengthening Radiation Protection Culture: A Review of Global Guidelines and Malaysian Regulatory Oversight

Nur Farzana Nazurah Rosli[1], Siti Amira Othman[1,*], Mazlinaa Mohd Halim[1], Muhammad Zarhin Roslin[1], Nur Alya Aqilah Mahamad Zaidi[1], Nur Ainaa Syamimi Mohd Hair[1], Nur Alia Qamarina Mohd Abdul Rashid[1]

[1] Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia, 84600, Pagoh, Johor, Malaysia

ARTICLE INFO

Article history:
Received 10 February 2026
Received in revised form 30 May 2026
Accepted 2 June 2026
Available online 22 August 2026

Keywords:
Radiation protection; ALARA; dose monitoring; AELB

ABSTRACT

Radiation protection is a critical practice designed to minimise the biological risks of ionising radiation to individuals and the environment. This review paper examines the integration of international safety standards with national regulatory frameworks, specifically focusing on the transition from the International Atomic Energy Agency (IAEA) Basic Safety Standards (BSS) to Malaysia's regulatory landscape governed by the Atomic Energy Licensing Board (AELB) under the Atomic Energy Licensing Act 1984 (Act 304). The study analyses the foundational principles of radiation protection: justification, optimisation (ALARA/ALARP), and dose limitation, which serve as the cornerstone for safe practices in medical and industrial sectors. The paper details the practical implementation of dose monitoring and risk assessment, particularly within diagnostic radiology departments. It evaluates various detection technologies, including Thermoluminescent Dosimeters (TLDs), Optically Stimulated Luminescent Dosimeters (OSLs), and Electronic Personal Dosimeters (EPDs), and highlights their roles in personal and area surveillance. Furthermore, the review explores how technological innovations such as the Internet of Things (IoT), Cloud-based dose management, and Artificial Intelligence (AI) are revolutionising compliance by enabling real-time monitoring and predictive safety analysis. Despite these advancements, the study identifies persistent challenges, such as technical difficulties in measuring neutron radiation and eye lens doses, human factors that lead to non-compliance with badge use, and global inconsistencies in the application of safety standards. Results from medical worker studies indicate that while most exposures remain well below international thresholds (e.g., 20 mSv/year for occupational workers), continuous education and robust quality assurance are vital. The paper concludes that Malaysia's regulatory framework effectively mirrors international best practices. It suggests that future efforts must focus on improving the affordability and sensitivity of real-time dosimetry while strengthening the organisational safety culture to ensure sustainable and effective radiation protection in an evolving technological era.

* *Corresponding author.*
E-mail address: sitiamira@uthm.edu.my

https://doi.org/10.37934/arca.44.1.7077

1. Introduction

Radiation protection is the practice of minimizing the harmful effects of ionizing radiation on humans and the environment. Radiation, which involves the transfer of energy through particles or electromagnetic waves, can alter the structure and function of human tissues when exposure occurs. Therefore, regulations are essential to ensure the safety of workers, the public, and the environment, especially in industries, medicine, and research where radiation is widely used. Without proper control, radiation exposure can lead to serious health risks that may not be immediately visible. The International Atomic Energy Agency (IAEA) provides global guidance through its Basic Safety Standards (BSS), which establish fundamental principles for the safe use of radiation. Many countries, including Malaysia, adopt these standards through national regulatory bodies such as the Atomic Energy Licensing Board (AELB) to ensure consistency with international safety practices [1].

As radiation use continues to expand across various sectors, monitoring and dose assessment have become increasingly important. Workers in radiation-related fields may be exposed under both controlled and uncontrolled conditions, and excessive exposure can cause serious biological effects. Radiation monitoring helps measure and evaluate exposure levels, while dose assessment ensures compliance with safety limits. Key principles such as ALARA (As Low As Reasonably Achievable) guide efforts to minimize exposure, supported by international recommendations from organizations like the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Advances in technology, including digital dosimetry and real-time monitoring systems, have improved the accuracy and efficiency of radiation tracking, although challenges remain in standardization, data reliability, and low-dose detection [2].

Risk assessment is another critical component of radiation protection, involving the identification of hazards, estimation of exposure levels, and implementation of control measures to keep risks as low as reasonably practicable (ALARP). Radiation has both beneficial and harmful effects, making its safe use essential for modern society. Effective radiation protection relies on three core principles: justification, ensuring that the benefits outweigh the risks; optimization, minimizing exposure through practical measures; and dose limitation, ensuring exposure does not exceed recommended limits. These principles are supported by engineering controls, administrative procedures, and personal protective equipment to maintain a strong safety culture.

Overall, radiation protection is a vital practice that combines international standards, national regulations, and modern technological advancements to safeguard human health. Continuous improvement in monitoring systems, regulatory enforcement, and safety awareness is necessary to address evolving challenges. Strengthening these efforts will help reduce exposure risks, improve compliance, and ensure sustainable and effective radiation safety practices across all sectors [3].

2. International Atomic Energy Agency (IAEA) Basic Safety Standards

As the use of radiation continues to expand across industries, medicine, and research, the International Atomic Energy Agency (IAEA) has developed a comprehensive set of safety standards to guide countries in managing radiation risks. These standards are organized within the IAEA Safety Standards Series, which provides a structured and globally recognized framework for radiation and nuclear safety. At the highest level are the Safety Fundamentals, which define the core principles of safety. These are supported by the General Safety Requirements (GSR) and Specific Safety Requirements (SSR). The GSR, divided into several parts, covers key areas such as regulatory frameworks, leadership and management, radiation protection, safety assessment, waste management, decommissioning, and emergency preparedness [4]. Meanwhile, the SSR focuses on specific facilities and activities, including nuclear power plants, research reactors, and the transport of radioactive materials. Together with supporting Safety Guides, these components form a unified system that ensures consistent safety practices worldwide. The main objective of the Basic Safety Standards (BSS) is to protect people and the environment from the harmful effects of ionizing radiation.

Radiation protection under the IAEA framework is based on three fundamental principles: justification, optimization, and dose limitation. Justification ensures that any use of radiation provides more benefit than harm. In medical applications, this principle is particularly important because the same individual receives both the benefit and the risk. It is applied at three levels: the general acceptance of radiation use in medicine, the justification of each specific procedure, and the evaluation of each individual exposure [5]. Optimization, guided by the ALARA (As Low As Reasonably Achievable) principle, focuses on minimizing radiation doses while still achieving the intended purpose. In medical imaging, this requires balancing dose reduction with maintaining sufficient image quality for accurate diagnosis. Dose limitation sets maximum permissible exposure levels to protect workers and the public. According to IAEA guidelines, occupational exposure is typically limited to 20 mSv per year, while public exposure should not exceed 1 mSv per year. However, for medical exposure, strict dose limits are not applied, as the focus is on ensuring that the benefits outweigh the risks.

In Malaysia, the use of ionizing radiation is regulated under the Atomic Energy Licensing Act 1984 (Act 304). This legislation provides the legal framework to control and ensure the safe use of radioactive materials and radiation-emitting equipment. The main regulatory authority responsible for enforcing this act is the Atomic Energy Licensing Board (AELB). AELB oversees licensing, inspection, and compliance to ensure that radiation practices in Malaysia align with international standards such as the IAEA BSS. Under Act 304, any individual or organization intending to use, store, or handle radiation sources must obtain a valid license from AELB. The licensing process includes specific conditions related to safety measures, operational limits, and authorized materials [6]. AELB also has the authority to suspend or revoke licenses if regulations are violated, ensuring strict control over radiation use and protecting public and environmental safety.

To implement the IAEA standards at the national level, AELB has developed various regulations and codes of practice, including the LEM/TEK guidelines. These documents translate international principles into practical requirements for local industries. For example, the Radiation Protection Licensing Regulations 1986 require organizations to obtain authorization before handling radioactive materials, aligning with the IAEA principle of regulatory control. AELB also mandates the appointment of a Radiation Protection Officer (RPO), as outlined in LEM/TEK-30, to ensure that a qualified individual is responsible for maintaining radiation safety within each facility. Additionally, organizations must establish a Radiation Protection Programme (RPP), which includes monitoring, training, and emergency preparedness measures, as specified in guidelines such as LEM/TEK-33 and LEM/TEK-57. These regulations also emphasize proper record-keeping of radiation exposure and operational data [7].

Furthermore, AELB provides detailed guidance on the safe transport and disposal of radioactive materials through documents such as LEM/TEK-58 and LEM/TEK-76. Training and competency requirements are also strictly enforced. Individuals working with radiation, particularly RPOs, must complete approved training programs and pass certification examinations [8]. Continuous professional development is required through Continuing Education Points (CEP) to ensure that personnel remain competent and up to date with current safety practices. Overall, Malaysia's implementation of radiation protection regulations demonstrates strong alignment with international standards, ensuring effective control, safety, and sustainability in the use of ionizing radiation.

3. Fundamentals Of Radiation Dose Monitoring

Radiation dose monitoring involves measuring and recording the amount of radiation received by individuals to ensure safety and compliance with established standards. It is guided by the ALARA (As Low As Reasonably Achievable) principle, which aims to minimize exposure while maintaining the intended benefit. The system used worldwide is based on three core principles—justification, optimization, and dose limitation established by the International Commission on Radiological Protection (ICRP) [9]. Monitoring serves several important purposes, including controlling occupational exposure, ensuring that dose limits are not exceeded, and maintaining long-term records for health assessment. According to the International Atomic Energy Agency (IAEA), both governments and employers share responsibility for implementing effective monitoring programs. Accurate dose measurement depends on proper calibration of dosimeters and understanding their response to different radiation types and conditions. In medical settings, correction factors are necessary when protective equipment such as lead aprons is used, as badge readings may not reflect the true body dose. Modern monitoring systems now combine personal dosimeters with centralized digital platforms, enabling better data analysis, trend identification, and improved safety practices [10].

Reliable radiation protection depends on accurate measurement using appropriate detectors and dosimeters. Different instruments are used depending on the radiation type and monitoring purpose [11]. Thermoluminescent dosimeters (TLDs) store radiation energy in crystal materials and release it as light when heated, providing stable and reusable measurements, although they do not offer real-time readings. Optically Stimulated Luminescent (OSL) dosimeters function similarly but use light instead of heat, allowing higher sensitivity and repeated readings. For real-time monitoring, Electronic Personal Dosimeters (EPDs) are widely used, as they provide immediate dose readings, alarms, and digital data storage. For area monitoring, ionization chambers offer high accuracy, while Geiger–Müller (GM) counters are portable and effective for detecting beta and gamma radiation, though they may saturate at high dose rates. Scintillation detectors are also commonly used due to their high sensitivity and fast response. Each instrument has its own advantages and limitations, making proper selection and regular calibration essential for accurate and reliable measurements [12].

Dose estimation methods range from simple badge readings to advanced computational models. Common personal dosimeters include TLDs, OSL badges, film badges, and EPDs, each differing in sensitivity, response, and real-time capability [13]. Measured values such as personal dose equivalents are converted into effective or equivalent doses using calibration coefficients and correction factors, especially when protective equipment is used. In medical procedures, double-badge methods are often applied to estimate accurate exposure levels for the body and eyes. In situations where direct measurement is not possible, dose reconstruction techniques are used, relying on environmental data, work history, and computational models such as Monte Carlo simulations [14]. Advances in computational dosimetry and data availability have significantly improved the accuracy of dose estimation for both workers and patients.

Radiation protection is governed by international and national regulations that establish safety limits and guidelines. The ICRP introduced key principles in its recommendations, which are further implemented by the International Atomic Energy Agency through the Basic Safety Standards (BSS). Scientific input from the United Nations Scientific Committee on the Effects of Atomic Radiation

(UNSCEAR) supports the development of these policies. Based on these guidelines, occupational exposure is generally limited to an average of 20 mSv per year over five years, with a maximum of 50 mSv in any single year, while public exposure should not exceed 1 mSv annually. In Malaysia, radiation use is regulated by the Atomic Energy Licensing Board (AELB) under the Atomic Energy Licensing Act 1984 (Act 304). AELB ensures compliance through licensing, inspections, and monitoring, requiring facilities to appoint Radiation Protection Officers and maintain exposure records [15].

Occupational dose monitoring is essential for protecting workers in both medical and industrial sectors. It involves identifying exposed workers, issuing dosimeters, conducting regular monitoring, and maintaining exposure records. In hospitals, workers in interventional radiology and cardiology often receive higher doses, so additional measures such as dual badges and eye dosimeters are used. In industries such as nuclear power and radiography, monitoring includes both personal and environmental measurements, with specialized detectors required for neutron radiation. Although regulations are well established, human factors such as improper badge usage can affect monitoring accuracy. Continuous training and feedback are therefore necessary to ensure compliance and maintain safety standards. Overall, improvements in technology and awareness have contributed to a gradual reduction in occupational radiation exposure [16].

Recent technological advancements have significantly improved radiation monitoring and safety compliance. Internet of Things (IoT)-based dosimeters enable real-time data collection and transmission to centralized systems, allowing faster and more efficient monitoring. Wearable smart dosimeters, including Bluetooth-enabled devices, allow workers to track their own exposure and upload data to cloud platforms. Cloud-based systems automate data recording, analysis, and reporting, improving accuracy and supporting regulatory compliance. The integration of artificial intelligence (AI) further enhances these systems by predicting exposure trends, detecting anomalies, and optimizing safety measures [17]. In addition, automated safety systems can trigger alarms or corrective actions when exposure exceeds safe limits. These innovations have been successfully implemented in hospitals and nuclear facilities, improving response time, accuracy, and overall safety performance.

Despite significant progress, several challenges remain in radiation dose monitoring. Accurate measurement of neutron radiation and eye lens doses continues to be difficult, particularly in medical environments. Differences in safety standard implementation across countries can also lead to inconsistent levels of protection. Human factors remain a concern, as some workers may neglect proper dosimeter use or fail to respond promptly to high exposure readings. While digital dosimeters offer real-time monitoring, their cost and accuracy still require improvement. Future efforts should focus on developing more affordable and precise real-time monitoring devices, enhancing computational models for dose estimation, and improving education and training. Greater collaboration and data sharing among organizations will also be essential to strengthen global radiation protection practices and ensure safer working environments [18].

4. Radiation Hazards in Work Areas

Hazard identification is an essential process used to determine whether a situation, equipment, or activity has the potential to cause harm. In diagnostic radiology departments, several hazards exist, particularly from ionizing radiation generated by X-ray and CT imaging, as well as strong magnetic fields produced by MRI systems. Exposure to ionizing radiation can lead to cellular damage, long-term health effects, and an increased risk of cancer, especially through stochastic effects that may occur even at low doses. In addition to radiation risks, other hazards include chemical exposure from disinfectants and contrast agents, electrical dangers such as shocks or burns, ergonomic issues from improper patient handling, and the risk of infection. Errors in imaging procedures, such as incorrect equipment settings or poor patient positioning, can further increase unnecessary radiation exposure. A lack of proper training and awareness among healthcare professionals also contributes to these risks, as underestimation of radiation dose and poor communication may lead to repeated or unnecessary examinations. Therefore, continuous education, effective communication, and a strong safety culture are crucial in minimizing hazards in radiology environments [19].

Dose exposure estimation plays a vital role in radiation protection by assessing the level of radiation received and its associated health risks. Research indicates that the likelihood of cancer increases with higher absorbed doses, making accurate dose estimation important for risk evaluation. Occupational exposure refers to radiation received by workers during their professional activities, excluding exempted sources. Among medical imaging techniques, CT scans typically deliver higher radiation doses compared to standard X-ray procedures, and exposure is commonly measured in units such as millisievert (mSv) for effective dose and milligray (mGy) for absorbed dose. Personal dosimeters are used to monitor cumulative exposure over time, and these readings are compared with safety limits set by organizations such as the International Commission on Radiological Protection and enforced nationally by bodies like the Atomic Energy Licensing Board. Regular monitoring ensures compliance with the ALARP (As Low As Reasonably Practicable) principle [20]. Studies have shown that radiation exposure among medical workers in hospital settings generally remains below international safety limits, indicating that proper safety measures and monitoring practices are effective in controlling occupational dose.

Mitigation of radiation exposure in diagnostic radiology is based on the core principles of justification, optimization, and dose limitation. Justification ensures that every medical exposure is necessary and that its benefits outweigh potential risks. Optimization, guided by the ALARA principle, focuses on reducing exposure to the lowest practical level by controlling key factors such as time, distance, and shielding. Minimizing exposure time, increasing distance from the radiation source, and using protective barriers such as lead aprons, shields, and lead-lined walls are essential practices. Dose limitation ensures that exposure levels remain within recommended thresholds, typically 20 mSv per year for occupational workers and 1 mSv per year for the public [21].

In clinical environments, occupational exposure mainly comes from scattered radiation during procedures. Protection strategies include engineering controls, administrative measures, and personal protective equipment such as lead aprons, thyroid shields, and leaded eyewear, which can significantly reduce radiation dose. Proper positioning of personnel, effective use of collimation, and installation of shielding devices further enhance safety [22]. For patients, mitigation focuses on optimizing imaging procedures to avoid unnecessary exposure by selecting appropriate techniques, minimizing scan areas, and using advanced filtration methods. Special care is required for sensitive groups such as pregnant women and children, where alternative imaging methods like ultrasound or MRI may be preferred. Additionally, regular equipment maintenance, quality assurance testing, and continuous training of healthcare personnel are essential to maintaining a strong and sustainable radiation safety culture [23].

5. Conclusion

To conclude, radiation protection is essential to ensure the safety of people and the environment from the harmful effects of ionizing radiation. The International Atomic Energy Agency (IAEA) Basic Safety Standards (BSS) serve as the main global framework guiding safe radiation practices, and many countries, including Malaysia, adopt these principles through national regulations. In Malaysia, the

Atomic Energy Licensing Board (AELB) implements radiation safety through the Atomic Energy Licensing Act 1984 (Act 304) and related codes of practice. AELB is responsible for licensing, inspections, and training to ensure that only qualified personnel handle radiation sources. Guidelines such as the LEM/TEK series translate international standards into practical applications, covering radiation protection programmes, monitoring, and waste management. Overall, Malaysia's regulatory system reflects strong alignment with IAEA standards while adapting them to local requirements to ensure safety remains the top priority.

Radiation protection and dose monitoring are also critical in minimizing occupational and public exposure. International organizations such as the International Commission on Radiological Protection (ICRP), United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), and the IAEA, together with AELB, provide guidelines based on the ALARA principle to keep radiation exposure within safe limits. The effectiveness of these standards depends on accurate instrumentation, proper calibration, and continuous monitoring. Recent technological advancements, including IoT-based dosimeters, wearable devices, cloud-based dose management systems, and AI-assisted analysis, have significantly improved real-time monitoring and compliance. However, challenges such as difficulty in measuring neutron and eye lens doses, inconsistent global regulations, human errors in dosimeter use, and high costs of advanced systems still exist. Future improvements should focus on developing more sensitive, affordable, and standardized monitoring systems, alongside stronger safety culture, training, and international collaboration.

In diagnostic radiology, occupational exposure mainly comes from scattered radiation rather than direct beams. Ensuring safety requires strict adherence to the principles of time, distance, and shielding. Protective equipment such as lead aprons, thyroid shields, and ceiling-mounted barriers, along with proper equipment use and maintenance, significantly reduces radiation dose for both patients and staff. Regular quality assurance (QA) testing and calibration of imaging equipment are essential to maintain performance and prevent unnecessary exposure. Personal monitoring devices such as thermoluminescent dosimeters (TLDs) are also important for tracking cumulative radiation doses and ensuring compliance with safety limits. Additionally, proper staff positioning and awareness of radiation scatter directions further reduce occupational risk.

Beyond technical measures, human and organizational factors play a crucial role in radiation safety. Continuous education, training, and professional development are necessary to maintain awareness and competency among healthcare workers. Institutions should implement regular workshops, refresher courses, and seminars to keep staff updated on radiation protection standards. Strong administrative support is also needed to ensure the availability and proper maintenance of protective equipment and to implement job rotation systems that reduce cumulative exposure. Ultimately, effective radiation protection requires a combination of technology, regulation, and human awareness. As radiological technology continues to advance, maintaining strong governance, adherence to international standards, and a culture of safety will be essential to achieving both diagnostic excellence and sustainable healthcare practice.

References

[1] Atomic Energy Licensing Board (AELB). 2020. Guidelines for Radiation Protection in Malaysia. Putrajaya: Atomic Energy Licensing Board Malaysia.

[2] Fratelli, Ilaria, Sara M. Carturan, Francesco Tommasino, Laura Basiricò, Felix Pino, Antonio Valletta, Marcello Campajola et al. "A wearable tool for real-time dose monitoring during cancer radiation therapies." *Science Advances* 11, no. 17 (2025): eadt7633. https://doi.org/10.1126/sciadv.adt7633.

[3] Garba, Idris, Penelope Engel-Hills, Florence Davidson, and Anas Ismail. "Radiation dose management system in computed tomography procedures: a systematic review." *Radiation Protection Dosimetry* 199, no. 10 (2023): 1063-1074. https://doi.org/10.1093/rpd/ncad124.

[4] Hernández-Gutiérrez, Carlos A., Marcelo Delgado-del-Carpio, Lizette A. Zebadúa-Chavarría, Héctor R. Hernández-de-León, Elias N. Escobar-Gómez, and Manuel Quevedo-López. "IoT-enabled system for detection, monitoring, and tracking of nuclear materials." *Electronics* 12, no. 14 (2023): 3042.https://doi.org/10.3390/electronics12143042.

[5] International Atomic Energy Agency (IAEA). 2014. Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (GSR Part 3). Vienna: IAEA. https://doi.org/10.61092/iaea.u2pu-60vm.

[6] International Atomic Energy Agency (IAEA). 2020. Advances in Radiation Protection Monitoring and Dosimetry Systems. Vienna: IAEA. IAEA

[7] International Atomic Energy Agency (IAEA). 2020. Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (GSR Part 3). Vienna: IAEA. IAEA Publication

[8] Knoll, Glenn F. *Radiation detection and measurement*. John Wiley & Sons, 2010. https://doi.org/10.1002/9783527693513.

[9] Lee, Won Jin, Eun Jin Jang, Kyeong Seo Kim, and Ye Jin Bang. "Underestimation of radiation doses by compliance of wearing dosimeters among fluoroscopically-guided interventional medical workers in Korea." *International journal of environmental research and public health* 19, no. 14 (2022): 8393. https://doi.org/10.3390/ijerph19148393.

[10] Radiation Detection and Measurement. n.d. Hoboken, NJ: John Wiley & Sons.

[11] Rehani, Madan M. "Patient radiation exposure and dose tracking: a perspective." *Journal of Medical Imaging* 4, no. 3 (2017): 031206-031206. https://doi.org/10.1117/1.JMI.4.3.031206.

[12] Spurn√Ω, Z. n.d. Thermoluminescent Dosimetry. Vienna: International Atomic Energy Agency. Retrieved from IAEA INIS Record

[13] International Commission on Radiological Protection (ICRP). 2007. The 2007 Recommendations of the International Commission on Radiological Protection (ICRP Publication 103). Annals of the ICRP 37 (2-4). https://doi.org/10.1016/j.icrp.2007.10.003.

[14] Torres, H., N. Baena, V. Vergara, and G. Perez. *Design and assembly of an IOT based device to determine absorbed dose of gamma and UV radiation in skin*. No. INIS-MX--3282. Sociedad Mexicana de Irradiacion y Dosimetria, Ciudad de Mexico (Mexico), 2019.

[15] Benzazon, N., et al. 2023. "Analytical Models for External Photon Beam Radiotherapy Dose Estimation." Medical Physics Journal. https://doi.org/10.3389/fonc.2023.1197079

[16] Chida, Koichi, Yuji Kaga, Yoshihiro Haga, Nozomi Kataoka, Eriko Kumasaka, Taiichiro Meguro, and Masayuki Zuguchi. "Occupational dose in interventional radiology procedures." *American Journal of Roentgenology* 200, no. 1 (2013): 138-141. https://doi.org/10.2214/AJR.11.8455

[17] Gómez-Ros, J. M., R. Bedogni, and C. J. R. M. Domingo. "Personal neutron dosimetry: state-of-the-art and new technologies." *Radiation Measurements* 161 (2023): 106908. https://doi.org/10.1016/j.radmeas.2023.106908

[18] Hattori, Kenshin, Yohei Inaba, Toshiki Kato, Masaki Fujisawa, Hikaru Yasuno, Ayumi Yamada, Yoshihiro Haga, Masatoshi Suzuki, Masayuki Zuguchi, and Koichi Chida. "Evaluation of a new real-time dosimeter sensor for interventional radiology staff." *Sensors* 23, no. 1 (2023): 512. https://doi.org/10.3390/s23010512

[19] International Atomic Energy Agency (IAEA). 2018. Occupational Radiation Protection: General Safety Requirements Part 3 (GSR Part 3). Vienna: International Atomic Energy Agency.

[20] International Commission on Radiological Protection (ICRP). 2007. The 2007 Recommendations of the International Commission on Radiological Protection (ICRP Publication 103). Oxford: Elsevier.

[21] Milder, Cato M., David Borrego, Dale L. Preston, Daphnée Villoing, Tae-Eun Kwon, Donald L. Miller, Bruce H. Alexander, Martha S. Linet, Choonsik Lee, and Cari M. Kitahara. "Occupational radiation dose trends in US radiologic technologists assisting with fluoroscopically guided interventional procedures, 1980–2020." *Journal of Vascular and Interventional Radiology* 35, no. 7 (2024): 1057-1065. https://doi.org/10.1016/j.jvir.2024.03.032