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Systematic Review

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Corresponding author:
Nihal Dağ,
Email: nihaldag@icloud.com.

Factors Affecting the Intervention of Health-Care Professionals in Radiological Events: A Systematic Review

Nihal Dağ MSc[1], Cüneyt Çalışkan MSc, MEds, PhD[2], Hüseyin Koçak MSc, PhD, DM[3], Gülcan Demir MSc, PhD[4] and İsmet Çelebi MPH, PhD[5]

[1]Department of Disaster Medicine, Hamidiye Institute of Health Sciences, University of Health Sciences, Istanbul Turkey; [2]Department of Emergency Aid and Disaster Management, Hamidiye Faculty of Health Sciences, University of Health Sciences, Istanbul Turkey; [3]Department of Emergency Aid and Disaster Management, Faculty of Health Sciences, Çanakkale Onsekiz Mart University, Çanakkale, Turkey; [4]Vocational School of Health Services in Sinop University Sinop, Turkey and [5]Paramedic of Department, Gazi University, Ankara, Turkey

Abstract

This research aims to explore the factors affecting the intervention of health-care professionals regarding a radiological event and to determine what actions they cause. In line with the keywords determined, a search was conducted on Cochrane, Scopus, Web of Science, and PubMed until March 2022. Eighteen peer-reviewed articles that met the inclusion criteria were reviewed. This systematic review was conducted using the PICOS and PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses)guidelines. Of the 18 studies included in the study, 8 were cross-sectional studies, 7 were descriptive studies, 2 were interventional studies, and 1 was a systematic review. As a result of the qualitative analysis, 7 factors affecting the intervention of health-care professionals in a radiological event were identified as follows: rarity of the event; inadequacy of health-care professionals against the radiological event; sensory responses; dilemma and ethical concern; communication, workload; and other factors. The most important factor affecting the intervention of health-care professionals in a radiological event is inadequate education about a radiological event, which influences the formation of other factors. These and other factors cause actions such as delayed treatment, death, and disruption of health services. Further studies are needed on the factors affecting the intervention of health-care professionals.

Radiological events are those that involve exposure to radiation from a radioactive source.[1] These events occur intentionally and unintentionally. Intentional or unintentional release of radiation, natural disasters, misuse of radioactive resources, exposure to uncontrolled (abandoned, lost, or stolen) radiation source, devastating attacks on national energy resources such as radiological dispersal devices and nuclear power plants, large-scale industrial releases, and covert placement of radioactive substances can be given as the examples.[2] Important events in history include the Chernobyl Nuclear Power Plant disaster as a result of an accident in 1986 and the Fukushima Nuclear Power Plant disaster as a result of a natural disaster in 2011.[3,4] In the recent history, there are reports recording the release of radioactive material as a result of the attack on the Zaporizhzhia Nuclear Power Plant in Ukraine during the war between Russia and Ukraine in 2022.[5] Again, in an analysis of terrorist attack weapons that took place between 1970 and 2019, only 12 of approximately 700,000 terrorist incidents were of radiological origin.[6] According to these data, although radiological release is rare, current geopolitical tensions and proliferation of nuclear weapons have raised concerns about the resumption of targeted radiological or nuclear events.[7] Radiological events result in large-scale evacuations, hospitalizations, deaths from radiation sickness, and long-term deaths.[8] Considering the radiological events in the past, it is seen that limited and decreasing resources, high number of victims seeking treatment for physical trauma, thermal burns and acute radiation, and high morbidity and mortality rates emerged as the problems that increased the demand on the health system and the health workforce.[7,9,10]

In disasters and emergencies, health-care professionals should manage victims of extraordinary events as well as maintain routine medical care in the field. For example, health-care professionals should have competencies such as identifying exposures and contamination in mass radiological releases, managing scarce resources, enforcing crisis care standards, protecting the workforce, creating a general message, understanding the victim's need, stabilizing the victim, helping decontamination, having knowledge of how to take medical precautions against danger, and taking part in coordinated cooperation with various health professionals for effective intervention.[7,10] In this direction, it generally requires health-care professionals to be aware of the difficulties they experience at the basic level to develop their preparation, skills, or

self-efficacy and to cope with the difficulties caused by radioactive events. In addition to the high awareness of health-care professionals in combating such events, it is also necessary to determine the limiting factors that affect their intervention in radiological events. There are many factors that affect the intervention of health-care professionals in radiological events. For example, after the explosion[11] in the Fukushima nuclear power plant on March 11, 2011, many factors were observed such as the personal safety concerns of health professionals due to the high radiation level of the casualties, the discussion among employees due to the lack of organization, and the availability of the appropriate hospital and ambulance. However, a study summarizing and evaluating these factors together was not found in the literature. In this systematic review, it was aimed to determine the factors affecting the intervention of health professionals in radiological events and to determine what actions they may cause.

Methods

Descriptive Concepts, Protocol, and Record

In this study, a systematic review of the articles and documents related to the factors affecting the intervention of health-care professionals in incidents involving radiological threats was conducted. An integrative review methodology, which is argued to include a variety of perspectives on a topic, is the broadest type of research review, and is currently important to health science and research, was used.[12] This review includes problem identification, literature search, data evaluation, data analysis, and data presentation. A protocol and record regarding the analysis methods and inclusion criteria of the study were not established. However, this systematic review follows The PICOS and PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines.[13]

Information Source and Search Strategy

Database searching was conducted with the combination of the following keywords: ((“Radiation” AND “health care workers”) OR (“Radiation” AND “health care providers”)) AND (“disaster*” OR “emergency*” OR “terrorism*” OR “accident*” OR “attack*” OR “crisis*” OR “catastrophe*” OR “hazard*” OR “nuclear*”) AND (“management*” OR “response*” OR “radioactive materials*” OR “ionizing*” OR “medical*” OR “plan*” OR “program*” OR “preparedness*”). The key terms were determined in consultation with researchers with studies on disaster management and CBRN (chemical, biological, radiological, nuclear). The search strategy was developed in partnership with a research team of experts in the fields of disaster medicine, disaster management, and public health. An extensive search was performed for relevant articles. Articles and reports published on Cochrane, Scopus, Web of Science, and PubMed until March 2022 were received. The references of the publications obtained within the scope of the research related to the research question were accessed through the Google scholar database. There was no publication date or publication restriction. The problem statement was determined as follows: *“What are the factors affecting the intervention of health-care professionals in radiological events?”*.

Within the scope of the determined question, the participants of the research (Participation) consisted of health-care professionals (P). The factors affecting the intervention of health-care professionals in radiological events (Intervention) were examined (I). A comparison (Comparison) of the actions of health staff toward these factors was conducted (C). The factors obtained from different articles and reports constituted the outcome of the research (Outcomes) (O). All studies published in English (Study designs) were included in the research.

Eligibility Criteria

Inclusion criteria:

1. Articles or reports addressing health-care professionals,
2. Articles or reports intentionally including at least 1 of the types of radiological hazards,
3. Articles or reports focusing on at least 1 of the factors affecting the intervention of health-care professionals in radiological events,
4. Articles or reports that are accessible and free of charge,
5. Articles or reports written in English.

Exclusion criteria:

1. Articles and reports that do not cover radiological disaster/accident events,
2. Articles and reports that do not meet the inclusion criteria.

Study Selection

The titles and abstracts of the articles were independently evaluated and screened by 3 referees in terms of suitability. The full text of the accessed articles was carefully and critically examined by the referees.

Data Extraction

A form (title, author, purpose, methods, factor, and action) was created to extract data from publications by content analysis.

Quality Assessment and Bias Risk

The Mixed Methods Appraisal Tool (MMAT) 2018 version was used to assess the quality of the articles included in the systematic review, which allows the assessment and inclusion of a variety of studies, including quantitative, qualitative, and mixed methods research designs. This assessment tool consists of 5 categories, each of which has 5 relevant specific criteria, including a qualitative set, a random set, a nonrandom set, an observational descriptive set, and a mixed method set. The 2018 version of the MMAT does not recommend scoring based on category criteria, but rather an explanation of what is met and what is not.[14]

The 2 authors reviewed each article according to the MMAT categories for risk of bias. The articles reviewed by a third author in case of any disagreement were resolved through negotiation or consultation. The results of the critical evaluation of the articles using the MMAT 2018 version included those articles meeting 3 to 5 (out of 5) criteria.

Data Synthesis and Analysis

It is not possible to use statistical methods, such as quantitative meta-analysis to analyze data due to the heterogeneity of results and the number of replicated or non-independent samples. For this reason, descriptive analysis and content/thematic analysis were used in the analysis of the data. The data from the reviewed literature were extracted independently with a form created by 1 of the authors. The accuracy and completeness of the extracted data were checked by 3 other authors.

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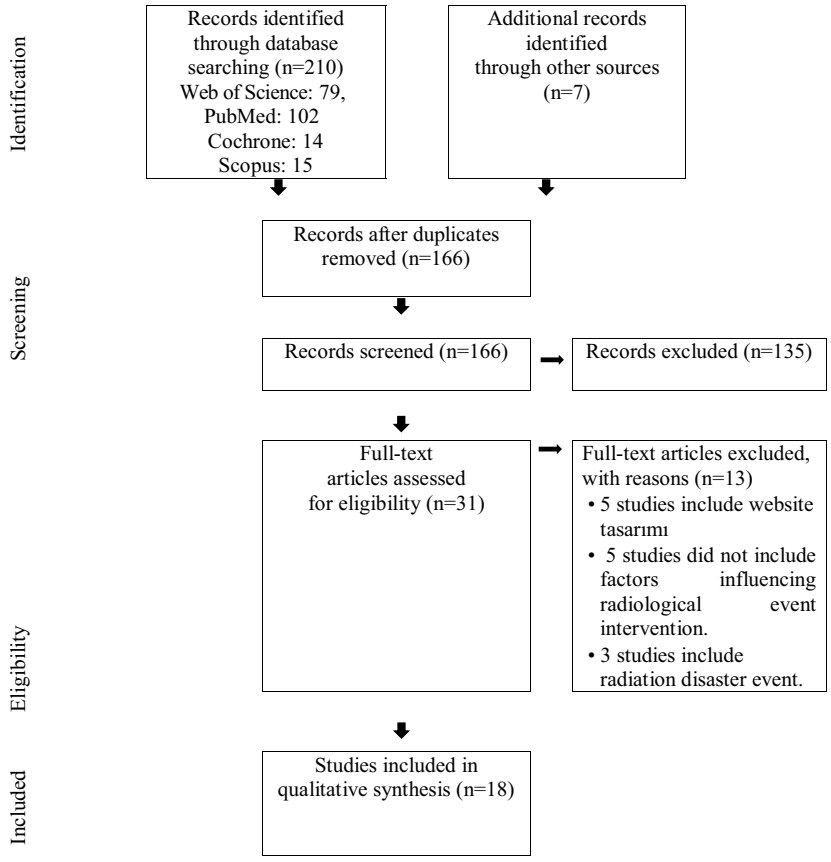

Figure 1. Flow of information through different phases of a systematic review.

Results

Characteristics of the "Included Studies"

By searching the Web of Science, Scopus, Cochrane, and PubMed databases with the keywords of the research, 210 studies were found. Because 51 of these studies were duplications and the abstracts of 135 studies did not meet the inclusion criteria of the study, their full texts were not read. The full texts of the remaining 24 studies were read, and 11 of them were included in the findings of the study. In addition, 7 studies found in the gray literature review were included in the findings of the study (Figure 1). The publication dates of the 18 studies included in the research findings range from 2004 to March 2022. Eight of these studies are cross-sectional survey studies, 7 are descriptive studies, 2 are interventional studies, and 1 is a systematic review.

Factors Affecting the Intervention of Health-Care Professionals in Radiological Events

In this study, the limiting factors affecting the intervention of health-care professionals in disaster/accident events involving radiological threats are summarized under 7 categories: rarity of the event; inadequacy of health-care professionals against the radiological event; sensory responses; dilemma and ethical concerns; communication, workload; and other factors (Table 1).

1. Rare occurrence of radiological emergencies

Health-care professionals face with many emergencies originating from nature, humans, and technology. Health-care professionals are responsible for diagnosis, treatment, and rehabilitation of the casualty in such emergencies. However, health-care professionals are less likely to encounter radiological events compared with many emergencies.[15] Rare occurrence of radiological events compared with other conditions is identified as a limiting factor affecting the intervention of health-care professionals.[10,15–18] This factor causes actions such as the lack or absence of experienced health staff to respond to the radiological emergency, difficulty in managing the event, unwillingness to receive training, and not providing medical support to the contaminated victim who needs therapeutic intervention.[10,15]

2. Inadequacy of health-care professionals against radiological events

Insufficient equipment, hospital, and staff. In the study, the factors affecting the intervention of health-care professionals in radiological threats were determined as some inadequacies regarding staff, equipment, and hospital. In 1 of the quantitative studies, it was mentioned that health staff did not have the appropriate medical evaluation and care capacity for a large number of injured people who needed medical intervention after a radiological exposure.[16] Another qualitative study suggested that the limited availability of appropriate care capacity and standard hospital protective clothing may result in inadequate emergency treatment of contaminated casualties.[19] Similarly, in 2 separate qualitative studies, a radiological accident in the past was mentioned. It was stated that in this accident, the contamination levels of the injured were higher than the ambulance contamination limit level criterion, which caused the ambulance staff to refuse to transport the patients.[18,20] It was also seen that their hospitals did not accept

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Table 1. Analysis of 18 included articles

No	Author name (Year)	Title	Purpose	Methods	Event type and characteristics	Factors	Action
1	Tominaga et al. (2014)	The Accident At The Fukushima Daiich Nuclear power Plant In 2011	This article introduces various problems triggered by an accident at a nuclear power plant and focuses on the radiation emergency medicine system and its consequences.	There is no research method. (Descriptive research)	Nuclear facility explosion affected by earthquake and tsunami	1. Patient contamination level above ambulance referral criteria, 2. Lack of hospital suitable for patient contamination level, 3. Disagreement between the responsible persons on the subject of referral, 4. Continuation of contamination after decontamination procedure, 5. Being concerned about the health effects of radiation in a public ambulance, 6. Limited knowledge of health-care professionals about radiation, 7. Lack of organization among different health-care professionals in hospitals for radiation emergency events, 8. Rare occurrence of radiological emergency	1-2. Failure to take patients to hospital, 3. After discussion, accepting transfer in case of any decontamination, 4. Hospital refusal to accept contaminated patients, 5. The public ambulance unable to reach the nuclear power plant 6. Feeling of anxiety, 7. Delayed agreement between different health-care professionals in hospitals on the admission of contaminated patients, 8. Lack of experienced personnel to intervene in a radiological emergency.
2	Hachiya et al. (2016)	Lessons Learned From The Accident At The Fukushima Dai-ichi Nuclear Power Plant—More Than basic Knowledge: Education And Its Effects Improve the Preparedness And Response To Radiation emergency	This article focuses on the problems that arose in response to the Tokyo Electric Power Company (TEPCO) accident at Fukushima Dai-Ichi NPP caused by the earthquake and tsunami.	There is no research method. (Descriptive research)	Nuclear facility explosion affected by earthquake and tsunami	1. Ionizing radiation not being felt by human senses, 2. Absence of symptoms immediately after exposure, 3. The radiation level being above the ambulance transportation limit criteria, 4. Ambulance staff's hesitation to take the contaminated patient for their own health insurance, 5. Interviewing the ambulance staff with experts on radiation protection.	1-2. Causing medical, environmental, psychosocial and economic problems, 3-4. Not being taken to the hospital, 5. Delayed agreement on admission of contaminated patients.

Table 1. (*Continued*)

3	McGann et al. (2015)	Radiologists: The Unsuspecting Subject Matter Experts	This study determines how prepared hospitals are to deal with mass casualties in the event of an attack involving a radiological dispersal device (RDD/"dirty bomb") or such a similar radiological event.	There is no research method. (Descriptive research)	–	1. Radiologists not being aware that they will be considered experts at the time of the radiological event, 2. "Golden hour" trauma ending before the radiological coordinating agency arrives at the scene, 3. Medical staff not knowing the differences in how to find the casualty and how to treat external radiation exposure and external radiation exposure, 4. One of the limitless effects of ionizing radiation being invisible, 5. Standard hospital barrier clothing being sufficient for the emergency treatment of a limited number of radiologically contaminated casualties.	1. Inability to intervene medically in a tragic radiological event, 2. Contaminated patients who are likely to arrive at the emergency department of a local hospital before they know that the event is radiological, 3. Failure to respond successfully to a radiation mass injury event, 4. Health workers having radiophobia.
4	Shah et al. (2021)	Nuclear Disaster Preparedness Level of Medical Responders in Pakistan	The aim of the study is to evaluate the current awareness and preparedness levels for nuclear and radiological disasters.	A descriptive cross-sectional epidemiological study	–	1. Exceeding the normal use capacity of medical responders in areas affected by the radiological event, 2. Most health-care professionals not taking any training course on nuclear and radiological safety or the treatment of contaminated patients, 4. Many health-care professionals having basic training and mostly lacking hands-on training and refresher courses, 5. Insufficient knowledge of the procedures for the use of personal protective equipment.	2. The lack of staff who could deal with patients at a moderate level after a radiological event 4. Not being sure about whether they could intervene in the event effectively in times of need, 5. Self-contamination of medical staff.

(*Continued*)

Table 1. (*Continued*)

No	Author name (Year)	Title	Purpose	Methods	Event type and characteristics	Factors	Action
5	Bouillon-Minois et al. (2021)	Stress among Emergency Health Care Workers on Nuclear or Radiation Disaster: A Preliminary State Survey	The main purpose of the study is to evaluate the subjective stress related to nuclear radiation disasters in emergency health workers. In addition, another aim of the study is to evaluate the knowledge, theoretical background and training of first responders during nuclear and radiation disasters.	A descriptive cross-sectional epidemiological study	–	1. An ethical dilemma between the obligations of health-care professionals and their own safety, 2. Overcrowding of the emergency room; lack of sleep; inadequate food intake before, during and after the shift; and being overly tired, 3. Not knowing where the personal protective equipment is in their center.	2. Causing burnout in health-care professionals.
6	Goto et al. (2014)	Health Literacy Training for Public Health Nurses in Fukushima: A Case-Study of Program Adaptation, Implementation and Evaluation	This study highlights the importance of providing health literacy training opportunities to professionals to strengthen the health system's access to accessible information and services.	Experimental study without control group	The Fukushima nuclear disaster	1. Having difficulties in the post-disaster stage to communicate evidence of the health risks of radiation exposure to the public	1. Negative risk communication between health-care professionals and the community.
7	McGhee et al. (2005)	Radiation Injuries, Triage, and Treatment After a nuclear terrorist attack	–	There is no research method. (Descriptive research)	–	1. High exposure to life-threatening radiation, 2. Fear of patient contamination, 3. Difficulty in determining the depth and extent of contamination of puncture wounds, and poor accessibility of these wounds, 4. Failure to give early intervention in radiation injuries, 5. The radioactive dissipation device causing mass injury.	1. Postponement of patient care, 2. Affecting the decisions of the responsible treatment team, 3. Difficulty in terms of decontaminating patients with puncture wounds, 4-5. Complicating the treatment process.
8	Tin et al. (2021)	Terrorism-Related Chemical, Biological, Radiation, and Nuclear Attacks: A Historical Global Comparison Influencing the Emergence of Counter-Terrorism Medicine	This study aims to provide the epidemiology of CBRN use in terrorism, to detail the specific agents used, and to develop training programs for response teams.	Systematic Review	–	1. Lack of global consensus on the best medical team composition for high threat responses 2. The challenge of rapid medical assessment and treatment of victims in an active "hot zone"	–

Table 1. (*Continued*)

9	Murray et al. (2021)	Radiation Emergency Readiness among US Medical Toxicologists: A Survey	The purpose of this study is to evaluate the comfort and knowledge levels of medical toxicologists in the USA. The study also aims to identify and evaluate experiences, comfort levels, attitudes and knowledge about radiation emergencies and injuries.	A descriptive cross-sectional epidemiological study	–	1. Rareness of large-scale radiation emergencies, 2. Lack of training in medical schools, postgraduate medical education, and advanced practice programs.	1. Lack of familiarity of health-care providers and emergency responders with the assessment and management of radiation injuries. 2. The lack of sufficient knowledge of the health workers in the field of radiology.
10	Christensen et al. (2014)	Management of Ionizing Radiation Injuries and Illnesses, Part 1: Physics, Radiation Protection, and Radiation Instrumentation	This article is an introduction to basic physics, ionizing radiation, radiation protection, and radiation instrumentation, and provides a basis for the management of the consequences of a radiological or nuclear event.	There is no research method. (Descriptive research)	–	1. The rarity of ionizing radiation injuries and diseases.	1. The inability of most doctors to manage such conditions.
11	Nagata et al. (2022)	Radiation Emergency Medical Preparedness in Japan: A Survey of Nuclear Emergency Core Hospitals	This study investigates the current status of Nuclear emergency hospitals in Japan, and identifies areas for improvement.	A descriptive cross-sectional epidemiological study	–	1. Most hospitals outside the crisis area not having the capacity to receive patients at the time of the incident, 2. Health workers having fears about the effect of radiation, 3. Risky communication for first responders in the event of a radiation disaster.	1. Death during referral to the hospital, 2. Difficulty in maintaining operations.
12	Smith et al. (2005)	Hospital Management of Mass Radiological Casualties: Reassessing Exposures From Contaminated Victims of an Exploded Radiological Dispersal Device	This study identifies the exposure of health-care providers in the emergency room due to a contaminated victim recovering from an RDD incident using a large but plausible source of radionuclide.	There is no research method. (Descriptive research)	–	1. Concern about the harmful exposures they may face when treating such patients if the patient is not completely decontaminated, 2. Pre-treatment decontamination not eliminating the danger	1. Failure to take quick decisions and unnecessary delay of treatment, 2. A critical exposure situation for both the patient and health-care professionals.
13	Matsuoka et al. (2012)	Concern over Radiation Exposure and Psychological Distress among Rescue Workers following the Great East Japan Earthquake Concern over Radiation Exposure and Distress	This study explores early psychological distress among DMAT members who provide care for earthquake victims in the event of potentially hazardous radiation exposure, and identifies whether there is a relationship between subjective anxiety about radiation exposure and psychological distress.	A descriptive cross-sectional epidemiological survey study	On March 1, 2011, the Great East Japan Earthquake and the ensuing tsunami severely damaged Japan's northeastern coastline and the Fukushima Daiichi nuclear power plant.	1. Concern about the health-care professionals' exposure to radiation.	1. Psychological stress among health-care professionals.

(*Continued*)

Table 1. (*Continued*)

No	Author name (Year)	Title	Purpose	Methods	Event type and characteristics	Factors	Action
14	Dallas et al. (2017)	Readiness for Radiological and Nuclear Events among Emergency Medical Personnel	This study assesses the relative knowledge, willingness to respond, and familiarity of US and Japanese emergency medical staff with the risks of nuclear/radiological contamination.	A descriptive cross-sectional epidemiological survey study	–	1. Lack of education and understanding of health implications and accepted protocols for appropriate response, 2. Reluctance of health staff to intervene in radiological emergencies that they are not familiar with.	1. Not knowing how to intervene in a patient contaminated with radiological particles, 2. Failure to participate in an emergency response involving the handling of casualties with potential for radioactive contamination.
15	Blumenthal et al. (2014)	A Sustainable Training Strategy for Improving Health Care Following a Catastrophic Radiological or Nuclear Incident	This article proposes a sustainable education strategy to disseminate the curriculum among the required communities.	There is no research method. (Descriptive research)	Nuclear device explosion	1. Fear of radiation, 2. Insufficient education, 3. Lack of authority or unclear authority, 4. The rarity of the event, 5. Being exposed to radiation, 6. The complexity of the radiological event.	1-6. Not being willing to receive education, 1-2. Delay of treatment, death, and illness, 4. Postponing education, 5. Absence from work or unwillingness to volunteer.
16	Robert Schleipman et al. (2004)	Radiation Disaster Response: Preparation and Simulation Experience at an Academic Medical Center	The aim of the study is to emphasize the trauma service capacity, communication, security and logistics functions of the exercise.	There is no research method. (Descriptive cross-sectional epidemiological study)	Exercise	1. Health-care professionals wearing protective clothing. 2. Inadequate staff and equipment, 3. Not understanding the risks at the scene, 4. Communication networks not being available (no signal; communication networks not operating), 5. Lack of coordination in patient flow.	1. Staff not knowing each other and having difficulty in communicating, 3. Failure to convey the risk at the scene to the responsible staff, 4. Requirement of additional staff to transmit information flow among staff.
17	Veenema et al. (2020)	Radiation Injury Treatment Network Medical and Nursing Workforce Radiation: Knowledge and Attitude Assessment	The purpose of this study is to explore the medical and nursing knowledge and self-perceptions of the health-care workforce of RITN program centers regarding medical effects of radiation, management of victims, clinical competence, and willingness to respond to radiation/nuclear events.	A descriptive cross-sectional epidemiological study	–	1. Insufficient education, 2. Few or no encounters with a radiological emergency, 3. Finding themselves inadequate for radiological emergencies, 4. Rare occurrence of radiological event.	2. Unwillingness to receive training for the radiological emergency, 3. Unwillingness to participate in patient care in a radiation-related emergency, 4. Disregard for the contaminated victim not related to therapeutic treatment by health-care professionals.

Table 1. (*Continued*)

18	Veenema et al. (2008)	Factors Affecting Hospital-based Nurses' Willingness to Respond to a Radiation Emergency	The objective of this study is to develop and implement a rapid survey to assess hospital-based nurses' basic knowledge, self-assessed clinical competencies, perceptions of personal safety, and willingness to intervene in a radiological emergency.	A descriptive cross-sectional epidemiological study	–	1. Health-care professionals having a concern about treating patients exposed to radiation, 2. Lack of clinical experience against radiological event, 3. Insufficient information about the radiological event, 4. Being concerned about own safety and family safety, 5. Severe radiation release event.	3. Delay or rejection of treatment of contaminated patients, 3. Inability to predict the level of exposure, 3-4. Unwillingness to participate in the intervention.

the injured because of the high contamination levels.[18,20,21] Based on these reasons, it is understood that the medical intervention of ambulances and hospitals in high contamination casualties was insufficient. In addition, in another study, it was emphasized that the number of specialist personnel to respond to the injured was insufficient when such events occurred.[20]

Lack of organization

There are many occupational groups in the health service system. Each of these occupational groups is responsible for fulfilling a different function. However, to perform these functions well, it requires all occupational groups to be organized in a team understanding. Among the studies included in the research, organizational inadequacy of health-care professionals against threatening radiological events was determined. A quantitative study called *Nuclear Emergency Core Hospitals* mentioned that it was difficult to organize medical intervention in radiological events.[21] In 2 qualitative studies describing the radiological events experienced in the past, it was stated that the ambulance staff had problems with the hospital supervisor and that the occupational groups responsible for such incidents in the hospital could not reach a common decision on accepting contaminated patients. Therefore, it is seen that patients could not access treatment for a long time.[18,20] Similarly, in another intervention study, it was mentioned that health staff was inadequate in organizing the flow of patients.[22] Finally, in a systematic analysis study, it was mentioned that medical teams did not have a global consensus on such events.[23]

Insufficient education (knowledge, skills, and experience)

Training of health-care professionals against radiological events helps them understand the effects of radiation on the health system, provide treatment, and make clinical decisions during the event. In the studies examined, it was found that there was a lack of knowledge, skills, and experience against radiological events, because technical knowledge was not included in the training of health-care professionals against such events. One of the main reasons for this deficiency was that radiological disaster was not included in the emergency medicine education curriculum.[18] In addition, the striking findings were that radiologists specialized in the field were not properly trained to medically respond to a tragic radiological event.[19] In addition, it was mentioned that health-care professionals did not want to receive training due to the rare occurrence of radiological disasters or the low probability of encountering them, that they could not receive training, and that additional training/technical support was not provided.[10,15,16,18,21,24] For this reason, it was stated that health-care professionals did not know where the personal protective equipment was, that they were afraid of risking their own health, and that they could not provide the medical treatment that the victim affected by the radiological release needed.[17,23–26] In 1 study, it was expressed that health-care professionals did not have sufficient experience due to the rare occurrence of a radiological event.[16] In other words, it was mentioned that the rare occurrence of the event makes medical management difficult.[27] In particular, the insufficient knowledge and experience of health-care professionals in determining the level of contamination of victims and the depth and extent of contamination of patients with penetrating injuries made it difficult to decontaminate patients.[18,27]

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3. Emotional reactions (anxiety, fear, stress, and panic)

Because radiation cannot be perceived by the human emotional and does not reveal symptoms early, it can cause anxiety, fear, stress, and panic in people. From the studies included in the research, it was determined that health-care professionals gave such emotional responses to radiological events. However, the reasons why health-care professionals felt anxiety, fear, stress, and panic about such events were that such events could not be perceived by the human emotional and did not cause sudden signs or symptoms, and that they lacked knowledge and skills. In 2 qualitative studies describing radiological accidents in the past, it was mentioned that ambulances could not reach the scene due to fear and anxiety about the effects of radiation on health.[18,20] Ambulances arriving at the scene were hesitant to accept patients for the same reason. In a qualitative study aimed at determining the exposure of health-care professionals in a mass radiological event, it was mentioned that health-care professionals were anxious to treat patients who could not be completely decontaminated.[28] In addition, in 2 qualitative studies, it was mentioned that these fears and concerns of health-care professionals affected their treatment decisions and that they had difficulty in continuing their operations.[21,27] In a survey conducted after the Fukushima earthquake in 2011, it was determined that health professionals had concerns about exposure to radiation.[29] It was mentioned that this concern caused stress and psychological problems among health-care professionals. In another quantitative study, it was mentioned that disasters of radiological origin could cause stress for health-care professionals both in daily life and at work.[25] Finally, such psychological reactions of health-care professionals to radiological events were described as radiophobia.[19]

4. Dilemma and ethical concerns

It was mentioned in the previous sections that health-care professionals may face fear, anxiety, and stress of endangering their own health due to lack of knowledge, skills, and experience against radiological events. In this section, the dilemmas and ethical concerns experienced by health-care professionals in treating patients were included. One of the main dilemmas of health-care professionals in a quantitative study was whether it was necessary to force the contaminated casualty to participate in decontamination practices. In addition, in this study, it was mentioned that there was an ethical dilemma between the patient responsibilities of health-care professionals and their own safety.[25] In a qualitative study addressing the responsibilities of health-care professionals, it was mentioned that radiologists, who are known as experts in a radiological event, were faced with a dilemma about how to intervene when needed.[19] In the quantitative study, in which another dilemma was addressed, it was emphasized whether an effective intervention could be given as a result of receiving basic-but-impractical radiological education in the early stages of the education process.[24]

5. Workload

In the studies examined, it was concluded that the workload of health professionals increased due to the massive occurrence of radiological events. In 2 studies, it was mentioned that radiological events could affect a large number of people and that most of the injured needed medical attention. For this reason, it was stated that an efficient medical intervention would be difficult with limited resources.[24,27] Another workload was the need for medical staff to quickly assess and treat the injured in the active hot zone.[23] In 1 quantitative study, lack of sleep, insufficient food intake, accumulated fatigue, and burnout due to excessive workload were mentioned.[25]

6. Communication

Communication problems of health professionals in radiological events were addressed in 3 survey studies included in the findings of the study. In 1 of these studies, it was mentioned that health-care professionals had difficulties in explaining the health risks of exposure to radiation in a language that the public could understand.[30] In another study, although it was stated that risk communication was important among health-care professionals, it was mentioned that such an infrastructure did not exist.[21] Finally, it was observed that health professionals had difficulty in communicating with each other due to having to wear protective clothing, and that they could not communicate quickly and effectively due to the problems experienced in the communication networks at the scene.[22]

7. Other factors

Among the studies included in the findings of the study, the factors affecting radiological intervention were classified under 6 categories, and the remaining factors were collected in this section. One of these factors was the inability to predict how health-care professionals would react during an incident, even though it was included in planning and training against radiological hazards.[25] Another factor was that first responders referred to local hospitals before arriving at the scene, as contaminated patients were unaware of the seriousness of their condition.[19]

Discussion

In this study, a total of 18 articles were examined in detail. In these articles, the factors affecting the intervention of health-care professionals in an event involving a radiological threat were investigated. These factors are rarity of the event; inadequacy of health-care professionals against a radiological event (equipment, training, organization); sensory responses (anxiety, stress, panic); dilemma and ethical concerns; communication, workload; and other factors. However, under the title of inadequacy of health professionals against radiological events, equipment, organization, and training are summarized under 3 subheadings, while sensory reactions are summarized under a single heading.

Insufficient training was considered as 1 of the limiting factors affecting the intervention of health-care professionals in 11 of the 18 articles included.[8,10,15–19,24–27] This factor causes health professionals not to understand the risks at the scene, to be worried, not to give medical attention or to be hesitant to give medical attention, and to endanger their own health, which leads to a shortage of staff who can provide appropriate treatment. Thus, it is necessary to make various improvements in training, which is located at the intersection of the factors affecting the intervention of health professionals in radiological events. In this direction, for example, after the Fukushima accident, the Science Council of Japan (2014) published recommendations for radiation health risk education to include health professionals in their curricula. The Council emphasizes that health-care professionals approached the event inconsistently and inappropriately because of their insufficient knowledge of radiation health risks.[31] Park and Yang (2021) found that being more knowledgeable about radiation protection affected the quality of health care, which is associated with better performance in radiation protection-related behaviors.[32] Especially such studies and the measurement of their outputs with different applications

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have the potential to reveal the relationship between education and other factors in a better way.

In the findings of the study, the most common factor after the lack of education of health professionals against radiological events is sensory reactions (fear and anxiety).[10,18,20,21,27,28] A health-care professional's emotional response to a radiological event results from lack of information, radiology being unavailable or confusing,[33] few or no experienced staff members, and potentially inadequate protective equipment.[34] In a study, the personal safety concern of health-care professionals against a radiological event was accepted as the primary determinant of their willingness to intervene in a radiological event.[35] With the CBRN courses developed especially in this direction, a positive interaction can be ensured between the knowledge and experience of health-care professionals and the feeling of safety against a radiological event and their willingness to intervene in the event. For example, it is known that special courses were developed in Japan to inform first responders in decontamination, triage, personal safety, and other areas in CBRN incidents under the all-hazards approach.[36] Improvements can be achieved in the sensory responses of health-care professionals that can be experienced in a real event, with courses developed in this way and the exercises embedded in their content.

There are many factors that cause the victim's treatment delay. One of these factors is the organizational inadequacy of health professionals. The main reasons for organizational inadequacy are the lack of education and practice of health workers, and their fear and anxiety about the event. One study highlights that, even if a well-organized system against a radiological incident is established, the lack of basic radiological knowledge among employees cannot effectively run the organization.[18] In addition, the proper functioning of this organization depends on previous plans, as well as the reaction of the health professional during an event.[20,37] This reaction of the health-care professional during a radiological event strongly affects the ethical and dilemma factor. Health-care professionals organize with many different intervention teams in a radiological event. However, the rare occurrence of a radiological event may cause a lack of organization among intervention teams. However, the rarity of a radiological event, the lack of experienced health staff,[16,18] and their unwillingness to receive training cause health professionals to feel unsafe[38] and similar actions.[10,15] These actions affect the health professional's response to a radiological event. International emergency plans have been developed to reduce the negative actions of health professionals against such incidents and to perform effective intervention.[39] However, the World Health Organization (WHO) recommends that existing operational and procedural arrangements, including occupational exposure assessment, monitoring, and training in emergency exposure situations, should be added to emergency plans to ensure health professionals' preparedness for a radiological event.[40]

Another factor that causes inadequate or delayed treatment of the injured is the lack of appropriate equipment, hospital, and staff. With this factor, problems such as the difficulty of decontaminating penetrating wounds and the death of the injured during transport arise.[21,27] In addition, the lack of equipment, hospitals, and staff causes an increase in the workload of health-care professionals. The main reason for the lack of staff is that the health workers do not come to work or leave the job because they do not want to intervene in such an event due to personal safety concerns.[41,42] In addition, although it was stated in many studies,[43–45] negative perceptions may also be caused by the lack of knowledge about the critical role of radiation protective personal equipment in protecting health-care professionals from ionizing radiation. To mitigate these actions, personal protective equipment must be available in the work area based on known or anticipated levels of contamination, expected work activity, worker health considerations, and radiological hazards that may be present. Another factor that causes an increase in the workload of health professionals is the massive occurrence of the event. In such a case, triage, care of patients with trauma, and subsequent evaluation of radiation and initiation of patient transfers will cause the hospital capacity to be exceeded.[46] This leads to problems such as fatigue, unhealthy diet, and mental deterioration of health professionals.

Finally, the factor affecting the intervention of the health-care professional in a radiological event is communication. Communication systems are formal or informal structures that organizations use to support their communication needs.[47] There are multiple communication systems to ensure proper and efficient communication of health managers and professionals in health care. A small malfunction in these communication systems can endanger the safety of both the patient and the staff. However, an effective communication and information flow between institutions and the public at the right time can reduce negative medical outcomes.[33] For this purpose, both national and international disaster communication systems have been developed.[48–52] However, since health professionals have to wear personal protective equipment in a radiological event,[21] they have difficulty in communicating with each other and cannot communicate quickly and effectively due to the lack of infrastructure.[22] Communication systems that allow health-care professionals to collaborate quickly and easily both within the same organization and between multiple organizations should be implemented.[53]

Limitations

This systematic review has limitations. The keywords determined by the researchers were limited to 4 electronic databases containing the academic literature. However, the studies that met the inclusion criteria of the study were included in the findings by scanning the gray literature. Another limitation is that the studies included in the findings were mostly qualitative. The lack of empirical studies makes it difficult to determine the factors affecting the intervention of health-care professionals in radiological release. Again, because the relevant literature evaluates the first response to radiological events within the scope of prehospital health professionals, a health professional discipline was not differentiated. Finally, most of the studies in the findings identified the factors affecting the intervention of health professionals in the radiological release events experienced in the past. However, it is thought that there may be other factors affecting the intervention of health professionals in such events. Such limitations are, in fact, typical of such studies in general.

Conclusions

There are 7 limiting factors that affected the intervention of health-care professionals in radiological events. Among the studies included in the findings, the factor that most affected the intervention was the insufficient education of health-care professionals. However, due to the rarity of radiological events, there was little or no education about this event, and it negatively affected the participation of health-care professionals in education. Thus, due to the rarity of the event, it was concluded that the insufficient education factor was seen as the factor that most affected the

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intervention of health-care professionals. These 2 factors cause many actions such as the fear of the health professional in intervening in the casualty, being worried and stressed because of not feeling safe, having difficulty in managing the scene, increasing the workload, and being in dilemma in responding to the casualty. In addition, these actions were considered as limiting factors affecting the intervention of health-care professionals.

In order for health professionals to give appropriate treatment to the casualty, studies should be carried out on other factors, especially on insufficient education. Thus, the actions caused by these factors and also detailed in the findings of the research can be prevented in the future. As a result of the literature review, it was determined that there were few studies related to the radiological event and that these studies were insufficient to address the factors affecting the intervention of health-care professionals. For this reason, it is recommended to carry out studies that explore the ways of finding solutions for the limiting factors affecting the intervention of health-care professionals in radiological events.

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