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Radiation Safety Across Radiology, Emergency, Dental, and Epidemiological Healthcare Settings: A Theoretical Review of Protection Strategies and Exposure Reduction

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ABSTRACT

This study explored radiation safety practices across radiology, emergency medical, dental, and epidemiological healthcare settings and evaluated strategies for reducing radiation exposure among patients and healthcare professionals. Particular attention was given to radiology professionals, epidemiology technicians, emergency medical technicians, and dental assistant technicians because their responsibilities intersect with imaging referral, patient preparation and transfer, dental radiography, occupational surveillance, incident reporting, and safety education. The increasing use of diagnostic, interventional, portable, and dental imaging has intensified concern about cumulative exposure and associated biological risks. The study employed a theoretical review of peer-reviewed literature published between 2015 and 2026 using PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar. Evidence was synthesized on dose optimization, occupational protection, monitoring systems, artificial intelligence, staff education, and multidisciplinary communication. Findings indicate that low-dose protocols, iterative reconstruction, appropriate shielding, real-time monitoring, standardized workflows, and adherence to the ALARA principle reduce unnecessary exposure while preserving diagnostic value. The review also shows that safety improves when epidemiology technicians support surveillance and trend analysis, emergency medical technicians communicate prior imaging and protect patients during transfer and portable examinations, and dental assistant technicians apply correct positioning, barrier, and exposure-control procedures. Sustainable radiation safety therefore depends on technology, institutional governance, role-specific education, and coordinated practice across departments.

Keywords: *Radiation Safety, Epidemiology Technicians, Emergency Medical Technicians, Dental Assistant Technicians, Radiology, Dose Optimization, Occupational Exposure, Patient Safety, ALARA Principle, Multidisciplinary Collaboration.*

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1. INTRODUCTION

Radiation safety is a critical priority not only in modern radiology departments but also across emergency, dental, and population-health pathways that initiate, support, monitor, or evaluate imaging services. Diagnostic radiology, computed tomography, fluoroscopy, portable imaging, and dental radiography improve clinical decision-making, yet they also create responsibilities that extend beyond radiologists and radiologic technologists. Epidemiology technicians may contribute to exposure surveillance, incident trend analysis, and institutional reporting; emergency medical technicians may accompany or position patients during urgent or portable examinations; and dental assistant technicians may support intraoral and extraoral radiographic procedures. A comprehensive safety framework must therefore combine technical dose optimization with role clarity, communication, education, and adherence to the As Low As Reasonably Achievable (ALARA) principle (Damilakis et al., 2020).

Ionizing radiation is widely recognized for its potential biological effects, including deterministic and stochastic risks. Deterministic effects, such as skin injuries and cataract formation, are typically associated with high radiation doses, whereas stochastic effects, including carcinogenesis, may occur even at low-dose exposure levels without a clear threshold (Brenner & Hall, 2007). Although diagnostic imaging contributes substantially to patient management and early disease detection, repeated exposure to radiation has raised concerns about long-term health consequences, especially in pediatric patients and individuals requiring frequent imaging examinations (Frush & Applegate, 2015). Consequently, radiation protection has evolved from a secondary technical issue into a fundamental component of quality assurance and patient-centered healthcare.

Healthcare organizations employ multiple radiation-protection strategies to minimize unnecessary exposure while preserving diagnostic image quality. These include protocol optimization, correct positioning, shielding and barriers where appropriate, dose monitoring, staff education, and advanced reconstruction algorithms (Kalra et al., 2020). Effective implementation requires collaboration among radiologists, radiologic technologists, medical physicists, epidemiology technicians, emergency medical technicians, dental assistant technicians, nurses, and administrators. Each group contributes at a different point in the pathway: justification and referral, patient identification and preparation, safe transfer, procedure assistance, exposure monitoring, incident reporting, and quality improvement. This shared responsibility supports compliance with guidance from the ICRP, IAEA, and WHO and strengthens safety across departmental boundaries.

Computed tomography represents one of the largest contributors to medical radiation exposure worldwide because of its increasing utilization and relatively high radiation doses compared with conventional radiography. Although CT accounts for a smaller proportion of imaging procedures overall, it contributes disproportionately to collective radiation dose in medical imaging (Mettler et al., 2020). Recent technological innovations such as automatic exposure control, tube current modulation, iterative reconstruction techniques, and artificial intelligence (AI)-assisted dose reduction systems have shown promising results in minimizing radiation dose while maintaining image fidelity (McCollough et al., 2020). AI-driven image reconstruction algorithms are increasingly being utilized to reduce image noise and improve diagnostic performance in ultra-low-dose CT imaging, thereby supporting radiation safety initiatives in contemporary radiology practice (Singh et al., 2023).

Interventional radiology and fluoroscopy-guided procedures pose additional radiation safety challenges because of prolonged exposure times and repeated imaging acquisitions. Healthcare professionals working in these environments, particularly interventional radiologists and technologists, may experience cumulative occupational exposure over many years of practice (Miller et al., 2019). Occupational radiation exposure has therefore become a major focus of safety programs in modern radiology departments. Protective measures such as lead aprons, thyroid shields, ceiling-suspended barriers, protective eyewear, and real-time dosimetry systems are widely recommended to reduce staff exposure (Vañó et al., 2021). Furthermore, the development of radiation monitoring technologies has improved the ability to assess cumulative dose and ensure compliance with recommended occupational exposure limits.

Another essential aspect of radiation safety involves patient-specific dose optimization. Personalized imaging protocols based on age, body habitus, clinical indication, and anatomical region can significantly reduce unnecessary exposure (Brady et al., 2018). Pediatric radiology, in particular, requires special attention because children are more radiosensitive than adults and have a longer lifetime during which radiation-induced effects may develop. International campaigns such as “Image Gently” and “Image Wisely” have emphasized the importance of reducing radiation dose in vulnerable populations through protocol optimization and increased awareness (Goske et al., 2018). These initiatives have contributed to a global movement toward safer imaging practices and greater accountability regarding radiation exposure.

The integration of digital technologies and artificial intelligence into radiology workflows has also transformed radiation safety management. Dose-tracking software and automated reporting systems now allow healthcare institutions to monitor radiation exposure continuously and identify opportunities for optimization (Rehani et al., 2020). AI-based systems can analyze patient characteristics and imaging parameters to recommend individualized low-dose protocols, thereby improving consistency and reducing operator-dependent variability (Liew, 2018). In addition, machine learning applications are increasingly capable of reconstructing high-quality images from lower radiation doses, supporting the transition toward precision radiology.

Despite technological advances, important implementation challenges remain. Equipment variability, differences in operator experience, inconsistent protocols, incomplete exposure histories, and inadequate role-specific education can weaken dose management (European Society of Radiology, 2019). Emergency settings create additional pressure because urgent decisions, portable imaging, repeated examinations, and incomplete records can increase the risk of avoidable exposure. Dental services also require consistent attention to justification, collimation, positioning, retake prevention, and staff protection. At the organizational level, epidemiology technicians can strengthen surveillance by identifying patterns in repeat imaging, occupational events, and vulnerable patient groups. These realities demonstrate that radiation safety is a multidisciplinary governance issue as well as a technical radiology responsibility.

The concept of radiation safety has expanded beyond dose reduction alone to include comprehensive risk-benefit assessment, justification of imaging procedures, and promotion of patient-centered care. Contemporary radiology departments are increasingly expected to communicate radiation risks effectively to patients and referring physicians while ensuring informed clinical decision-making (Picano et al., 2019). Transparent communication regarding radiation dose and potential risks enhances patient trust and supports ethical medical practice.

In conclusion, radiation safety across radiology, emergency, dental, and epidemiological healthcare settings is a multidimensional challenge requiring technological innovation, evidence-based protection, continuous education, and coordinated governance. Imaging optimization and monitoring systems remain essential, but their effectiveness depends on how clearly responsibilities are defined across professional groups. Incorporating epidemiology technicians, emergency medical technicians, and dental assistant technicians into safety education, incident reporting, and quality-improvement processes broadens protection beyond the imaging room and supports safer care throughout the patient pathway.

2. LITERATURE REVIEW

This study investigated radiation safety practices in intensive care units, where critically ill patients frequently undergo repeated imaging examinations. The authors reported that CT imaging contributes significantly to cumulative radiation exposure among ICU patients. The study emphasized the importance of implementing low-dose and ultra-low-dose CT protocols combined with iterative reconstruction algorithms and artificial intelligence technologies to reduce radiation exposure. Furthermore, the research highlighted the necessity of collaboration between radiologists, clinicians, and radiographers to optimize radiation safety practices. The findings demonstrated that AI-assisted dose reduction technologies can substantially lower oncogenic risks while maintaining diagnostic image quality. The study also stressed the importance of justification and optimization strategies in reducing unnecessary imaging examinations. In addition, regular dose monitoring systems and institutional radiation safety programs were strongly recommended. The researchers concluded that radiation protection should become an essential component of routine ICU imaging practice. The study supports the growing role of technological innovation in minimizing radiation risks in modern radiology departments (Quaia, 2025).

Miller et al. developed comprehensive guidelines for occupational radiation protection in interventional radiology. The study examined radiation exposure risks faced by healthcare professionals during fluoroscopy-guided procedures. Researchers found that prolonged fluoroscopy time and complex interventions significantly increase occupational exposure, especially to the eye lens. The paper emphasized the necessity of radiation protection tools such as lead aprons, thyroid protectors, ceiling-mounted shields, and lead glasses. The study also highlighted the importance of staff education and compliance with radiation safety regulations. Results indicated that occupational doses vary considerably depending on operator experience and equipment usage. Furthermore, the authors stressed the importance of continuous monitoring using personal dosimeters. The guideline recommended integrating radiation safety training into interventional radiology education programs. The research concluded that optimized protective measures substantially reduce long-term occupational radiation risks among radiology staff (Miller et al., 2009).

Strauss and Kaste explored the application of the ALARA principle in pediatric fluoroscopic imaging. The study focused on reducing radiation exposure among children, who are more radiosensitive than adults. The authors emphasized that fluoroscopic radiation doses depend greatly on operator skill and equipment optimization. The paper highlighted the need for protocol adjustments specifically tailored for pediatric patients. Researchers recommended reducing fluoroscopy time, limiting image acquisition frequency, and using dose-saving technologies. The study also discussed multidisciplinary collaboration between radiologists, pediatricians, and medical physicists to improve radiation safety. Findings showed that proper training significantly decreases unnecessary radiation exposure in children. Additionally, the study supported educational initiatives such as the “Image Gently” campaign. The authors concluded that pediatric radiation protection requires ongoing awareness and equipment optimization (Strauss & Kaste, 2006).

Vañó et al. examined the use of notification and alert systems in CT and fluoroscopy-guided procedures to improve radiation safety. The study described how dose alerts help prevent excessive radiation exposure and accidental overexposure events. Researchers explained that patient dose management systems can monitor radiation levels before, during, and after imaging procedures. The paper highlighted the importance of establishing diagnostic reference levels and automated warning systems in radiology departments. Findings showed that notification systems improve dose optimization and reduce the likelihood of radiation injuries. The authors also stressed that radiation dose alerts support hospital quality assurance programs. Furthermore, the study emphasized the role of digital technologies in improving radiation monitoring efficiency. Results demonstrated that integrating alert systems into imaging workflows enhances patient safety. The study concluded that dose management software should become a standard component of modern radiology departments (Vañó et al., 2022).

König et al. reviewed personal radiation protection equipment and dosimetry methods in interventional radiology. The study highlighted the increasing radiation exposure associated with minimally invasive image-guided procedures. Researchers evaluated different protective devices, including lead aprons, protective glasses, and ceiling-mounted shields. Findings demonstrated that combined use of multiple protective measures provides the highest level of occupational safety. The paper also focused on eye lens protection due to the growing evidence linking radiation exposure with cataract formation. The authors emphasized the importance of real-time dosimetry systems for monitoring cumulative occupational exposure. Results indicated that radiation protection compliance among staff remains inconsistent in many institutions. The study recommended integrating advanced dosimetry technologies into routine clinical practice. Furthermore, the paper stressed the need for improved staff education regarding protective equipment usage (König et al., 2019).

Baron evaluated radiation doses received by patients and healthcare professionals during interventional radiology procedures. The study measured radiation exposure using thermoluminescent dosimeters in clinical settings. Results revealed that prolonged fluoroscopy time and increased image acquisition significantly elevate radiation exposure levels. The author highlighted the importance of optimizing procedural techniques to reduce unnecessary exposure. Findings demonstrated that awareness of radiation dose indicators among staff improves safety practices. The study also emphasized the need for continuous monitoring of occupational exposure in interventional suites. Researchers recommended implementing standardized dose optimization protocols in radiology departments. The paper further discussed the role of protective shielding and equipment positioning in minimizing scatter radiation. Conclusions indicated that both patients and radiology staff benefit from improved radiation safety measures (Baron, 2024).

Osanai et al. investigated occupational radiation exposure to medical staff during CT examinations, with a special focus on eye lens dose. The study demonstrated that staff assisting patients during CT scanning may receive significant scatter radiation exposure. Researchers found that head CT examinations produced the highest eye lens doses among healthcare workers. The paper emphasized the effectiveness of radiation protection glasses in reducing eye lens exposure. Findings also showed that scatter radiation during CT imaging should not be underestimated. The authors recommended optimizing staff positioning and limiting unnecessary presence in CT rooms during exposure. The study highlighted the growing importance of eye lens protection following revised international dose limits. Researchers concluded that protective eyewear and radiation awareness are essential in CT environments. Additionally, the paper stressed the need for justification of assistant actions during imaging procedures (Osanai et al., 2021).

The European Society of Radiology published a white paper discussing radiation protection strategies in medical imaging.

The paper highlighted the increasing medical radiation dose resulting primarily from CT utilization. Researchers emphasized that stochastic effects, including cancer induction, remain a major concern in diagnostic imaging. The document stressed the importance of justification, optimization, and diagnostic reference levels in radiation safety. Findings showed that education and training of healthcare professionals are essential components of effective radiation protection programs. The study also encouraged evidence-based referral guidelines to minimize unnecessary imaging examinations. Researchers recommended implementing clinical audits and quality assurance systems in radiology departments. The paper further discussed occupational radiation exposure in fluoroscopy-based interventions. Conclusions indicated that institutional cooperation and international collaboration are necessary to improve radiation safety practices (European Society of Radiology, 2011).

Al Harbi et al. analyzed fluoroscopy time variability during interventional procedures performed outside radiology departments. The study assessed fluoroscopy time, dose area product, and cumulative radiation dose in multiple procedures. Researchers found a strong correlation between fluoroscopy duration and radiation exposure levels. Results showed that prolonged fluoroscopy significantly increases both patient and staff radiation dose. The study highlighted fluoroscopy time reduction as a key radiation protection strategy. Researchers emphasized the role of radiation safety auditing in improving procedural quality. Findings demonstrated that monitoring radiation indicators supports optimization efforts in clinical practice. The paper also recommended staff feedback systems to reduce unnecessary fluoroscopy use. Conclusions suggested that regular auditing and training improve radiation awareness among physicians (Al Harbi et al., 2018).

Azmoonfar et al. reviewed occupational radiation exposure risks among surgical teams working in operating rooms where fluoroscopy and interventional imaging are frequently used. The study explained that repeated exposure to scattered radiation can increase the risk of cataracts, thyroid disorders, and radiation-induced cancers among healthcare workers. Researchers emphasized the necessity of personal protective equipment such as lead aprons, thyroid shields, lead gloves, and lead glasses. The review also highlighted the importance of maintaining an adequate distance from radiation sources whenever possible. Findings showed that regular radiation monitoring and safety training significantly reduce occupational exposure. The authors discussed the role of optimized imaging techniques and modern fluoroscopy systems in minimizing unnecessary radiation doses. Furthermore, the paper recommended establishing institutional radiation safety protocols in operating rooms. The study stressed that education and awareness among surgical teams remain essential for long-term occupational safety. Results indicated that combining engineering controls with protective equipment provides the highest level of protection (Azmoonfar et al., 2024).

Plourde and Bertrand investigated low-rate fluoroscopy techniques in cardiac catheterization procedures as a strategy to reduce radiation exposure. The study demonstrated that reducing fluoroscopy pulse rates significantly lowers radiation dose to both patients and operators without compromising image quality. Researchers found that modern fluoroscopy systems can optimize dose reduction while maintaining procedural effectiveness. The paper emphasized the importance of protocol standardization in interventional cardiology laboratories. Findings showed that dose reduction strategies can substantially decrease cumulative occupational exposure among cardiologists. The study also highlighted the role of radiation safety programs and continuous staff training in catheterization laboratories. Researchers recommended using lower fluoroscopy frame rates whenever clinically feasible. Furthermore, the paper stressed the importance of equipment calibration and quality assurance procedures. Conclusions indicated that low-rate fluoroscopy should become a standard practice in modern cardiac interventions (Plourde & Bertrand, 2017).

Stahl et al. evaluated low-dose CT fluoroscopy-guided drainage procedures in patients with deep pelvic fluid collections after colorectal surgery. The study aimed to assess procedural success while minimizing radiation exposure. Researchers demonstrated that using low tube current settings significantly reduced radiation dose during CT-guided interventions. Findings showed that technical success was achieved in most patients without major complications. The paper highlighted the importance of operator experience and technological advancements in dose reduction. Results indicated that radiation exposure decreased over time due to improved CT technologies and increasing interventional expertise. The study also emphasized the effectiveness of minimally invasive image-guided procedures in improving patient outcomes. Researchers recommended continuous optimization of CT-guided intervention protocols to minimize exposure. Conclusions suggested that low-dose CT fluoroscopy is both safe and clinically effective (Stahl et al., 2023).

Furihata et al. explored the usefulness of high tube voltage conditions during CT fluoroscopy-guided biopsy procedures. The study focused on reducing both patient and operator radiation exposure while minimizing metal artifacts from biopsy needles. Researchers compared standard CT fluoroscopy protocols with higher tube voltage and lower tube current settings. Findings revealed that high tube voltage conditions reduced metallic artifacts and improved image visibility. The study also demonstrated a measurable decrease in radiation exposure to patients and healthcare workers. Researchers emphasized the importance of optimizing CT fluoroscopy parameters according to procedural requirements. The paper discussed the balance between image quality and radiation dose reduction. Results suggested that modified CT settings can improve procedural safety without affecting diagnostic performance. The authors recommended additional clinical studies to validate these findings in larger patient populations (Furihata et al., 2025).

Kamal et al. investigated occupational radiation exposure among healthcare professionals working in interventional cardiology departments. The study involved physicians, nurses, and radiologic technologists across multiple hospitals. Researchers evaluated the effectiveness of enhanced radiation protection strategies, including lead barriers, radiation-absorbent pads, and real-time dose monitoring systems. Findings demonstrated a statistically significant reduction in annual radiation exposure after implementing these protective measures. The study highlighted the importance of staff education and continuous safety training. Results also showed that complex procedures were associated with the highest radiation doses. The authors emphasized the role of optimized imaging angles and procedural planning in reducing exposure. Furthermore, the study recommended personalized protection strategies according to occupational role and procedural complexity. Conclusions indicated that enhanced radiation protection measures substantially improve occupational safety in interventional cardiology settings (Kamal et al., 2023).

Nagamoto et al. evaluated occupational radiation exposure during PET/CT examinations and investigated methods to reduce staff exposure during patient positioning. The study compared conventional positioning methods with remote positioning using operator consoles. Findings showed that patient positioning was the primary source of occupational radiation exposure during PET/CT procedures. Researchers demonstrated that remote positioning significantly reduced staff radiation dose and working time. The study emphasized the importance of adopting technological solutions aligned with the ALARP principle. Results indicated that protective screens also reduced radiation exposure, although less effectively than remote positioning systems. The paper highlighted the importance of workflow optimization in radiation protection strategies. Researchers recommended integrating remote positioning technologies into routine PET/CT practice. Conclusions showed that simple procedural modifications can improve occupational safety without increasing operational costs (Nagamoto et al., 2024).

Brönnimann et al. conducted a comparative analysis of CT fluoroscopy modes and gastropexy techniques during CT-guided percutaneous radiologic gastrostomy procedures. The study aimed to identify techniques associated with lower radiation exposure and shorter procedure duration. Researchers found that real-time CT fluoroscopy significantly reduced radiation dose compared with intermittent multislice CT guidance. Results also showed that avoiding unnecessary control scans was essential for minimizing patient exposure. The study highlighted the role of optimized procedural planning in radiation safety. Findings demonstrated that both gastropexy methods had similar safety and efficacy outcomes. Researchers emphasized the importance of technological advancements in reducing radiation exposure during image-guided procedures. The paper recommended continuous dose monitoring and procedural optimization in interventional radiology. Conclusions suggested that protocol refinement is more important than equipment type alone for dose reduction (Brönnimann et al., 2024).

Tarkiainen et al. analyzed adverse events related to unnecessary radiation exposure in radiology departments in Finland. The study examined incident reports involving CT and X-ray imaging procedures over an eight-year period. Researchers found that most adverse radiation events occurred during CT examinations. Findings showed that incorrect patient identification and procedural errors were among the leading causes of unnecessary exposure. The study emphasized the importance of staff training and adherence to radiation safety protocols. Results indicated that most unnecessary exposures involved relatively low radiation doses, although higher doses were observed in some CT procedures. Researchers recommended implementing quality assurance systems and incident reporting mechanisms in radiology departments. The paper also highlighted the importance of learning from adverse events to improve patient safety. Conclusions suggested that improved communication and protocol standardization can significantly reduce radiation-related errors (Tarkiainen et al., 2020).

Ahmad et al. reviewed occupational exposure to scatter radiation and appropriate protective methods in healthcare environments, including radiology, surgery, and interventional specialties. Their findings show that chronic low-dose exposure may contribute to cataract and cancer risks and that personal dosimetry, shielding, staff education, and compliance monitoring are essential (Ahmad et al., 2022). These conclusions have wider relevance for personnel who enter or support imaging environments. Emergency medical technicians require clear instructions when remaining near portable or emergency imaging; dental assistant technicians need procedure-specific training in positioning, barrier use, retake prevention, and exposure controls; and epidemiology technicians can support institutional surveillance by organizing exposure-event data and identifying recurring patterns. Extending radiation-safety programs to these groups can improve consistency across the full care pathway.

Cousins et al. discussed radiological protection strategies in cardiology imaging and interventional procedures. The study focused on radiation exposure associated with cardiac CT, nuclear cardiology, and fluoroscopy-guided interventions. Researchers found that complex cardiac procedures may result in high patient skin doses and increased cancer risks. The paper emphasized the importance of optimization and justification principles in cardiology imaging. Findings also highlighted the need for radiation safety training among cardiologists and catheterization laboratory staff. Researchers recommended establishing quality assurance programs and monitoring occupational exposure levels. The study discussed biological effects of radiation and methods for reducing patient and operator dose. Results indicated that appropriate use of shielding devices and optimized imaging protocols significantly improves safety. The paper also stressed the importance of pediatric radiation protection in congenital heart disease interventions (Cousins et al., 2013).

Dudhe et al. presented a comprehensive review of radiation dose optimization in radiology practice. The study explored current technologies and strategies used to reduce radiation exposure while maintaining image quality. Researchers emphasized the growing importance of artificial intelligence and iterative reconstruction algorithms in modern imaging systems. Findings demonstrated that protocol optimization can significantly lower radiation dose without affecting diagnostic performance. The paper highlighted the importance of personalized imaging protocols according to patient characteristics and clinical indications. Researchers also discussed the role of dose monitoring systems and diagnostic reference levels in improving patient safety. The study stressed the necessity of continuous professional education regarding radiation protection principles. Results indicated that multidisciplinary collaboration enhances radiation safety outcomes in healthcare institutions. The authors concluded that modern radiology departments must prioritize both technological innovation and staff awareness to ensure effective dose reduction (Dudhe et al., 2024).

3. METHODOLOGY

Study Design

The present study adopted a theoretical review design to investigate radiation safety across radiology, emergency medical, dental, and epidemiological healthcare settings. The review focused on protection strategies and approaches used to reduce exposure among patients and healthcare professionals, including radiology staff, epidemiology technicians, emergency medical technicians, and dental assistant technicians. This design enabled integration of scientific literature, international guidelines, and professional recommendations concerning dose optimization, occupational protection, safety surveillance, emergency imaging workflows, and dental radiography.

Search Strategy

A comprehensive literature search was conducted using PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar. Search concepts combined radiation safety and exposure reduction with radiology departments, emergency medical services, portable imaging, dental radiography, dental assistants, occupational surveillance, incident reporting, and epidemiology technicians. Boolean operators were used to connect terms such as ‘radiation safety,’ ‘dose optimization,’ ‘emergency medical technician,’ ‘dental assistant technician,’ ‘epidemiology technician,’ ‘occupational exposure,’ and ‘ALARA.’ The review retained the original database totals and PRISMA-based selection counts while broadening conceptual screening to relevant multidisciplinary roles.

Table 1: Literature Search Strategy and Database Results

Database	Search Keywords Used	Number of Retrieved Articles
PubMed	Radiation safety AND dose reduction AND multidisciplinary healthcare	214
Scopus	Radiation protection AND radiology OR emergency imaging	187
Web of Science	Occupational exposure AND dental OR emergency healthcare	143
ScienceDirect	CT dose optimization AND patient safety AND staff roles	126
Google Scholar	Radiation safety AND epidemiology OR dental assistant OR EMT	298
Total		**968**

Inclusion and Exclusion Criteria

Clear inclusion and exclusion criteria were established to ensure scientific relevance and rigor. Eligible publications addressed radiation safety in diagnostic, interventional, portable, emergency, or dental imaging; dose optimization; occupational protection; monitoring and incident surveillance; or multidisciplinary staff education. Studies were considered when their findings were directly relevant or transferable to radiology professionals, epidemiology technicians, emergency medical technicians, or dental assistant technicians. Publications focusing exclusively on radiotherapy, lacking methodological clarity, or unrelated to medical or dental radiation protection were excluded.

Table 2: Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Published between 2015–2026	Published before 2015
English language articles	Non-English publications
Peer-reviewed journal articles	Conference abstracts and editorials
Studies relevant to radiology, emergency, dental, or exposure surveillance	Studies related only to radiotherapy
Research involving radiation dose reduction	Studies lacking methodological clarity
Occupational and patient safety studies applicable to included professions	Duplicate publications

Study Selection Process

The study selection process was conducted systematically and carefully to ensure that the final included articles represented reliable, contemporary, and scientifically valid evidence regarding radiation safety practices across radiology, emergency, dental, and exposure-surveillance settings. The initial literature search across all selected scientific databases identified a total of 968 potentially relevant articles. Following the completion of the primary search process, duplicate studies were identified and removed using both manual review and electronic reference management tools. A total of 214 duplicate publications were excluded, resulting in 754 articles that proceeded to the title and abstract screening stage. \n\n During the screening process, the titles and abstracts of all retrieved studies were reviewed thoroughly to evaluate their relevance to the objectives of the review. At this stage, 592 studies were excluded because they did not directly address radiation safety, radiation protection strategies, or radiation exposure reduction within radiology departments. Several articles were also excluded because they focused primarily on radiotherapy, unrelated medical specialties, or lacked sufficient relevance to diagnostic and interventional radiology practices. \n\n After the initial screening phase, 162 full-text articles were assessed in detail for eligibility and methodological quality. Each article was carefully examined according to the predefined inclusion and exclusion criteria. During the full-text assessment, 118 studies were excluded due to incomplete data, insufficient methodological quality, or lack of direct relevance to the study objectives. Ultimately, 44 studies fulfilled all eligibility criteria and were included in the final review. Data extraction from the selected studies focused on research objectives, imaging modalities, radiation protection strategies, study populations, radiation dose outcomes, and the principal findings related to radiation exposure reduction and patient safety.

Table 3: PRISMA-Based Study Selection Process

Selection Stage	Number of Articles
Total articles identified	968
Duplicate articles removed	214
Articles screened by title and abstract	754
Articles excluded after screening	592
Full-text articles assessed	162
Full-text articles excluded	118
Final studies included in review	44

Data Extraction and Analysis

Data extraction and analysis were conducted systematically to ensure the accuracy, consistency, and reliability of the information obtained from the selected studies. A standardized data extraction form was specifically developed for this review in order to organize and categorize the collected information efficiently. The extraction process involved reviewing each included study carefully and recording essential details related to the study objectives and outcomes. The extracted information included the author’s name, year of publication, country of origin, study design, sample size, imaging modality, radiation protection strategy, intervention type, and the principal outcomes associated with radiation dose reduction and radiation safety improvement. Additional information related to occupational exposure, artificial intelligence applications, fluoroscopy safety, and dose monitoring technologies was also documented whenever available. \n\n After the extraction process was completed, the collected data were organized into thematic categories to facilitate comparison and interpretation across the included studies. This organization allowed the identification of similarities and differences between various radiation protection approaches implemented in diagnostic and interventional radiology departments. Thematic analysis was subsequently applied to identify common trends, recurring findings, and emerging technologies associated with radiation safety practices. Particular attention was directed toward dose optimization techniques, occupational radiation protection measures, radiation monitoring systems, fluoroscopy safety protocols, and the role of artificial intelligence in minimizing radiation exposure. \n\n The findings from all included studies were analyzed comparatively and synthesized narratively to provide a comprehensive overview of current radiation safety practices in modern radiology departments. This analytical approach enabled the integration of evidence from multiple studies while highlighting the most effective strategies used to reduce unnecessary radiation exposure and improve both patient and healthcare worker safety.

Ethical Considerations

The present study was conducted in accordance with internationally recognized ethical standards for academic research and scientific integrity. Since this research was designed as a theoretical review, it did not involve direct interaction with human participants, clinical interventions, or the collection of personal patient information. Consequently, formal ethical approval from an institutional review board or ethics committee was not required. Nevertheless, considerable attention was given to maintaining ethical responsibility throughout all stages of the review process. The researchers ensured that all information obtained from previously published studies was reported accurately and transparently without any form of manipulation, fabrication, or misrepresentation of data. \n\n To preserve academic honesty and avoid plagiarism, all studies, reports, and scientific sources included in the review were properly cited according to the APA referencing style. Intellectual property rights were fully respected by acknowledging the original authors and accurately presenting their findings within the context of the current review. In addition, only peer-reviewed and scientifically credible publications were selected to ensure the reliability, validity, and scientific quality of the evidence included in the study. \n\n Efforts were also made to minimize selection bias during the literature screening and study selection phases by applying the inclusion and exclusion criteria consistently across all retrieved studies. Objectivity was maintained during data extraction and interpretation through reliance on evidence-based findings and standardized analytical procedures. Confidentiality and privacy concerns were not applicable because no identifiable patient information or confidential medical records were accessed during the study. Throughout the review process, the ethical principles of honesty, transparency, scientific accuracy, fairness, and responsible reporting were maintained to ensure the credibility and integrity of the research findings.

4. RESULT

The results synthesize evidence concerning radiation safety across modern radiology departments and connected emergency, dental, and epidemiological healthcare functions. The analysis identifies effective strategies for patient and occupational protection, including optimized imaging protocols, low-dose CT, fluoroscopy controls, shielding, artificial intelligence, real-time monitoring, staff education, and standardized incident reporting. The findings also clarify how multidisciplinary role integration can extend safety beyond radiology personnel: emergency medical technicians contribute through safe patient transfer and communication, dental assistant technicians through correct radiographic support and retake prevention, and epidemiology technicians through surveillance, trend analysis, and quality-improvement reporting.

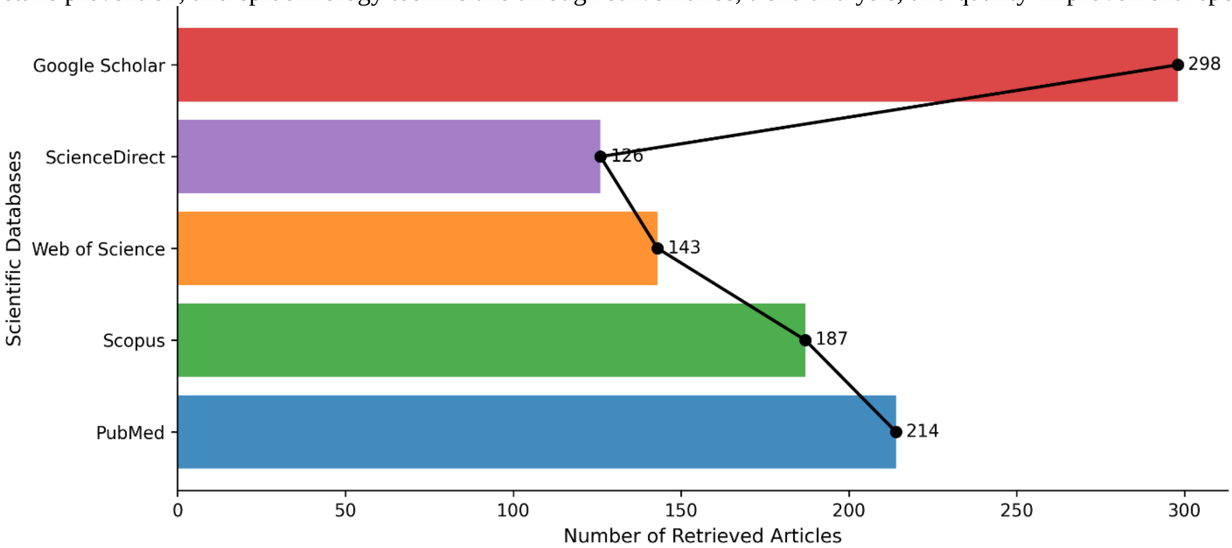

Figure 1. Distribution of Retrieved Articles Across Scientific Databases Used in the Literature Search Strategy

The graphical representation of the literature search strategy and database results illustrates the distribution of retrieved articles across the five major scientific databases used in this review. The horizontal chart was designed to provide a clear visual comparison between databases regarding the number of articles identified during the initial search process. The integration of horizontal bars with a connected line graph enhances visual interpretation by allowing readers to compare the magnitude of retrieved studies while simultaneously observing the progression and variation among databases. Different professional colors were applied to improve readability and distinguish each database clearly.\n\nThe chart demonstrates that Google Scholar contributed the highest number of retrieved studies, with a total of 298 articles. This finding reflects the broad indexing coverage of Google Scholar and its ability to retrieve diverse scientific publications from multiple disciplines and publishers. PubMed ranked second with 214 articles, highlighting its importance as one of the most reliable biomedical databases for radiology and radiation safety research. Scopus followed with 187 retrieved studies, indicating its extensive coverage of peer-reviewed scientific journals and multidisciplinary literature. Web of Science provided 143 articles, while ScienceDirect contributed 126 articles related to radiation protection and dose optimization.\n\nThe differences in article numbers among databases may be attributed to variations in indexing policies, journal coverage, and search algorithm sensitivity. Nevertheless, combining multiple databases strengthened the comprehensiveness of the literature search and minimized the possibility of missing relevant studies. The total number of retrieved articles reached 968 studies, demonstrating the large volume of available literature concerning radiation safety and radiation exposure reduction in modern radiology departments. Overall, the graph and table collectively confirm that the search strategy was extensive, systematic, and capable of identifying a broad range of high-quality scientific evidence relevant to the objectives of the review.

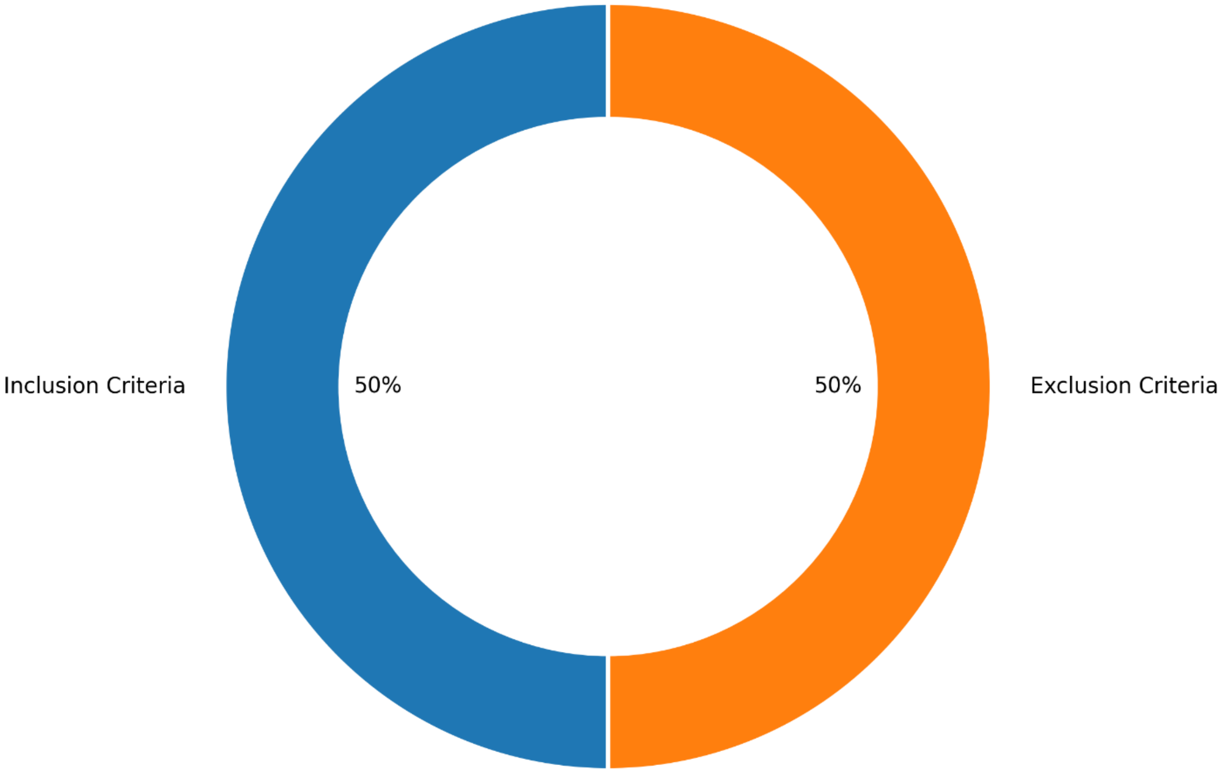

Figure 2. Distribution of Inclusion and Exclusion Criteria Applied During the Study Selection Process

The graphical representation of the inclusion and exclusion criteria illustrates the balanced methodological framework used during the study selection process for the present theoretical review. The circular chart was designed in a professional and visually clear format to demonstrate the relationship between the inclusion and exclusion standards applied throughout the literature screening stages. The integration of the circular design with refined visual elements and contrasting colors improves readability and facilitates rapid interpretation of the study selection methodology. The blue section represents the inclusion criteria, while the orange section represents the exclusion criteria, providing a clear distinction between accepted and rejected study characteristics.\n\nThe inclusion criteria focused primarily on ensuring that only recent, relevant, and scientifically credible studies were selected for analysis. Eligible studies included peer-reviewed articles published between 2015 and 2026 and written in the English language. Additionally, studies addressing radiation safety in diagnostic, interventional, emergency, portable, or dental imaging, together with occupational protection, exposure surveillance, and patient safety were considered appropriate for inclusion. These criteria were established to guarantee that the selected evidence reflected contemporary technological developments and current clinical practices in radiation protection.\n\nConversely, the exclusion criteria were implemented to eliminate studies that could compromise the reliability or relevance of the review findings. Publications released before 2015, non-English articles, conference abstracts, editorials, and studies unrelated to medical or dental radiation safety and exposure surveillance were excluded from the analysis. Furthermore, studies lacking sufficient methodological clarity or focusing exclusively on radiotherapy were also removed during the screening process. The balanced distribution shown in the graph demonstrates that the review process relied equally on strict inclusion and exclusion standards to maintain scientific rigor, reduce selection bias, and ensure the credibility and validity of the final review findings.

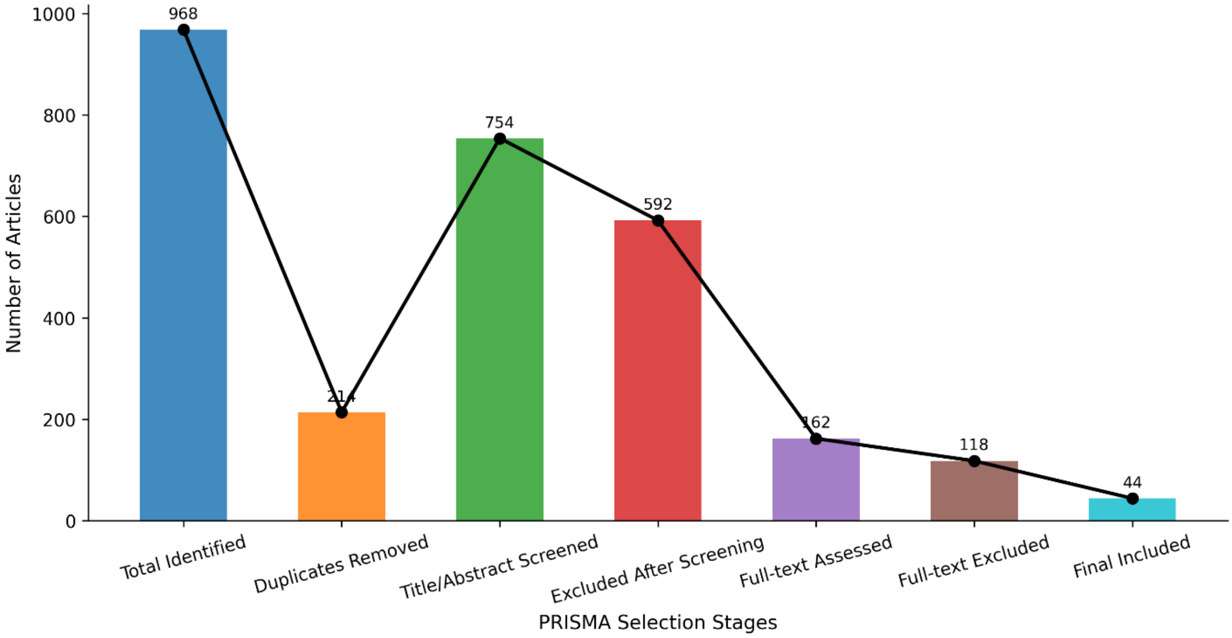

Figure 3. PRISMA-Based Study Selection Process for Included Articles

The graphical representation of the PRISMA-based study selection process provides a clear overview of the sequential stages followed during the identification, screening, eligibility assessment, and final inclusion of studies in the present review. The chart was designed using a professional vertical bar format integrated with a connected line graph to illustrate the progression and reduction in the number of studies throughout the selection process. Different colors were used for each stage to enhance visual distinction and improve the overall readability of the figure. The integration between the bars and line graph allows readers to observe both the numerical distribution and the transition between selection phases in a simplified and visually effective manner.\n\nThe chart demonstrates that the initial literature search yielded a total of 968 articles from all selected scientific databases. Following the removal of 214 duplicate studies, 754 articles remained for title and abstract screening. This stage represented one of the most critical phases in the review process because it enabled the researchers to evaluate the preliminary relevance of each study to the objectives of the review. During the screening process, 592 studies were excluded because they did not directly address radiation safety practices or exposure reduction across the included healthcare settings.\n\nSubsequently, 162 full-text articles were assessed carefully for eligibility according to the predefined inclusion and exclusion criteria. After detailed evaluation, 118 studies were excluded due to insufficient methodological quality, incomplete data, or lack of direct relevance to the review topic. Ultimately, 44 studies fulfilled all eligibility requirements and were included in the final analysis. The gradual reduction illustrated in the graph reflects the rigorous and systematic nature of the PRISMA selection methodology. Overall, the chart and table confirm that the study selection process was comprehensive, transparent, and methodologically reliable, ensuring that only high-quality and relevant evidence was incorporated into the final review.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This theoretical review examined radiation safety across radiology, emergency, dental, and epidemiological healthcare settings, emphasizing protection strategies and exposure reduction for patients and healthcare professionals. The systematic search identified 968 records and retained 44 peer-reviewed studies after application of the predefined criteria. Evidence supports protocol optimization, low-dose imaging, iterative reconstruction, artificial intelligence, fluoroscopy controls, monitoring systems, protective equipment, and the ALARA principle. The expanded analysis further demonstrates that radiation safety depends on coordinated responsibilities. Epidemiology technicians can support surveillance and analysis of exposure-related events; emergency medical technicians can reduce risk through accurate communication, safe transfer, and compliance during portable or urgent imaging; and dental assistant technicians can contribute through patient preparation, positioning, barrier practices, and prevention of unnecessary retakes. Radiation protection is therefore best understood as an institution-wide safety system rather than a responsibility confined to radiology departments.

5.2 Recommendations

The findings support continuous improvement in radiation safety across imaging and connected clinical services. Healthcare institutions should implement standardized protocols aligned with ICRP, IAEA, and WHO guidance and maintain the ALARA principle across diagnostic, interventional, emergency, portable, and dental imaging. Role-specific training should be provided to radiology personnel, epidemiology technicians, emergency medical technicians, and dental assistant technicians. Training for epidemiology technicians should address exposure surveillance, incident classification, trend reporting, and support for quality-improvement indicators. Emergency medical technicians should receive practical guidance on imaging-area access, patient transfer, portable examinations, communication of prior imaging, and compliance with staff instructions. Dental assistant technicians should receive regular education on patient identification, positioning, collimation, barrier use, retake prevention, and occupational protection. Institutions should also strengthen dose tracking, incident reporting, audits, and interdisciplinary case review so that safety information follows the patient across departments. Future research should empirically evaluate knowledge, compliance, and training outcomes among these professional groups.

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