Iran Red Crescent Med J. 2019 May; 21(5):e87107. doi: 10.5812/ircmj.87107.

Published online 2019 May 28. **Research Article**

Emergency Department Preparedness of Hospitals for Radiation, Nuclear Accidents, and Nuclear Terrorism: A Qualitative Study in Iran

Milad Ahmadi Marzaleh [1], Rita Rezaee [2], Abbas Rezaianzadeh [3], Mahnaz Rakhshan [4], Gholamhassan Haddadi [5] and Mahmoudreza Peyravi [6, 7, *]

[1] Ph.D. Candidate of Health in Disasters and Emergencies, Student Research Committee, Department of Health in Disasters and Emergencies, Health Human Resources Research Center, School of Management and Medical Informatics, Shiraz University of Medical Sciences, Shiraz, Iran
[2] Associate Professor, Health Human Resource Development Research Center, Department of Health Information Management, Health Human Resources Research Center, School of Management and Medical Informatics, Shiraz University of Medical Sciences, Shiraz, Iran
[3] Professor, School of Health, Department of Epidemiology, Shiraz University of Medical Sciences, Shiraz, Iran
[4] Associate Professor, Department of Nursing, School of Nursing and Midwifery, Shiraz University of Medical Sciences, Shiraz, Iran
[5] Associate Professor, Department of Radiology, Ionizing and Nonionizing Radiation Research Center, School of Paramedical, Shiraz University of Medical Sciences, Shiraz, Iran
[6] Assistant Professor, Department of Health in Disasters and Emergencies, Health Human Resources Research Center, School of Management and Medical Informatics, Shiraz University of Medical Sciences, Shiraz, Iran
[7] Research Center for Emergency and Disaster Resilience, Red Recent Society of the Islamic Republic of Iran, Tehran, Iran

[*] *Corresponding author*: Assistant Professor, Department of Health in Disasters and Emergencies, Health Human Resources Research Center, School of Management and Medical Informatics, Shiraz University of Medical Sciences, Shiraz, Iran. Tel: +98-7132340776, Fax: +98-7132340039, Email: peyravi110@gmail.com

Received 2018 December 05; **Revised** 2019 May 15; **Accepted** 2019 May 18.

Abstract

Background: The emergency department is the entrance gate of patients to a hospital. Hospitals are confronted with major challenges in radiation, nuclear accidents, and nuclear terrorism. Iran is also at risk of disasters, accidents, and threats, so, the possibility of nuclear and radiation accidents cannot be neglected.
Objectives: The present study aimed to extract the effective factors in emergency department preparedness of hospitals for radiation, nuclear accidents, and nuclear terrorism in Iran.
Methods: This qualitative study was conducted using in-depth semi-structured interviews with 32 key informants selected through purposive and snowball sampling. Experts were from seven different specialties. Data were analyzed using the thematic analysis method in order to extract the effective factors in emergency department preparedness of hospitals for radiation, nuclear accidents, and nuclear terrorism in Iran in 2019. The interviews were held in the cities of Bushehr, Tehran, Shiraz, and Isfahan from September 2018 to February 2019.
Results: Effective factors in emergency department preparedness of hospitals were categorized into staff preparedness, equipment preparedness, and system preparedness with 20 subcategories. The experts emphasized that training courses and exercises could enhance the preparedness and response to these accidents.
Conclusions: This study showed that the emergency departments of hospitals in Iran have many challenges. When the country moves towards having nuclear technology, must also provide the infrastructure of the preparedness. There must be an attempt to reduce these challenges by providing financial and structural support. Identifying effective factors in preparation can be helpful in setting up programs for emergency department preparedness of hospitals against nuclear and radiation accidents.

Keywords: Accident, Emergencies, Disaster, Emergency Department, Hospital, Iran, Nuclear, Preparedness, Qualitative Research, Radiation, Radioactive Hazard Release, Terrorism

1. Background

Today, as the use of nuclear technology has spread in various industries throughout the world, the risk of nuclear accidents and damage has also increased (1). In recent years, the risk of terrorist attacks and accidental radiation has been on the rise, as well. Many countries in the world spend millions of dollars to fight terrorism. Preparedness is an important part of the crisis management cycle; thus, prior planning is required for any crisis management. In today's world, we need to realize and understand theoretically the issues of nuclear weapons so that an appropriate response is taken during such accidents (2).

Radiation emergencies possibly occur at any time; Therefore, all countries must prepare for such an emergency. In particular, after the Chernobyl nuclear power-

house accident in 1986, significant national and international advances have been made in response to these accidents. Fukushima disaster made it a topical issue again to consider the preparedness. Radiation emergencies can cause devastating effects not only through accidents but also through nuclear terrorism. Handling these challenges requires necessary measures to be taken to protect the facilities against malicious and illegal actions and accidents, as well as public health. The safety and security actions have common goals and the systems must complement each other to reach the defined goals. Therefore, a coordinated approach is essential in nuclear safety and security (3). Hospitals should train decontamination teams and design decontaminated areas with special showers and proper ventilation systems. These hospitals also require anti-doping; otherwise, they must already be coordinated with other hospitals and supplying centers (4).

Although many disasters such as storms and tornadoes may occur abundantly, nuclear and chemical accidents pose destructive effects on many health centers and have a very wide psychological impact on hospital staff. In the event of Fukushima Dai-Chi, there was a hospital near the accident site; many of its staff, in particular, the doctors, left the hospital, which caused problems in providing services to patients. From the moral perspective, functional roles in complex situations such as radiation accidents should be understood well by doctors and nurses (5). Studies show that awareness in response to radiation accidents is very weak in the medical community, and they are much worried about dealing with these patients (6). Holding exercises and educational programs for the staff is an appropriate response to these accidents (7).

The emergency department is the entrance gate of patients to the hospital. Hospitals are confronted with major challenges in radiation, nuclear accidents, and nuclear terrorism. As Iran is at risk of disasters and other types of threats, nuclear and radiation accidents are likely to occur. Knowing the factors influencing the radiation accident preparedness is a must in every society; the experts' views of these accidents can reflect the importance of this issue. Studies conducted so far have focused on the existing defaults (established standards), but it is necessary to recognize and review these factors with regard to the context of each society and the opportunities and threats of that society and according to the views of individuals and experts. The innovation of this study is that interviews were held with a wide range of specialists from different fields who had experience of working with radiation patients, had high knowledge of the subject, and were from various organizations.

2. Objectives

The present study was conducted using a qualitative content analysis approach with the aim of extracting effective criteria of emergency department preparedness in a hospital for radiation and nuclear accidents and nuclear terrorism in Iran by interviewing the experts.

3. Methods

This study was conducted using a descriptive qualitative method in 2019. Data were collected through interviews with specialists and key informants. The thematic analysis method was used to analyze the data and extract effective criteria of emergency department preparedness in hospitals for radiation and nuclear accidents and nuclear terrorism in Iran. The experts were selected from Bushehr, Tehran, Shiraz, and Isfahan to be interviewed from September 2018 to February 2019.

3.1. Participants

In-depth semi-structured interviews were held with experts in the emergency medicine specialty, nuclear engineering, nuclear medicine, medical physics, health in disasters, passive defense, radiobiology, and radiation protection. Data analysis was conducted using the thematic analysis method. It was not possible to find experts experienced in both radiation issues and hospital emergencies, and in the area of crisis and disasters, as well as in nuclear and nuclear emergencies. The data were extracted from interviews with specialists working at governmental and non-governmental centers. However, many of these people worked at universities and research/therapeutic centers. Therefore, the interviews with different people were conducted by the triangulation technique. Based on the knowledge of experts, we looked for the factors influencing emergency department preparedness. The viewpoint of the individuals was analyzed based on science and awareness.

The inclusion criteria included the holders of master's or general medicine degrees, work experience in hospitals, health centers or emergency hospitals, or managerial work in crisis management, having executive records and related studies, and willingness to participate in the study. If any of the experts, before or during the interview, was not willing to participate, they would be excluded from the study.

A purposive and snowball sampling method was used in this study; that is, each specialist introduced the next specialist. Individuals who met the inclusion criteria were identified. Then, the interviews were held after explaining

the goals and relevance of the study to the individuals, obtaining their consent, and making an appointment at the right time. Numbers #1, #2, etc. were used to name the subjects. The names of people were not included in the demographic forms.

3.2. Data Collection

In-depth semi-structured interviews were conducted with individual experts. The interviews were conducted face-to-face or by telephone. Using open and semi-structured questions, the experts were asked to talk about the emergency preparedness of hospitals for radiation accidents. The experts were asked the following semi-structured questions: (1) "In your opinion, at the time of accidents and disasters, in which aspects is the hospital emergency most vulnerable?" (2) "What do you think should happen in the emergency department of hospitals before radiation incident?" and (3) "In your opinion, which factors affect the emergency preparedness of hospitals in nuclear and radiation accidents?" Probing questions like "How", "Why" and "can you tell me more about …?" were also asked during the interviews.

In addition, when talking about the subject under discussion, several other aspects of the interviewees which were raised during the dialogue were examined. Moreover, other probing questions were asked. In total, 35 interviews were conducted with 32 specialists. The interviews continued until data saturation. Each interview lasted about 30 to 75 minutes. The mean length of each interview was 54 minutes. Two experts refused to participate in the study for security reasons. During the study, an expert dropped the interview due to the lack of time. The interviews were conducted by the researcher. In order to prevent possible bugs in the voice recording of the experts, the interviews were recorded by two recorders and immediately implemented.

3.3. Data Analysis

The data analysis was done during data collection. All interviews were transcribed verbatim immediately after recording. The researchers also took notes during the interviews. Two researchers coded the data. Thematic analysis was used for data analysis. This analysis consists of six steps: (A) familiarity with the data (and extracting concepts from items): immersion in the data and frequent readout of the data were done actively; (B) creation of initial codes (or assigning a code to each of the concepts and their main and minor categorization): primary codes were extracted from the text and data. Hierarchical coding was used for encoding the data. The hierarchical method was actually used for categorization and classification. The encoding was done manually; (C) search for themes: categorizing different codes was done in the form of potential themes and sorting all data summaries in the form of specified themes. In this stage, the analysis of the codes started; (D) review of classes, subclasses, and themes: in this stage, reviewing the codes of classes and subclasses was performed regarding the dataset; (E) definition and naming of classes, subclasses, and themes: defined classes and subclasses were analyzed again to determine which aspects of data and subclasses were included in each class; (F) preparation of the report: the final analysis and reporting were done (8). If necessary, the interviews were given to the individuals to correct or add, if they had any problems. Finally, interview transcripts were analyzed manually, code and themes were categorized, and classes and subclasses were extracted. After analyzing the interview transcripts, 214 codes were finally extracted, which were classified into three classes and 20 subclasses by removing duplicate codes and re-analyzing.

3.4. Rigor

Guba and Lincoln's criteria were applied to ensure the accuracy of the qualitative data, as follows (9).

- Trustworthiness: It is the same as internal validity, meaning that contributors and experts believe that the meaning given to conditions or position or the reality of the findings is related to their own social context. This was ensured by long-term conflict and direct observation, reviewing by colleagues, reviewing by contributors, self-reviewing by researchers, using the triangulation technique, and researcher credibility.
- Transformability: It is equivalent to external validity; it means that the results of the study are transmitted in the same situation or similar contributors. The researchers achieved this goal by providing more details about contributors and using special encoding procedures.
- Dependability: It is equivalent to reliability and means how much the results and findings of the interviews are reliable. The researchers achieved this by thinking on the data stability and providing complete details on the interviews.
- Conformability: It is used to confirm the findings. To achieve conformability, the objective indicator was used in the study. This means that a number of interview transcripts were provided to methodologists and researchers who were familiar with qualitative studies to ensure the accuracy of the analysis process.

3.5. Ethical Considerations

The researchers obtained a recommendation letter from the Vice-Chancellor for Research of the Faculty along with approval from the Shiraz University of Medical Sciences with code IR.SUMS.REC.1397.808, presenting them to

the research units. By introducing themselves to the contributors and explaining the purpose of the study, as well as ensuring them that all recordings during the interviews would remain confidential, the researchers selected participants who were willing to participate in the study. Meanwhile, participants were assured that they could withdraw from the interview process at any stage.

4. Results

Of the 32 participants, 23 were men. Their mean age was 43.96. The demographic and occupational characteristics of the participants are shown in Table 1.

Table 1. Demographic and Occupational Characteristics of the Contributors

	No. (%)
Gender	
Male	23 (71.87)
Female	9 (28.12)
Level of education	
Doctor of philosophy	17 (53.12)
Specialist physician	12 (37.5)
Master of science	3 (9.37)
Field of study	
Emergency medicine	8 (25)
Medical physics	7 (21.87)
Health in disasters and emergencies	6 (18.75)
Nuclear medicine	4 (12.5)
Nuclear engineering	3 (9.37)
Passive defense	3 (9.37)
Radiobiology and radiation protection	1 (3.12)

The factors affecting the emergency department preparedness in hospitals for radiation and nuclear accidents and nuclear terrorism in Iran were categorized into three main domains: staff preparedness, stuff preparedness, and system preparedness. The frequency and percentage of subclasses are given in Table 2.

4.1. Staff Preparedness

Staff preparedness is one of the most important components of an effective response to radiation accidents. Staff preparedness included six subcategories: education, the safety of the loved ones and family, knowledge and awareness, staff security, psychological preparedness, and triage and decontamination.

Emergency staff and emergency equipment of hospitals are not prepared for radiation terrorist accidents.

Table 2. Categories and Subcategories Obtained from Interviews with Participants to Extract Effective Criteria in the Preparedness of Hospitals for Radiation and Nuclear Accidents and Nuclear Terrorism in Iran

Category	No. (%)
Staff preparedness	
Education	26 (9.21)
Support, safety, and communication with family and loved ones	3 (1.06)
Awareness and knowledge	10 (3.54)
Staff security	7 (2.28)
Mental health needs of staff and patients and the presence of psychologists	5 (1.77)
Triage and decontamination teams	13 (4.60)
Stuff preparedness	
PPE (personal protective equipment)	21 (7.44)
Radiation detectors	23 (8.15)
Antidotes	18 (6.38)
Decontamination equipment	19 (6.73)
Air purifier	3 (1.06)
Medications	24 (8.51)
System (structure) preparedness	
Training and exercise	25 (8.86)
Incident command system	9 (3.19)
Response plan to disasters	15 (5.31)
Security	9 (3.19)
Internal and external coordination	16 (5.67)
Information and communication	19 (6.73)
Waste and sewage management	11 (3.90)
Allocating a place inside or outside the emergency department	6 (2.1)

The participants' concerns were categorized into six categories: (1) Hospital overwhelming, (2) Safety of the loved ones and family, (3) Possible staff, (4) Lack of preparedness, (5) Contamination, and (6) Self-protection.

Experts considered education as a very important principle of preparedness. If continuous training programs are held for all emergency department staff, their knowledge and awareness will increase about these accidents. Many key informants pointed out that the main problem in preparedness is the lack of training courses:

A 43-year-old man, an emergency medicine expert said: "Unfortunately, hospitals hold no or very few training courses on radiation accidents for their staff. This is important in that the staff do not expose themselves to these risks. In addition, they should get familiar with various syndromes that occur after radiation, such as acute radiation syndrome" (P. 2).

4.2. Stuff Preparedness

According to the participants' statements, stuff/facility preparedness includes six subclasses personal protective equipment (PPE), radiation detectors, antidotes, air purifier, decontamination device, and medications.

Preparedness for dealing with patients exposed to radiation needs the self-defense of emergency department staff. The whole emergency department staff should be trained to wear PPE correctly and fast, and there must be an appropriate number of the trained staff in emergency departments. Moreover, they should be aware of the different types of PPE and their applications. Different detectors such as personal detectors, dosimeters, film badges, ionization chambers, Geiger-Muller counters, and scintillation counters should also be available in emergency departments. A summary of the remarks of experts is given below.

A 52-year-old woman, a medical physics expert, said: "I visited various hospitals, but I did not see Geiger-Muller counters for measuring environmental radiation. All emergency departments should also have environmental dosimeters that should be calibrated continuously. Of course, there should be dosimeters based on the type of radiation in different types. If a nuclear accident causes high exposure to radiation, the dose should be estimated biologically" (P. 15).

4.3. System and Structure Preparedness

System and structure preparedness included eight subclasses including incident command system, disaster plan, security, acceptance capacity, inter-sectoral coordination, waste and sewage management, information and communication, and space creation. Experts argued that training the staff will be more practical by doing exercises. Disaster plan and HICS should also be set up in emergency departments to achieve the main goal that is an appropriate response to the accident and maintenance of the safety of the staff by the unity of the command and effective use of resources. Information should also be provided from authorized centers, and any information and news that reach emergency departments should be validated. Various channels should exist to communicate with inside and outside the hospital. New communication technologies should also be used, such as the Internet of objects (IOT), cyberspace, and hotline. Emergency departments security must be provided with control and supervision of protection and security staff.

Experts stated that in order to respond appropriately to radiation and nuclear accidents, there should be multilayer communication and intra-hospital coordination among various units of the hospital with the emergency department, as well as among related organizations such as the police, the Atomic Energy Agency, and Operations Guidance Center.

A 39-year-old man, a health in disasters expert, said: "When these accidents happen, in order to deliver good services, a desirable coordination must be provided before the accident among relief organizations, Atomic Energy Agency, fire stations, emergency departments, the Red Crescent, and especially the police" (P. 1).

5. Discussion

This is the first qualitative study about the emergency department preparedness in hospitals concerning radiation and nuclear accidents and nuclear terrorism in Iran. No qualitative study has been conducted in this regard in Iran; however, a few international studies are found. This study provides a comprehensive overview to be used by experts and readers about the issue of preparedness for these accidents. Considering the fact that the key informants in this study were from a wide range of specialties, the preparedness for radiation accidents was examined in different aspects. All experts agreed that preparedness was much more important than other crisis and disaster management phases. According to key informants, very good measures are taken in Iran; however, special plans and coordination are required relative to other disasters and accidents. In order to provide an appropriate response to radiation and nuclear accidents, all the emergency department staff must work in harmony together.

The study of Becker and Middleton (10) on the preparedness of nurses and physicians during radiological terrorist attacks showed that the staff and emergency equipment of hospitals were not prepared for radiation terrorist accidents. The participants' concerns were categorized into six groups: (1) Overwhelming of the hospital; (2) Safety of the loved ones and family; (3) Staff challenges; (4) Lack of preparedness; (5) Contamination; and (6) Self-protection. Many of the extracted factors in the mentioned study were similar to those of the present study. Because of the significance of preparedness, countries where radiation accidents already happened are relatively more prepared because they have real experiences about these accidents. However, due to the lack of precise information about nuclear and radiation accidents in Iran, it is not possible to interpret this information accurately.

At the time of the accident, emergency department staff are worried about their families and loved ones, which causes them not to have enough focus on caring for the injured (6, 11, 12). Experts stated that the staff should be able to communicate with their families either face-to-face or

by phone, and be aware of their conditions; thus, they can perform their duties properly.

Many people move toward emergency departments after radiation and nuclear terrorist accidents while they many fears of being contaminated with radiation. The permanent presence of a psychologist in the emergency department can calm the atmosphere (4, 13, 14). The emergency department staff might also experience undesirable psychological symptoms. The psychological effects of radiation on the response forces and medical staff depend on various factors such as personality traits and ability to cope with stress. The results of the study indicated that the presence of psychologists can play an important role in calming the injured and treatment staff and the psychologist can provide counseling and guidance for people with psychological disorders or even healthy people who are scared.

The formation of rapid reaction teams that are already coordinated is very effective in encountering these accidents. The hospital crisis committee should hold constant systematic training courses on radiation and nuclear accidents for all emergency department staff (6, 15-17). Training and exercise were the most frequent factors expressed by the specialists to improve the readiness, which indicate the great importance of these two factors in preparedness. If the staff's awareness and knowledge of dealing with the injured or the circumstances of the radiation accident are high, their safe behaviors will enhance.

Several teams in the emergency department have to be formed to respond properly to radiation and nuclear accidents, including the victim delivery and transfer team, surveillance and triage team, emergency preparation team, para-clinical service team, a team for decontaminating the spaces and stuff, and a team for handling contaminated corpses (18, 19). In some cases, the collaboration of specialized teams outside the hospital may be useful.

The members of nuclear triage and decontamination teams should be determined separately in the emergency department. As much as possible, the members of this team should not be part of the emergency department and should be formed independently (13, 20, 21). The formation of decontamination and triage teams can be more effective in responding effectively to these accidents. Given that triage in radiation and nuclear accidents is different from that in normal conditions, the triage teams should try to be trained, equipped, and always ready. Participation in maneuvers is effective in increasing the performance of these teams.

Radiation detectors such as Geiger-Muller counters, scintillation counters, personal dosimeters, and personal protective equipment should be available in emergency departments. In addition, the whole emergency department staff should be trained to wear the PPE properly (6, 22, 23). The amount of radiation received by the person is quickly measured with detectors and treatment is prioritized according to the amount of radiation received. The required drugs and chelating agents in emergency departments should be available in advance because the immediate treatment of the injured individuals is in high priority (4, 6, 20, 24). Many experts emphasized the process of decontamination and self-protection. When radiation-exposed people are admitted to the hospital, the decontamination process should start immediately. Throughout this period, the staff should use appropriate PPE to prevent themselves from contamination. For preventing the contamination of the staff and hospital infrastructures, the contaminants should be removed outside the emergency department or at the emergency department entrance door to prevent the patients and the injured from entering the hospital and limiting the secondary contamination of the wards.

Emergency departments must continuously exchange information of the accident with the Operations Control Center and Hospital Crisis Committee, which is a rich source of information and receives valid information instantly from responsive organizations. During such accidents, it is important to have quick access to additional information. For example, the distance to the hospital and the type of radiation should be considered. Information sources can also be obtained from the fire department, EMS, and the local police. Launching hotlines helps quickly transfer the information between the commanders.

The most important component of preparedness in radiation accidents is maneuvering and training. Exercises should be done periodically at least two times a year in order to increase the preparedness of the staff. Tabletop training is the most accurate and low-cost type of training. However, real training is costly and people respond realistically to hypothetical accidents (4, 13).

Incident Command System (ICS) is a system for the efficient use of resources and coordination of the services in accidents. ICS must be established in emergency departments before the occurrence of accidents and the responsibilities of each section should be identified. ICS makes it possible for the unit command, common language, efficient use of resources and facilities, and unity of the command to handle the accident (21).

Different spaces are required including a place to wear personal protective equipment, ambulance station and victim delivery, inspection area and the injured triage, a space for treatment of non-contaminated radiation area, contaminated space, decontamination area, showers for the outpatient injuries, equipment collection area and the contaminated waste, a place to handle the worried healthy

people, showers for the outpatient ward and bathroom for the medical staff at the emergency department (18, 25). These spaces should be set up during the preparation phase.

The emergency department of the hospital is at risk of radiation and nuclear accidents, and the best way to prevent contamination is to investigate, and accurately monitor the situation. Hospital emergency departments are the gateways for the patients' entrance to the hospital and, if the appropriate follow-up measures are not taken, there is a possibility of contamination of other sections. Humans are the most important resources in the emergency departments of hospitals. However, most studies have focused on teaching, training, PPE, radiation detectors, and response plans to disasters because these factors are of the main areas of preparedness for disasters and accidents. All crisis management phases require a comprehensive and complete plan, but usually, the measures taken prior to the accident are more important and have the most protective effect in the accidents (26, 27). Surge capacity is one of the most important measures to increase preparedness when exposed to radiation accidents. Usually, 20% of the hospital emergency capacity is devoted to critical situations. Therefore, the emergency department staff should be familiar with methods and approaches to increase surge capacity (28). Experts stated that although significant progress has been made regarding the preparedness of emergency department hospitals in Iran, there are still many obstacles and challenges.

In response to radiation accidents, coordination and collaboration between and within the organizations are required. Therefore, prior to the accident, there should be appropriate coordination between the trustees in handling such accidents. Policymakers should pay more attention to the issue of radiation and nuclear accidents because such accidents may occur in any place and at any time. The government's financial support can solve many problems in equipping and preparing emergency departments in hospitals. Several studies have reported relatively similar factors in terms of preparedness for radiation accidents. The results of this study could be used to develop a comprehensive tool for assessing the emergency preparedness of hospitals for radiation, nuclear accidents, and nuclear terrorism.

Like many other studies, this study also had some limitations such as inability to interview all the key informants, especially nuclear specialists, for security reasons. For this reason, the available people were interviewed. It was also tried to have a good relationship with contributors by persuading and making mutual interactions. For future research, it is suggested that interviews be held with health and medical staff who are in contact with patients and are exposed to radiation.

This study has several implications, the first of which is assigning special training for preparing the staff as the most important component of preparation; the second is preparing and setting up guidelines and instructions for all emergency department staff; the third is that all efforts for preparing the emergency department must be made before the accident; and the fourth is that all the components of preparedness are interrelated; hence, integrity in preparation must be provided.

This study showed that the emergency departments of Iranian hospitals have many challenges. When we move toward nuclear technology, we must also provide the infrastructure of preparedness. There must be an attempt to reduce these challenges by considering financial and structural support. Identifying effective factors in preparation can be effective in setting up programs for emergency department preparedness of hospital against nuclear and radiation accidents. Additionally, due to the extracted factors, the emergency departments of hospitals can be more equipped to deal with these accidents. In order to provide an appropriate response to radiation and nuclear accidents, we must develop all the components of preparedness in a coordinated and coherent manner.

Acknowledgments

This paper was extracted from a Ph.D. dissertation written by Milad Ahmadi Marzaleh in the field of Health in Disasters and Emergencies, which was approved and financially supported by the Shiraz University of Medical Sciences, Shiraz, Iran (Grant No. 97-01-07-17271).

Footnotes

Authors' Contribution: Mahmoudreza Peyravi, Rita Rezaee, Abbas Rezaianzadeh, Mahnaz Rakhshan, Gholamhossein Hadadi, and Milad Ahmadi Marzaleh were responsible for the study conception and design. Mahmoudreza Peyravi, Rita Rezaee, Abbas Rezaianzadeh, Mahnaz Rakhshan, and Gholamhossein Hadadi supervised the whole thesis. Milad Ahmadi Marzaleh and Rita Rezaee prepared the first draft of the manuscript. Rita Rezaee, Mahmoudreza Peyravi, and Milad Ahmadi Marzaleh conducted the data analysis, made a critical revision to the paper for important intellectual content, and supervised the study. All authors read and approved the final manuscript.

Conflict of Interests: The authors have no conflicts of interest to declare.

Ethical Approval: The researchers presented approval obtained from the Shiraz University of Medical Sciences with code IR.SUMS.REC.1397.808 to the research units.

Funding/Support: This project was supported in part by a grant from the Shiraz University of Medical Sciences with the code 97-01-07-17271.

Patient Consent: Informed consent was obtained from all individuals participating in the study.

References

1. Davari F, Zahed A. A management plan for hospitals and medical centers facing radiation incidents. *J Res Med Sci*. 2015;**20**(9):871–8. doi: 10.4103/1735-1995.170615. [PubMed: 26759575]. [PubMed Central: PMC4696373].
2. Aggrawal A. Terrorism: Nuclear and biological terrorism. *Encycl Forensic Legal Med (Second Ed)*. 2016:533–44. doi: 10.1016/b978-0-12-800034-2.00374-8.
3. Mustonen R. *Preparedness and response to radiological emergencies*. Finland: Radiation and Nuclear Safety Authority (STUK); 2018.
4. Moore BL, Geller RJ, Clark C. Hospital preparedness for chemical and radiological disasters. *Emerg Med Clin North Am*. 2015;**33**(1):37–49. doi: 10.1016/j.emc.2014.09.005. [PubMed: 25455661].
5. Narita M, Tokuda Y, Barnett P. Professionalism of physicians at a major teaching hospital during the Fukushima nuclear disaster. *QJM*. 2016;**109**(7):447–8. doi: 10.1093/qjmed/hcw063. [PubMed: 27121040].
6. Dallas CE, Klein KR, Lehman T, Kodama T, Harris CA, Swienton RE. Readiness for radiological and nuclear events among emergency medical personnel. *Front Public Health*. 2017;**5**:202. doi: 10.3389/fpubh.2017.00202. [PubMed: 28868272]. [PubMed Central: PMC5563314].
7. Jackson MA. *Emergency preparedness for a radiological disaster: Davis-besse nuclear power plant release*. Dayton, Ohio: Wright State University; 2015.
8. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol*. 2006;**3**(2):77–101. doi: 10.1191/1478088706qp063oa.
9. Schwandt TA, Lincoln YS, Guba EG. Judging interpretations: But is it rigorous? trustworthiness and authenticity in naturalistic evaluation. *N Directions Eval*. 2007;**2007**(114):11–25. doi: 10.1002/ev.223.
10. Becker SM, Middleton SA. Improving hospital preparedness for radiological terrorism: perspectives from emergency department physicians and nurses. *Disaster Med Public Health Prep*. 2008;**2**(3):174–84. doi: 10.1097/DMP.0b013e31817dcd9a. [PubMed: 18813129].
11. Rassin M, Avraham M, Nasi-Bashari A, Idelman S, Peretz Y, Morag S, et al. Emergency department staff preparedness for mass casualty events involving children. *Disaster Manag Response*. 2007;**5**(2):36–44. doi: 10.1016/j.dmr.2007.03.002. [PubMed: 17517361].
12. Veenema TG, Lavin RP, Bender A, Thornton CP, Schneider-Firestone S. National nurse readiness for radiation emergencies and nuclear events: A systematic review of the literature. *Nurs Outlook*. 2019;**67**(1):54–88. doi: 10.1016/j.outlook.2018.10.005. [PubMed: 30579562].
13. Lim HCS, Ng KS, Tan HH, Leong KWG. Hospital preparedness for radiation emergencies and medical management of multiple combined radiation injury victims. *Proc Singapore Healthcare*. 2011;**20**(3):197–207. doi: 10.1177/201010581102000309.
14. Bauer MW, Gylstorff S, Madsen EB, Mejlgaard N. The Fukushima accident and public perceptions about nuclear power around the globe – a challenge and response model. *Environ Commun*. 2018;**13**(4):505–26. doi: 10.1080/17524032.2018.1462225.
15. Hung KKC, Lam ECC, Wong MCS, Wong TW, Chan EYY, Graham CA. Emergency physicians' preparedness for CBRNE incidents in Hong Kong. *Hong Kong J Emerg Med*. 2017;**20**(2):90–7. doi: 10.1177/102490791302000204.
16. Kosai S, Yamasue E. Recommendation to ASEAN nuclear development based on lessons learnt from the Fukushima nuclear accident. *Energy Policy*. 2019;**129**:628–35. doi: 10.1016/j.enpol.2019.02.058.
17. Kim TY, Lee K, Lee U, Chung SW, Ha SH, Chae S. Development of a radiological training scenario for local government staff in the case of a radioactivity release accident at a nuclear power plant. *J Korean Soc Hazard Mitigation*. 2019;**19**(1):361–71. doi: 10.9798/kosham.2019.19.1.361.
18. Schleipman AR, Gerbaudo VH, Castronovo FP Jr. Radiation disaster response: Preparation and simulation experience at an academic medical center. *J Nucl Med Technol*. 2004;**32**(1):22–7. [PubMed: 14990671].
19. Mizoguchi M. Challenges of agricultural land remediation and renewal of agriculture in iitate village by a collaboration between researchers and a non-profit organization. In: Nakanishi T, O'Brien M, Tanoi K, editors. *Agricultural implications of the fukushima nuclear accident (III)*. Singapore: Springer; 2019. p. 177–90. doi: 10.1007/978-981-13-3218-0_16.
20. Mortelmans LJM, Gaakeer MI, Dieltiens G, Anseeuw K, Sabbe MB. Are Dutch hospitals prepared for chemical, biological, or radionuclear incidents? A survey study. *Prehosp Disaster Med*. 2017;**32**(5):483–91. doi: 10.1017/S1049023X17006513. [PubMed: 28478772].
21. Mitchell CJ, Kernohan WG, Higginson R. Are emergency care nurses prepared for chemical, biological, radiological, nuclear or explosive incidents? *Int Emerg Nurs*. 2012;**20**(3):151–61. doi: 10.1016/j.ienj.2011.10.001. [PubMed: 22726947].
22. Mortelmans LJ, Van Boxstael S, De Cauwer HG, Sabbe MB, Belgian Society of E, Disaster Medicine S. Preparedness of Belgian civil hospitals for chemical, biological, radiation, and nuclear incidents: Are we there yet? *Eur J Emerg Med*. 2014;**21**(4):296–300. doi: 10.1097/MEJ.0000000000000072. [PubMed: 23978957].
23. Aguiar Torres L, Dos Santos Rodrigues A, Linhares D, Camarinho R, Nunes Pascoa Soares Rego ZM, Ventura Garcia P. Buccal epithelial cell micronuclei: Sensitive, non-invasive biomarkers of occupational exposure to low doses of ionizing radiation. *Mutat Res Genet Toxicol Environ Mutagen*. 2019;**838**:54–8. doi: 10.1016/j.mrgentox.2018.12.009. [PubMed: 30678828].
24. Nishikawa Y, Kohno A, Takahashi Y, Suzuki C, Kinoshita H, Nakayama T, et al. Stable iodine distribution among children after the 2011 fukushima nuclear disaster in Japan: An observational study. *J Clin Endocrinol Metab*. 2019;**104**(5):1658–66. doi: 10.1210/jc.2018-02136. [PubMed: 30535265]. [PubMed Central: PMC6441009].
25. Dorr HD, Meineke V. Appropriate radiation accident medical management: necessity of extensive preparatory planning. *Radiat Environ Biophys*. 2006;**45**(4):237–44. doi: 10.1007/s00411-006-0068-x. [PubMed: 17047978].
26. Brevard SB, Weintraub SL, Aiken JB, Halton EB, Duchesne JC, McSwain NE Jr, et al. Analysis of disaster response plans and the aftermath of Hurricane Katrina: Lessons learned from a level i trauma center. *J Trauma*. 2008;**65**(5):1126–32. doi: 10.1097/TA.0b013e318188d6e5. [PubMed: 19001986].
27. Djalali A, Castren M, Khankeh H, Gryth D, Radestad M, Ohlen G, et al. Hospital disaster preparedness as measured by functional capacity: A comparison between Iran and Sweden. *Prehosp Disaster Med*. 2013;**28**(5):454–61. doi: 10.1017/S1049023X13008807. [PubMed: 23962358].
28. Kaji AH, Lewis RJ. Hospital disaster preparedness in Los Angeles County. *Acad Emerg Med*. 2006;**13**(11):1198–203. doi: 10.1197/j.aem.2006.05.007. [PubMed: 16885400].