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Optimizing Radiation Safety In Diagnostic Imaging: A Collaborative Approach Between Radiology, Nursing, And Medical Physics

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Abstract
The exponential growth of diagnostic imaging over the past two decades has revolutionized disease detection but has also heightened concern over patient and staff exposure to ionizing radiation. Computed tomography (CT), interventional radiology, nuclear medicine, and hybrid imaging modalities have dramatically increased average per-capita radiation doses worldwide, with children, pregnant women, and healthcare workers at particular risk (Mettler et al., 2009). Regulatory bodies such as the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) have long advocated the "as low as reasonably achievable" (ALARA) principle and established diagnostic reference levels (DRLs) to guide dose optimization (ICRP, 2007; IAEA, 2019). However, global evidence shows that compliance with these principles varies widely between institutions, and that radiation protection measures are inconsistently implemented unless supported by multidisciplinary teams and robust institutional policies (Martin et al., 2015).

This review examines how a collaborative framework between radiology, nursing, and medical physics can transform radiation safety in diagnostic imaging from a set of technical guidelines into a living, team-based culture. Radiologists bring clinical justification and protocol optimization expertise; nurses provide patient preparation, screening, education, and real-time safety monitoring; and medical physicists ensure equipment calibration, dosimetry, and regulatory compliance. Together, these disciplines can develop integrated safety committees, dose-tracking systems, and education modules that reduce unnecessary exposures while preserving diagnostic quality. The review highlights global best practices, regulatory standards, and regional considerations such as Saudi Arabia's Vision 2030 healthcare transformation**,** which explicitly prioritizes patient safety and modernization of diagnostic services (Kingdom of Saudi Arabia Vision 2030, 2018). It argues that only a multidisciplinary model can sustainably address rising imaging volumes, workforce gaps, and public concerns about radiation risks. By analyzing the unique contributions of each discipline and proposing an integrated model tailored to both global and Saudi contexts, this paper provides a roadmap to achieving world-class radiation safety in diagnostic imaging.

1. Introduction

Diagnostic imaging is one of the cornerstones of modern medicine, allowing clinicians to visualize internal structures non-invasively and diagnose conditions with unprecedented accuracy. The last two decades have witnessed explosive growth in imaging modalities such as CT, digital mammography, nuclear medicine, and hybrid modalities like PET/CT and SPECT/CT. Global CT volume alone has increased more than threefold, from fewer than 40 million scans annually in the 1990s to more than 120 million scans per year today (Mettler et al., 2009). In Saudi Arabia and across the Gulf region, increased availability of imaging services through government and private sector investment has dramatically expanded access, supporting national strategies such as **Vision 2030** that emphasize early detection and prevention of chronic diseases (Kingdom of Saudi Arabia Vision 2030, 2018).

However, the same technologies that offer diagnostic benefits also expose patients and staff to ionizing radiation. CT scans deliver doses tens to hundreds of times greater than conventional X-rays, and repeated exposures can accumulate over a lifetime, increasing the risk of stochastic effects such as cancer (Berrington de González et al., 2009). Vulnerable populations, including children, pregnant women, and healthcare workers in interventional suites, are at heightened risk. Moreover, while MRI and ultrasound are non-ionizing, the majority of high-volume modalities — particularly CT and fluoroscopy — still rely on X-rays, making dose optimization and safety culture imperative.

Radiation protection principles have been codified by international authorities for decades. The ICRP's three foundational principles — justification (imaging should be performed only when benefits outweigh risks), optimization(exposures kept as low as reasonably achievable, ALARA), and dose limitation (for occupational exposure) — form the bedrock of radiation safety worldwide (ICRP, 2007). The IAEA promotes these standards globally through its Radiation Protection of Patients program, encouraging countries to establish diagnostic reference levels (DRLs) for common procedures (IAEA, 2019). In Saudi Arabia, the National Center for Radiation Protection (NCRP) under the Saudi Food and Drug Authority (SFDA) enforces regulations and inspection protocols for medical imaging facilities, aiming to align national practice with international benchmarks (SFDA, 2021).

Yet compliance with these principles in daily clinical practice depends on the coordinated action of multiple professionals. Radiologists are responsible for choosing the right test and tailoring exposure parameters; nurses ensure proper patient preparation, shielding, and monitoring during procedures; and medical physicists design, calibrate, and audit equipment while training staff in radiation protection principles. Without structured collaboration, dose-reduction strategies may be inconsistently applied, communication gaps can lead to repeated imaging, and staff may be insufficiently trained in real-world safety measures (Martin et al., 2015).

In Saudi Arabia and similar rapidly developing healthcare systems, the challenge is particularly acute. Imaging demand is growing, workforce training has lagged behind technology acquisition, and public awareness of radiation risks remains limited. For example, a 2020 survey found that many Saudi patients undergoing CT scans were unaware of radiation exposure levels and potential risks, indicating a need for better patient education and staff communication (Al-Gahtani et al., 2020). Vision 2030 provides an opportunity to address these gaps by embedding radiation safety into healthcare transformation initiatives, but success requires a multidisciplinary model where radiologists, nurses, and medical physicists jointly develop protocols, monitor outcomes, and reinforce a safety culture.

This review examines the distinct contributions of each of these disciplines to radiation safety and proposes an integrated model for diagnostic imaging. It also explores challenges such as workforce shortages, cost constraints, and technological disparities, while highlighting future directions including artificial intelligence (AI), tele-radiology, and dose registries. By framing radiation safety as a shared responsibility rather than a technical afterthought, this paper underscores the potential for collaboration to protect patients, empower staff, and sustain public trust in diagnostic imaging.

2. Radiology's Role

Radiologists are at the forefront of diagnostic imaging and are thus pivotal to optimizing radiation safety. Their first responsibility is justification of imaging requests, ensuring that every exposure to ionizing radiation is medically warranted. Evidence shows that up to 20–50% of imaging studies may be unnecessary or could be substituted with non-ionizing alternatives such as ultrasound or MRI (Berrington de González et al., 2009). By critically reviewing referrals and discussing indications with referring physicians, radiologists reduce unnecessary exposures. They also play a key role in selecting the appropriate imaging modality and tailoring protocols to patient-specific factors such as age, body habitus, and clinical urgency (Mettler et al., 2009).

Another essential contribution is protocol optimization. Modern imaging systems allow considerable flexibility in exposure parameters such as kilovoltage peak (kVp), milliampere-seconds (mAs), pitch, and automatic exposure control settings. Radiologists, working closely with medical physicists, can customize these parameters to achieve diagnostic quality images at the lowest reasonable dose — the ALARA principle (ICRP, 2007). For example, in pediatric CT, low-dose protocols with iterative reconstruction techniques have reduced effective doses by more than 50% without loss of diagnostic accuracy (Gore et al., 2015). Radiologists also oversee the development of standardized dose reference levels (DRLs) to benchmark performance across institutions, a practice supported by the IAEA and widely adopted in Europe and North America (IAEA, 2019).

Radiologists also lead education and communication efforts**.** They inform patients and families about the benefits and risks of imaging procedures, obtaining informed consent for higher-dose studies such as fluoroscopy or nuclear medicine scans. In addition, radiologists guide non-radiology clinicians and nurses on appropriate imaging protocols, particularly when imaging is urgently required or involves vulnerable populations like pregnant women. This communication ensures that safety considerations are understood by all stakeholders, not just radiology staff.

Finally, radiologists play a key role in quality assurance and audit. By maintaining dose-tracking systems and participating in multidisciplinary radiation safety committees, they monitor trends, identify outliers, and implement corrective actions. For instance, integrating real-time dose monitoring software into picture archiving and communication systems (PACS) allows radiologists to analyze cumulative exposures and adjust protocols accordingly (Bardo et al., 2017). This continuous feedback loop is critical to sustaining long-term improvements in radiation safety culture.

3. Nursing's Role

Nurses form the patient-facing frontline of diagnostic imaging and thus play a crucial role in safeguarding patients from unnecessary radiation exposure. Their responsibilities begin with patient education and screening**.** Before imaging, nurses routinely assess pregnancy status, verify allergies to contrast agents, and ensure that patients understand the procedure's risks and benefits. This is especially vital in Saudi Arabia and other conservative settings, where cultural sensitivities may prevent patients from volunteering information unless explicitly asked by trained staff (Al-Gahtani et al., 2020). By identifying contraindications early, nurses prevent inadvertent exposures to high-risk groups such as pregnant women or children.

During imaging procedures, nurses implement radiation protection practices based on the principles of time, distance, and shielding. They minimize the time patients and staff spend near active radiation sources, maximize distance from the X-ray beam, and ensure that appropriate lead shielding is used to protect radiosensitive organs (ICRP, 2007). For example, in fluoroscopy-guided procedures, nurses position lead aprons and thyroid shields, monitor patient positioning to avoid repeat exposures, and assist in adjusting equipment to achieve optimal dose distribution (Mahmood et al., 2019). Their vigilance reduces unnecessary retakes, which are a significant source of excess dose.

Nurses also function as patient advocates and communicators, explaining procedural steps and reducing anxiety, which in turn minimizes motion artifacts and the need for repeat imaging. Research shows that effective nurse-led communication can reduce pediatric sedation rates and improve image quality, indirectly contributing to dose reduction (Goodman et al., 2018). Additionally, nurses monitor vital signs and patient comfort during imaging, particularly in interventional or nuclear medicine procedures that may last several hours, ensuring both clinical safety and procedural efficiency.

Beyond direct patient care, nurses contribute to multidisciplinary training and safety culture**.** They participate in radiation safety committees, relay feedback from patients to technical and medical staff, and champion continuous education initiatives. In Saudi Arabia, where national regulations now mandate staff training in radiation protection, nurses are increasingly recognized as key partners in institutional compliance and accreditation (SFDA, 2021). By embedding radiation safety into everyday nursing practice, institutions create a culture where safety is not an afterthought but an integral part of patient care.

4. Medical Physics' Role

Medical physicists provide the technical backbone of radiation safety in diagnostic imaging. They are responsible for the design, calibration, and maintenance of imaging equipment to ensure optimal performance at the lowest achievable dose. This includes acceptance testing of new machines, routine quality control (QC) checks, and verification of manufacturer specifications. By identifying equipment malfunctions early, physicists prevent inadvertent overexposure to patients and staff (Martin et al., 2015).

Another central task is dosimetry and dose optimization. Medical physicists measure radiation output using phantoms, dosimeters, and specialized software to calculate patient and staff doses. These measurements inform the development of diagnostic reference levels (DRLs) and institutional dose limits (IAEA, 2019). They also assist radiologists in selecting exposure parameters tailored to specific patient groups, such as children or bariatric patients, and evaluate the performance of automatic exposure control systems. With advances in technology, physicists are increasingly involved in implementing iterative reconstruction, spectral imaging, and AI-driven dose modulation**,** which further reduce dose while maintaining image quality (Shah et al., 2021).

Medical physicists also play a critical role in education and compliance. They train radiology and nursing staff on radiation protection principles, safe equipment operation, and new regulatory requirements. In Saudi Arabia, the SFDA and National Center for Radiation Protection require periodic training and certification for staff working with ionizing radiation, and physicists are often the primary trainers in these programs (SFDA, 2021). Their expertise ensures that safety protocols are evidence-based and aligned with both international standards (ICRP, IAEA) and national regulations.

Finally, physicists contribute to research and innovation, developing new metrics for dose optimization and collaborating with engineers and software developers to create real-time dose tracking systems. This forward-looking role enables hospitals to stay ahead of regulatory requirements and adopt cutting-edge safety technologies. By embedding physicists into multidisciplinary safety teams, institutions ensure that technological advances translate directly into patient protection.

5. Collaborative Model Proposal

Optimizing radiation safety cannot be achieved by any one discipline alone; it requires a structured collaborative model**.** In this framework, radiologists, nurses, and medical physicists jointly develop protocols, review outcomes, and conduct safety audits under the guidance of a hospital radiation safety committee. This committee meets regularly to review dose data, incident reports, and regulatory changes, ensuring that policies are updated and disseminated to all staff (IAEA, 2019).

At the operational level, the workflow begins with radiology, where imaging requests are justified and protocols selected. Nurses then screen and prepare patients, applying shielding and assisting with positioning to avoid repeat exposures. Medical physicists calibrate equipment, verify dose parameters, and analyze cumulative exposure data to identify trends or outliers. Together, they form a closed-loop system where feedback from one group informs adjustments by the others. For example, if physicists detect higher-than-expected doses in pediatric CT scans, they alert radiologists to review protocols and nurses to reinforce positioning or sedation practices, thereby reducing repeat imaging (Goodman et al., 2018).

Such a model can be implemented at Saudi tertiary hospitals, where Vision 2030's digital health initiatives already support integrated electronic health records (EHRs). Embedding dose-tracking modules in EHRs allows seamless communication of patient dose history across departments and even across institutions, preventing cumulative overexposure when patients undergo multiple imaging studies at different sites (Kingdom of Saudi Arabia Vision 2030, 2018). Moreover, training programs can be co-designed by all three disciplines to ensure consistency in staff knowledge and practice.

6. Challenges and Future Directions

Despite clear benefits, implementing multidisciplinary radiation safety models faces significant challenges. Workforce shortages are a key barrier: many hospitals, particularly in low- and middle-income countries, lack sufficient medical physicists or radiation safety officers to support every imaging unit (Martin et al., 2015). Radiologists and nurses may also have limited time to attend safety training, and high patient volumes can pressure staff to prioritize throughput over optimization. Addressing these gaps requires strategic investment in training, recruitment, and retention of specialized personnel.

Technology access and cost constraints also limit progress. Advanced imaging systems with real-time dose monitoring and AI-driven optimization remain expensive and may be concentrated in tertiary centers. Without equitable distribution, rural and smaller hospitals risk lagging behind in safety standards, perpetuating disparities in patient exposure. National health systems must therefore include radiation safety in procurement criteria, ensuring that new equipment purchased under Vision 2030 or similar programs meets international safety benchmarks (SFDA, 2021).

Another challenge is variable adherence to safety protocols. Even when policies exist, lack of enforcement or inconsistent communication between radiology, nursing, and medical physics departments can lead to drift from best practices. Regular audits, safety drills, and transparent reporting of dose metrics are needed to sustain improvements. Cultural change also matters: institutions must cultivate a "safety first" mindset where every staff member feels responsible for radiation protection, not just designated officers (IAEA, 2019).

7. Conclusion

Radiation safety in diagnostic imaging is no longer the sole responsibility of radiologists or technical staff; it is a shared mission requiring coordinated action among radiology, nursing, and medical physics. Radiologists justify and optimize imaging protocols, nurses protect and prepare patients, and medical physicists ensure equipment calibration, dosimetry, and staff training. Together, these disciplines create a robust safety culture that aligns with international standards such as the ICRP and IAEA guidelines while adapting to national priorities like Saudi Arabia's Vision 2030 healthcare transformation. Although challenges remain — including workforce limitations, cost barriers, and variability in adherence to protocols — a multidisciplinary, collaborative model offers the most effective pathway to reduce unnecessary radiation exposure, improve patient outcomes, and sustain public trust in diagnostic imaging. By uniting clinical expertise, patient advocacy, and technical innovation, healthcare systems can ensure that diagnostic imaging remains both powerful and safe.

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