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ORIGINAL ARTICLE

Beyond Radiation Exposure: Investigating the Complex Dimensions of Safety in the Catheter Laboratory

Radyasyonun Ötesinde: Kateter Laboratuvarında Güvenliğin Karmaşık Boyutlarını İncelenmesi

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Abstract

Introduction: Catheterization laboratories are high-risk clinical environments where complex procedures are performed under time pressure and with radiation exposure. Qualitative research addressing the lived experiences of healthcare professionals in cath labs remains limited. This study aims to explore in depth the perceptions and experiences of healthcare professionals working in cath labs regarding patient and staff safety.

Methods: This study used a qualitative research design based on interpretative phenomenological analysis. A total of 24 healthcare professionals from various occupational groups working in cath labs across Türkiye were included in the study through purposive and snowball sampling. Data were collected through semi-structured interviews and analyzed inductively using a thematic content analysis. Data analysis was performed using NVivo 10 software.

Results: Two main themes emerged from this study: Risks and Measures. The most frequently reported risk was radiation exposure, followed by infection, pharmaceutical hazards, patient falls, excessive workload, and untrained personnel. Regarding safety measures, participants emphasized the importance of using radiation-protective equipment, maintaining accurate medical records, adhering to aseptic practices, implementing fall prevention strategies, ensuring adequate staffing levels, verifying patient identities, and maintaining patient confidentiality and privacy.

Discussion and Conclusion: This study revealed that safety practices in cath labs are predominantly shaped around radiation hazards, while a more holistic safety perspective tends to be overlooked. The lack of standardized protocols and heavy reliance on individual initiative were particularly noteworthy. The findings suggest that comprehensive and systematic strategies addressing all dimensions of risk are necessary to establish a sustainable safety culture in cath labs.

Keywords: Cardiac catheterization laboratory; Health services administration; Patient safety; Radiation protection; Safety management

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Advances in healthcare technology, increasing patient expectations, and the pursuit of longer, healthier lives have led to the delivery of more complex and multidisciplinary care. While healthcare systems aim to promote individual and public well-being, service delivery processes remain inherently vulnerable to errors. Despite professionals' efforts, medicine cannot be entirely error-proof.[1,2]

Medical errors can occur across all areas of healthcare. In particular, ambulatory surgical units are considered high-risk environments due to high patient turnover and the need for rapid decision-making.[3] Cath labs are complex and high-risk environments due to intensive procedures, radiation exposure, advanced equipment, and the need for coordinated multidisciplinary care.[4–8] Safety culture refers to the shared values and practices within a healthcare setting that prioritizes patient and staff safety. Thus, in cath labs, a strong safety culture is essential to ensure coordinated and reliable care. These procedures result in long-term radiation exposure for patients and healthcare workers, potentially leading to important health problems.[9]

Moreover, these laboratories integrate various advanced technologies and medical devices. Mobile X-ray systems, anesthesia machines, monitoring devices, electrocautery instruments, sharp surgical tools, and oxygen and carbon dioxide units are used simultaneously. The individual and combined use of these devices significantly increases the potential for safety risks.[10] Hence, cath labs should be considered in terms of medical interventions and critical areas requiring risk management from a technological safety perspective.[11]

In addition, the use of pharmaceutical agents, including cardiac medications, narcotics for sedation or anesthesia, and contrast media, presents further risks. Improper dosage, poor documentation, or unmonitored use of narcotics may compromise patient safety.[12] Iodine-based contrast agents used in vascular imaging also pose nephrotoxic risks, especially in patients with pre-existing kidney conditions.[13]

Due to the nature of procedures performed, catheterization labs operate with highly multidisciplinary teams. Cardiologists and cardiovascular surgeons can perform surgical and interventional procedures in some hybrid laboratories jointly.[14] Depending on the patient's condition, these may include cardiologists, cardiovascular surgeons, radiologists, anesthesiologists, nurses, imaging technicians, and other specialists.[15]

Although patient safety is widely studied in interventional cardiology, qualitative research on healthcare professionals' experiences in cath labs remains limited, with most studies focusing on radiation risks. However, healthcare professionals are the ones directly involved in managing patient care, responding to emergent situations, and adapting to systemic limitations in real-time. Exploring their lived experiences offers critical value in identifying hidden risks, workarounds, and practical safety strategies.

From the limited studies, Doorey et al.[4,12] identified communication failures as key contributors to safety lapses in catheterization laboratories. Gatt[10] emphasized that nurses and technicians play a vital but often underappreciated role in procedural safety. These findings support the need to further explore staff experiences as a means of developing effective safety practices. This study aims to identify perceived safety risks and current practices among cath lab staff based on their experiences.

Materials and Methods

This section presents the methodological foundation of the study. The study adhered to the Standards for Reporting Qualitative Research (SRQR) guidelines by O'Brien et al.[16]

Research Methodology

This research employed a qualitative methodology with interpretative phenomenology, drawing on the foundational perspectives of Creswell[17] and Merriam and Tisdell.[18] The research process was guided by the framework proposed by Smith and Osborn.[19]

Data analysis was conducted an inductive approach, consistent with the principles by Creswell.[17] This study explored the "Patient and Health Workforce Safety in Cath Lab" phenomenon. This study defines "patient and health workforce safety in cath lab" as "the prevention of physical, procedural, and environmental risks that may harm patients or healthcare professionals during diagnostic and interventional procedures in cath lab."

Participants of the Study

In line with the study's objectives, participants were recruited using purposive and snowball sampling to ensure the inclusion of individuals with direct, relevant experience. The researcher identified participants through professional contacts and an online platform used by cath lab coordinators in Türkiye. His involvement in this group stemmed from prior clinical experience in cath labs.

Eligible participants were full-time cath lab healthcare

professionals with at least one year of experience who provided informed consent. Interviews continued until data saturation was reached, with no new themes emerging.

This study employed a semi-structured interview method to collect data. Ethical approval for this study was obtained from Çankırı Karatekin University (Session 11, dated 17.01.2024). This study was conducted under the principles of the Declaration of Helsinki. Data collection occurred in Türkiye between February 5 and May 18, 2024. Participants were initially contacted by phone and informed about the study. Each interview was scheduled for approximately 30 minutes and held at a location chosen by the participant. Data were collected from 24 participants via online interviews with 14 participants (58%) and face-to-face interviews with 10 participants (42%).

Before each session, informed consent was obtained, and confidentiality was ensured. The researcher introduced himself. Participation was voluntary, and participants could withdraw at any time. With consent, interviews were audio-recorded. The semi-structured interviews were conducted using the following central questions.

1. What is your age?
2. How many years of professional experience do you have?
3. What is your role in the cath lab?
4. What measures do you take to ensure employee safety in the cath lab?
5. What measures do you take to ensure patient safety in the cath lab?
6. What types of medical records do you keep for safety?
7. What are the most significant risks to patient and employee safety?
8. What measures should be taken to improve patients' and employees' safety in the cath lab?

Data Analysis

The interview data were initially transcribed using the Dictation tool in Microsoft Office 365. Each recording was carefully reviewed again, and necessary corrections were made. The finalized transcripts were shared with the participants for confirmation. The data were analyzed using an inductive approach. The analysis process involved content, thematic, and descriptive methods. Initially, the data were coded, and the codes were refined through repeated readings. To ensure the trustworthiness of the coding, an independent researcher who was not involved in the study reviewed the analysis.[20]

The findings were organized into themes. Descriptive interpretations were reinforced with verbatims.[21] Qualitative data analysis was conducted using NVivo 10 software (QSR International Pty Ltd., Melbourne, Australia).

Role of the Researchers

The researcher adopted a reflexive approach, intentionally setting aside personal background and assumptions. Nonetheless, potential areas of subjectivity in interpretation are acknowledged. With thirteen years of experience as a lead technician in a cath lab in Ankara, the researcher also served as a board member of the Turkish Society of Cardiology Technicians and Nursing Project Group, visiting numerous labs across Türkiye. He currently works as an academic in health management.

Validity and Reliability of the Study

Interview recordings were transcribed and initially reviewed by the researcher. As a single researcher conducted the study, an external reviewer verified the transcripts. Thematic coding followed, supported by repeated readings to identify patterns and relationships. The independent researcher reviewed the resulting themes. The researcher's role was clearly defined and reported with complete transparency.

Results

The descriptive findings related to the participants are summarized in Table 1.

As shown in Table 1, The participants' mean age was 36.2±6.4 years (min: 26, max: 52), and their mean length of professional experience was 13±8,3 years (min: 4, max: 29). Of the participants, 50.0% (n=12) were female.

Table 2 presents the themes identified through the analysis, along with the number of sources and references contributing to each theme. Within Measures, "Radiation Protection and Safety" was the most frequently discussed sub-theme (n=24; r=62). In the Risks category, the most frequently cited issue was radiation exposure (n=22; r=29).

Figure 1 presents the themes and their relationships.

Theme I: Risks

Factors threatening patient and staff safety in the cath lab were categorized under the main theme of "Risks," which formed the study's central focus (n=24; r=53). Participants assessed these hazards within both physical and structural contexts. Key subthemes included: Radiation Exposure (n=22; r=29), Infectious Risk (n=12; r=15), Pharmaceutical Risk (n=7; r=8), Fall Risk (n=7; r=7), Excessive Workload (n=6; r=8), and Untrained Personnel (n=5; r=6).

Table 1. Descriptive findings of the participants

Participant no	Profession	Gender	Age	Experience (years)	Nodes	References
Participant_15	Technician	♂	43	13	17	43
Participant_16	Technician	♂	35	8	16	36
Participant_23	Nurse	♂	35	10	15	29
Participant_5	Nurse	♀	38	15	15	34
Participant_6	Senior nurse	♀	45	26	15	31
Participant_7	Nurse	♀	35	12	15	33
Participant_8	Physician	♂	32	8	15	27
Participant_10	Physician	♂	47	15	14	31
Participant_14	Nurse	♀	38	16	14	22
Participant_18	Technician	♀	29	4	14	34
Participant_20	Senior technician	♂	48	28	14	32
Participant_12	Technician	♂	29	6	13	19
Participant_13	Technician	♂	32	6	13	21
Participant_22	Senior nurse	♀	48	25	13	30
Participant_3	Physician	♂	33	8	13	36
Participant_2	Physician	♀	38	13	12	27
Participant_21	Senior technician	♂	52	28	12	20
Participant_9	Technician	♂	26	6	12	21
Participant_1	Anesthesia technician	♀	28	4	11	25
Participant_17	Physician	♀	34	5	11	26
Participant_19	Physician	♂	35	8	11	25
Participant_24	Senior nurse	♀	48	29	11	23
Participant_11	Nurse	♀	35	13	10	15
Participant_4	Technician	♂	30	6	10	21

Radiation exposure emerged as the most emphasized risk (n=22; r=29), consistent with its prominence among safety measures (n=24; r=62). Participants often equated radiation protection and safety for patients and staff. They noted constant exposure due to the nature of the procedures and expressed concern over its potential long-term health effects.

> "*When we talk about staff safety, the first thing that comes to mind is radiation safety. Some procedures can take a very long time.*" (Technician, ♂, Age: 43, Exp.: 13)

Infectious Risk

Cath labs are sterile environments where invasive procedures are performed. Infectious Risk emerged as the second most prominent concern among participants (n=12; r=15), emphasizing the importance of adhering to aseptic protocols. As one participant stated:

> "*We pay particular attention to sterilization for the sake of the patient. To prevent infections, we use gloves, sterile gowns, masks, and caps.*" (Physician, ♂, Age: 47, Exp.: 15)

In addition to preventing patient infections, participants also stressed the importance of protecting staff:

> "*The main risks in the catheter lab are blood-borne diseases and medication errors. We work in high-stress environments, we deal with blood, and we work in very close proximity to patients.*" (Technician, ♂, Age: 43, Exp.: 13)

Pharmaceutical Risk

Pharmaceutical safety emerged as another critical concern among participants (n=7; r=8). Particular attention was drawn to potential adverse drug reactions during clinical procedures. One participant expressed:

> "*The development of IV and oral drug reactions in patients is a significant risk.*" (Technician, ♂, Age: 43, Exp.: 13)

Table 2. Findings on themes of patient and health workforce safety in cath lab

Name	Sources (n)	Ref. (r)
Safety of patients and healthcare workforce	24	146
Measures	24	126
Radiation protection and safety	24	62
Radiation protection equipment	24	30
Continuous education	7	11
Update technology	5	7
Dosimeter	5	6
Periodic health examination	2	2
Medical records	24	31
Documented records	21	26
Hospital information system (HIS)	21	21
Teleradiology	12	12
Aseptic measures	16	28
Fall prevention	11	11
Healthcare workforce	6	7
Identification check	4	6
Patient privacy	3	3
Risks	24	53
Radiation exposure	22	29
Infectious risk	12	15
Pharmaceutical risk	7	8
Fall risk	7	7
Excessive workload	6	8
Untrained personnel	5	6

Ref: References; n: Number of sources; r: Number of references.

Of particular note were concerns regarding the nephrotoxic effects of contrast agents frequently used for imaging purposes in catheterization procedures:

> "*The most important risks are high-dose radiation and the use of nephrotoxic agents in patients.*" (Technician, ♀, Age: 29, Exp.: 4)

Fall Risk

Participants identified fall risk as one of the significant safety concerns within the cath lab (n=7; r=7). The issue was particularly emphasized to vulnerable patient populations, such as the elderly or those with impaired consciousness. One participant stated:

> "*Our priority is maintaining their privacy and addressing the fall risk because most patients are elderly, and sometimes we even deal with unconscious patients.*" (Physician, ♂, Age: 32, Exp.: 8)

Excessive Workload

Excessive workload was identified as a critical factor contributing to physical exhaustion and an increased risk. Participants noted that due to workforce shortages and high patient volume, maintaining consistent attention and care could sometimes become compromised (n=6; r=8). One participant elaborated:

> "*There are too many outpatient cases daily, and numerous procedures are performed.*" (Technician, ♂, Age: 43, Exp.: 13)

Staff shortages were also cited as a key driver of the excessive workload:

> "*One of our biggest problems is the lack of personnel, doctors, nurses, technicians.*" (Senior Nurse, ♀, Age: 48, Exp.: 25)

Untrained Personnel

Untrained personnel were identified as a direct threat to patient safety (n=5; r=6). Participants expressed concerns, particularly regarding the assignment of newly recruited staff to active duties without sufficient training or experience. One participant emphasized:

> "*The most important risks are X-rays and untrained, inexperienced staff.*" (Technician, ♂, Age: 35, Exp.: 8)

In addition to posing threats to radiation safety, untrained personnel were also reported to violate aseptic protocols:

> "*Applying proper sterile techniques is essential, especially considering that we participate in procedures.*" (Nurse, ♂, Age: 35, Exp.: 10)

Theme II: Measures

All precautions responding to the identified safety risks were categorized under the Measures theme (n=24; r=126). Participants implemented a variety of structural, technological, and individual-level interventions to ensure safety within the cath lab. Within this context, the most frequently emphasized subthemes were grouped as follows: Radiation Protection and Safety (n=24; r=62), Medical Records (n=24; r=31), Aseptic Measures (n=16; r=28), Fall Prevention (n=11; r=11), Healthcare Workforce (n=6; r=7), Identification Check (n=4; r=6), and Patient Privacy (n=3; r=3).

Radiation Protection and Safety

Radiation protection and safety were the most frequently emphasized measures for all participants (n=24; r=62).

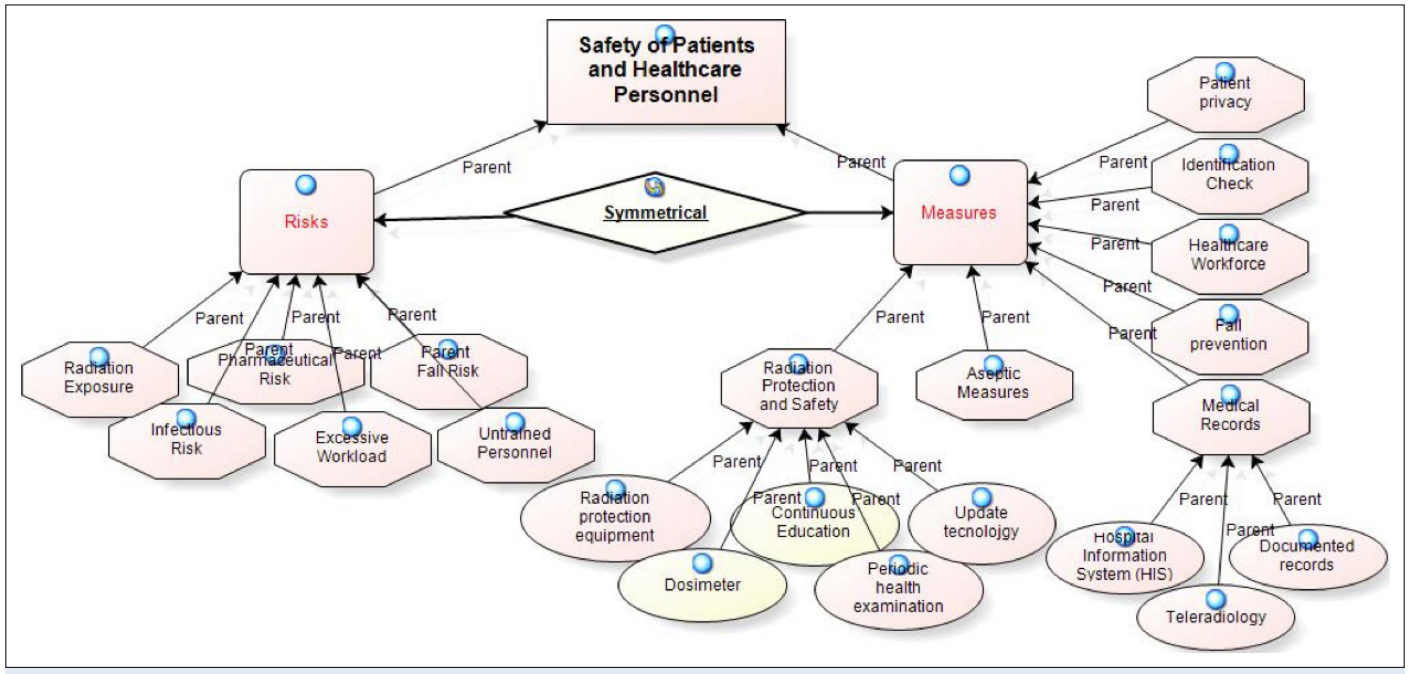

Figure 1. Thematic map of the safety of patients and healthcare workforce.

Particular attention was given to the routine use of protective equipment, such as lead aprons, thyroid shields, and lead glasses (n=24; r=30). As one participant explained:

> "*To protect ourselves from radiation, we use lead vests, neck shields, protective glasses, and, for sterilization, gowns, gloves, masks, and caps.*" (Physician, ♀, Age: 34, Exp.: 5)

> "*Innovative solutions related to radiation, improvements in sterilization, the use of new technologies, and staff training are all necessary.*" (Physician, ♂, Age: 47, Exp.: 15)

Participants also highlighted the necessity of using dosimeters (n=5; r=6) to monitor exposure levels and conducting periodic health screenings (n=2; r=2) to detect any long-term effects:

> "*We undergo periodic health checkups, and use shielding to reduce exposure to blood. We also use dosimeters regularly to track radiation exposure.*" (Senior Technician, ♂, Age: 52, Exp.: 28)

Medical Records

Medical Records emerged as a significant domain supporting patient safety through systematic documentation (n=24; r=31). Participants emphasized that maintaining organized and consistent records facilitates the monitoring and follow-up of patients. Practices that stood out included the use of documented records (n=21; r=26), the Hospital Information System (HIS) (n=21; r=21), and teleradiology (n=12; r=12). Findings revealed that digital and hardcopy documentation methods are used concurrently. One participant described this dual-recording approach:

> "*We document all procedures on the patient, the medications, and the catheters and materials, both in the computer system and handwritten records. We also store the patient's imaging data.*" (Anesthesia Technician, ♀, Age: 28, Exp.: 4)

Moreover, different cath labs employ varying medical record systems with no overarching standardization. There was no laboratory where vital signs and clinical interventions were recorded in real-time during procedures.

Aseptic Measures

Aseptic Measures were identified as essential for reducing infection risk in the cath lab (n=16; r=28). Participants emphasized the importance of hand hygiene and the use of sterile materials as key components of infection prevention. These practices were considered essential for protecting patients from healthcare-associated infections. As one participant noted:

> "*To prevent patients from acquiring infections. For this purpose, we use gloves, sterile gowns, masks, and caps.*" (Physician, ♂, Age: 47, Exp.: 15)

Fall Prevention

Fall Prevention was crucial for patient safety in the cath lab (n=11; r=11). Participants noted that many patients are elderly or physically frail. Therefore, immobilization techniques are routinely used. One participant stated:

> "*Most patients are either weak or frail, so the risk of falling is high. We take preventive measures to avoid falls.*" (Anesthesia Technician, ♀, Age: 28, Exp.: 42)

Healthcare Workforce

Participants identified excessive workload as a major risk to patient and staff safety in the cath lab. They emphasized that qualified personnel are essential for effective safety implementation (n=6; r=7). Insufficient staffing was seen to hinder the consistent application of safety measures. One participant noted:

> "*One of our most important problems is the shortage of personnel. This includes doctors, nurses, and technicians, but we especially lack cleaning staff.*" (Senior Nurse, ♀, Age: 48, Exp.: 25)

Identification Check

Identification Check is a safety practice that prevents errors by verifying patients' identity information (n=4; r=6). Participants noted that confusion can arise, particularly when patients have similar names, making identity verification essential in ensuring safety. One participant explained:

> "*For us, identity verification is critical in terms of safety. That is why we compare the patient's ID with the medical file and wristbands.*" (Technician, ♂, Age: 43, Exp.: 13)

Patient Privacy

Patient Privacy became an important subtheme tied to ethical and legal responsibilities (n=3; r=3). Participants described taking specific precautions during procedures. One participant emphasized:

> "*Our main priority for patients is maintaining their privacy and preventing falls because most of our patients are elderly, and sometimes even unconscious.*" (Physician, ♂, Age: 32, Exp.: 8)

Discussions

This study examined safety in cath labs based on the experiences of healthcare professionals. Two main themes emerged: Risks and Measures. Participants identified multiple threats, along with corresponding preventive actions. Figure 1 illustrates a clear link between risks and measures. Despite similar practices across labs, a standardized approach to safety was lacking. Radiation exposure was the most frequently cited risk, with participants expressing concern over long-term effects. Safety was often equated with radiation protection, reflecting the high exposure levels in cath labs. A U.S. study supports this, showing that interventional cardiology accounts for 45% of total medical radiation exposure and that cardiologists face 2–3 times more exposure than radiologists.[8]

Radiation exposure in cath labs can lead to both acute and chronic health problems for patients and healthcare professionals.[22,23] Despite its importance, radiation risk dominates safety concerns in cath labs, often overshadowing other hazards. This phenomenon may be linked to what the literature refers to as "radiophobia," an excessive or irrational fear of ionizing radiation, often fueled by incomplete knowledge or institutional overemphasis on radiation safety training. These findings may reflect an organizational culture that unintentionally promotes radiophobia.[24]

Infectious risk was frequently cited as a major safety concern. Participants observed that basic aseptic practices were sometimes neglected, particularly under heavy workloads and time pressure. Given the arterial and venous access in cardiac procedures, cath labs inherently carry a high risk of infection.[6,25] In this context, the present study's findings are consistent with the existing literature. However, rather than implementing a systematic infection control strategy, units tend to adapt their practices based on local resources.

Cath labs are clinical environments where numerous drugs and contrast agents are routinely used. Among these, the nephrotoxic effects of contrast media used for imaging have been particularly emphasized.[13] Due to these associated hazards, participants in the study frequently highlighted the risks associated with pharmaceuticals and emphasized the importance of preventive measures.

Fall Risk was also identified as another significant safety threat, particularly during patient mobilization and procedural stages. Participants emphasized that patients undergoing diagnostic and therapeutic procedures in cath labs are often elderly and physically fragile. In a study by Cardoso et al.,[26] fall risk was identified as a critical component of patient safety programs in cath labs.

This study revealed that healthcare workers are often required to care for a large number of patients with limited staff. This situation hindered the effective implementation of safety strategies. The literature similarly characterizes cath labs as high-paced and high-demand units, particularly due to the frequency of emergency cases they handle.[27] Higher workloads were associated with an increased likelihood of complications.[28] International literature confirms that staffing inadequacies are a shared concern across many health systems.[27,28] For example, Lindsay et al.[28] noted that overburdened staff and lack of support services were associated with increased procedural risks in high-volume cardiac units. The cleaning staff shortages in this study highlight a broader gap in organizational planning, where procedural turnover is high, and sterility is crucial.

Another prominent concern by participants was the presence of Untrained Personnel. Vincent Gatt[10] emphasized that the training and experience of cath lab personnel are crucial factors in successfully implementing safety strategies. The literature underscores the importance of proper education and knowledge, particularly in ensuring radiation safety.[29]

The Medical Records theme highlights the beneficial role of record-keeping systems in promoting safety. Another key finding was the lack of standardization among the cath labs. In their study outlining best practices in cath labs, Naidu et al.[7] emphasized the importance of medical documentation in ensuring the continuity of patient care. In contrast, the present study found that hemodynamic data are not standardly recorded in an electronic format. The limited emphasis on identity verification may stem from the fact that such procedures are often shaped by organizational culture. Naidu et al.[7] emphasized the need for implementing procedural checklists during clinical interventions.

The findings indicate that numerous factors influence patient and healthcare worker safety in cath labs. While the precautions taken against key risks are undoubtedly important, the lack of standardization in their implementation poses a threat to long-term safety strategies. The study's themes directly support these observations. The assurance of patient and employee safety in healthcare institutions is also essential for the sustainability of human resource management.[30] Additionally, supporting this process with innovation empowers employees in healthcare institutions.[31]

The study was conducted with 24 participants, which may limit the generalizability of the findings. While beneficial for contextual understanding, the researcher's professional background in the cath lab may have subtly influenced the interpretation of findings despite efforts to bracket prior assumptions.

Conclusion

This qualitative study identified key safety risks in catheterization laboratories, including radiation exposure, infection, pharmaceutical reactions, falls, and issues related to staffing and documentation. Based on the lived experiences of healthcare professionals, the findings emphasize the need for system-level safety strategies, such as adequate staffing, standard protocols, ongoing training, and technological integration, to foster a resilient and comprehensive safety culture.

Ethics Committee Approval: The Çankırı Karatekin University Ethics Committee granted approval for this study (date: 17.01.2024, number: 11).

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