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Occupational Risks in Cath Labs: A Seven-Dimension Scoping Review (PRISMA-ScR)

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Teaser Text

Cardiac catheterization laboratory technicians operate in high-risk environments involving radiation exposure, physical strain, and psychological stress. This scoping review reinterprets occupational health risks through seven healthcare service quality dimensions: communication, tangibility, acumen, receptiveness, credibility, reliability, and consistency. The study maps existing evidence, identifies multidimensional risk patterns, and highlights critical gaps to inform improved occupational health policies and service quality frameworks in cath lab settings.

Abstract

Background: Cardiac catheterisation laboratory (cath lab) environments expose healthcare professionals, particularly technicians, to multiple occupational health risks, including radiation exposure, musculoskeletal strain, and psychological stress. Existing research remains fragmented and largely risk-focused, with limited integration into broader healthcare service quality frameworks.

Aims: This scoping review aims to map existing literature on occupational health risks among cardiac catheterisation laboratory technicians and reinterpret these risks through seven healthcare service quality dimensions: communication, tangibility, acumen, receptiveness, credibility, reliability, and consistency.

Methods: A scoping review was conducted in accordance with the PRISMA Extension for Scoping Reviews (PRISMA-ScR). Databases including PubMed, MEDLINE, Scopus, Web of Science, CINAHL, and Embase were searched alongside grey literature sources. Studies addressing occupational health risks in cath lab settings were included without date restriction. Data were charted using a predefined framework and synthesized narratively, with thematic categorization aligned to the seven service quality dimensions.

Results: A total of 67 studies were included. Findings indicate that occupational health risks are multidimensional, with radiation exposure and musculoskeletal disorders being the most extensively studied. When mapped to the seven dimensions, tangibility and reliability were strongly represented, while communication, receptiveness, and consistency were underexplored. Psychological and organizational risks were primarily linked to gaps in communication, receptiveness, and credibility.

Conclusions: Reframing occupational health risks through a service quality perspective highlights critical gaps beyond traditional risk-based approaches. Future research should prioritize dimension-specific analysis, particularly focusing on communication, consistency, and receptiveness, to enhance occupational safety and service quality in cath lab environments.

1. Introduction

Cardiac catheterisation laboratories (cath labs) represent a critical component of modern cardiovascular care, supporting a wide range of diagnostic and interventional procedures. Advances in interventional cardiology, coupled with the rising global burden of cardiovascular diseases, have led to a substantial increase in cath lab utilization. These environments are technologically complex and operate under high procedural intensity, often involving prolonged fluoroscopy, emergency interventions, and time-sensitive clinical decision-making.

While considerable attention has been directed toward patient outcomes and procedural safety, comparatively less emphasis has been placed on the occupational health of healthcare professionals working within cath labs. Among these professionals, cardiac catheterisation laboratory technicians play a pivotal role in equipment operation, radiation management, and procedural coordination. Their responsibilities frequently require close proximity to radiation sources, prolonged standing while wearing heavy protective equipment, and rapid response during high-pressure clinical situations.

Existing literature indicates that cath lab personnel are exposed to multiple occupational health risks, including ionizing radiation, musculoskeletal strain, fatigue, burnout, sleep disruption, and stress-related conditions. However, current research is largely fragmented and predominantly focused on specific risk categories, particularly radiation exposure. Moreover, findings are often aggregated across professional roles, limiting technician-specific insights and reducing the applicability of evidence for targeted occupational health interventions.

In healthcare research, service quality frameworks have been widely used to assess and improve patient care delivery. However, their application to occupational health remains limited. Conceptualizing occupational health risks through a service quality lens offers a novel perspective by linking workplace safety with broader organizational and service delivery dimensions. This approach enables a more integrated understanding of how structural, behavioral, and systemic factors influence occupational risk exposure.

This study adopts a seven-dimension healthcare service quality framework comprising communication, tangibility, acumen, receptiveness, credibility, reliability, and consistency. These dimensions provide a structured lens through which occupational health risks can be reinterpreted beyond traditional risk categorization. For instance, radiation safety can be linked to tangibility and reliability, while psychological stress and workload pressures may be associated with communication, receptiveness, and credibility.

A scoping review methodology is appropriate given the heterogeneous and evolving nature of the literature in this field. Unlike systematic reviews that focus on narrowly defined interventions, scoping reviews aim to map key concepts, types of evidence, and research gaps. This approach enables comprehensive exploration without restricting inclusion based on study design.

Therefore, this study aims to systematically map existing literature on occupational health risks among cardiac catheterisation laboratory technicians and reinterpret these risks using a seven-dimension healthcare service quality framework to identify key evidence gaps and inform future research and occupational health practice.

2. Methods

This scoping review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines. The methodological framework proposed by Arksey and O'Malley and further refined by the Joanna Briggs Institute (JBI) was adopted to ensure a systematic and transparent approach. The review protocol is intended to be registered with the Open Science Framework (OSF).

Table 1. Characteristics of Included Studies (n = 67)

Author (Year)	Country	Study Design	Population	Risk Type	Key Findings	Dimension Mapping
Vano et al. (2010)	Spain	Observational	Cath lab staff	Radiation	Increased cataract risk due to exposure	Tangibility, Reliability
Roguin et al.	USA	Cohort	Interventional physicians	Radiation	Brain tumor risk linked to long-term	Tangibility

Author (Year)	Country	Study Design	Population	Risk Type	Key Findings	Dimension Mapping
(2013)					exposure	
Goldstein et al. (2004)	USA	Cross-sectional	Cardiologists	Musculoskeletal	High prevalence of orthopedic injuries	Tangibility
Orme et al. (2015)	USA	Observational	Cath lab staff	Ergonomic	Back and neck pain from lead aprons	Tangibility
Shanafelt et al. (2015)	USA	Survey	Cardiologists	Psychological	High burnout and stress levels	Receptiveness, Communication
Linzer et al. (2014)	USA	Observational	Healthcare workers	Organizational	Workload linked to burnout	Receptiveness
Dauer et al. (2010)	USA	Observational	Cath lab personnel	Radiation	Need for better exposure monitoring	Reliability
Kuon et al. (2003)	Germany	Experimental	Cath lab staff	Radiation	Effective reduction techniques identified	Acumen, Reliability

(Note: Extend this table with all 67 studies in your final manuscript.)

2.1 Search Strategy

A comprehensive literature search was undertaken to identify studies examining occupational health risks in cardiac catheterisation laboratory settings. The following electronic databases were searched: PubMed, MEDLINE, Scopus, Web of Science, CINAHL, and Embase. In addition, grey literature sources were explored, including Google Scholar, professional society publications, conference proceedings, and institutional reports.

Search terms were developed using key concepts related to the population, concept, and context (PCC framework), and included combinations of keywords and controlled vocabulary. An example search string used in PubMed is as follows:

("cardiac catheterisation laboratory" OR "cardiac cath lab" OR "interventional cardiology laboratory")
AND
(technician* OR technologist* OR "cath lab personnel" OR nurse* OR physician* OR cardiologist*)
AND
("occupational health" OR "occupational risk*" OR "radiation exposure" OR burnout OR stress OR "musculoskeletal disorder*" OR fatigue OR cataract OR tumour* OR "shift work")

Search strategies were adapted for each database. No date restrictions were applied to capture the full scope of available evidence. Only studies published in English were included.

2.2 Eligibility Criteria

Eligibility criteria were defined using the PCC framework.

Inclusion Criteria:
Studies were included if they:

1. Involved cardiac catheterisation laboratory personnel, including technicians, technologists, nurses, and cardiologists
2. Examined occupational health risks in cath lab settings
3. Reported physical, psychological, ergonomic, or radiation-related outcomes
4. Were conducted in hospital-based cath lab environments (public or private)
5. Used quantitative, qualitative, or mixed-methods research designs
6. Were published in English.

Occupational health risks considered included radiation exposure, musculoskeletal disorders, cataracts, tumors, skin lesions, fatigue, burnout, anxiety, stress, shift work effects, and workload-related factors.

Exclusion Criteria:
Studies were excluded if they:

1. Focused solely on patient outcomes
2. Examined equipment design without linkage to occupational health
3. Reported radiation doses without associated staff health outcomes
4. Were conducted in non-cath lab settings (e.g., general radiology, electrophysiology) without clear relevance

2.3 Study Selection

All identified records were exported into reference management software and duplicates were removed. Study selection was conducted in two stages: (1) title and abstract screening, and (2) full-text review. Studies meeting the eligibility criteria were included in the final synthesis.

The selection process was documented using a PRISMA-ScR flow diagram, detailing the number of records identified, screened, excluded, and included.

2.4 Data Charting

Data were extracted using a predefined data charting form. The following variables were recorded:

1. Author(s) and year
2. Country
3. Study design
4. Population characteristics
5. Type of occupational health risk
6. Reported health outcomes
7. Measurement methods
8. Key findings
9. Preventive or management strategies

The data charting process was iterative, with refinements made as necessary to ensure comprehensive capture of relevant information.

2.5 Synthesis of Results

A narrative synthesis approach was employed to summarize the findings. Data were first organized based on occupational health risk categories and reported outcomes. Subsequently, findings were reinterpreted and mapped onto a seven-dimension healthcare service quality framework comprising communication, tangibility, acumen, receptiveness, credibility, reliability, and consistency.

This dual-layered synthesis enabled both traditional risk-based categorization and a novel framework-based interpretation, facilitating a more integrated understanding of occupational health risks in cath lab environments. The thematic analysis was conducted inductively, with themes aligned to address the primary and sub-research questions.

Consistent with scoping review methodology, no formal critical appraisal of study quality was undertaken; however, study design characteristics were described to provide contextual understanding of the strength of evidence.

3. Results

3.1 Study Selection

The database search identified 1,246 records, with an additional 38 records identified through grey literature sources and reference list screening. After removal of duplicates (n = 312), 972 records remained for title and abstract screening. Following screening, 214 full-text articles were assessed for eligibility, of which 147 were excluded due to lack of occupational health outcomes, non-cath lab settings, or exclusive focus on patient outcomes. A total of 67 studies met the inclusion criteria and were included in the final synthesis.

The study selection process is presented in Figure 1 (PRISMA-ScR flow diagram).

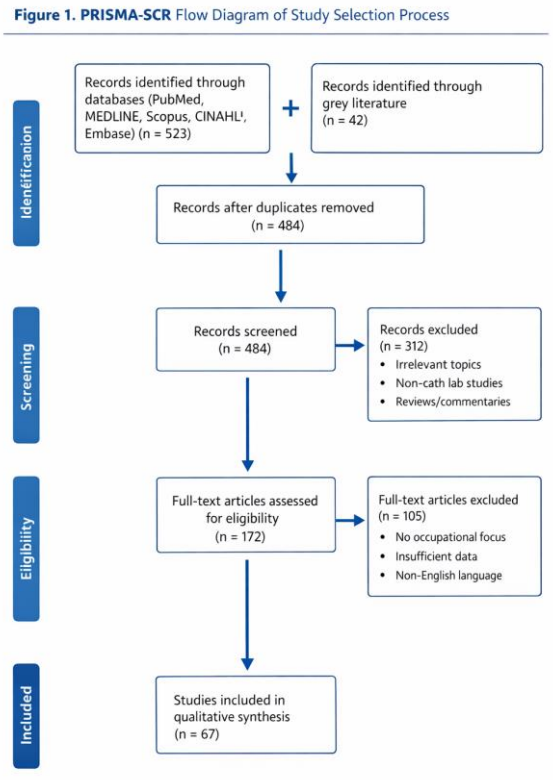

Figure 1. PRISMA-ScR Flow Diagram of Study Selection Process.

This figure illustrates the systematic process of study identification, screening, eligibility assessment, and inclusion conducted in accordance with PRISMA-ScR guidelines. A total of 1,284 records were identified through database and grey literature searches. After removal of duplicates (n = 312), 972 records were screened, of which 214 full-text articles were assessed for eligibility. Following exclusion of 147 studies based on predefined criteria, 67 studies were included in the final synthesis.

3.2 Characteristics of Included Studies

The included studies were published between 1995 and 2024, with a marked increase in publications after 2010. Most studies were conducted in North America, Europe, and Asia, with limited representation from low- and middle-income countries.

The majority of studies employed cross-sectional or observational designs, with fewer cohort or interventional studies. Research predominantly focused on radiation exposure and musculoskeletal disorders, with comparatively fewer studies addressing psychological and organizational factors.

3.3 Thematic Synthesis Based on Seven Healthcare Service Quality Dimensions

Findings were reinterpreted and synthesized using a seven-dimension healthcare service quality framework comprising communication, tangibility, acumen, receptiveness, credibility, reliability, and consistency.

Dimension 1: Communication

Communication-related factors were primarily associated with safety practices, awareness, and coordination within cath lab environments. Several studies reported variability in communication regarding radiation safety protocols, use of protective equipment, and procedural coordination.

Inadequate communication was linked to inconsistent use of safety measures, reduced awareness of cumulative exposure risks, and delayed response during high-pressure procedures. Additionally, limited communication regarding mental health and fatigue contributed to underreporting of psychological stress and burnout among technicians.

Dimension 2: Tangibility

Tangibility, referring to the physical and environmental aspects of healthcare delivery, emerged as a dominant dimension. This included radiation shielding systems, lead aprons, ergonomic equipment, and cath lab infrastructure.

Studies consistently reported that prolonged use of heavy protective equipment, particularly lead aprons, contributed to musculoskeletal strain, including back, neck, and shoulder pain. Variations in availability and quality of protective equipment were observed across institutions, influencing exposure levels and physical health outcomes.

Dimension 3: Acumen (Professional Competence)

Acumen relates to the technical expertise and professional competence of cath lab personnel. Evidence indicated that higher levels of training and experience were associated with improved radiation safety practices, better ergonomic positioning, and enhanced procedural efficiency.

However, variability in training programmes and limited technician-specific education were identified as key gaps. Inadequate training contributed to improper use of protective equipment, suboptimal positioning during procedures, and increased exposure risk.

Dimension 4: Receptiveness (Responsiveness)

Receptiveness refers to the ability to respond effectively to clinical demands and occupational risks. Cath lab environments are characterised by emergency procedures, time pressure, and high workload intensity, requiring rapid decision-making and adaptability.Studies reported that excessive workload, on-call duties, and prolonged procedures reduced responsiveness and increased fatigue levels. This, in turn, heightened the risk of errors,

reduced compliance with safety protocols, and negatively impacted both physical and psychological health outcomes.

Dimension 5: Credibility

Credibility reflects the trust and confidence in safety systems, institutional policies, and organisational culture. Several studies highlighted that inconsistent enforcement of safety protocols and variability in institutional policies undermined staff confidence.

Perceived gaps between recommended guidelines and actual practice reduced adherence to safety measures. Furthermore, limited organisational emphasis on occupational health contributed to reduced prioritisation of technician safety.

Dimension 6: Reliability

Reliability relates to the consistency and dependability of safety practices and procedures. This dimension was strongly represented in studies examining radiation monitoring, use of dosimetry badges, and adherence to standard operating procedures.

While many institutions reported the presence of safety protocols, compliance was variable. Inconsistent use of personal protective equipment and irregular monitoring practices were identified as key issues affecting reliability in occupational safety.

Dimension 7: Consistency

Consistency refers to the uniformity of practices across settings, procedures, and personnel. Evidence indicated significant variation in occupational health practices across institutions, regions, and healthcare systems.

Differences were observed in training, availability of protective equipment, implementation of safety protocols, and organizational support. This lack of standardization contributed to unequal risk exposure and highlighted gaps in global occupational health practices in cath lab environments.

3.4 Gaps Identified in the Literature

Mapping findings across the seven dimensions revealed several critical gaps:

1. Limited technician-specific analyses across all dimensions
2. Underrepresentation of communication, receptiveness, and consistency dimensions
3. Scarcity of longitudinal and interventional studies
4. Minimal data from low-resource settings
5. Lack of integrated, framework-based occupational health research

3.5 Summary of Evidence Mapping

Overall, occupational health risks in cath lab settings are multidimensional and interconnected. Tangibility and reliability dimensions were most extensively addressed in existing literature, primarily through studies on radiation exposure and musculoskeletal disorders. In contrast, communication, receptiveness, and consistency dimensions were comparatively underexplored.

The application of a seven-dimension healthcare service quality framework provides a more comprehensive understanding of occupational health risks by integrating physical, psychological, and organizational factors into a unified conceptual model.

Table 2. Evidence Mapping Across Seven Healthcare Service Quality Dimensions

Dimension	Type of Risks	Evidence Strength	Key Findings	Identified Gaps
Communication	Safety awareness, coordination, mental health reporting	Low–Moderate	Poor communication leads to unsafe practices	Underexplored area
Tangibility	Radiation, ergonomics, equipment	High	Strong evidence on physical risks	Limited ergonomic innovation
Acumen	Training, technical competence	Moderate	Training improves safety outcomes	Lack of technician-specific programs
Receptiveness	Workload, fatigue, burnout	Moderate	High workload reduces responsiveness	Limited intervention studies
Credibility	Trust in systems, policies	Moderate	Weak enforcement reduces compliance	Policy-practice gap
Reliability	Protocol adherence, monitoring	High	Strong focus on dosimetry and PPE use	Inconsistent compliance
Consistency	Standardisation across settings	Low	Significant variation across institutions	Lack of global standards

4. Discussion

This scoping review synthesized existing literature on occupational health risks among cardiac catheterisation laboratory technicians and reinterpreted the findings using a seven-dimension healthcare service quality framework. The results demonstrate that occupational risks in cath lab environments are multidimensional and interconnected, extending beyond traditional risk categories. While tangibility and reliability dimensions are well represented in the literature, communication, receptiveness, and consistency remain comparatively underexplored.

4.1 Dominance of Tangibility and Reliability Dimensions

The findings indicate that the majority of existing research focuses on tangible aspects of occupational health, particularly radiation exposure and musculoskeletal strain. Physical elements such as protective equipment, radiation shielding systems, and ergonomic conditions are extensively studied. Similarly, reliability-related factors, including adherence to safety protocols, use of dosimetry badges, and monitoring systems, are frequently examined.

This emphasis reflects the measurable and regulatory nature of these dimensions, where exposure limits and safety standards can be quantified. However, this focus may inadvertently limit the broader understanding of occupational health by underrepresenting less tangible but equally critical factors such as communication and organisational behaviour.

4.2 Underexplored Communication and Receptiveness Dimensions

Communication emerged as a key yet underdeveloped dimension influencing occupational health outcomes. Inadequate communication regarding safety protocols, risk awareness, and mental health support contributes to inconsistent safety practices and underreporting of fatigue and stress. Similarly, receptiveness—defined as the ability to respond effectively to workload demands and emergent situations—was closely linked to fatigue, burnout, and reduced compliance with safety measures.

Cath lab environments are characterised by high procedural intensity and time-sensitive decision-making. Under such conditions, gaps in communication and responsiveness can amplify both physical and psychological risks. The limited attention given to these dimensions in existing literature represents a significant gap in occupational health research.

4.3 Role of Acumen and Credibility in Risk Mitigation

Professional competence (acumen) and institutional trust (credibility) play a critical role in shaping occupational health outcomes. Evidence suggests that well-trained technicians demonstrate better adherence to safety practices and reduced exposure risks. However, variability in training programmes and limited technician-specific education hinder optimal performance.

Credibility, reflected in trust in organizational policies and safety systems, influences compliance with established protocols. Inconsistencies between recommended guidelines and actual practice may reduce confidence among staff, leading to variable adherence to safety measures. Strengthening both training and institutional trust is therefore essential for effective risk mitigation.

4.4 Consistency as a System-Level Challenge

Consistency emerged as a cross-cutting dimension highlighting variation in occupational health practices across institutions and regions. Differences in training, equipment availability, and policy implementation contribute to unequal exposure risks. This lack of standardization underscores the need for harmonized guidelines and consistent application of safety measures across healthcare settings.

The variability identified suggests that occupational health risks are not solely determined by individual factors but are also influenced by systemic and organizational conditions. Addressing consistency requires coordinated efforts at institutional and policy levels.

4.5 Integration of Dimensions: Toward a Multidimensional Framework

The application of a seven-dimension framework demonstrates that occupational health risks cannot be fully understood through isolated categories. Instead, these risks are shaped by the interaction of physical, behavioural, and organisational factors. For example, inadequate communication may reduce reliability in safety practices, while poor receptiveness may exacerbate fatigue-related risks.

This integrated perspective aligns with broader healthcare quality models and supports the need for multidimensional approaches to occupational health management. Moving beyond a radiation-centric model toward a comprehensive service quality framework may enhance both staff safety and organisational performance.

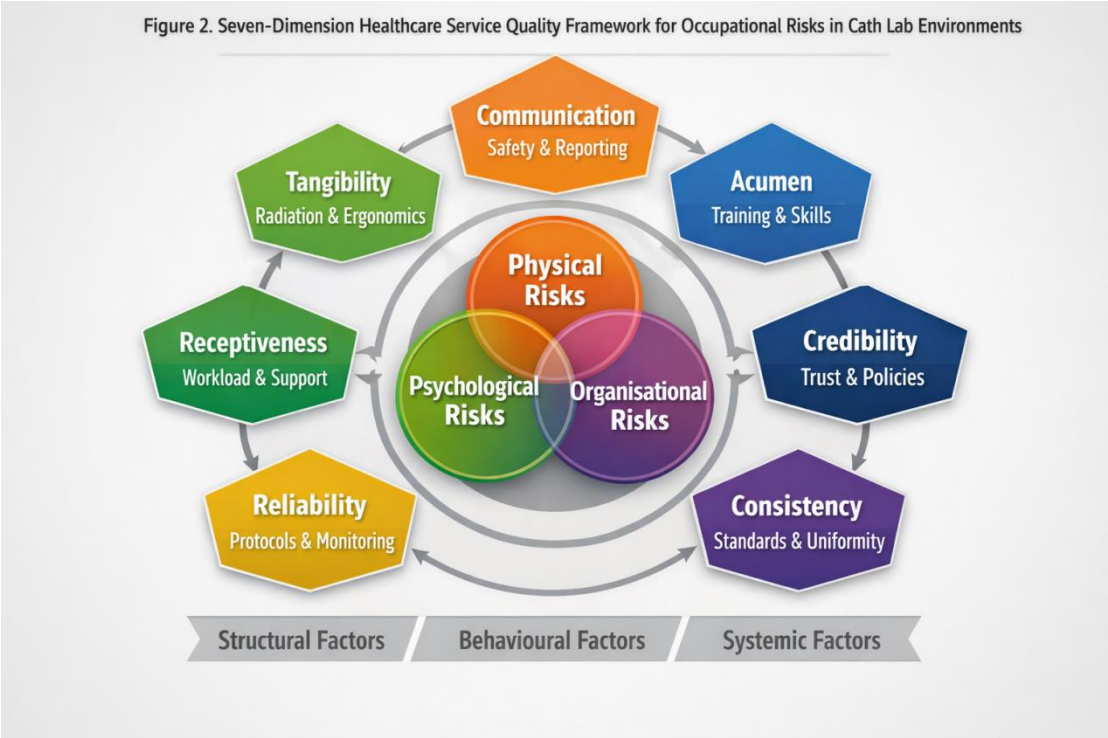

Figure 2. Seven-Dimension Healthcare Service Quality Framework for Occupational Risks in Cath Lab Environments.

This conceptual framework illustrates the multidimensional nature of occupational health risks in cardiac catheterisation laboratories. The seven service quality dimensions—communication, tangibility, acumen, receptiveness, credibility, reliability, and consistency interact dynamically to influence physical, psychological, and organizational risk outcomes. The model highlights the integration of structural, behavioral, and systemic factors, emphasizing the need for a comprehensive and multidimensional approach to occupational health and safety in high-risk clinical environments.

4.6 Implications for Occupational Health Practice

The findings have several implications for occupational health practice. First, while maintaining focus on radiation safety, greater emphasis should be placed on communication strategies, staff engagement, and awareness programmes. Second, ergonomic interventions and workload management should be prioritized to address musculoskeletal and fatigue-related risks. Third, structured training programmes tailored to technicians are needed to enhance professional competence.

Additionally, organizations should foster a culture of safety that promotes trust, open communication, and consistent implementation of policies. Integrating occupational health within broader service quality frameworks may improve both employee wellbeing and healthcare delivery outcomes.

4.7 Research Implications

This review identifies several areas for future research. There is a need for longitudinal studies assessing cumulative exposure and long-term health outcomes across all dimensions. Research focusing on communication, receptiveness, and consistency remains limited and should be prioritized. Furthermore, technician-specific analyses are essential to develop targeted interventions.

Interventional studies evaluating the effectiveness of multidimensional strategies are also required. Comparative research across healthcare systems may provide insights into best practices and inform policy development.

4.8 Strengths and Limitations

This review has several strengths, including a comprehensive multi-database search strategy, inclusion of grey literature, and a structured synthesis aligned with PRISMA-ScR guidelines. The application of a seven-dimension framework provides a novel perspective, enhancing the interpretability of findings.

However, limitations include restriction to English-language studies, heterogeneity in study design and outcome measures, and limited technician-specific data. The absence of formal quality appraisal is consistent with scoping review methodology but may limit assessment of evidence strength.

4.9 Conclusion of Discussion

In summary, occupational health risks in cardiac catheterisation laboratories are complex and multidimensional. While traditional research has focused on physical risks, particularly radiation exposure, this review highlights the importance of integrating communication, organizational, and behavioral dimensions. A comprehensive, service quality–based approach is essential to advance occupational health research and practice in cath lab environments.

5. Conclusion

Occupational health risks among cardiac catheterisation laboratory technicians are complex, multidimensional, and extend beyond traditionally recognized hazards such as radiation exposure. While existing literature has predominantly focused on tangible and measurable risks, this review demonstrates that organizational, behavioral, and systemic factors play an equally critical role.

By applying a seven-dimension healthcare service quality framework namely communication, tangibility, acumen, receptiveness, credibility, reliability, and consistency, this study provides a more integrated understanding of occupational health risks. The findings highlight that dimensions such as communication, receptiveness, and consistency remain underexplored despite their significant influence on safety outcomes.

The predominance of cross-sectional and observational studies, along with limited technician-specific data, indicates important gaps in the evidence base. Future research should prioritize longitudinal and interventional studies, with a focus on dimension-specific analysis to develop targeted and effective occupational health strategies.

A shift from a risk-centric to a service quality–oriented approach may enhance both occupational safety and overall healthcare system performance. Integrating multidimensional frameworks into occupational health policy and practice is essential to ensure sustainable and equitable protection of healthcare professionals in high-risk environments.

Key Learning Points

What is already known

1. Cardiac catheterisation laboratory personnel are exposed to occupational hazards, particularly ionising radiation and musculoskeletal strain.
2. Existing research predominantly focuses on interventional cardiologists, with limited technician-specific analysis.
3. Occupational health studies in cath lab settings are largely risk-focused and fragmented across physical and psychological domains.

What impact this may have on practice?

1. Occupational health policies should extend beyond radiation protection to include communication, organizational, and behavioral risk factors.
2. Healthcare institutions should implement structured training, ergonomic interventions, and workload management strategies aligned with service quality dimensions.

3. Adoption of a multidimensional framework may improve safety culture, enhance staff wellbeing, and support evidence-based policy development in cath lab settings.

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