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Quality management and certified medical physicist's role in radiology for radiation dose optimisation: a literature review until 2024

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Abstract – This review aims to propose effective steps for optimizing radiation doses in radiology, covering both diagnostic and interventional aspects, and to explore associated challenges in dose optimization and quality assessment in radiological departments, emphasizing the role of certified medical physicists. Evidence for cancer risk from radiation doses below 100 mSv remains limited, with only a small but significant increase observed in a 70-year follow-up of Hiroshima and Nagasaki A-bomb survivors, underlining ongoing scientific debate. Through a rigorous selection process, 67 relevant articles/reports covering the period from 1982 to 2024 were selected from databases like PubMed, Scopus, and Web of Science after screening titles and abstracts and evaluating full-text articles meeting inclusion criteria. Advancements in digital radiography, mammography, fluoroscopy, and interventional radiology have reshaped imaging techniques. Traditional methods, augmented by digital tools and algorithms, helps optimize radiation exposure and image quality. Innovations such as ultra-low-dose imaging in mammography aim to enhance cancer detection with reduced radiation. Optimization in fluoroscopy and interventional radiology involves a sophisticated strategy, considering both equipment protocols and operator behavior. Collaboration between medical physicists and optimization teams aligns protocols with equipment functionality. ISO-defined quality management principles guide the establishment of quality in radiology departments through components like quality control and assurance. Dosimetry helps monitor equipment performance and help estimate individualized radiation dose, ensuring patient safety. Medical physicists might lead the development and supervision of performance indicators, helping in the evaluation of departmental performance. . Collaborative initiatives and emerging technologies, including artificial intelligence, reinforce the ongoing journey of dose optimization in radiology. These strategies will shape the future of radiological imaging, enabling personalized patient care and advancing the understanding of health and disease. Haut du formulaire

Keywords: optimization / radiology / certified medical physicist / radiation dose / quality

1 Introduction

Ensuring accurate disease diagnosis and enhancing patient treatment are essential components of healthcare. Over the past five decades, technological advancements have transformed medical imaging, particularly the use of ionizing radiation. This shift from analog to digital, including multidetector-row CT and advanced panoramic and cone beam CT technologies, has expanded imaging services beyond traditional radiology, permeating various clinical specialties. However, access to imaging services remains unbalanced across countries, with the cutting-edge imaging modalities present only in the major metropolitan medical institutions (ICRP, 2010; IAEA, 2015).

The increased adoption of medical imaging has led to a rise in utilization trends. The 2008 UNSCEAR report highlights this trend, particularly due to the increased use of CT (UNSCEAR, 2008). However, the use of ionizing radiation carries a cancer risk, necessitating strict safety standards. The IAEA emphasizes optimization in radiation protection, aiming to keep patient exposure to the minimum necessary for diagnostic or interventional purposes (IAEA, 2014, 2018).

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Similarly, NCRP Report 184 notes a continued increase in radiological procedures in the United States up to 2016, although less dramatically than between the early 80s and 2006 (NCRP, 2009, 2019). Research from over 135 million imaging exams between 2000 and 2016 in Canada and the U.S. shows the highest annual increase in CT exams occurred in the early 2000s (Smith-Bindman *et al.*, 2019; Tsapaki, 2020).

Diagnostic radiology has evolved from using simple equipment with minimal radiation to complex equipment requiring higher doses and greater accuracy. This evolution has expanded the concept of quality in radiology, emphasizing a broader framework of excellence and the essential role of clinically certified medical physicists (IAEA, 2021).

In many low and middle-income countries, imaging equipment often lacks proper supervision, with quality assessments primarily during licensing inspections. This approach is inadequate for ensuring equipment safety and overall diagnostic facility excellence, including staff and procedures (Delis *et al.*, 2017).

This review addresses optimizing radiation doses in radiology, considering both diagnostic and interventional aspects. It proposes steps to achieve this objective and discusses the challenges in dose optimization and quality assessment, highlighting the role of certified medical physicists.

2 Methods

2.1 Selection criteria for studies

The studies chosen for the narrative review adhered to specific selection criteria designed to guarantee the incorporation of pertinent and dependable research. The inclusion criteria encompassed studies published in indexed peer-reviewed scientific journals, with a specific focus on radiology optimization and quality assessment for both diagnostic and interventional aspects. To maintain language consistency, only studies published in English or French were considered. Through the application of these criteria, a thorough and targeted collection of studies was identified for detailed analysis.

2.2 Data analysis and quality assessment for selected studies

The process of selecting studies for the present review followed a systematic approach to ensure the identification of pertinent and high-quality research (Appendix 1). Starting with a literature search conducted between December 2023 and April 2024, 97 potentially relevant articles and reports were initially identified. The screening process involved reviewing titles and abstracts to assess their relevance to the topic of this narrative review. Subsequently, full-text articles were obtained for the studies meeting the inclusion criteria. A comprehensive evaluation of these full-text articles was then conducted, leading to the exclusion of studies that did not meet the specified criteria or lacked relevant data. This rigorous selection process led up to the inclusion of a final set of 67 studies in this narrative review.

3 Results

The studies included in this narrative review collectively highlight the significance of optimizing radiation doses in both diagnostic and interventional radiology and quality assessment procedures. Moreover, these studies highlight the central role of certified medical physicists in ensuring the effectiveness of these processes. The results are categorized based on the specific radiological modalities studied, detailing specific actions and responsibilities for each radiology team member in the optimization process, emphasizing their integral participation in an overarching quality assurance program.

3.1 Essential optimization implied by risks associated to low radiation doses

The cancer risk associated with diagnostic radiology, particularly in high-dose procedures like CT scans, remains a topic of ongoing debate (Brenner *et al.*, 2007; Mathews *et al.*, 2013; Bawazeer *et al.*, 2022; Bertho *et al.*, 2023). European projects like the “Implications of Medical Low Dose Radiation Exposure” (MEDIRAD) and “Epidemiological study to quantify risks for pediatric computerized tomography and to optimize doses” (EPI-CT) are underway to address low-dose radiation risk and radiation protection in medical practice. Despite a 70-year follow-up of A-bomb survivors in Hiroshima and Nagasaki, direct epidemiological data indicate only a small but statistically significant increase in cancer risk, highlighting the ongoing debate within the scientific community regarding the significance of cancer risk at low radiation doses (Brenner *et al.*, 2007; Tsapaki, 2020).

Key reports, including BEIR VII 2006 and UNSCEAR 2008, recommend the “linear no-threshold model” (LNT) as a reasonable framework for understanding the relationship between low-dose ionizing radiation and solid cancer incidence (National Research Council, 2006; UNSCEAR, 2008). These findings highlight the importance of optimizing radiation doses, especially for specific patient groups such as pediatrics, pregnant individuals, and those requiring repeated exams due to clinical conditions.

3.2 Levels of radiation exposure

With the increasing use, diversity, and complexity of X-ray procedures, the critical question arises regarding the associated radiation dose levels. This consideration is essential for strategic planning in the optimization process. Radiological examinations typically range from sub-mSv (chest X-ray) to dozens (even hundreds) of mSv (CT or interventional procedures). Technological advancements have provided opportunities to reduce radiation doses in medical imaging. The international literature has predominantly focused on CT due to its higher doses compared to other conventional X-ray techniques (National Research Council, 2006; Brenner *et al.*, 2007; UNSCEAR, 2008; El Mansouri *et al.*, 2022, 2024; Talbi *et al.*, 2022; MirDerikvand *et al.*, 2023).

Concerns about radiation dose in CT have led to increased research for accurate dose estimation and optimization tools. The 2011 Summit on Management of Radiation Dose in CT sponsored by the National Institute of Biomedical Imaging and Bioengineering, the Coalition for Imaging and Bioengineering Research, the National Institute of Child Health and Human Development, and the National Heart Lung and Blood Institute and supported by the U.S. Food and Drug, emphasized the goal of reducing the effective dose for routine abdomen and pelvis CT from 10 mSv to less than 1 mSv. Despite the benefits of optimization tools, addressing the need to select and implement optimized protocols across numerous hospitals and CT imaging centers arises a significant challenge.

This challenge extends to interventional procedures, where sophisticated machines offer preset examination protocols for ease of use, while proper implementation is not guaranteed. Even assuming optimal protocol settings for clinical tasks, understanding their practical application is essential for efficient utilization of manufacturer-offered tools and successful optimization. Unfortunately, universal implementation remains elusive (Housni *et al.*, 2023).

3.3 Steps towards successful optimization process

3.3.1 Quality Assurance program

Numerous international or national organizations have proactively proposed distinct quality assurance protocols customized to various modalities within the realm of medical physics. Consequently, the responsibility lies with medical physicists to orchestrate a comprehensive quality assurance program that aligns with the criteria for optimized procedures in radiology. This imperative task is necessary in addressing the factors contributing to excessively high patient doses, which are commonly attributed either to suboptimal equipment performance or inadequately optimized examination protocols (IAEA, 2012).

In the pursuit of successful optimization processes, the foundational step involves the establishment of a robust quality assurance program. The World Health Organization (WHO) defines a quality assurance program as an organized effort. Its primary objective is to ensure that images generated during X-ray imaging procedures exhibit consistently high quality, providing sufficient diagnostic information at the most economical cost and with the minimal possible patient's radiation dose. This highlights the significance of balancing between patient dose and image quality, while considering various clinical factors, including the judicious use of contrast agents (WHO, 1982; IAEA, 2012).

A wealth of knowledge and guidance is available through reports disseminated by authoritative bodies such as the International Atomic Energy Agency and the European Commission (EC) on matters pertaining to quality assurance and dosimetry in diagnostic radiology. Professional medical physics societies, including the American Association of Physicists in Medicine (AAPM), the European Federation of Organizations for Medical Physics (EFOMP), and the French Association of Medical Physics, actively contribute to the discourse by generating guidance documents on quality control. The creation of a strong quality assurance program is the primary requirement, regardless of the particular procedure or guidelines followed. . This foundational step is imperative for ensuring the efficacy of patient dose optimization efforts, thereby reinforcing the important role played by medical physicists in upholding the highest standards in radiological practices (AAPM, 2002; IAEA, 2007, 2011; EC, 2012; Greffier *et al.*, 2017; EFOMP, 2015).

3.3.2 Optimization team and attributions

The optimization team, comprising radiologists, medical physicists, and radiation technologists, collaborates synergistically to integrate clinical expertise, technical proficiency, and practical considerations. This multidisciplinary approach is essential for achieving an optimal balance in image quality and radiation dose across diverse radiological procedures. Establishing an optimization team is paramount for refining radiological procedures. Each member of this collaborative unit contributes distinctively, ensuring a comprehensive approach to harmonizing image quality and radiation dose, as reflected in literature (IAEA, 2013; Tahiri *et al.*, 2022; Gingold, 2017).

The radiologist assumes a key role within the optimization team, offering invaluable insights to ensure whether task-specific image quality is adequately maintained. Their clinical expertise is essential in optimization efforts with the clinical requirements of specific tasks, safeguarding diagnostic accuracy. The medical physicist leads the optimization process by implementing various methodologies as detailed in existing literature. In many instances, their active involvement extends to the actual optimization of examination protocols, leveraging their technical capacity to balance between optimal image quality and radiation doses. This requires a comprehensive understanding of the technical intricacies of radiological equipment and the strategic application of optimization techniques. As for the radiation technologist, their role is to check if the modified (optimized) protocol is appropriate within the clinical workflow. Their responsibility encompasses careful execution to ensure alignment with the intended goals of achieving optimal image quality at the designated radiation dose. Practical considerations, efficiency, and adherence to established protocols constitute integral aspects of their contribution (IAEA, 2013; Tahiri *et al.*, 2022; Gingold, 2017; Sensakovic *et al.*, 2017).

The optimization team engages in collective decision-making to identify critical clinical tasks, examination types, and X-ray modalities necessitating optimization in terms of radiation exposure. Given the substantial variability across medical institutions in modalities, examination types, and frequencies, these determinations are appropriately made at the institutional local level. Upon identification of relevant examination types, collaborative efforts with clinicians ensure establishing clinically appropriate image quality requirements, ensuring optimization aligns precisely with institutional diagnostic needs.

3.3.3 Establishing diagnostic reference levels (DRLs)

DRLs, endorsed by organizations like the ICRP, are crucial for optimization, indicating dose levels above which exposures are inappropriate. DRL values depend on specific exposure circumstances.

Establishing DRLs is essential for evaluating doses and examination quality. This involves comparing local dose values with DRLs or benchmarks and understanding their complexities. The optimization team plays a pivotal role in managing these difficulties to ensure that radiological procedures achieve the optimal balance between diagnostic efficacy and patient safety (El Mansouri *et al.*, 2022; Talbi *et al.*, 2022).

The team starts by identifying critical exams and clinical tasks, establishing a baseline for patient doses. This includes precise dose measurements and image quality assessments based on set of reference criteria (IAEA, 2007). Radiologists evaluate image quality, while medical physicists measure patient doses using standard metrics and procedures. The results are compared with local or national DRLs or benchmarks, considering image quality evaluations (ICRP, 2017; IAEA, 2018). This analysis identifies exams needing optimization. Reviewing all protocols at one institution can be resource-intensive, requiring dedicated efforts of many person-day (IAEA, 2007, ICRP, 2017).

Misinterpretations of DRLs are common, with some assuming optimization is achieved if doses are below DRLs, potentially ignoring other important factors (Rehani, 2015). The optimization team must navigate these complexities when establishing DRLs for each procedure. Reference Levels (RLs) follow this rationale, allowing practitioners to compare patient doses for specific procedures to national or local RLs. This comparison helps assess and optimize radiation practices. The French Society of Medical Physics advocates using dose reference levels for systematic assessment and optimization (Greffier *et al.*, 2017).

3.3.4 Computed tomography

Numerous articles in current literature propose a myriad of strategies for optimizing CT protocols, as evidenced by the wealth of advanced techniques discussed. These encompass tube modulation to dynamically adjust tube current based on anatomy, kV modulation customized to smaller size and younger patients, z-axis overscan for comprehensive coverage with minimized radiation exposure, scan length limitation to focus on clinically relevant anatomy, and the utilization of iterative reconstruction algorithms for improved image quality and potential dose reduction. Additionally, the incorporation of dual-energy imaging is outlined, particularly for contrast-enhanced exams in patients with renal function concerns, offering diagnostic advantages while potentially lowering radiation dose. Furthermore, the integration of machine learning and artificial intelligence algorithms emerges as a promising avenue for personalizing CT protocols to individual patient characteristics and specific clinical scenarios. Collectively, these strategies represent cutting-edge developments in CT imaging, reflecting a commitment to achieving an optimal balance between diagnostic accuracy and patient safety (Eberhard *et al.*, 2020; Greffier *et al.*, 2020; El Mansouri *et al.*, 2022, 2024; Nhila *et al.*, 2023; Khallouqi *et al.*, 2024; Sekkat *et al.*, 2024).

3.3.5 Radiography

Traditional methods for optimizing radiographic imaging doses per examination involve techniques such as increasing kV, decreasing mAs by using AEC (automatic exposure control), reducing exposure time, ensuring appropriate positioning, and using collimation to focus on the specific body region clinically required (Körner *et al.*, 2007; Talbi *et al.*, 2022). The advent of digital radiology has expanded the potential for dose reduction due to the dynamic range of digital detectors. Digital images can be assessed using manufacturer-provided software or free tools like ImageJ, offering functions such as panning, zooming, grayscale inversion, distance and angle measurement, and windowing to enhance image appearance (Schindelin *et al.*, 2015). Image processing, a key feature of digital radiography, significantly influences the visual representation of the image. However, during the transition to the digital environment, there is a potential for increased radiation dose, often attributed to a perceived lack of visual control (IAEA, 2015). Current advancements include image processing techniques and noise reduction algorithms, complementing traditional optimization strategies for achieving optimal radiographic imaging. Monitoring patient doses, using exposure indices or relevant dose quantities like the Kerma-Area Product (KAP), contributes to the optimization of radiographic procedures.

3.3.6 Mammography

Optimization is particularly important in mammography, especially for the early detection of breast cancer in asymptomatic women. Recent advancements, including breast tomosynthesis and contrast-enhanced mammography, have contributed to the expanded utilization of mammographic imaging. However, accurately estimating breast dose in the context of these emerging technologies remains a challenge. Notably, the introduction of ultra-low-dose craniocaudal images in digital mammography holds promise for the screening of a predominantly young and asymptomatic population. These ultra-low-dose images don't only meet the screening needs of this demographic but also serve as a foundational basis for further research in optimizing a low-dose approach, thereby contributing to the ongoing evolution of mammographic imaging practices (Bluekens *et al.*, 2015; Talbi *et al.*, 2022; Tahiri *et al.*, 2024).

3.3.7 Fluoroscopy and interventional radiology

Even if contemporary X-ray angiography machines incorporate advanced technological features that hold potential for dose optimization, their utilization and impact on radiation dose necessitate clear comprehension by the users (Chambers *et al.*, 2018).

A consistent theme across literature studies focusing on radiation protection in fluoroscopy is the acknowledgment that optimizing patient dose in interventional procedures results from an interconnection between modifying equipment protocols and influencing operator behavior, rather than merely altering protocol characteristics. Recommendations include the active utilization of digital processing, customizing examination protocols, selectively removing the antiscatter grid in specific clinical scenarios (*e.g.*, spinal digital subtraction angiography), reducing pulse rate and frame rate, defaulting to low-level fluoroscopy mode, and implementing continuous dose monitoring alongside patient follow-up (Jones *et al.*, 2014; Greffier *et al.*, 2017; Chambers *et al.*, 2018; Panick *et al.*, 2018; Liu *et al.*, 2019).

3.3.8 Aligning protocols with equipment functionality

Optimizing radiation dose through the modification of examination protocols is a complex task, requiring the expertise of a medical physicist. This process is undertaken collaboratively with the optimization team, following the establishment of a quality assurance program and the delineation of tasks for each team member, as well as the definition of a baseline for reference. While contemporary medical technology offers various tools for this purpose, engaging in dose optimization necessitates an in-depth understanding of machine performance and the impact of technical parameters, post-processing algorithms, and other features on image quality and radiation dose. Therefore, the medical physicist must thoroughly study technical documentation to comprehend the unique features and optimization tools of each machine. Manufacturer-provided application specialists play a fundamental role in offering advanced knowledge, best practices, and valuable insights specific to the model under consideration (Gingold, 2017; Sensakovic *et al.*, 2017).

3.4 Quality: an essential component of optimization in radiology

3.4.1 Definitions for quality

To comprehensively establish criteria for quality services in diagnostic radiology, a clear definition of quality is imperative at the first level. Consequently, and according to the International Organization for Standardization (ISO), quality is defined as the "degree to which a set of inherent characteristics of an object (product, service, process, system) fulfills requirements (need or expectation that is stated, generally implied or obligatory)" (ISO, 2015).

At the second level, quality definition should be escalated to the healthcare context. In that regard, WHO delineates six essential dimensions of quality that a healthcare system must encompass (WHO, 2006): Effectiveness, Efficiency, Accessibility, Patient-Centeredness, Equity and Safety.

These six dimensions require different levels containing various objectives and procedures, this is why a quality management system must be clearly defined and include three fundamental components:

- Quality Control.
- Quality Assurance.
- Quality Management.

The International Basic Safety Standards (BSS) requires the existence of a solid system of management and also presents a definition of each of the three mentioned components (IAEA, 2014):

- Quality Control (QC) as a reactive process to control the products quality. Its evolution should be followed through a QA program.
- Quality Assurance (QA) as a program that ensures the products quality.
- Quality Management as the complete activities for managing the products quality and it encompasses both QA and QC.

3.4.1.1 Quality control

QC is a foundational element of quality management and defined as the most basic form of quality-related activities, ensuring that systems meet established standards. It offers a snapshot of performance, comparing it to benchmarks (ISO, 2015). Despite its importance, QC is sometimes limited to equipment measurements, which can lead to a misconception of quality control at this basic scale. Consequently, in that regard the AAPM through the Task 151 has noted that "*Quality control in medical imaging is an ongoing process and not just a series of infrequent evaluations of medical imaging equipment*" (Jones *et al.*, 2015).

Performance testing verifies medical radiological equipment reliability and safety, guided by various recommendations. Medical physicists play a central role in performing or supervising these measurements, occasionally delegating responsibilities to radiation technologists. In this context, it is noteworthy to precise that QC is not the only role of medical physicists in diagnostic radiology as noted by the AAPM (Moores *et al.*, 1991).

Carefully reviewing literature in both IAEA and AAPM reports has led us to propose the next table which presents the distribution of responsibilities among radiological professionals in the context of a comprehensive QC program in diagnostic radiology (Appendix 2) (AAPM, 2002; IAEA, 2013).

3.4.1.2 Quality assurance

A reactive process is needed to follow the evolution of QC. For this, QA is defined to be the process which ensures and provide confidence that the concerned system performance will keep matching to the established benchmarks (ISO, 2015).

In accordance with international BSS guidelines, radiological facilities must establish QA systems overseen by medical physicists to meet specific requirements. In diagnostic radiology, this QA program covers QC and spans the entire imaging process, starting with a needs analysis and system evaluation before installation (Part, 2011; IAEA, 2015). QA includes aspects such as room design, equipment selection, installation oversight, acceptance testing, ongoing maintenance, and equipment disposal.

3.4.1.3 Quality management

Quality management, as defined by ISO 9000, is the comprehensive framework governing all aspects of quality within organizations. It involves setting quality policies, defining objectives, and implementing processes like planning, assurance, control, and improvement (ISO, 2015). ISO identifies seven key quality management principles (West, 2000): prioritizing customer satisfaction, effective leadership, engaging and empowering employees, adopting a process-oriented approach, continuous improvement, making decisions based on evidence, nurturing positive relationships.

Effectively applying these principles in radiology can lead to substantial advantages for the department. It is advisable for the department to designate a quality manager or team responsible for establishing and sustaining the quality management system. To ensure the smooth operation of this system, it is beneficial to establish a quality committee. This committee's role is to periodically assess and evaluate the facility's QA program. The committee should comprise individuals such as physicians, radiographers, medical physicists, nurses, administrative staff, and others as relevant to the department's operations.

3.4.2 Maintaining quality in radiology

In radiology, as in many fields requiring quality monitoring, "quality" is a common term, often claimed by most departments. But how to confirm that a diagnostic radiology department truly provides high-quality services? Without specific criteria, quality remains a vague concept. To genuinely assess quality, we must use concrete evaluation and quantification methods, involving objective measurements and peer reviews.

3.4.2.1 Record-keeping

While the record-keeping process may be time-consuming, its significance in the form of a quality manual remains crucial within any quality management system. This documentation serves as an internal reference for employees, outlining quality objectives and departmental policies while also delineating the necessary procedures for achieving these objectives. Externally, it communicates the implementation of the quality management system to partners and serves as evidence of compliance with quality benchmarks. Effective organization and teamwork are essential for maintaining and updating this documented manual, ensuring its accessibility to all stakeholders involved. It should strike a balance between comprehensiveness and conciseness while maintaining clarity and consistency to facilitate implementation. Radiology is living a digital age, the traditional hardcopy quality manual may no longer be essential, as it can be integrated into the facility's IT system providing easy access for all staff. An illustrative example of this documentation structure and content is presented in Appendix 3 (Dance *et al.*, 2014).

3.4.2.2 Dosimetry

While radiation dose is essential for imaging, it carries potential risks, necessitating careful management to minimize exposure while maintaining diagnostic quality. Appendix 4 presents at table that illustrate the key purposes of dosimetry in diagnostic radiology based on IAEA report's findings (IAEA, 2007):

Within the framework of quality assurance, dosimetry assumes an important role as it can be linked to different components and, to some extent, utilized as a performance indicator to evaluate the quality of radiological services. For example, dosimetry as part of equipment performance testing ensures proper and consistent X-ray source calibration, essential for maintaining diagnostic accuracy. Furthermore, dosimetry in standard radiological practices helps derive typical doses, enabling comparisons with established DRLs and driving quality optimization efforts.

However, given the wide spectrum of techniques and modalities in diagnostic radiology, relevant dosimetry can become complex. Competent professionals in dosimetry, such as medical physicists, are essential for its accurate implementation. It is the responsibility of registrants and licensees to ensure that patient dosimetry is conducted and documented by or under the supervision of a medical physicist, using calibrated dosimeters, and adhering to internationally or nationally accepted protocols.

3.4.2.3 Performance Indicators (PIs) in diagnostic radiology

In diagnostic radiology, to achieve continuous improvement with measurable results, clear essential Performance Indicators (PIs) are essential (Delis *et al.*, 2017**)**. The team collaborates to identify relevant PIs aligned with department practices and challenges. As quality matures, PIs evolve accordingly. Medical physicists play a key role in developing and monitoring technical PIs due to their expertise in measurement. For practical examples of departmental PIs Appendix 5 presents some of the indicators that offer a practical means of assessing and enhancing the performance and quality of a diagnostic radiology department.

4 Discussion

An international agreement of the optimization strategy enhancement in diagnostic radiology, as a fundamental task of radiological teams, has already been established in literature through organizations like IAEA, ICRP, and others. This shows the huge importance of patient radiation protection.

Collaborative initiatives present commitment to safety, while the IAEA's International Action Plan emphasizes education and support. Challenges in dose optimization are multifaceted, requiring more than technical changes due to evolving technology and diverse protocols. Collaborative projects, like HERCA and COCIR, aim to reduce exposure (Tsapaki *et al.*, 2018; HERCA, 2020).

Medical physicists play a fundamental role, following equipment performance, protocols, and staff practices. New tools like RDSR, PDMS, and AI offer promise for optimization. Amidst technological evolution, the pursuit of dose optimization remains a complex, yet collaborative, journey Parakh *et al.*, 2016; Kortesniemi *et al.*, 2018).

In radiology and diagnostic imaging, the optimization process takes center stage amidst a wave of technologies and studies. The emergence of artificial intelligence (AI) and machine learning (ML) algorithms holds immense potential, enhancing image interpretation, workflow efficiency, and clinical decision support, all of which can be finely tuned through optimization (Chartrand *et al.*, 2017).

Additionally, a developing field is the use of sophisticated imaging methods to investigate the influence of the human microbiome on health and disease. As this emerging field improves, optimization strategies will be vital in utilizing its capabilities. By visualizing and comprehending the complex interactions between the human body and its microbiota, radiologists can optimize diagnostic and therapeutic approaches for a diverse range of conditions, demonstrating the indispensable nature of optimization in shaping the future of radiology (Gollub *et al.*, 2017).

5 Conclusion

While medical imaging has significantly advanced clinical practices, the potential errors in X-ray machines necessitate thorough monitoring through quality assurance programs. To uphold safety and effectiveness, the use of X-ray machines should be individualized, emphasizing both image quality and appropriate dose levels. The optimization process, a collaborative effort among key professionals, concentrates on enhancing equipment performance, customizing examination protocols, and promoting responsible staff behavior. The medical industry plays a key function by offering advanced radiation dose optimization tools and comprehensive training, extending beyond basic machine operation to encompass the application of preset examination protocols. Clinically certified diagnostic radiology medical physicists take a central role in daily imaging activities, leading the optimization process to ensure the safe and efficient use of X-ray technology, thereby contributing to heightened patient care and overall healthcare quality.

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Conflicts of interest

The authors declare no conflict of interest.

Data availability statement

No new data were created or analysed during this study. Data sharing is not applicable to this article.

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Appendix 1 Search strategy summary.

Items	Specification
Date of Search	The literature search was conducted between December 2023 and April 2024.
Databases and other sources searched	PubMed, Scopus, Web of Science.
Search terms used	**MeSH terms:** X-ray diagnosis; ionizing radiation; medical imaging; health care quality assurance; quality control; computed tomography; X-ray; radiography; mammography; fluoroscopy; interventional radiology; artificial intelligence, machine learning. **Free text search terms:** UNSCEAR; IAEA; AAPM; ICRP; EOFMP; linear no-threshold model; world health organization; international organization for standardization; International Basic Safety Standards; medical physicist; dose optimization; diagnostic reference level.
Timeframe	The literature search covered studies published up to January 2024.
Inclusion and exclusion criteria	**Inclusion criteria:** Studies published in indexed peer-reviewed scientific journals. Research on radiology optimization and quality assessment for both diagnostic and interventional aspects. Studies conducted in English or French. **Exclusion criteria:** Studies published in non-peer-reviewed sources. Research not related radiology optimization and quality assessment for both diagnostic and interventional aspects. Studies published in languages other than English or French.
Selection Process	The process of selecting studies for our review followed a systematic approach to ensure the identification of pertinent and high-quality research. Commencing with a literature search conducted between December 2023 and April 2024, we initially identified 97 potentially relevant articles and reports. The screening process involved reviewing titles and abstracts to assess their relevance to our research question. Subsequently, full-text articles were obtained for the studies meeting the inclusion criteria. A comprehensive evaluation of these full-text articles was then conducted, leading to the exclusion of studies that did not meet the specified criteria or lacked relevant data. This rigorous selection process culminated in the inclusion of a final set of 65 studies in our narrative review.

Appendix 2 Proposed task for: CMP, Radiologist and Technologist.

QC task	Responsible radiological professional
Administering and overseeing QC program	Radiologist
Carrying out day-to-day QC activities	Radiation Technologist
Designing and implementing QC program	Certified Medical Physicist (CMP)
Collaborating with radiologist on QC program	Certified Medical Physicist (CMP)
Troubleshooting issues during QC	Certified Medical Physicist (CMP)
Regular equipment evaluation and calibration	Certified Medical Physicist (CMP)

Appendix 3 Proposition for quality manual structure for clinical radiology departments.

Organizational framework

- Mission and vision: Defining the department's purpose and future goals.
- Service population: Understanding the community served by the department.
- Department structure: Describing the organizational hierarchy.
- Strategic planning: Outlining long-term strategies for success.

Resources managing

- Human resources: Covering staff qualifications and roles.
- Facilities and infrastructure: Discussing physical spaces and equipment.
- Imaging equipment: Details about radiological devices.
- IT and data security: Addressing information technology and data protection.
- Specialized equipment: Describing any unique tools or technologies.
- Financial management: Discussing budget and financial resources.

Radiation safety protocols

- Safety oversight: Explaining the radiation safety committee's role.
- Local safety rules: Guidelines specific to radiation safety.
- Safety procedures: Detailed radiation safety measures.

QA and improvement

- Quality committee: The committee responsible for maintaining quality.
- QA: Methods for ensuring high-quality radiology services.
- Continuous improvement: Strategies for ongoing enhancement.
- Document management: Procedures for organizing critical documents.
- Incident reporting: Handling and reporting incidents and errors.

Guidelines of clinical practice

- Patient preparation: Instructions for patient readiness.
- Examination protocols: Detailed steps for radiological examinations.
- Post-examination procedures: Guidelines for post-exam protocols and documentation.

Appendix 4 Quality manual structure for clinical radiology departments key purposes of dosimetry in diagnostic radiology.

Equipment performance testing	Development of guidance levels – optimization (including Diagnostic Reference Levels – DRLs)	Patient-specific dosimetry (dose estimation)
Ensures the accurate calibration and consistent performance of X-ray sources, a critical part of Quality Control (QC).	Involves establishing dose benchmarks to optimize imaging procedures, fostering quality improvements.	Directly contributes to patient safety in radiological practices by estimating individualized radiation dose.

Appendix 5 Examples of diagnostic radiology performance indicators (PIs).

Patient or Procedure Identification Errors: Measuring the rate of errors in patient or procedure identification.
Equipment under Regular QC: Counting the number of equipment units undergoing routine Quality Control (QC) procedures with established protocols
Local Dose Records: Monitoring the number of examinations for which local dose records are available.
Incident Reporting: Tracking the number of reported incidents, including contrast medium reactions, cardiopulmonary collapse, and patient falls.
Annual Training Hours: Recording the total annual hours of training, both internal and external, for department staff.
Procedure Documentation: Counting the number of documented and utilized procedures.
Standardized Procedure Compliance: Calculating the percentage of standardized radiological procedures with established examination protocols.
Complaints from Stakeholders: Keeping tabs on the number of complaints received from all stakeholders, including referring physicians, patients, and staff.
Image Rejection and Retake Rate: Analyzing the rate of image rejections and retakes, along with in-depth result analysis.
Turnaround Time: Measuring the turnaround time for various examinations and patients, including emergency, external, and in-patients.