



Strategic Dimensions of Risk Management in Dealing with CBRNE Events in Military Hospitals: A Qualitative Analysis with a Policy Approach from the Perspective of Experts

Akbar Javan Biparva ¹, Ali Nasiri^{2,3}, Mazyar Karamali⁴, Taha Nasiri ^{4,5}

¹Student Research Committee, Baqiyatallah University of Medical Sciences, Tehran, Iran; ²Health Management Research Center, Life Style Institute, Baqiyatallah University of Medical Sciences, Tehran, Iran; ³Department of Health in Disasters and Emergencies, Baqiyatallah University of Medical Sciences, Tehran, Iran; ⁴Health Management Research Center, Baqiyatallah University of Medical Sciences, Tehran, Iran; ⁵Department of Health Services Management, Faculty of Health, Baqiyatallah University of Medical Sciences, Tehran, Iran

Correspondence: Taha Nasiri, Health Management Research Center, Baqiyatallah University of Medical Sciences, Tehran, Iran. Department of Health Services Management, Faculty of Health, Baqiyatallah University of Medical Sciences, Tehran, Iran, Tel +098 9122684867, Email dr.tahaf5@yahoo.com

Background: Risk management means identifying, assessing, and controlling risks to reduce and minimize potential negative consequences. Identifying the dimensions and components of risk management in CBRNE incidents creates a systematic and organized format that allows hospitals to act efficiently in the face of various threats, especially CBRNE incidents, and prevent irreparable damage.

Methods: This qualitative study with descriptive exploratory approach was conducted in 2025. Data were collected using semi-structured interviews, purposive sampling, and the participation of 14 experts and officials, and analyzed using the framework analysis method.

Results: In the qualitative study, the dimensions and components of risk management were identified and determined in each stage of the risk management cycle (prevention, preparedness, response, and recovery). So that prevention, preparedness, response, and recovery have 7, 6, 7, and 8 main components, respectively.

Conclusion: Risk management components in CBRNE incidents in military hospitals help reduce response time, secure staff and patients, optimize resources, effectively coordinate teams, and learn from the incident. Through risk assessment, response planning and exercises, logistics management, biosafety and security, information management, ongoing training, and post-event review, this framework leads to adaptation to specific military threats and improves operational efficiency in critical situations.

Keywords: risk management, hazardous substances, biohazard release, chemical hazard release, military hospitals

Introduction

Today, accidents and disasters have taken up a large part of the resources and programs of governments. Every day, the media carries information about various accidents worldwide, and statistics show a growing increase in accidents in every corner of the world. More than 90% of deaths in developing and underdeveloped countries are caused by accidents and disasters. Iran is a developing country in Asia prone to various natural and artificial accidents and disasters, and is considered one of the most vulnerable countries in the world.¹ CBRNE incidents involve the uncontrolled release or use of chemical, biological, radiological, nuclear, or explosive materials, often causing mass casualties, societal disruption, or environmental damage through accidents, terrorism, or military actions.² Currently, the level of awareness of the use of chemical, microbial, and nuclear agents in everyday industrial and non-industrial CBRNE accidents has increased.³ Formulas and instructions for producing many chemicals that can have military or terrorist applications are safely available to everyone in written sources, especially on the Internet and virtual networks, without supervision. On the

other hand, vast amounts of dangerous chemicals are produced, transported, stored, and used for industrial and domestic purposes every day.⁴

Health is the first and most important demand and concern of people in such incidents. Therefore, the health sector has a special place among all the elements involved in managing incidents and disasters.¹ Hospitals and health center staff are also directly affected by incidents and crises.⁵ In fact, hospitals are the most pragmatic units in the health care system by attracting the most material and human capital.⁶ In general, hospitals, as fixed and specialized centers providing medical services with facilities and experienced staff, are considered one of the essential components of the response process to unexpected incidents, which are responsible for preserving the lives and health of the injured.⁵

CBRNe incidents can be catastrophic, making preparedness essential for healthcare systems; disaster preparedness involves protective measures before, during, and after incidents. Hospital preparedness plus staff readiness are vital for managing emergencies, including CBRNe events, with a well-developed emergency response plan to avoid disorganization. So holistic, well-structured risk management system is necessary for health systems to understand, learn from, and address systematic risks.^{7–10}

Risk management in healthcare involves identifying, assessing, and controlling risks to reduce negative impacts on patients, staff, and facilities. It is crucial in hospitals to prepare for and respond to adverse events through strategic planning, expert input, and holistic approaches. This process helps mitigate threats, supports safety and resilience, and also enables value creation and innovation, especially in the context of evolving challenges like CBRNE incidents.¹¹

On the basis of the results of some investigations, six main challenges of “management and leadership”, “planning”, “prevention and mitigation”, “preparedness”, “response”, and “recovery” in the field of in military hospitals exist. Also poor communication and coordination in the crisis team are among the most critical challenges in military hospitals.¹²

In the face of (CBRNE) events in military hospitals, risk management is of particular importance as a critical boundary between the efficiency of health services and the sustainability of military operations. Identifying the strategic dimensions and components of risk management in CBRNE incidents creates a systematic and organized format that allows hospitals to act efficiently in the face of various threats, mainly chemical, biological, radiological, nuclear, and explosive CBRNE incidents, and prevent irreparable damage. Therefore, risk management in hospitals, in addition to the medical aspect, also includes other elements to provide the necessary preparedness in all areas. This research, with descriptive exploratory approach, examines which strategic dimensions in risk management in military hospitals are more important and have executive priority for facing CBRNE events and how they are effectively applied in policymaking or organizational-level decision-making. It helps to provide policy frameworks and management approaches to provide an effective and sustainable response to CBRNE events in military hospitals.

Methods

The study was conducted in 2025 by using a qualitative method, descriptive exploratory approach and guided framework analysis. Semi-structured interviews sessions were conducted to identify the strategic components and dimensions of risk management in dealing with CBRNE events in military hospitals, from the perspective of experts in this field (academic officials and university faculty members). The sampling was purposive and heterogeneous (participants with maximum diversity) and continued until sufficient data were collected. This method seeks to collect data from participants with rich information and adequate experience in the phenomenon under study, and those who desire to participate. The inclusion criteria for the study were having at least 5 years of executive experience and a willingness to participate. An interview guide was developed for the interview, and the interviews were conducted based on it. The interview questions were about what key dimensions and components, experts and officials suggest in the field of preventing or reducing vulnerability, preparedness, response, and recovery from CBRNE incidents. About 14 interviews were conducted with an average time of about 40±15 minutes. After obtaining the consent of the participants in the study, their views were recorded and implemented immediately after the completion of each interview. The framework analysis method was used to analyze the data (Table 1).

The process of framework analysis method consists of five stages (Data Familiarization, Identifying a Thematic Framework, Indexing, Charting, Mapping, and Interpretation):¹³

Table 1 Profile of Interviewees (Expert & Experience)

ID	Gender	Position/Professional Role	University/Institution	Experience in Crisis Management (Years)	Interview Date	Interview Type
1	Woman	Professor of Health in Disasters and Emergencies	Tabriz University of Medical Sciences	2	2025-07-23	In-person
2	Man	Professor of Health in Disasters and Emergencies	Tabriz University of Medical Sciences	5	2025-08-03	In-person
3	Woman	Professor of Health in Disasters and Emergencies	Tabriz University of Medical Sciences	1	2025-07-08	In-person
4	Man	Professor of Health in Disasters and Emergencies	Tabriz University of Medical Sciences	7	2025-08-26	In-person
5	Man	Professor of Health in Disasters and Emergencies	Tabriz University of Medical Sciences	3	2025-06-29	In-person
6	Man	Professor of Medical Accidents and Emergencies Center	Tabriz University of Medical Sciences	6	2025-06-27	In-person
7	Woman	Head of Medical Accidents and Emergencies Center	Tehran University of Medical Sciences	2	2025-09-06	Remote work
8	Man	Professor of Health in Disasters and Emergencies Group	Tehran University of Medical Sciences	9	2025-09-01	In-person
9	Man	Head of Crisis Prevention and Management Organization	Tehran University of Medical Sciences	9	2025-09-10	Remote work
10	Woman	Professor of Health in Disasters and Emergencies Group	Tehran University of Medical Sciences	2	2025-09-05	In-person

Data Familiarization

In this stage, after the researchers became acquainted with the transcripts from interviews, they developed an overall understanding of the data. In this stage, the research objectives were reviewed to ensure that the collected data were aligned with the aims of the study.

Identifying a Thematic Framework

During the familiarization process, ideas that emerged while reading the transcripts were extracted. To organize a thematic framework, recurring ideas identified during familiarization were grouped into clusters of similar ideas or developed into themes. At this stage, the researchers developed a thematic framework specifically for the dimensions of prevention, preparedness, response, and recovery was modeled based on existing literature and documents.

Indexing

This involves identifying units or segments of data that are related to a specific theme. This stage includes reviewing the transcripts and interview notes and noting the themes present within the data. In this stage, two researchers analyzed the data to help reduce bias and increase accuracy. Both researchers transcribed, coded, and analyzed all data. The extracted codes were then categorized into themes and subthemes based on comparisons of similarities and differences.

Charting

After indexing the data according to the thematic framework, the data were summarized in thematic tables. This means that a summary of the original data was placed in the cells of the table, allowing all the data to be viewed in one place. The ease of viewing the data in a table helps the researcher interpret the information more effectively and pay closer attention to data that may lack clarity.

Mapping and Interpretation

The final stage involves presenting a map and providing a comprehensive interpretation of the data in order to synthesize them. In this phase, the tables are reviewed to gain an overall understanding of the entire dataset. Data synthesis involves defining concepts, illustrating the relationships between them, clarifying the nature of the phenomenon, and providing explanations and recommendations. These concepts and relationships should be derived from the perspectives, beliefs, and values of the participants. This stage enables the research team to compare and interpret participants' perspectives and interpretive patterns regarding the phenomenon under study.

The member checking method was used to examine the validity of the study. To check the validity, the transcripts were given to four participants to ensure their accuracy, and their comments were applied after review by the research team. Also, two researchers reviewed the initial codes, subthemes, and main themes, and then the results were confirmed. To ensure the transferability of the data, purposive sampling and rich data description were used.

In this study, ethical issues were observed, including obtaining permission from the Ethics Committee of Baqiyatallah University of Medical Sciences (IR.BMSU.BAQ.REC.1403.202), obtaining permission from the university’s Vice Chancellor for Research, providing sufficient information at the beginning of the study to inform participants of what was going to be done, obtaining written informed consent for data collection and voluntary participation of individuals to participate in the study, the freedom of experts to cooperate or not to cooperate in the study, respect for the independence and decision-making of participants, and non-publication of the names of participants in the research.

Results

Risk management in CBRNE incidents in military hospitals requires a comprehensive approach at four levels of risk management, including prevention, preparedness, response, and recovery. In the area of prevention and vulnerability reduction, key dimensions and components of risk management include management framework and leadership, asset and supply chain management, technical and equipment capacity building, incident prevention and mitigation, training, practice, and safety culture, response and continuity of operations, cybersecurity, and privacy. (Table 2).

In preparedness and vulnerability reduction for CBRNE incidents, it is essential first to have a clear management and leadership framework. Risk assessment aligned with operational priorities aligns operational planning and resource

Table 2 Key Dimensions and Components of Risk Management in Preventing the Occurrence and Reducing Vulnerability to CBRNE Incidents

Component	Main Theme/ Definition	Sub-Themes	Quotation
Key dimensions and components of risk management in preventing the occurrence and reducing vulnerability to CBRNE incidents	Management and Leadership Framework	Strong and clear governance: Establish clear responsibilities between clinical, safety, security, and command-and-control units; establish risk management committees with defined roles. Documented policies and procedures: Develop safety standards, CBRNE response protocols, and unit risk assessment processes. Sustainable resource allocation: Budget, personal protective equipment (PPE), decontamination facilities, and ongoing training.	P8: "Defining clear responsibilities between clinical units by defining clear tasks, boundaries, and reporting lines prevents confusion, overlapping duties, and delays in response".
	Asset and Supply Chain Management	Access control and tracking of sensitive locations: Accurate location of chemical and biological materials, locking and entry/exit recording. Secure supply chain: Selection of reliable suppliers, review of safety standards, supply and storage of sensitive materials in accordance with physical and biological standards. Safe protection and maintenance of equipment: Planning for preventive maintenance and periodic testing of equipment such as decontamination and specialized medical equipment.	P7: "Planning for preventive maintenance and periodic testing of equipment includes regularly scheduling repairs, performing emergency inspections, and performing functional tests to maintain the efficiency, safety, and availability of equipment".
	Technical and Equipment Capacity Building	Secure physical infrastructure: Standard laboratories with adequate ventilation, bio-alarms, hazardous waste spaces, and hazardous contact control areas. Cybersecurity and data security: Securing decision-making systems, communications, and patient data; implementing backup and recovery procedures. Personal protective equipment and decontamination: PPE appropriate for chemical, biological, and radiological environments, and walk-through decontamination facilities for contaminated environments.	P1: "Decontamination facilities for contaminated environments include separate sections and controlled entry/exit routes, disinfection stations, and ventilation and safety systems to prevent the spread of contaminants and reduce the risk of exposure to hazardous sources".

(Continued)

Table 2 (Continued).

Component	Main Theme/ Definition	Sub-Themes	Quotation
	Incident Prevention and Mitigation	Access control for hazardous materials: registration and entry/exit protocols, periodic monitoring of warehouses. Safety-friendly chain of processes: Designing safe processes from entry to exit of patients and materials, minimizing incorrect contacts and user errors. Operational security in harsh environments: Resilience of systems and technologies in the event of power outages, fires or security conflicts.	P12: "Periodic warehouse monitoring includes regular inventory inspections, reconciliations with product lists, and deviation reports to reduce the persistence of safety hazards and increase logistics efficiency".
	Training, Practice, and Safety Culture	Documented and Periodic Training: Introductory courses and ongoing refresher courses in chemical, biological, radiological/nuclear, and explosives. Crisis Scene Exercises (Drills): Regular exercises with diverse scenarios to improve team coordination and process efficiency. Safety Culture and Reporting Without Fear of Punishment: Encourage Near Miss reporting and non-blame review for organizational learning.	P5: Regular exercises with diverse scenarios are designed to improve team coordination and process efficiency, to enhance rapid response and coordination between units by simulating different situations.
	Response and Business Continuity	Rapid response protocols and crisis lines: Quickly implement initial measures, isolate contaminated areas, and maintain the resilience of critical services. Quarantine, decontamination, and safe disposal: Safe processes for storing, transporting, and disposing of hazardous materials and biological/chemical waste. Change management and crisis communications: Secure internal and external communication tools to inform employees and external stakeholders.	P4: "Rapidly implement initial post-incident measures with a focus on immediate response, protecting people, and reducing initial damage, until specialized teams arrive".
	Cybersecurity and Privacy	Strong authentication and access management: Tightly control access to patient data and decision support systems. Network Security	P10: "Tight access control to patient data is achieved by implementing multi-factor authentication, access level management, and complete logging to track activities and prevent unauthorized access".

allocation. At the operational level, we need operational readiness and continuous training, adequate technical and logistical readiness, and a sustainable safety culture that also includes employees' mental health. Cybersecurity and data protection also ensure that a rapid and secure response to threats is carried out and information privacy is maintained (Table 3).

In response to CBRNE incidents, key dimensions of risk management include the command and control framework (ICS/IMS), detection, screening, and triage, personnel safety and workplace protection, scene management and isolation, resource and logistics management, clinical processes and continuity of care, and continuous learning, review, and improvement (Table 4).

In CBRNE incident rehabilitation, key dimensions include post-event assessment and review of protocols and processes through AAR (As-done Review), along with employee health and mental health management, post-incident supply chain and logistics management, and cleanup, decontamination, and restoration of the workplace. Rehabilitation assessment processes and criteria should include critical indicators. Communication with stakeholders and the community is also essential to maintain transparency, public trust, and cooperation in rehabilitation. Assessing the long-term risks of exposure to CBRNE materials, implementing safety measures, and updating protocols are also essential components (Table 5).

Table 3 Key Dimensions and Components of Risk Management in CBRNE Incident Preparedness

Component	Main Theme/ Definition	Sub-Themes	Quotation
Key dimensions and components of risk management in CBRNE incident preparedness	Management and Leadership Framework	Designation of the Incident Response Team: CBRNE with clear roles for clinical, safety, security and command-and-control units (ICS/Incident Command System). Documented policies and procedures: protocols for diagnosis, patient isolation, decontamination, waste disposal and continuity of operations. Resource and budget planning: ongoing allocation, PPE, measuring equipment, drugs and specialist materials and antidotes, and financial and logistical support plan	P6: "There are clear lines of communication between clinical, safety, security and command units to reduce delays in decision-making".
	Risk Assessment and Operational Planning	Identify threats and vulnerabilities: Create and update hazard maps and risk matrices for chemical, biological, radiological, and explosive agents. Business Continuity Planning: Scenarios for power outages, communications outages, or loss of access to critical resources and alternative methods. Layout security zones within the facility: Define hot/warm/cold zones and safe lines of contact for patients and staff.	P9: "Definition of hot/warm/cold zones to differentiate the level of risk and severity of restrictions in clinical and critical spaces, with the aim of reducing contact with hazardous sources and improving management of personnel and patient traffic"
	Operational Readiness and Training	Basic safety and CBRNE hazard awareness training: PPE, limitations, and proper donning/doffing of protective equipment. Command and Control (ICS) training: operational roles, communications, and coordination with emergency and security forces. Diagnosis and triage training in CBRNE situations: rapid diagnosis, patient separation, and isolation procedures. Training in working with related equipment and technologies: PPE, VOC radiation measurement devices, decision support systems, and decontamination methods. Regular exercises and drills: combined CBRNE scenarios, post-exercise review, and continuous improvement.	P10: "Operational roles include site management, overseeing day-to-day operations, and coordinating with relief and security teams for a rapid and organized response to emergencies".
	Technical and Logistic Readiness	Personal Protective Equipment (PPE) and Safety Gear: Protective clothing, appropriate masks, specialized gloves, eye protection, and head protection. Measurement and monitoring systems: Gravity/geometers, radiation diffusers, VOC gas monitors and ventilation systems with appropriate filters. Waste logistics and decontamination: Standards for handling, storing and disposing of biological/chemical/noise waste. Crisis communications and backups: Secure communication channels, spare batteries, radio equipment and emergency telephones. Cyber preparedness and data protection: Regular backups, encryption of sensitive data, strong access management.	P13: "The availability of contamination and fluid resistant coatings, disposable or reusable garments with high maneuverability and user protection in contaminated environments"
	Safety Culture and Mental Health	Near Miss Reporting and Non-Judgemental Incidents: Simple, anonymized processes for reporting errors and deficiencies. Organizing for mental health in crises: Access to psychological support, stress management, and employee rehabilitation programs. Team training and effective communication: Practice communication skills, conflict management, and coordination between units.	P2: "Use integrated reporting forms with anonymization options and a quick registration process to reduce psychological barriers and increase employee engagement".
	Cybersecurity and Data Protection	Secure access to sensitive patient data: Strong authentication, access control, and encryption. Operational systems security: Protecting decision support systems, detecting cyber events, and responding to attacks.	P3: "Use encryption for data in transit and raw data at rest, along with access control and secure key management in the event of a security breach".

Table 4 Key Dimensions and Components of Risk Management in Response to CBRNE Incidents

Component	Main Theme/Definition	Sub-Themes	Quotation
Key dimensions and components of risk management in response to CBRNE incidents	Command and Control Management Framework (ICS/IMS)	Establish a CBRNE response team with defined roles: Incident Commander, Safety Officer, Liaison Officer, Operations/Logistics, Medical Branch Director and other relevant roles. Clear communication channels: Constant lines of communication between the incident scene, emergency operations center and support units within the hospital. Documented and updated guidelines: Protocols for diagnosis, triage, decontamination, waste disposal and continuity of operations.	P3: "Establish clear communication channels, response timescales and discrete reporting procedures that allow for rapid and seamless coordination".
	Screening & Triage	Rapid CBRNE Agent Detection Protocols: Chemical, Biological, Radiological, and Explosive Detection using available kits and tools. Triage and Isolation Lane Management: Rapid separation of patients into HOT/WARM/COLD and isolation lanes until the agent and threat severity are determined. Secure Entry and Exit Codes to the Scene: Clear pathways for patients, response teams, and waste with contamination control.	P1: "Performing initial tests with validated kits and standard devices for rapid identification of the agent, while adhering to safety protocols and promptly reporting to responsible units".
	Personnel Safety and Workplace Protection	Personal protective equipment (PPE) appropriate to the threat level: protective clothing, mask/PSA or PAPR, face shield, specialized gloves, head protection, etc with entry/exit protocol. Pollution control and proper ventilation: Proper ventilation in hospital spaces and use of appropriate filters in contaminated areas. Decontamination and safe disposal of waste: Standard methods for collecting, storing and disposing of biological/chemical waste in compliance with national and international laws.	P10: "Use protective filters with appropriate efficiency, such as HEPA, replace filters promptly, and check seals and air distribution systems to reduce the release of contaminants and hazards".
	Scene Management and Isolation	Definition of zones within the hospital: Zones (HOT contaminated, WARM potential contamination and COLD clean/non-threat) with clear entry and exit routes. Communication channels with rescue and security units: Coordination with emergency, police, fire, and health organizations to exchange information and resources. Environmental safety enclosure: Gas/toxin monitoring and controlled ventilation to prevent the spread of contamination	P4: "Rapidly identify hazardous gases and toxins, by installing continuous sensors with alarm thresholds and implementing rapid response protocols in the event of a leak or contamination".
	Resource Management and Logistics	PPE and Diagnostics Inventory Calibration and Management: Systems for monitoring inventory, expiration dates, and rapid ordering in times of crisis. Specialty Medicines and Kits: Inventory of disinfectants, antibiotics, supportive medications, and diagnostic kits. Supply Chain and Critical Support: Liaison with suppliers, support camps, and relief networks to quickly secure essentials	P1: "There is a regular maintenance and inspection process to prevent drugs from going past their expiration date, update inventory levels, and report shortages to the supply unit".
	Clinical Processes and Continuity of Care	Continuity of care for routine and emergency patients: Design separate treatment lines for patients with CBRNE threats and other patients. Continuous patient monitoring and assessment: Monitoring vital signs, repeated assessments, and assessing response to treatments. Staff mental health support program and fatigue management: Regular breaks, psychological counseling, and support for teams during the crisis.	P12: "Establish separate treatment pathways in line with safety standards to reduce the risk of cross-contamination and maintain the efficiency of treatment teams, so that patients with CBRNE threats are quickly and safely separated from other patients".
	Learning, Review, and Continuous Improvement	Lessons Learned: Using Previous Experiences Periodic Reviews and Continuous Optimization: Regular Planning, Evaluation of Key Performance Indicators, Review of Protocols, Review of Infrastructure	P2: "Create system reports of every major and minor event with important points, sources of error, and corrective suggestions".

Table 5 Key Dimensions and Components of Risk Management in Rehabilitation in CBRNE Incidents

Component	Main Theme/ Definition	Sub-Themes	Quotation
Key dimensions and components of risk management in CBRNE incident rehabilitation	Post-Event Assessment	Full environmental safety assessment: Checking the stability of structures, the presence of residual contaminants, new threats, and employee safety. Clinical and health impact review of personnel: Assessing the condition of injured persons, following up on short-term and long-term complications of employees at risk. Organizational and functional review: Analyzing the performance of ICS/IMS, communication channels, resource management and continuity of operations.	P2: "The condition of the injured must be assessed immediately and accurately, short-term and long-term complications must be followed up, and the necessary care must be provided for their rehabilitation".
	Employee Health and Mental Health Management	Assessment of physical and mental health of personnel: medical examination, screening, fatigue assessment and effects of exposure to hazardous substances. Standard psychological support and rehabilitation: group and individual counseling, access to psychological support services and stress management. Gradual return to work programs: assignment of lighter tasks and gradual increase in responsibilities based on the personnel's condition.	P4: "Group and individual counseling is provided to improve mental health, manage stress, and improve teamwork to increase feelings of solidarity and social support".
	Cleaning, Decontamination and Reconstruction of the Workplace	Decontamination upgrade protocol: eliminate sources of contamination, clean spaces in compliance with safety standards, and screen air and water cleanliness. Prepare and implement a space reconstruction plan: structural repairs, ventilation inspection, reconstruction of isolated areas, and reopening of service routes. Review waste management: careful control of residual waste, tracking and safe burial or return to the logistics cycle.	P1: "Root assessment of structural problems, strengthening of components, and implementation of safe repairs should be carried out to restore stability and reduce future risks".
	After Action Review (AAR)	Collect lessons learned: Interview personnel, collect performance data, and identify deficiencies. Update protocols and processes: Revise SOPs, checklists, and incident report forms based on AAR findings Prepare retraining programs: Design return-to-work training courses, remedial exercises, and improved workshops.	P6: "Checklists and incident report forms should be designed simply and correctly to enable accurate and comprehensive reporting of the results of actions taken".
	Supply Chain and Logistics Management after an Incident	Inventory and supply chain reconstruction: Assess the status of PPE, drugs, diagnostic kits and critical supplies; resupply them quickly. Review third-party contracts and partnerships: Update service levels, support contracts and emergency contact channels with suppliers.	P9: "Replenish supplies, improve inventory turnover, coordinate with suppliers, and implement emergency processes to continue to protect employees and ensure operations".
	Communication with Stakeholders and the Community	Transparent communication to senior management and staff: reports on scene status, reconstruction and return to work plans. Communication with families and the local community: Secure communication about staff status and services provided	P11: "Scene status reports are prepared in a consistent and up-to-date manner to clearly record details of the incident, the restorations carried out, and the safety status of the workplace".
	Rehabilitation Evaluation Processes and Criteria	Key Performance Indicators (KPIs) for rehabilitation: Time to return to normal operations, percentage of personnel rehabilitation, safety and health indicators. Periodic review and coordination with other units: Periodic meetings to review rehabilitation progress and coordinate with neighboring hospitals and health authorities.	P11: "Periodic meetings are held to review the progress of rehabilitation to ensure regular assessments of the status of recovery, the appropriateness of rehabilitation plans, and the support needs of staff".
	Technical and Safety Aspects in Rehabilitation	Addressing long-term risks of exposure to CBRNE materials: Continuous exposure monitoring, long-term health surveillance programs, and implementing safety measures and updating protocols to reduce long-term risks.	P7 "Long-term risks of exposure to CBRNE materials are regularly reviewed to assess and manage long-term effects on the health of workers, the environment and the community".

Discussion

Risk management in CBRNE incidents in military hospitals involves a comprehensive and multidimensional approach designed to effectively mitigate risks and ensure the safety and care of casualties.¹² This approach, at four levels of risk management including prevention, preparedness, response, and rehabilitation, enables military hospitals to function as treatment centers and as CBRNE crisis management centers with effective preventive, preparedness, and response capabilities.

In prevention and vulnerability reduction, management frameworks are crucial to enable organizations to effectively manage complex risks and thus ensure resilient and sustainable performance in the face of CBRNE threats.¹⁴ Asset management in healthcare facilities requires a multi-layered approach that includes physical and cyber security measures.^{15,16} Effective supply chain risk management is also crucial to maintain the integrity and security of these materials during storage, transportation, and use.¹⁴ Technical and equipment capacity building in CBRNE incident risk management includes equipping operational teams with personal protective equipment (PPE), decontamination kits, hazardous materials identification equipment, and physical and data security systems, which should be accompanied by continuous training and updating of experts' knowledge.¹⁵ Efforts to prevent incidents and reduce their likelihood of occurrence are possible by reducing the risks of unauthorized access and misuse, and designing secure processes.¹⁴ Conducting training and crisis simulation exercises and creating a safety culture ensures long-term employee motivation and readiness.¹⁷ Continuity of operations is maintained through ongoing risk assessments, capacity building, resource management, and response protocols, enabling threat management as emphasized in authoritative guidelines and tools. Various malicious actors can carry out¹⁸ Cyber threats to create fear, damaging infrastructure. Standard practices, awareness, training, and strong legal frameworks are needed to reduce vulnerabilities, increase cyber resilience, and tightly control access to data and systems at all operational levels.¹⁹

In the area of preparedness, a clear management and leadership framework is essential to clarify roles, responsibilities, and decision-making processes, align operational planning, and allocate resources with risk assessment based on operational priorities.¹⁴ CBRNE risk assessment frameworks are a comprehensive and systematic process that helps to safely and effectively manage threats posed by sensitive materials and include the design of various mechanisms from identification to response.¹⁴ Operational preparedness requires continuous training, adequate technical and logistical support, and a sustainable safety culture that includes mental health considerations for personnel.²⁰ Regular training exercises,¹⁷ updating response plans,¹⁸ and strengthening technical and logistical infrastructure, such as equipment and strategic reserves, along with safety standards, data documentation, cybersecurity, and data protection, ensure a rapid and safe response while maintaining information confidentiality.^{14,19}

In response to CBRNE incidents, a command and control management (ICS/IMS) framework is also essential, as it clarifies roles, responsibilities, and decision-making processes and enables a coordinated and efficient response to the incident.¹⁴ Detection, differentiation, and prioritization in the face of CBRN incidents include rapidly identifying chemical, biological, radiological, and nuclear hazardous agents using specialized equipment and spot tests.²¹ Personnel safety and workplace protection in CBRN risk management require complete adherence to appropriate personal protective equipment and the implementation of safety protocols to minimize exposure to hazardous agents during scene management.²² Areas within the hospital are divided into three main zones: the contaminated zone (HOT), where contact with hazardous materials occurs, the contaminated zone (WARM), where personnel and equipment are prepared for decontamination measures, and the clean or non-threat zone (COLD), which is safe and free from contamination. Each area has designated entry and exit routes to control access and prevent the spread of contamination. In addition, communication channels are established with relief and security units to exchange information and coordinate resources.²³ Efficient supply chains and critical support systems ensure timely coordination with suppliers, support camps, and relief networks to quickly provide essential resources, facilitating effective response and continuity of care.²⁴ Continuity of care for routine and emergency patients in CBRNE incidents includes designing separate treatment lines to prevent cross-contamination between CBRNE incident patients and others.²⁵ In addition, staff mental health support programs focus on regular breaks, psychological counseling, and fatigue management to maintain team effectiveness and well-being during crises.²⁶ Lessons learned in CBRNE incident management include using previous

experiences to enhance response effectiveness.¹⁴ Periodic reviews and continuous optimization are conducted through regular planning, evaluation of key performance indicators, revision of protocols, and evaluation of infrastructure. This constant cycle of reflection and improvement ensures that preparedness capabilities evolve in line with emerging threats and lessons learned from real-world incidents and exercises.¹⁴

Rehabilitation of CBRNE incidents includes monitoring delayed health effects, managing psychological impacts on responders, and integrating lessons learned to increase future preparedness and resilience.² Managing employee health and mental health in CBRNE risk management includes ongoing physical and psychological assessment of personnel, using individual and group counseling to reduce stress and provide psychological support, and rehabilitation programs for a gradual return to work. Training and preparing employees for CBRNE threats through specialized courses and creating a supportive environment are essential to promote their resilience and health.² Cleanup, decontamination, and remediation in CBRN risk management are critical processes that aim to remove or neutralize hazardous agents from people, equipment, and environments to ensure safety and prevent secondary contamination.²⁷ Evaluating the effectiveness of actions taken and comprehensively documenting lessons learned helps to continuously evaluate and revise protocols and processes, forming a reliable organizational learning cycle that includes individual learning, mental models, organizational memory, and environmental feedback.^{28,29} Supply chain management involves continuously monitoring inventory, assessing expiration and usability, and ensuring rapid replenishment to maintain readiness. Efficient supply chain coordination and deployment protocols ensure timely access to critical emergency resources for optimal protection and patient care.³⁰ Effective stakeholder and community communication in CBRN risk management is essential for a coordinated response and public trust. This includes transparent information sharing, multi-agency collaboration, and tailored messaging to address diverse audience needs, increasing preparedness and reducing misinformation during crises.³¹ Resilience assessment processes in CBRNE risk management include analyzing the performance of the response system, identifying strengths and weaknesses, and reviewing the effectiveness of ongoing training and exercises. Resilience measures focus on improving team capabilities, ensuring employee safety, and enhancing equipment and operational capacities, which are achieved through ongoing assessments and organizational reviews.²² Ongoing personnel training, frequent workplace safety assessments, and assessing long-term risks of exposure to CBRNE materials are among the most critical factors in ensuring employee health and the effectiveness of the response to CBRNE incidents.²³

The proposed framework for risk management of CBRNE incidents in military hospitals is not a simple collection of prevention, preparedness, response, and rehabilitation activities. It is a tightly integrated system where each domain reinforces and amplifies the others, creating a resilient and adaptive hospital ecosystem. Prevention reduces likelihood and impact, informing targeted preparedness and robust risk assessment; preparedness provides clear leadership, continuous training, and enduring safety culture that enable a swift, coordinated response; the response component establishes structured command, optimized zone control, secure supply chains, and effective communication, which in turn safeguard ongoing operations and patient care; rehabilitation closes the loop by monitoring long-term health outcomes, supporting responders, and incorporating lessons learned back into planning, training, and structural improvements. This integration yields synergistic benefits: faster detection and containment, safer care pathways, preserved personnel health and morale, stronger organizational memory, and a dynamic capacity to evolve with new threats. In sum, the framework's interdependencies enable sustained operations, rapid recovery, and continuous improvement.

Conclusion

Policymakers and managers of universities and military hospitals should take a practical improvement approach to prevention, preparedness, response, and recovery. In prevention, we can improve supply chains and assets by implementing strong management and leadership frameworks, developing technical capacities, and establishing a safety and mental health culture among employees by establishing a risk management working group, publishing an annual risk assessment and planning to reduce risks enables faster identify and reduces technical and operational risks. In the area of preparedness and response to incidents, by standardizing Incident Specific Operating Procedures aligned with Incident Command System, regular exercises, strengthening a safety culture, and comprehensive support, also resource planning and ongoing training, we can maintain operational readiness, ensure adequate technical and logistical provision, and

foster a sustainable safety culture so that effective command-and-control and clinical processes with continuity of care are possible and operationally applied in the face of incidents. At the recovery level, post-event assessment, protocol review through After Action Review, post-incident supply chain management, and workplace cleanup can ensure efficient recovery and use vital indicators as evaluation criteria. Also, continuous communication with stakeholders and the community is needed to maintain transparency and public trust, and safety measures should be implemented to address the long-term risks of CBRNE exposure. Ultimately, these integrated and interconnected approaches strengthen the resilience and preparedness of the military hospital health system against future threats and provide continuous improvement through continuous protocol updates and continuous learning.

Ethical and Consent Statements

This study was approved by the Research Ethics Committee of Baqiyatallah University of Medical Sciences (Code: IR.BMSU.BAQ.REC.1403.202). The participants of study informed consent included publication of anonymized responses/direct quotes.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors declared no conflicts of interest in this work.

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