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X-RAY Radiation Safety Program

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Abstract

In the context of X-ray facilities, this project addresses the crucial need for radiation safety, specifically regarding healthcare personnel, like hospital cleaners, who are exposed to radiation for extended periods. Due to their proximity to X-ray facilities, hospital cleaners are subjected to the risk of ionizing radiation exposure, whereas there is a scarcity of real-time data on exposure in these existing safety standards. It is also recommended that a GPS device be used for real-time mapping and exposure tracking so that interventions can be directed and cleaner safety can be improved.

Keywords
X-ray facilities, radiation safety, real-time monitoring, healthcare workers, GPS devices, and ionizing radiation.

1. Introduction
Radiation safety in X-ray facilities is a significant concern for patients, doctors, and hospital staff. Over the years, ionizing radiation has become an important diagnostic and treatment modality used in various hospital departments such as surgery, radiology, and interventional cardiology. Despite its benefits, the tool also has harmful effects, including cancer risk for people exposed to ionizing radiation (Hamzian et al. 2022). As such, radiation safety programs protect staff, especially hospital cleaners who spend considerable time in and around the X-ray rooms after patients and doctors, from the harmful waves.

Radiation-related safety measures and protection are of utmost importance when protecting the health and ensuring the well-being of all patients and healthcare providers in different hospitals. Even though X-ray facilities are essential for therapeutic and diagnostic purposes, they come with the intrinsic dangers of exposure to ionizing radiation (Guide 2018). It is also essential to define dangerous, mild, and normal exposure levels to radiation depending on the regulatory standards. The reduction of radiation exposure is of the utmost significance, even though X-rays offer vital diagnostic advantages. The utilization of a real-time monitoring system has the likeliness to deliver timely alarms, which, in turn, enables proactive responses so that the hazards of exposure can be minimized.

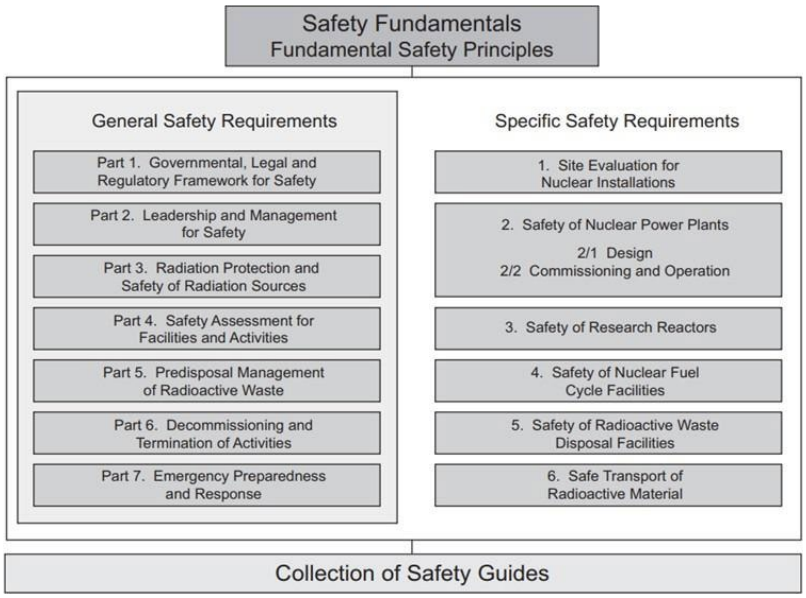

Figure 1. The long-term structure of the IAEA Safety Standards (Source: Guide 2018)

The radiation safety program has three main objectives. First, it aims to investigate how exposure to occupational radiation affects healthcare workers, focusing on potential health impacts and long-term consequences. Second, it seeks to evaluate the effectiveness of existing health and safety protocols, as well as preventive measures, in minimizing the risks associated with X-ray radiation. This involves assessing current practices and identifying areas for improvement. Lastly, the program proposes the installation of radiation monitoring devices in critical areas of hospitals. These devices will help track radiation levels and ensure that healthcare workers are adequately protected from excessive exposure, thereby enhancing overall safety in the workplace.

Methods

The radiation safety program includes several practical methodologies to mitigate the risks of radiation exposure in hospitals. These methodologies encompass understanding the risks posed by radiation, evaluating current safety regulations and practices, improving radiation monitoring systems, maintaining equipment, ensuring patient safety, monitoring radiation levels, investigating incidents, and continually assessing and developing safety measures. This study will specifically focus on "Monitoring of radiation and dosimetry." As part of this focus, radiation monitoring devices such as GPS, cameras, time/area exposure trackers, and IoT radiation monitoring devices will be deployed in key hospital areas prone to X-ray radiation exposure. The primary solution proposed is the use of GPS devices to measure both environmental and occupational radiation exposure, enhancing the overall safety of healthcare workers.

2. Literature Review

2.1 Occupational radiation exposure for healthcare workers

In the realm of healthcare, where the utilization of X-ray technology is pervasive for diagnostic and therapeutic purposes, the welfare of healthcare workers regarding radiation exposure stands as a paramount concern. Healthcare workers, including radiologists, radiologic technologists, nurses, and support staff, are routinely exposed to ionizing radiation in their daily tasks (Yashima & Chida 2022). While important for patient care, such exposure concerns these workers' occupational safety. Thus, strong radiation safety protocols are necessary to reduce these dangers and protect healthcare workers. First, radiation and its effects on the body must be understood to create efficient safety measures. The energy of ionizing radiation removes firmly bonded electrons from atoms, forming ions. These ions may harm cell molecular structures, producing tissue damage, sickness from radiation, cancer, and genetic abnormalities.

Due to radiation exposure and closeness, healthcare professionals are at more risk than the general population. Healthcare worker radiation safety initiatives emphasize education and training. Radiation workers must understand radiation physics, radiation safety, and radiation-emitting device operation. Training programs should stress the ALARA (As Low As Reasonably Achievable) concept, limiting radiation exposure via imaging protocol optimization, patient placement, and shielding device deployment (Sherer et al. 2021). Additionally, strict safety rules and procedures must be implemented to reduce exposure. This involves using lead aprons, thyroid shields, and lead glasses to reduce radiation exposure to essential organs. Working with radiation sources requires specific timing, distance, and shielding rules. Radiation equipment must be calibrated and maintained to provide accurate dosimetry and reduce risks.

Healthcare worker's radiation safety protocols also need radiation exposure monitoring. Dosimeters like film badges or electronic dosimeters measure worker radiation exposure. By analyzing individual exposure levels, healthcare institutions will observe patterns, evaluate safety practices, and resolve issues quickly. In addition, regulation dosage limitations prohibit excessive radiation exposure and related health consequences. Healthcare facilities must promote safety and communication in addition to individual monitoring. Open discussion about radiation safety, reporting occurrences or near misses, and offering feedback and improvement opportunities enable healthcare professionals to actively protect themselves and their coworkers (Siewert et al. 2019). Radiology divisions, radiation safety employees, and occupational health specialists must work together to create radiation safety protocols that meet each healthcare setting's requirements.

2.2 Effectiveness of present preventive measures in minimizing the risks of X-Ray

As opined by Shi et al. (2022), concerns amongst the general public about the potential risks related to being exposed to X-ray radiation are rising aligning with the growing number of X-ray examinations, which are being performed in clinical settings. Here, the application of preventive measures is evident when minimizing the risks of X-rays in hospital settings. An evaluation of the risk-benefit ratio should be carried out whenever medical therapies and X-ray screening are required, with the potential objective of achieving exposure that can be avoided.

On the contrary, Yıldız et al. (2022) opined that imaging procedures performed at various hospital units, including bone densitometry machines, fixed X-ray machines, computed tomography, and mammography, include determining both maximum and minimum values of X-rays that are produced. In hospitals and other types of health institutions, ionizing radiation poses a major threat, particularly for workers working in radiotherapy, nuclear medicine, and radiology. This is especially true for professionals who work in these fields. An increased risk of certain diseases, including skin, thyroid, breast, bone marrow, and lung cancers, is associated with radiation exposure.

Figure 2. Measuring emission of radiation to the environment during X-ray imaging (Source: Yıldız et al. 2022)

2.3 Effectiveness of current health & safety protocols in minimizing the risks of X-Ray

The implementation of health and safety guidelines is of utmost importance when minimizing the risks linked with X-ray operations, not only for patients but also for healthcare professionals. If other imaging techniques, which require lower radiation doses, are capable of offering adequate diagnostic information, then alternative imaging techniques should be examined. A skilled medical expert must provide clinical justification for each X-ray procedure (Del Rosario Pérez 2013). Training of healthcare professionals regarding the safe application of X-rays is significant. Radiation safety protocols, strategies for dose optimization, and radiation physics are some of the topics that should be included in the training.

Radiation doses, which are received by staff and patients, should be monitored regularly so that compliance with regulatory dose limitations can be ensured and attempts to optimize radiation doses can be supported. On the other hand, Frane & Bitterman (2020) opined when quality assurance processes are put into place; they guarantee that radiation safety protocols are followed in a consistent manner and that X-ray equipment is operating at its highest possible level. Before deciding to order X-ray tests, medical professionals should first undertake a complete assessment through which the advantages of the operation can be determined when compensating for the potential drawbacks.

2.4 A radiation monitoring device in major hospital areas in improving protection for healthcare workers

According to the continuation and evolution of nuclear technology and its usage in different fields since its introduction, safety related to radiation has become a significant concern to the environment and humans. As stated by Ahmad et al. (2021), the role of radiation monitoring in detecting preventive radiological nuclear is of utmost importance in the field of hospitals, nuclear facilities, or any related activities related to radioactive materials. In such a manner, radiation monitoring acts as a tool through which the risks of radiation exposure can be measured while reaping its advantages accordingly. The incapability of radiation monitoring devices to offer real-time information makes it comparatively less efficient. Recently, the usage of Internet of Things (IoT) technology has been providing necessary solutions to these limitations. Thus, a "Global Positioning System (GPS)" is useful in obtaining the location of the radiation, and this information can be further observed in real time with the help of a web server.

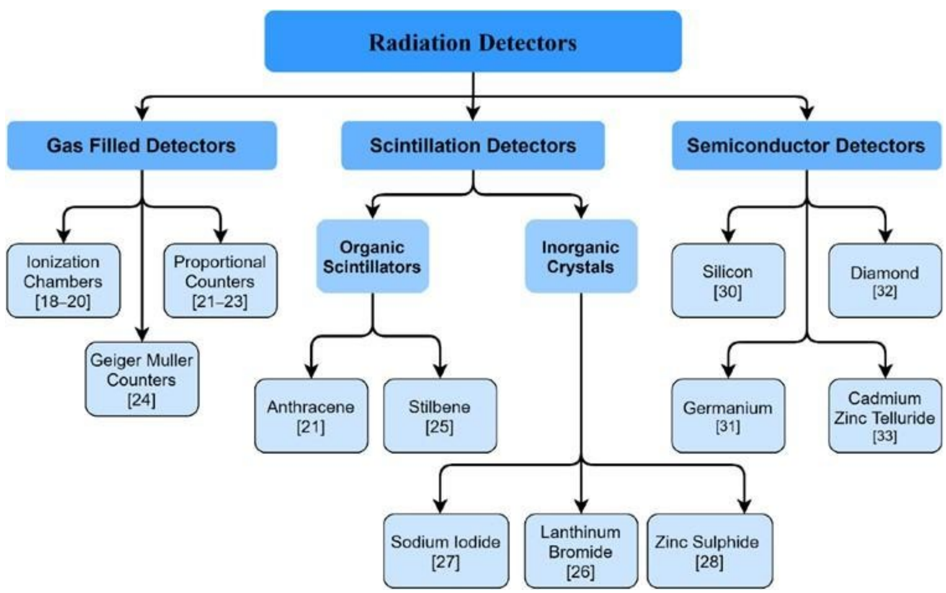

Figure 3. The categorization of radiation detectors utilized in radiation monitoring (Source: Ahmad et al. 2021)

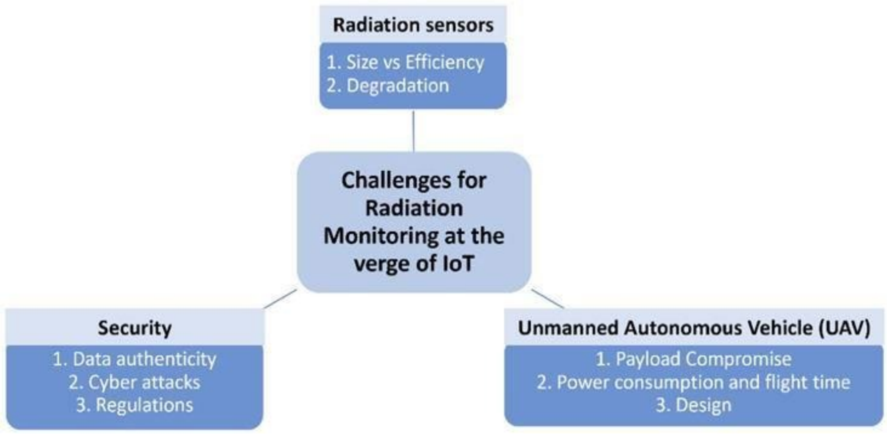

Figure 4. Summarization of problems of radiation monitoring with the help of IoT (Source: Ahmad et al. 2021)

The presence of background radiation is constant, and it is usually measured at around 2.4 millisieverts (mSv) each year (US EPA 2019). On the contrary, this is regarded as a safe amount for prolonged exposure. When a single X-ray examination is performed, exposure levels that fall between 0.1 and 1 mSv are regarded to be mild. It has been recommended that a range of 1-5 mSv could be considered a potential threshold for "mild" because it is higher compared to the background, although still very low in comparison with diagnostic X-rays (Busby 2009). A yearly dose limit of 20 milliseconds (mSv) is the maximum that the ICRP advises for occupational exposure. It is considered potentially life-threatening to get an acute radiation dosage, which, in turn, is greater than 0.5 Gray (Gy) or 500 millisieverts (mSv) during a short period (for example, hours to days) (ICRP, 2020). Due to the increased risk of cancer over time, chronic exposure to radiation doses that are higher than the regulation limitations, like the annual doses of 50 mSv for radiation workers, can also be counted as harmful.

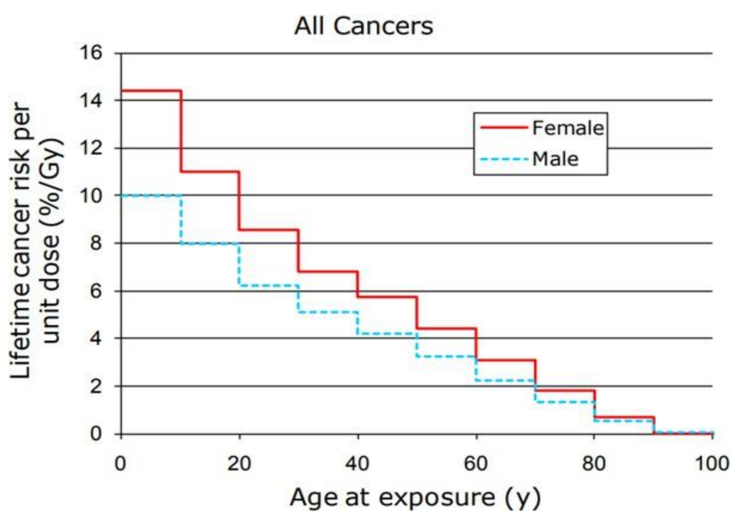

Figure 5. Lifetime threats of incidents of cancer by sex and age for all cancers due to whole-body irradiation (Source: Wall et al. 2011)

3. Literature Gap

Although the literature study discusses many safety protocols that are already in place, like monitoring, optimization, and justification, it needs to provide more information on how real-time monitoring devices might interface with these policies. Traditional radiation monitoring and dosimetry methods in healthcare are covered in existing studies, although IoT-based solutions for real-time radiation exposure risk management are not. Research on how to use real-time information from these devices to optimize safety practices for staff protection and assess suitable responses (evacuation vs. heightened vigilance) and trigger alerts needs to be included. Thus, the potential problems, effectiveness, and practicality of using IoT-enabled radiation monitoring systems in hospitals to develop radiation safety for healthcare workers need further study.

4. Project Stages

Stage 1: Understanding the Risks of Radiation Exposure

Developing an effective radiation safety program for hospital cleaners requires a comprehensive understanding of the risks linked to radiation exposure. According to Rahman et al. (2023), X-rays can cause genetic mutations and increase a person's lifetime possibility of developing cancer. Unintentional exposure to too many of the bad waves, as may be the case for cleaning staff, can also lead to hair loss, burns, and cataracts if they eye (Karavas et al., 2022). Unfortunately, the cleaning staff may have inadequate knowledge or be completely unaware of such risks. It is therefore important to assess the hospital's staff's understanding of the exposure risks and facilitate awareness in the initial stages of the project.

Stage 2: Assessment of Current Practices and Regulations

After assessing and helping hospital staff understand the radiation exposure risks, it would be essential to evaluate the current practices as well as regulations in hospitals. Radiation safety has been a major concern in indoor and outdoor environments of hospitals (Rahman et al., 2023). As such, hospitals need to implement various initiatives and adhere to set regulations to improve radiation safety. As part of the project, on-site visits to hospitals and interviews with major stakeholders, including administrators, frontline staff, and radiology safety officers, would be important. Such visits would involve evaluating the developed and implemented protocols, training programs, and monitoring practices. A thorough assessment would reveal the practice gaps, exposing areas that need improvement.

Stage 3: Improving Radiation Monitoring for Cleaners

The main aim of this project is to improve radiation surveillance to enhance safety for hospital cleaners. Indeed, the cleaning staff risk exposure to ionizing radiation as they spend significant time in and around x-ray rooms. Thus, it is critical to consider their safety through improved radiation monitoring. The project proposes the use of GPS to provide real-time data that assist in keeping track of radiation doses.

5. Tools for Implementation

The project will use a GPS given to cleaners to implement radiation safety programs. The tool will supply real-time data, making it possible to keep track of exposure to ionizing radiation. A GPS will enable real-time location tracking of the cleaning staff within the hospital. Further, the tool will assist in radiation exposure mapping, making it possible to determine high radiation dose areas and patterns of exposure. The mapping will inform targeted interventions, including emergency response, to enhance the safety of the cleaners.

Implementation of a GPS device will involve several activities. First, a needs assessment will be done, and training will be provided on the use of the tool. Conducting a needs assessment is crucial because it will reveal the cleaning staff's challenges and requirements. Training will then help educate the cleaners on how the device works and how it can improve radiation safety. Second, pilot implementation will be rolled out in selected hospitals to check if the device is effective and practical. Feedback from staff will help in the pilot testing. Third, the tool will be fully deployed across all targeted facilities after a successful testing phase. Effective collaboration between the hospitals' administrators and cleaners will facilitate the implementation. Lastly, regular monitoring and assessment will enable the continued efficacy of the radiation safety programs.

The project follows various stages and proposes an implementation tool to develop an effective radiation safety program. The program focuses on meeting the safety needs of hospital cleaners and recognizing the risks associated with radiation. A successful implementation of GPS devices will help safeguard the health and well-being of cleaning staff in hospitals who often work in and around risky hospital environments.

6. Results and Discussion

Hospital cleaners who get ionizing radiation benefit from X-ray installations with real-time GPS monitoring. This improves vulnerable medical personnel's health and safety, as well as Increases radiation safety using contemporary monitoring and safety systems. Real-time radiation monitoring and mapping using GPS is a novel risk assessment and reduction tool (Ahmad et al. 2021).

Hospitals use GPS trackers to detect radiation exposure and improve worker safety and cleanliness. This approach collects live data on exposure levels, a significant improvement over earlier technologies that may not provide rapid feedback on possible threats. This technology cuts the period between radiation exposure detection and response by providing real-time monitoring, possibly decreasing chronic ionizing radiation health hazards. This initiative emphasizes real-time data to improve radiation safety and provide a more flexible radiation security system. This connection allows safety measures to be dynamically updated depending on exposure levels instead of static standards. Thus, this unique technique makes hospital workers safer and more responsive by immediately addressing and lowering radiation exposure hazards. Radiation safety is improved via real-time monitoring. Instead of fixed guidelines, this integration should make radiation safety more dynamic and allow immediate exposure-based modifications. Workers may be protected or restricted in high-radiation hospitals. This data-driven approach may help hospitals create better safety measures based on exposure trends.

GPS radiation monitoring devices may alter hospital housekeeping and staff training and awareness (Rajendran et al. 2021). Radiation exposure data may help employees comprehend job risks. Safety standards encourage compliance and develop a safety culture as workers realize their immediate benefits. Exposure tracking helps assess and improve radiation safety programs.

Real-time monitoring is beneficial, but the project values radiation safety holistically. Monitoring needs technical skills, communication, training, and stakeholder engagement. Hospital management, safety authorities, cleaners, and others must adopt GPS-based monitoring systems. Stakeholder involvement needs assessment, and continual education is needed to adopt and utilize this technology. Real-time Radiation Monitoring GPS gadgets increase radiation protection. This solution gives hospital cleaners and other healthcare workers fast, actionable data to be safe. Success depends on its ability to seamlessly integrate with existing safety procedures, create a safety culture, and include all stakeholders in a safer workplace. Ionizing radiation in X-ray facilities may be reduced via innovation and safety, safeguarding healthcare workers.

7. Conclusion

Real-time radiation monitoring GPS systems in X-ray facilities increase hospital housekeeping and worker safety. This innovative method provides hospital radiation exposure data quickly and reliably. The project protects hospital maintenance and care personnel by providing real-time exposure hotspots and trend data. GPS technology monitors and intervenes to improve radiation safety. The entire strategy prioritizes hospital staff well-being and raises radiation safety standards. Success depends on stakeholder engagement, continuous education, adaptive technology integration, and human-centric safety measures from concept to implementation. This initiative makes healthcare safer and more informed by improving hospital personnel health and safety.

References

Ahmad, M. I., Ab. Rahim, M. H., Nordin, R., Mohamed, F., Abu-Samah, A., & Abdullah, N. F. , Ionizing radiation monitoring technology at the verge of internet of things. Sensors, 21(22), 7629. https://www.mdpi.com/1424-8220/21/22/7629, 2021

Busby, B. , Radiation. In Information Resources in Toxicology (pp. 395-400). Academic Press,(2009).. https://doi.org/10.1016/B978-0-12-373593-5.00044-6

Del Rosario Pérez, M. ,Justification of medical exposures Referral criteria and clinical decision support What do we need from ICRP in medicine? Public Health and Environment, 2, 1–44(2013).,https://www.icrp.org/docs/Maria%20Perez%20referral%20criteria%20and%20clinical%20decision%20support%20 radiological%20protection%20aspects%20for%20justification.pdf,

Frane, N., & Bitterman, A. , Radiation safety and protection. https://europepmc.org/article/nbk/nbk557499, 2020

Guide, S. S. ,Radiation protection and safety in medical uses of ionizing radiation. IAEA safety standards series No. SSG-46,(2018). . http://regelwerk.grs.de/sites/default/files/cc/dokumente/DS399%20STEP%2012.pdf

Hamzian, N., Asadian, S., & Zarghani, H. ,A study of radiation protection standards compliance in hospital radiographic departments in Iran. Journal of Biomedical Physics & Engineering, 12(5), 513–520,(2022). . https://doi.org/10.31661/jbpe.v0i0.2108-1375.

ICRP. ,The 2007 Recommendations of the International Commission on Radiological Protection. ICRP,(2020). . https://www.icrp.org/publication.asp?id=ICRP%20Publication%20103

Karavas, E., Ece, B., Aydın, S., Kocak, M., Cosgun, Z., Bostanci, I. E., & Kantarci, M. ,Are we aware of radiation: A study about necessity of diagnostic X-ray exposure. World Journal of Methodology, 12(4), 264–273,(2022). . https://doi.org/10.5662/wjm.v12.i4.264.

Rahman, M. M., Rahman, M. S., Khan, M. H. R., & Yeasmin, S. ,Assessment of radiation level and potential risk to public living around major hospitals in central and western Bangladesh. Heliyon, 9(9), e19774,(2023). . https://doi.org/10.1016/j.heliyon.2023.e19774.

Rajendran, S., Giridhar, S., Chaudhari, S., & Gupta, P. K. ,Technological advancements in occupational health and safety. Measurement: Sensors, 15, 100045,(2021). .https://www.sciencedirect.com/science/article/pii/S2665917421000076

Sherer, M. A. S., Visconti, P. J., Ritenour, E. R., & Haynes, K. W. ,Radiation Protection in Medical Radiography - E-Book: Radiation Protection in Medical Radiography - E-Book. In Google Books. Elsevier Health Sciences, (2021). https://books.google.com/books?hl=en&lr=&id=PX05EAAAQBAJ&oi=fnd&pg=PP1&dq=Training+programs+sho uld+stress+the+ALARA+(As+Low+As+Reasonably+Achievable)+concept

Shi, H. M., Sun, Z. C., & Ju, F. H. ,Recommendations for reducing exposure to medical X ray irradiation. Medicine International, 2(4), 1-7,(2022). . https://www.spandidos-publications.com/10.3892/mi.2022.47

Siewert, B., Brook, O. R., Swedeen, S., Eisenberg, R. L., & Hochman, M. ,Overcoming Human Barriers to Safety Event Reporting in Radiology. RadioGraphics, 39(1), 251–263,(2019). . https://doi.org/10.1148/rg.2019180135

US EPA. ,Radiation Sources and Doses. US EPA. https://www.epa.gov/radiation/radiation-sources- and-doses,(2019, March 28).

Wall, B. F., Haylock, R., Jansen, J. T. M., Hillier, M. C., Hart, D., & Shrimpton, P. C. ,Radiation Risks from Medical X-ray Examinations as a Function of the Age and Sex of the Patient. In GOV.UK (pp. 1–70),(2011). . https://assets.publishing.service.gov.uk/media/5a7e2bfded915d74e6224921/HPA-CRCE-028_for_website.pdf

Yashima, S., & Chida, K. (2022). Awareness of Medical Radiologic Technologists of Ionizing Radiation and Radiation Protection. International Journal of Environmental Research and Public Health, 20(1), 497. https://doi.org/10.3390/ijerph20010497

Yıldız, A., Köse, E., & Demirtaş, Ö. C. (2022). Analysis of precautions taken for protection from X-rays in a hospital in Gaziantep in the context of workplace health and safety. Journal of Radiation Research and Applied Sciences, 15(4), 100453. https://www.sciencedirect.com/science/article/pii/S1687850722082206

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