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A qualitative study on preparedness requirements for responding to chemical, biological, radiological, and nuclear incidents in Iran

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Abstract

Background and purpose The sudden increase in the number of exposed individuals, diverse injuries, damage to health equipment, and disruptions in health services highlight the need for a structured response to radiological and nuclear incidents. This study aims to identify the requirements for responding to CBRN incidents in Iran. This research contributes to a deeper understanding of the complexities involved in CBRN preparedness and response in Iran, highlighting areas for potential improvement and policy development.

Methodology This qualitative research conducted in 2023 involved semi-structured interviews with 32 specialists selected through purposive sampling until data saturation was reached. Thematic analysis was employed to analyze the data.

Findings The requirements for responding to CBRN incidents were categorized into three main classes with nine subcategories:

Training Effective training content, establishment of specialized training centers, identification of target audiences, educational needs assessment, and continuous education.

Drills Implementation of various operational drills and their content.

Emergency response planning Elements of response plans and evaluation of these plans.

Conclusion Timely and appropriate responses from the health system during critical phases after such incidents are crucial for mitigating adverse health effects. This study provides insights into the necessary requirements for enhancing readiness in the health sector as Iran progresses towards adopting modern technologies.

Keywords CBRN incidents, Emergency response, Qualitative analysis, Iran, Public safety

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Introduction

Preparedness is a vital component of disaster management [1]. Pre-planning is essential due to the high stakes involved in nuclear incidents. Hospitals must utilize trained personnel to respond effectively as teams during such emergencies [2]. Responders face dangerous and stressful situations that impact their physical and mental health; hence, prior planning can reduce negative impacts and facilitate appropriate decision-making [3]. The Centre for Research on the Epidemiology of Disasters (CRED) has published its latest report for 2023, which highlights that 399 natural disasters have occurred worldwide, resulting in 86,473 fatalities. These disasters have affected 93.1 million people, causing over $202.7 billion in damages to different communities [4]. Disasters, accidents, pandemics, and terrorist attacks can rapidly escalate medical needs. Chemical/biological/nuclear incidents may occur via terrorist attacks or due to noncompliance with safety standards in radiological equipment. Such events can lead to various traumas and acute radiation syndromes requiring coordinated management at multiple levels [5]. From 1944 to 2018, there were 407 civilian radiological disasters worldwide resulting in injuries and fatalities. Notable historical events include the bombings of Hiroshima and Nagasaki during World War II and the Chernobyl disaster in 1986 [6]. Reports indicate that while national response structures exist, only 50% have comprehensive standard operating procedures (SOPs) due to varying performance during COVID-19. The pandemic highlighted gaps in training and resources that hindered hospitals' abilities to maintain normal operations [7]. To enhance readiness for CBRN incidents:

- Establish structured training programs for emergency staff.
- Conduct regular drills to practice responses.
- Develop comprehensive emergency response plans involving all relevant organizations [7].

For effective, timely, and impactful responses to incidents, it is essential that response structures not only have the appropriate equipment but also possess the necessary knowledge to utilize these tools effectively. Undoubtedly, the knowledge and awareness of rapid response structures are significant factors in adapting to incidents and crises. CBRN incidents lead to substantial human casualties and injuries, thereby increasing the immediate, medium, and long-term medical needs that the affected region cannot adequately meet [8]. This imbalance between needs and capacities can result in a reduction in both the quantity and quality of services provided, as well as existing systemic or operational weaknesses within organizations [9]. The COVID-19 pandemic highlighted that due to a lack of training and resources related to disasters, many hospitals could not maintain normal operations for even a week. Therefore, preparedness for rapid disaster response is a critical global issue [10]. Given the rapid impact of CBRN incidents on society, particularly on health systems, a different approach is required to achieve health response objectives [11]. CBRN factors bring about a wide range of physical, financial, and psychological consequences for communities [12]. Reports on the frequency of CBRN incidents indicate an upward trend in such events [13]. These experiences underscore the need for improved collaboration and coordination, as well as stronger national response capacities to detect, respond quickly, and control major health threats at their source to ensure global health security. The successful response of health systems to CBRN incidents depends on appropriately adjusting organizational and medical priorities to optimize resource use and deploy necessary surplus facilities [13]. This holistic approach will ultimately improve the overall efficacy of responses to CBRN incidents and other emergencies.

Due to Iran's political geography and location in the strategic region of the Middle East, this country has always been affected by crises related to neighboring countries, and man-made disasters such as war, chemical, microbial, and especially nuclear pollution always threaten the country (14, 15). Therefore, conducting a comprehensive study to identify specific requirements and best practices that are contextually relevant to Iran is essential. Such an initiative would facilitate the development of tailored strategies aimed at enhancing the nation's preparedness and response capabilities concerning CBRN incidents. Ultimately, this will contribute to both national and regional safety, fostering resilience against potential CBRN threats.

Studies showed that the average percentage of preparedness of Iranian hospitals in biological incidents is insufficient and weak. Although hospitals had the highest level of preparation in wave capacity management and communication, they had the least preparation in having biological consultants, meeting management, and post-incident recovery [16, 17].

The studies of Yarmohammadian et al. in Iran have demonstrated a low percentage of training received by hospital staff regarding CBRN incidents [18]. the studies of Beikmohammadi et al. (2023) have also shown that In the nuclear and radiological dimensions, the level of hospital preparedness against nuclear and radiological incidents is in average or poor condition [15].

The present study was conducted with the aim of extracting the requirements for responding to chemical, biological, radiological, and nuclear (CBRN) incidents in Iran. This focus is essential given the potential threats posed by such incidents, which can lead to significant

human casualties and increased medical needs that local capacities may struggle to meet. Reports indicate that many health systems worldwide have faced challenges during crises like the COVID-19 pandemic due to insufficient training and preparedness, leading to significant operational disruptions. In conclusion, enhancing the readiness of response structures through comprehensive training programs and strategic planning is vital for effectively managing CBRN incidents. Therefore, the present study was carried out with the aim of extracting the requirements for response to chemical, biological, radiation and nuclear accidents in Iran.

Methodology

This study employed a qualitative approach conducted in 2023. Data were collected through interviews with specialists and experts. Semi-structured in-depth interviews were conducted with 32 professionals selected via purposive sampling. These experts, who had management and operational experience in responding to CBRN incidents, represented various fields. The data analysis utilized thematic analysis to extract the requirements for the response structure to chemical, biological, radiological, and nuclear (CBRN) incidents in Iran. Interviews were conducted with professionals from both governmental and non-governmental sectors, many of whom worked in universities and research or medical centers. To enhance the credibility of the study, a triangulation technique was employed, involving multiple data sources or methods for analysis. The perspectives of participants were analyzed based on their knowledge and awareness.

Inclusion criteria

The study included individuals with experience in providing medical services during past incidents and disasters, those actively involved in large-scale emergencies or disasters in a medical response management role (such as heads of emergency management centers, Red Crescent rescue operation leaders, military medical commanders, and community health service providers). Participants also included volunteers from the Red Crescent and military personnel involved in past incidents, as well as policymakers from the Ministry of Health. Participants had to have relevant operational experience and studies related to the field and a willingness to participate.

Exclusion criteria

The exclusion criteria for this study encompassed individuals who possessed less than two years of experience in medical response to incidents or disasters. Additionally, participants who demonstrated an unwillingness to engage in the study or to provide informed consent were also excluded. Furthermore, it was stipulated that those who opted not to participate could withdraw from the interview and the study at any point.

Sampling and data analysis

The study utilized purposive and snowball sampling methods to identify eligible individuals. After explaining the study's objectives and relevance to potential participants, consent was obtained, and interviews were scheduled at convenient times. Confidentiality was maintained throughout the process. To understand the current state of response processes by organizations involved in CBRN incidents in Iran, a qualitative content analysis approach was applied. In-depth semi-structured interviews were conducted face-to-face. Using open-ended and semi-structured questions, experts were asked to discuss pre-hospital rapid responses to CBRN incidents. The following semi-structured questions were posed:

1) How should the response to a CBRN incident be structured?
2) What challenges do you perceive in responding to a CBRN incident?
3) If you have experience responding to CBRN incidents, could you share your experiences?
4) What factors do you believe are crucial for enhancing preparedness structures for CBRN responses?
5) What preparations and requirements do you think are necessary for improving the response process to CBRN incidents?

Follow-up questions such as: "How?", "Why?", "Can you explain more about…?" were also asked during the interview.

Data analysis occurred concurrently with data collection. All interviews were transcribed verbatim immediately after recording. The researcher also took notes during the interviews. To enhance reliability, two researchers coded the data. For data analysis, a guided content analysis method based on Granheim and Lundman's proposed stages was employed. This method aimed at qualitatively analyzing research content with the goal of interpreting textual data. Through systematic classification, both manifest and latent themes within the text were identified. Following this method, the following steps were undertaken: (1) Transcribing interviews shortly after they occurred; (2) Reading through all interview texts for an overall understanding; (3) Identifying meaning units and extracting initial codes; (4) Classifying similar initial codes into broader categories based on similarities and differences according to a predetermined structure; (5) Determining latent content within the data [19]. Ultimately, after analyzing interview transcripts, 205 codes were extracted which were then categorized

into five main categories and twelve subcategories after removing duplicates. To ensure the trustworthiness of our research, we incorporated Guba and Lincoln's four criteria—credibility, transferability, dependability, and confirmability—throughout the data gathering and analysis processes [20]. Credibility was achieved through member checking and triangulation, ensuring that participants validated our interpretations and that data was collected from multiple sources. For transferability, we provided comprehensive descriptions of the context and participants, allowing readers to assess the applicability of our findings to similar settings. Dependability was maintained by creating a detailed audit trail of the research process, enabling external verification. Finally, confirmability was ensured by grounding our findings in participant quotations and clearly linking the data to our conclusions, thereby minimizing researcher bias and reinforcing the objectivity of our analysis.

Findings

All 32 participants in the study were male, with an average age of 41.36 years (Table 1).

Enhancing preparedness

According to Table 2, enhancing preparedness is one of the most crucial components of rapid response structures for effective engagement in CBRN incidents. This concept consists of three subcategories: **Training**, **Exercises**, and **Emergency Response Programs**. Experts emphasized that training is a fundamental principle for preparedness. Implementing structured and continuous training programs for all emergency department personnel would significantly increase their awareness and knowledge regarding these incidents. Many key informants pointed out that the primary issue in preparedness is the lack of training courses.

Table 1 Demographic and occupational characteristics of the participants

Feature		Number
Gender	Male	32
Education level	PhD	14
	Specialist Physician	6
	Master's degree	5
	bachelor's degree	5
	Associate degree	2
Field of study/ work	Health in disasters and emergencies	12
	Emergency specialist	6
	Neurologist	2
	Medical emergencies	5
	Nursing	4
	Environmental Health	3

Training

Continuous educational programs for all pre-hospital staff are essential to improve their knowledge and awareness of CBRN incidents. Numerous key experts highlighted that the main challenge in preparedness is the absence of training courses. One participant expressed, *"Unfortunately, the pre-hospital system does not conduct training courses on CBRN incidents for its personnel, or if they do, these are very limited. Based on field experiences, conducting such training is crucial to prevent personnel from exposing themselves to these risks and to familiarize them with various syndromes that may arise after such incidents"* $(_{16})$[1]. Another participant noted the need for increased knowledge among staff: *"A significant concern is that many EMS personnel currently in the pre-hospital sector are inexperienced and have not undergone specific training related to this field. When faced with these rare incidents, they become confused. A critical issue during missions is that colleagues do not know what actions to take when encountering a chemical casualty because they lack skills... they haven't attended any courses... they have just graduated. The lack of knowledge, skills, resources, and equipment leads to personnel making arbitrary decisions or working blindly with patients"* (P_1).

Exercises

Increasing preparedness for timely and appropriate responses during incidents and disasters requires comprehensive exercises. Experts stated that the training received by personnel becomes more practical through exercises. One participant remarked, *"Given that CBRN incidents occur infrequently, we should establish a CBRN training center in the pre-hospital sector to enhance our preparedness and make our training more effective"* (P_{15}). Another participant emphasized the importance of experience: *"I have participated in many drills with the Red Crescent and Foundation of Martyrs, experiencing tough conditions; however, most of the individuals deployed with us had not understood or experienced such situations, which caused problems. In disaster scenarios, it takes two or three days for inexperienced individuals to adapt to conditions. This mismatch during the initial days disrupts our performance"* (P_{12}).

Emergency response programs

All participants in the study agreed on the necessity of a written strategic plan that outlines organization, mission, and supportive services for response phases during incidents and disasters. The emergency operations program includes practical response plans during emergencies. One participant noted: *"...when the ammonia leak incident occurred in Firozabad, we wanted to send*

[1] Participant No.

Table 2 Categories and subcategories extracted from interviews

Categories	Subcategories	Codes
Training	Effective training content	Principles of wearing PPE
		Understanding PPE levels
		Principles of PPE removal
		CBRN training topics
		Syndromic approach in initial response
		Health approach to unusual diseases
		Chemical triage principles
		Biological triage principles
		Security considerations
		Tactical mission principles
		Radiological and nuclear triage principles
		Triage principles in MCI
		24-hour reporting principles
		Risk communication principles
		Situation and scene management principles
		Training from call to dispatch
		Logistics management training
		CBRN-based incident command training
		Decontamination training in chemical incidents
		Decontamination training in biological incidents
		Decontamination training in radiological and nuclear incidents
		Decontamination training in MCI
		Familiarization with zoning via software
		Familiarization with physical zoning
	Establishment of Specialized Training Centers	Simulation-based training center establishment
		Clinical approach training center establishment
	Identification of Training Audiences and Needs Assessment	Availability of CBRN training courses for sensitive areas
		Presence of CBRN structures in sensitive areas
		Availability of CBRN training for managers
	Refresher courses for medical centers	Pre-hospital approach
	Continuous Training	Training repetition every six months

Table 2 (continued)

Categories	Subcategories	Codes
Exercises	Implementation of various operational exercises	Decontamination-focused exercises
Exercise Requirements	Exercises with unknown agent scenarios	FULL SCALE exercises
	Tabletop exercises	Functional exercises
	Content Elements of Exercises	Triage content exercises at the scene
		Zoning content exercises
		Agent identification content exercises
		Chemical agent content exercises
		Biological agent content exercises
		Radiological and nuclear agent content exercises
	Exercises with PPE	Focus each exercise on a specific CBRN branch
		Exercises based on existing threats
		Exercises in sensitive areas of the country
	Emergency Response Program	Program Elements
		Existence of Contingency Plans
		EMS as Pre-Hospital Sector Authority
		RRT Structure
		Initial Structure Adjustment Based on Incident Type
		Necessity of Deploying Specialists to Scene in MCI
		Existence of Vaccination and Primary Chemoprophylaxis
		Existence of Prevention, Diagnostic, and Treatment Guidelines
		Existence of Responsibilities for Regulatory Organizations
		Increased Mobility through Staff Consolidation
		Existence of Incident Command Post (ICP)
		Existence of Sample Referral Guidelines
		Necessity for MSDS Chemical Substance Identification
		Existence of Protocols for Security Incidents Handling
		Existence of Zoning Guidelines
		Existence of Decontamination Guidelines

forces but did not know if any rescue organizations had already arrived at the scene to gather information from them. When such incidents occur, an appropriate operational plan must be established beforehand focusing on pre-hospital sectors in CBRN events among rescue organizations, the Atomic Energy Organization, fire department, ambulance services, Red Crescent, and especially police" (P_7). Another participant added: *"...considering that we have experienced many incidents here, whenever we wanted to deploy a medical team near the disaster area to initiate rescue and medical actions, the primary risk we faced was environmental contamination due to infected individuals potentially spreading contamination and causing secondary contamination; thus, immediate containment measures must be implemented. For example, we should have isolated aid posts for these individuals or separate locations for trauma victims"* (P_{10}). This comprehensive approach emphasizes the critical need for structured training programs, practical exercises, and strategic emergency response planning to enhance overall preparedness for CBRN incidents.

Discussion

Given that the design of response structures is part of preparedness phase programs, all experts emphasized that preparedness is significantly more critical than other stages of disaster and incident management. However, it is essential to have specific and appropriate planning and coordination for various disasters and incidents. Tsujiguchi and colleagues, in their study examining the lessons learned from Japan and South Korea regarding pre-hospital medical response training for nuclear and radiological incidents, highlighted that effective information gathering and management are crucial for effective response in disaster management, particularly in nuclear incidents. Rapid response and timely medical interventions are vital for increasing the survival chances of victims, with essential life-saving needs needing to be met in the early hours following such incidents [21]. Razak et al. conducted a study in the UK to explore responses to chemical, biological, radiological, and nuclear (CBRN) incidents within emergency units. The study revealed that CBRN incidents present unique hazards, necessitating specialized training and exercises for responders. A significant portion of those responding to these incidents had not received adequate training to identify and operate in contaminated environments resulting from such events [22]. Adopting a coherent educational and training approach in many countries has been recognized as a significant step toward improving the quality and professionalism of deployed teams. The findings of the current investigation indicate that implementing structured and continuous training programs for all emergency department personnel significantly increases their awareness and knowledge about these incidents. Building and enhancing the preparedness capacity of responders before deployment represents an investment by organizations forming response teams [23].

The findings of the present study showed a unanimous consensus on the critical importance of providing comprehensive education to all sectors of the health system regarding essential risk management principles that pertain to disasters and health-related issues during emergencies. This educational initiative aims to foster a cohesive and unified understanding among all stakeholders, ensuring that they are well-prepared to address the complexities and challenges that arise in disasters [24]. In this context, Farhat et al. (2022) noted that rescue teams without pre-established operational plans, clear responsibilities, or necessary equipment led to confusion and chaos among themselves and patients [25]. Another finding based on participant experiences indicated that although guidelines have been developed by the health working group for disasters, there remains a deficiency in training due to a lack of qualified instructors. Accordingly, Jalaei et al. (2014) found that training programs for CBRN response structures are ineffective due to several reasons: (a) training programs do not provide comprehensive skills based on competencies; (b) the quality and quantity of educational programs are insufficient; (c) there are no standard criteria for structuring management training courses for CBRN incidents; (d) there is a limited number of professional trainers available for CBRN incident response training [26]. The findings of the study underscored the crucial importance of establishing a comprehensive strategic plan. This plan clearly outlines the organization's framework, mission, and the essential support services tailored to address different phases of response during incidents and disasters. The emergency operations program is meticulously crafted, incorporating practical response protocols aimed at ensuring efficient management of emergencies. This structured approach not only enhances readiness but also fosters a swift and coordinated response to a variety of unforeseen events. The more frequent, simpler, and more focused the exercises are, the greater their impact [27]. Regularly scheduled additional training exercises can enhance the attitudes, knowledge, and skills of response structures during disasters. Training should be conducted at regular intervals for all levels of the structure. Currently, knowledge about CBRN incidents is recognized as a significant challenge. Local, national, and international communities and organizations must enhance their preparedness for such events [28]. According to a study by Cape Niche (2021) in Japan, these structures are essential at the incident scene; thus, teams have been formed locally with a focus on disaster hospitals to be deployed immediately upon request to affected areas

[29]. In research conducted by Peter Oldenberger et al. (2017), participants suggested a deployment timeframe of 6 to 24 h for domestic and international missions [30]. In another study by Iyama et al. (2021), which introduced a framework for CBRN response structures, a timeframe of 6 to 24 h was also established for the "call to deployment" period for level teams [31]. This discussion underscores the critical importance of structured preparedness initiatives, specialized training programs, effective communication strategies, and timely operational readiness in enhancing overall disaster response capabilities across various contexts.

The findings derived from investigations into chemical, biological, radiological, and nuclear (CBRN) incident response elucidate several critical domains warranting further scholarly inquiry. Key areas for future research include the necessity of exploring adaptable frameworks for preparedness tailored to the diverse range of CBRN incidents. Additionally, there is a pressing need for focused research aimed at the development of specialized training curricula that specifically address the unique hazards associated with CBRN scenarios. Furthermore, such research should encompass an analysis of the competencies essential for effective response, culminating in the establishment of standardized criteria for training programs.

Limitation

Accessing to some key stakeholders, such as government officials or military personnel, was challenging due to political sensitivities. However, we attempted to increase the comprehensiveness of the data by gathering input from more individuals and experts.

Conclusion

The finding of the study emphasizes the critical importance of enhancing preparedness in response to Chemical, Biological, Radiological, and Nuclear (CBRN) incidents, based on the collective experiences of participants who have dealt with such emergencies. This enhancement involves a comprehensive approach categorized into three essential components: Training, Exercises, and Emergency Response Programs. Experts in the field have underscored training as a foundational principle for bolstering the capabilities of responders. Recognizing the necessity for enhanced training and skills development in health responses to CBRN incidents, experts advocate for comprehensive exercises. These exercises are pivotal as they transform theoretical training into practical, real-world applicability. Participants also emphasized that effective response actions must encompass the development of operational plans and processes to guarantee the continuity of key activities during incidents. To maintain continuity in executing operations, missions, or tasks essential for appropriate responses during CBRN events, several specific requirements must be met. These include not only upgrading existing capacities but also improving information and communication systems, refining operational emergency response plans, and fostering both inter- and intra-organizational coordination.

Author contributions

VH, HKK, and SN designed the project, contributed to supervision, and revised and corrected the manuscript. HKK, MA and PN coordinated and helped to draft and finalize the manuscript. SN, HKK, and VH performed data acquisition and interpretation and wrote the manuscript. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study was part of a project supported by the Iranian Red Crescent Society with IR.RCS.REC.1403.027 ethical code. The researchers obtained ethical approval from the Ethics Committee in Research of the Vice-Chancellor of Education, Research, and Technology of the Red Crescent Society of the Islamic Republic of Iran. They introduced themselves to the participants, explained the research's purpose, and assured them of the confidentiality of their information. Participants who agreed to participate in the study were selected and informed consent to participate was obtained from all of the participants in the study. They were informed that they could opt out of the interview process at any stage if they wished to discontinue their participation.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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