

# Hospital Preparedness Measures for Biological Hazards: A Systematic Review and Meta-Synthesis

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## ABSTRACT

**Background:** Biological hazards are one of the most important and common types of hazards in emergencies and disasters. Hospital preparedness measures for biological hazards are essential for a proper response and mitigation of its effects. The aim of this systematic review is to investigate hospital preparedness measures for biological hazards.

**Methods:** For this research, electronic databases including Web of Science, PubMed, ScienceDirect, Scopus, ProQuest, Google Scholar, and Cochrane Library from March 1950 to June 2019 were searched. Key words such as hospital, emergency department, preparedness, plan, management, and biological hazards were used in combination with the Boolean operators OR and AND. A thematic synthesis approach through the use of MAXQDA software was applied to analyze the data.

**Results:** In total, 5257 articles were identified, in which 23 articles meet the inclusion criteria for entering the process of final analysis. The findings showed three main administrative, specialized, and logistical issues regarding preparedness measures for biological hazards in hospitals.

**Conclusion:** Hospital preparedness for biological hazards is one of the most important hospital disaster plans. Results of this systematic review present valuable advice for policy-makers and hospital managers to prepare and enhance hospital performance against biological hazards.

**Key Words:** hospital, preparedness, biological hazards, disasters, health services

Biological hazards refer to biological agents that pose a threat to the human health. Biological agents, including samples of a microorganism, viruses, or toxins (from a biological source) are used in bioterrorism to spread infectious diseases.<sup>1,2</sup> Biological hazards can be classified as natural, accidental, or intentional.<sup>3</sup> Natural biological hazards have caused epidemics, pandemics, and emerging and re-emerging infectious diseases, resulting in a substantial rate of morbidity and mortality.<sup>4</sup> The burden of infectious diseases can be challenging because such diseases occur at different time scales and are influenced by demographic, epidemiological, and aging factors.<sup>5</sup> Also, antimicrobial resistance is rising globally. It poses a significant threat of growing concern to human health and is the greatest challenge for countries around the world.<sup>6,7</sup> Intentional biological hazards, also known as biowarfare and bioterrorism, can be broadly defined as the deliberate use of biological agents against civilian populations to intentionally produce disease or intoxication.<sup>8-10</sup> Examples of accidental biological hazards are occupational exposure to biological agents and accidents in laboratories. Laboratory workers are exposed to biological hazards during collecting or testing biological materials and samples. In addition, physicians, nurses, and other health workers may be exposed when they perform

medical activities such as surgical or invasive procedures.<sup>11</sup>

The most common characteristics of biological hazards include biological weapons that are easily available and cheaper to produce and potentially could have destructive power. Also, even the low-scale use of biological weapons, as was observed in the anthrax attacks, can cause large-scale social, mental, and economic effects.<sup>12</sup> Biological hazards can cause great mortality, morbidity, and hospitalization with great impact on the community. Therefore, biological hazards have become one of the most serious public health threats to the health system, especially hospitals.<sup>13,14</sup>

The arrival of the first Ebola patient in the emergency department of a hospital in metropolitan Dallas generated considerable media attention and fear of outbreak in the US. Rate of emergency department visits increased significantly and remained elevated for several months.<sup>15</sup> After the September 11, 2001 attacks, the United States experienced anthrax attacks as acts of bioterrorism. Letters containing anthrax spores were mailed to homes, the Senate, and major newsrooms, resulting in morbidity and mortality and effectively disrupting community and health systems.<sup>16,17</sup> The Coronavirus Disease 2019 (COVID-19) Outbreak in

TABLE 1

**Databases and search strategy****Databases**

Web of Science, PubMed, Cochrane Library, Scopus, ScienceDirect, Google Scholar, ProQuest, Federal Emergency Management Agency (FEMA), World Health Organization (WHO), and United Nations Office for Disaster Risk Reduction (UNISDR)

**Key words**

("Hospital" OR "clinic" OR infirmary" OR "hospice" OR "emergency room" OR "emergency department") AND ("preparedness" OR "readiness" OR "preparation" OR "management" OR "mitigation" OR "response" OR "plan" OR "model" OR "protocol" OR "program" OR "countermeasures" OR "strategy") AND ("biologic disaster" OR "biologic emergency" or "bioterrorism" or "biologic attack" or "biologic event" or "biologic threats" or "biologic crisis" or "biologic risk" or "biologic hazards" or "biologic catastrophe" or "biologic incident" or "biologic accident")

China and then around the world created a serious challenge for hospitals due to its high human-to-human transmission.<sup>18</sup>

Health systems and hospitals are the first responders to biological threats, and they play a critical role. Therefore, large quantities of pharmaceuticals and medical supplies in hospitals may be required.<sup>13,19</sup> Because of increasing worldwide threats of biological hazards, hospitals confront the challenge of implementing responses and providing medical services to such events that may require immediate decontamination, treatment, and care of large numbers of casualties, as well as increased attention on the protection and safety of personnel.<sup>19</sup> Hospital preparedness measures are an essential component of disaster preparedness for mass casualty events, and they need to address all hazards, including biological hazards such as biowarfare agents, bioterrorism, emerging and reemerging infectious disease outbreaks, and pandemics.<sup>20,21</sup> These measures offer practical guidance for hospitals.

Due to the important role of hospital preparedness, especially in response to biological hazards, it is important to focus on hospital and personnel preparation and in detail the activities and guidelines they must follow. In this regard, the previously performed studies mainly have focused on the importance of programs and plans. Some studies have shown that a large proportion of hospitals around the world are poorly prepared to confront biological hazards and inappropriately respond to massive casualty of any kind, either in their capacity to care for large numbers of victims or in their ability to provide care in coordination with external organizations and hospitals.<sup>22-24</sup> Therefore, the objective of the present study was to perform a systematic review to summarize and review the existing models, programs, plans, or protocols for hospital preparedness against biological hazards. The output and results of the present study may help hospital managers, authorities in health systems, and policy-makers to promote hospital preparedness for appropriate response to biological hazards.

**METHODS****Definitional Concepts**

In this study, we conducted a systematic review of articles and documents related to hospital preparedness for biological hazards. This systematic review follows the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) guidelines.<sup>25</sup>

**Data Sources and Searches**

This systematic review was performed to review available published articles, documents, reports, and guidelines. The key terms were identified and selected by consulting experts in disaster management and biological hazards, and the search strategy was developed in partnership with a research team and medical information specialists. A comprehensive literature search was performed using scientific databases and gray literature from March 1950 to June 2019, as shown in Table 1.

After conducting a comprehensive search for the relevant articles, reference lists of the retrieved articles were searched to obtain unpublished relevant data. We used EndNote version X9 to manage the search library, screen for duplicate articles, and extract irrelevant articles.

**Eligibility Criteria**

Inclusion and exclusion criteria were as follows.

**Inclusion criteria:**

1. Articles or documents addresses the hospitals preparedness in disasters.
2. Consideration of at least one of the types of the biological hazards including natural and intentional.
3. The full text of articles was available and free.
4. The study was published in English language.

**Exclusion criteria:**

1. Articles published in a language other than English.
2. Literature that did not satisfy the inclusion criteria.
3. Studies that investigated the preparedness measures of locations other than hospitals.

**Study Selection**

In the first step, duplicate articles were eliminated via EndNote version X9. Articles were screened through assessing the titles and abstracts for eligibility by 2 reviewers independently. The full text of the retrieved articles was reviewed carefully and critically by the reviewers.

**Data Extraction**

A form was used to extract the data and included the following factors: (1) name of the first author, (2) year of publication, (3) title, (4) study design, (5) aim of the study, and (6) main findings (Table 2).

TABLE 2

## Characteristics of the included studies

Author/year of publication	Title	Study aims	Study design/method	Main findings
Sharp et al (1998)	Medical preparedness for a terrorist incident involving chemical or biological agents during the 1996 Atlanta Olympic Games	Highlights some issues with which the nation is faced in trying to develop an effective medical response to biological threat.	Cross-sectional	General recommendations and observations to guide future preparedness and response activities: specialized assessment team, specialized training for first-responders, stockpiling and distribution of antimicrobials and antidotes, enhanced surveillance, augmented clinical capabilities, developing and implementing emergency public health interventions, recognizing an incident and rapidly characterizing the agent, providing appropriate decontamination and medical care to exposed persons, emergency response operations and coordination.
Loutfy et al (2003)	Hospital preparedness and SARS	Discuss the multidisciplinary and cross-departmental response used during Severe Acute Respiratory Syndrome (SARS) outbreak	Perspectives/lessons learned	Preparation factors, including building preparation and engineering, personnel, departmental workload, policies and documentation, infection control, personal protective equipment, training and education, public health, management and administration, follow-up of SARS patients, and psychological and psychosocial management and research.
Shapiro (1998)	Surge capacity for response to bioterrorism in hospital clinical microbiology laboratories	Identify barriers to surge capacity in the setting of a bioterrorism event and to identify solutions	Workflow analysis	Hospitals must provide increased numbers of biological safety cabinets and increase the amount of space dedicated to clinical microbiology laboratories. Laboratories should undertake limited cross-training of technologists, ensure that adequate packaging supplies are available, and be able to move to a 4-day blood culture protocol.
Katona (2002)	Bioterrorism preparedness: A generic blueprint for health departments, hospitals, and physicians	Presentation of a plan for hospitals	Qualitative study	Preparedness efforts should include (1) enhancing the public health, emergency medical services, intelligence, and law enforcement infrastructures; (2) strengthening the on-site medical response capability; (3) maintaining stockpiles of pharmaceuticals and vaccines; (4) having rapid laboratory diagnostic capability to qualify, quantify, and fingerprint clinical and environmental isolates; (5) developing programs to educate the physician, public health, and public communities; and (6) gathering good pre-attack intelligence.
Shaikh (2006)	Practical aspects of implementation of a bioterrorism preparedness program in a hospital setting	Presentation of a biologic disaster or bioterrorism preparedness program	Qualitative study	Practical aspects of implementation of a bioterrorism preparedness program are as follows: have a written bioterrorism preparedness plan; incorporate internal mechanisms for intensified surveillance; ensure appropriate internal and external mechanisms of communication; test the plan periodically through drills; incorporate flexibility and build redundancy for key components of the plan; address logistics involving surge capacity; improve collaboration with community physicians, area hospitals, and local health departments; emphasize community preparedness.
Schultz et al (2002)			Qualitative study	

**TABLE 2**

**Continued**

Author/year of publication	Title	Study aims	Study design/method	Main findings
	Bioterrorism preparedness I: the emergency department and hospital	Addresses hospital preparedness for response to a bioterrorism incident		Hospital preparedness for response to a bioterrorism incident includes the following aspects: A basic bioterrorism incident management plan, risk assessment, capabilities and capacity evaluation, supplies and logistics, facility protection, decontamination, expansion of services and alternative care sites, staff education and training, command and control, and coordination and communication.
Scharoun et al (2002)	Bioterrorism vs. health security: crafting a plan of preparedness	This article explores proper plans of preparedness for the eventuality of the unthinkable	Qualitative study	The most important components of a bioterrorist attack plan are detection and surveillance, diagnosis and characterization of biological and chemical agents, staffing supplies and pharmaceuticals, the Emergency Medical Treatment and Active Labor Act (EMTALA), and hospital security.
Niska (2008)	Hospital collaboration with public safety organizations on bioterrorism response	Identify hospital characteristics that predict collaboration with public safety organizations on bioterrorism response plans and mass casualty drills	A complex survey/questionnaire	The majority of hospitals involve public safety organizations in their emergency plans or drills. Bed capacity was most predictive of drilling with these organizations. The information from this study can be useful to emergency response planners in deciding whether to allocate funding to the types of hospitals that already do well in the area of public safety collaboration or to the hospitals that could benefit from further improvements in this area.
White (2002)	Hospital and emergency department preparedness for biologic, chemical, and nuclear terrorism	Presenting of the measures for hospital and emergency department preparedness for biologic terrorism	Qualitative study	Hospitals are key partners in the effective response to a community disaster. They must upgrade emergency management (EM) plans to include planning for nuclear, biological, chemical (NBC) agents through the use of an all-hazards, flexible approach. Issues such as communication, command, and coordination are as important as equipment and supplies.
Luther et al (2006)	Issues associated in chemical, biological and radiological emergency department response preparedness	Examines the experience of one emergency department's attempt to implement a new hospital emergency plan, for chemical biological radiological (CBR) threat	Qualitative study	Readiness preparation for biological incidents must include regular training on local and national levels, while having tried and tested systems in place for automatic, measured responses. Only then will emergency personnel be able to provide timely, appropriate, and safe interventions for a suspected CBR incident for the best possible outcome for all involved.
Lepler and Lucci (2004)	Responding to and managing casualties: detection, personal protection, and decontamination	Describes some of the key elements in a preparedness plan	Qualitative study	Key elements in a preparedness plan, specifically early detection of biologic terrorism, decontamination, and personal protection.
Ippolito et al (2006)	Hospital preparedness to bioterrorism and other infectious disease emergencies	Discuss some components of hospital preparedness to emergency response to infectious diseases	Qualitative study	Components of hospital preparedness for infectious disease include clinical awareness and education, infection control, initial investigation and management, surge capacity communication, and caring for staff and others affected by the emergency.

(Continued)

TABLE 2

Continued

Author/year of publication	Title	Study aims	Study design/method	Main findings
Bennett (2006)	Chemical or biological terrorist attacks: an analysis of the preparedness of hospitals for managing victims affected by chemical or biological weapons of mass destruction	Examine the current preparedness of hospitals in the state of Mississippi to manage victims of terrorist attacks involving chemical or biological weapons of mass destruction (WMD)	A self-administrated questionnaire survey	Major efforts to improve the preparedness of hospitals: documented and functional preparedness plans, diagnostic laboratory capability, availability of decontamination facilities, availability of pharmaceutical procedures and supplies, and ability to increase surge capacity.
Kao et al (2017)	Taiwan's experience in hospital preparedness and response for emerging infectious diseases	To introduce the structure and operation of the CDCMN and the advantages and challenges of this system	Cross-sectional	The Taiwanese experience shows an example of a collaboration between the public health system and the medical system that may help other public health authorities plan management and hospital preparedness for highly infectious diseases.
Case et al (2001)	Hospital preparedness for biological and chemical terrorism in central New Jersey	Examines the preparedness of the 11 acute-care hospitals to care for victims of biological and chemical terrorist incidents	Qualitative survey	Hospitals should be included in local disaster drills, and hospital drills should include tests of their relationships with other agencies. It is necessary to expand the attention currently being paid to planning for the health care response to biological terrorism. In the absence of local stockpiles, hospitals should coordinate their efforts and be prepared to support each other on short notice with supplies and medications.
Chan et al (2002)	Hospital preparedness for chemical and biological incidents in Hong Kong	To outline the efforts of the Hong Kong Hospital Authority in formulating a hospital response to incidents involving hazardous materials	Qualitative survey	Hospital preparedness for chemical and biological incidents such as the following: recognition and identification of hazardous materials, assessment of the conditions, decontamination of casualties of hazardous materials, decontamination facilities in accident and emergency departments, protection of staff and facilities, and training of emergency personnel.
Koenig et al (2006)	Medical strategies to handle mass casualties from the use of biological weapons	Discusses the main operational and logistical issues of import in the medical management of mass casualties from the use of biological weapons	Qualitative study	Key necessities for preparation to bioterrorism events include incident management system, surge capacity and alternate sites of care, detection/epidemiologic investigation, multidisciplinary coordination and communications, risk communications, quarantine and isolation, securing health care facilities decontamination, personal protective equipment (PPE) for health care providers, stockpiling, mass prophylaxis and vaccination, psychological aspects, and mortuary affairs.
Niska and Burt (2005)	Bioterrorism and mass casualty preparedness in hospitals: United States, 2003	Examines the content of hospital terrorism preparedness emergency response plans	Survey interview	Components of hospital terrorism preparedness: emergency response planning, training and practicing for terrorism, equipment and specialized care units for terrorism-related incidents, emergency response plans, mass casualty resources, and mass casualty drill. Hospitals collaborated on drills most often with emergency medical services, fire departments, and law enforcement agencies.
Rinnert (2001)				

**TABLE 2**

**Continued**

<b>Author/year of publication</b>	<b>Title</b>	<b>Study aims</b>	<b>Study design/method</b>	<b>Main findings</b>
Wetter et al (2001)	Local perspectives on bioterrorism. An approach to terrorism preparedness: Parkland Health and Hospital System	To develop an approach to preparedness in the Parkland Health and Hospital System	Qualitative Study	Preparedness Functions may be applicable biologic attack: safety and security, decontamination, acute and definitive medical care, resource procurement and management and communications.
Mortelmans et al (2017)	Hospital preparedness for victims of chemical or biological terrorism	Examine hospital preparedness for incidents involving chemical or biological weapons	Cross-sectional questionnaire survey	Hospital emergency departments generally are not prepared in an organized fashion to treat victims of chemical or biological terrorism. The planned federal efforts to improve domestic preparedness will require substantial additional resources at the local level to be truly effective. A clear need exists for the planners of the domestic preparedness program to confront the large deficiencies in local preparedness and the possible ineffectiveness of a program that is critically dependent on such preparedness.
Rebmann et al (2009)	Are Dutch hospitals prepared for chemical, biological, or radionuclear incidents? A survey study	To evaluate the chemical, biological, radiological, and nuclear (CBRN) preparedness of Dutch acute hospitals	A descriptive, cross-sectional study	The observation was that despite a high-risk perception of threats, there are serious gaps in the preparedness of Dutch hospitals for treating patients involved in CBRN incidents. Aspects of achieving adequate CBRN-incident preparedness include decontamination and PPE, hospital disaster planning, availability of antidotes, and isolation facilities.
Hui et al (2007)	Hospital infectious disease emergency preparedness: a survey of infection control professionals	Evaluate U.S. hospitals' current readiness to respond to a bioterrorism attack or outbreak of an emerging or reemerging infectious disease	Cross-sectional	United States hospitals lack negative pressure, health care workers, and medical equipment/supplies for surge capacity. Hospitals must continue to address gaps in infectious disease emergency planning.
Hui et al (2007)	An analysis of the current status of hospital emergency preparedness for infectious disease outbreaks in Beijing, China	Evaluate status of hospitals preparedness for infectious disease outbreaks	Surveyed by a standardized questionnaire	Emergency preparedness for infectious disease at hospitals in Beijing was in an early stage of development. Comprehensive measures should be developed and implemented to enhance their capacity for infectious disease emergency.

### Quality Assessment and Risk of Bias

Standard quality assessment of the retrieved articles was conducted by Critical Appraisal Skills Programmed (CASP)<sup>26</sup> and STROBE tools and checklists.<sup>27</sup> Two authors reviewed each article independently for the risk of bias. Any disagreements were resolved through discussion or consultation with a third reviewer.

### Data Synthesis and Analysis

Due to the heterogeneity of outcomes and the number of repeated or non-independent samples, the most appropriate approach for qualitative meta-synthesis is descriptive and contextual analysis of the collected data.<sup>28,29</sup> A thematic synthesis approach was used to gather information and identify all themes. The inductive analysis was performed by the 2 authors in 3 stages: (1) extraction of findings and coding of findings for each study; (2) grouping of findings (codes) according to their topical similarity to determine whether findings confirm, extend, or refute each other; and (3) abstraction of findings (analyzing the grouped findings to identify additional patterns, overlaps, comparisons, and redundancies to form a set of concise statements that capture the content of findings). The initial synthesis of studies was conducted separately for each of the included article formats. One author extracted data from the included studies into an extraction datasheet. The accuracy and completeness of the extracted data were checked by 2 other authors.

## RESULTS

5251 articles from databases and 6 articles from other sources were identified. In total, 5257 articles were found in the primary literature search. First, 879 duplicated articles were removed by the first author. Then, 4378 articles were screened by reviewing their titles and abstracts and 4262 articles were deleted, so 116 articles remained. In the next stage, the full texts of the 116 articles were assessed and read. Finally, 23 articles met the criteria for entering the process of systematic review. Figure 1 illustrates the study identification and selection process.

### Administrative and Management Hospital Preparedness Measures

#### *Hospital Preparedness Plans*

Disaster preparedness can be defined as planning, infrastructure, knowledge, capabilities, and education comprising the main elements of maintaining preparedness.<sup>30</sup> Appropriate preparedness can only be obtained through hospital preparedness plans.<sup>31</sup> Lack of preparedness plans in hospital negatively impacts the response activities of hospitals, such as managing victims and patients exposed to biological agents.<sup>32</sup> Plans must also establish orientation and training programs for staff who participate in response operations that address roles and

responsibilities, information and skills required, monitoring of staff knowledge, skills, competencies, participation, incident reporting, and program evaluation.<sup>33</sup> The plan should address the physical infrastructure needs of the biological hazards response plan, such as biocontainment areas in the emergency department, or the hot zones and isolation units.<sup>34</sup> The hot zone is the area in which the incident occurred and in which contamination exists. All individuals entering the hot zone must wear the appropriate levels of PPE and be decontaminated before leaving.<sup>35</sup> Components of hospital preparedness plans for biological hazards include procedures for activation, notification, structure of the command and response communications and media relations, evacuation and establishment of alternate care sites, personnel and facility protection, and recovery issues.<sup>33,36</sup>

#### *Risk Assessments*

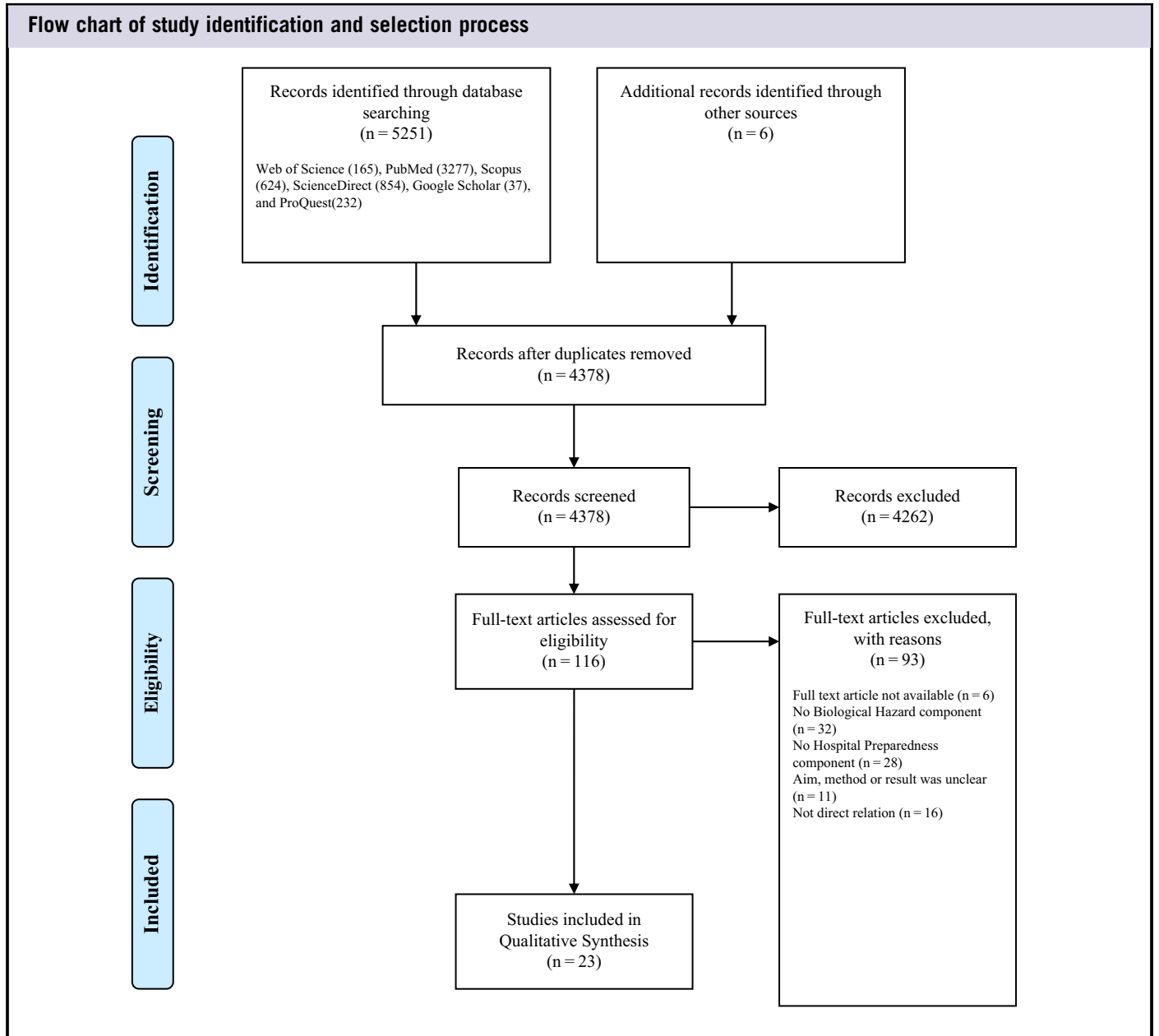
Risk assessments include evaluation of hazards or potential threats, profiling of hazards maps, capacity assessment and estimation of potential human and economic losses based on the exposure and vulnerability of community or hospital to the threats and incidents.<sup>37</sup> Assessments should be conducted in structural, nonstructural, and functional aspects.<sup>38,39</sup>

Vulnerabilities of hospital should be forecasted, and the risk assessment should include the entire service area of the hospital.<sup>33</sup> Hospitals and laboratories are recommended to consider biosafety and biosecurity issues and to prepare their response plans based on the most likely risks and categorization of biological agent groups. Risk assessment identifies the severity of infection, the potential for transmission to exposed people and to the wider community or environment, the possibility of patient admissions, and availability of effective prophylaxes and treatments.<sup>39</sup>

#### *Hospital Incident Command System (HICS)*

A biological hazards will need a developed incident management and command system to integrate the different response functions.<sup>33</sup> An important strategy for organizing hospital staff for mass casualties resulting from exposure to a biological agent is to implement a Hospital Incident Command System (HICS). HICS provides a common disaster language, a representative authority or a commander, and a flexible infrastructure framework for the disaster response that can expand as needed, depending on the size and complexity of the incident.<sup>40</sup> According to the situation and the type of hazards, the commander may choose to activate a medical-technical specialist officer unit with an infectious disease physician on staff. In situations involving a hazardous material (HazMat), such as internal or external biological agent release, the commander activates the HazMat branch subgroup of the operations section. The HazMat branch will have the

FIGURE 1



personnel and equipment to address agent recognition, monitoring, and victim decontamination.<sup>41,42</sup>

### Hospital Collaboration

Biological hazards pose unique challenges to hospitals because they may go unrecognized for days, with the possibility of victims and patients admitting to different hospitals. Collaboration and information sharing with other hospitals and community physicians could provide the possibility of identifying suspected exposure to the biological agent. The local health department would obtain information from hospitals as part of the laboratory or syndromic surveillance

system. Mutually, the hospitals would benefit from the health department's information regarding a suspected case of biologic hazards or bioterrorist agent, in a timely manner.<sup>34,42</sup> Hospitals were required to collaborate with the following:

- Local public health system and the medical system
- Law enforcement
- Emergency medical services (EMS)
- HazMat teams
- Centers for Disease Control (CDC) and the local health department
- Environment agency
- Water authority



## Hospital Preparedness Measures for Biological Hazards

- Military medicine experts
- Physicians and fire departments<sup>43-45</sup>

During disasters and emergencies, hospitals must collaborate about surge capacity in equipment and supplies, deployment of physicians and other hospital staff, and use of spaces.<sup>46</sup>

### *Health Risk Communications*

Risk communication encompasses provision of exact, timely, complete, and easily understood information to the community about the following:

- The incident
- Control and mitigation effort
- Safety self-protection
- Provision of information to hospital staff about diagnosis
- Interventions after and post exposure
- Communication with families and others close to those affected by the emergency
- Communication with the news media
- Communication within and between all those involved in emergency management<sup>39</sup>

Internal hospital communications involve the need to communicate with the following parties:

- Staff concerning the nature of the event
- Implement the hospital disaster plan
- Activate the staff “call back” and rotation system to ensure adequate manpower
- Provide critical incident stress debriefing for both personnel and their families<sup>47</sup>

During biological incidents, effective risk communication will play an important role in providing essential information to the public and hospital staff.<sup>40</sup> Inappropriate communication could result in rumors and incorrect information spreading, which may result in overwhelming the hospital, especially emergency rooms, because of surge of patients and inappropriate induced demand.<sup>48</sup>

## Specialized Hospital Preparedness Measures

### *Early Detection and Surveillance System*

The aim of a syndromic surveillance system is to provide an early warning for the onset of an epidemic, as well as tracking and quick recognition of epidemics, which allow more effective health care responses, especially in the event of a bioterrorist attack.<sup>49</sup> Early detection is essential for preparedness against a biological hazard, including the provision of chemoprophylaxis, early proper medical therapy and vaccination to improve the chance of survival, and also public health measures such as quarantine and isolation.<sup>50,51</sup> It is critical to recognize the symptoms of a bioterrorist agent and differentiate it from symptoms common to other disease.<sup>48</sup> Specifically, surveillance systems can reduce the infection with a pathogen in order to detect the disease or an outbreak caused by

a biological agent and improve its early detection.<sup>52</sup> Patients infected with a biological agent may initially appear to have a routine medical illness.<sup>40</sup> Syndromic surveillance uses health-related data that precede diagnosis and signal a sufficient probability of a case or an outbreak to warrant hospital response.<sup>53</sup>

### *Diagnostic Laboratories*

During biological hazards, hospitals should strengthen their diagnostic laboratory capability for rapid detection and identification of biological agents. For example, blood culture bottles and possibly continuous-monitoring blood culture instruments should be stockpiled. In the case of a surge of patients' specimens, hospital laboratories should have a limited number of level II Biological Safety Cabinets (BSC), with isolation and negative pressure rooms.<sup>54</sup> Therefore, assigning additional space to diagnostic laboratories and modifying the existing airflow in rooms are essential.<sup>55</sup> Laboratory experts and technicians should be trained in bioterrorism, because they are one of the first responders to detect the presence of an unusual biological agent or disease process. Procedures need to be in place for the safe handling and transport of specimens to specialized laboratories.<sup>36</sup>

### *Personnel and Facilities Protection*

Most of the time, infected patients and victims exposed to biological agents are not decontaminated upon their arrival to the hospitals. Therefore, the staff and facilities may be exposed to the biological agents.<sup>56</sup> Hospital staff involved in direct handling of infectious patients should be protected by appropriate PPE. Also, hospital personnel should be trained and adapted to the use of PPE.<sup>23,56,57</sup> PPE includes masks, gloves, protective clothing, eye shields, face shields, shoe covers, and also powered air purifying respirator (PAPR) devices.<sup>24,58</sup> Ideally, for agents transmitted by respiratory droplets, an N-95 mask would theoretically be adequate. In an ideal situation, a high-efficiency particulate air (HEPA) filter mask might be more appropriate.<sup>40</sup>

### *Mass Prophylaxis and Vaccination*

Some diseases caused by biological agents, such as anthrax, tularemia, and plague, can be prevented through adequate antibiotic prophylaxis. The aim of any hospital prophylaxis plan is to provide a unit in order to maintain staff such as emergency department and laboratory personnel who may have early exposure to the biological agent during and after a bioterrorism event. Staff and their family would get prophylaxis only if they were considered to have likely been exposed to biological agents.<sup>59</sup> Hospital staff may not want to come to the hospital, particularly without some prophylaxes.<sup>44,60</sup> Thus, pharmaceuticals and vaccines must be distributed quickly and efficiently to first responders before disease transmission to others.<sup>44</sup> Post-exposure vaccination and prophylaxes are

essential measures to reduce morbidity and mortality after biological hazards.<sup>40</sup>

### *Patients and Facility Decontamination*

With biological hazards, such as overt release of a biological weapon, decontamination will play a role in patient management. The presence of decontamination facilities outside and downwind of a hospital is necessary.<sup>61</sup> For biological agents such as anthrax spores, which can survive in the environment for decades, decontamination has been recommended.<sup>62,51</sup> Specific hospital personnel who perform triage and stabilizing should be trained to perform decontamination activities.<sup>47</sup> Decontamination facilities should consider shelter, warm water, and clothing for operations in winter.<sup>22</sup> Use of external decontamination facilities that can be activated quickly, barriers to provide patient privacy, and the use of warm water and soap should be sufficient to remove most biological agents.<sup>33</sup> Internal decontamination stations protect against warm and cold weather but have the disadvantage of permitting contaminated patients and victims to enter the hospital.<sup>63</sup>

### *Education and Exercise*

All hospital staff should be trained and educated on all aspects of biological hazards.<sup>64</sup> The main components of an education plan include agent detection and recognition, hospital incident command structure, response support, personnel safety and protection, decontamination, isolation and quarantine, infection-control policies and procedures, triage, prophylaxis activities, psychological effect management, risk communication, treatment, and fatality management.<sup>58</sup> Hospitals should begin by testing their preparedness plan with regular exercises to assess performance and to ensure correct staff response.<sup>56</sup> Exercises should be performed to recognize weakness; enhance teamwork; improve coordination; and promote skills, knowledge, and competencies.<sup>34,65</sup> Hospital exercises might be crafted to reflect the hospital preparedness status for biological attacks and those for severe epidemics and pandemics, thus encouraging the hospital to review its status.<sup>66</sup>

### *Psychological Effects Management*

A key component of any biological hazards preparedness plan will be providing psychological care to exposed victims, involved hospital personnel, and affected communities.<sup>40</sup> Psychological and psychosocial support for both patients and the hospital staff are necessary during the biological hazards. Staff are affected by the fear of contracting infectious disease and the anxiety caused by their families', friends', and colleagues' disease. Patients experience stress because of their quarantine and isolation, fear for their lives, guilt, anger, anxiety, and depression. Psychological teams in hospitals (including social workers, security personnel, psychiatric nurses, psychiatrists, and infectious disease specialists) can develop a plan for biological hazards in relationship with

hospitals' psychiatry departments to manage and care for the psychological impact on patients and hospital staff.<sup>57</sup>

### *Biological Hazard Specialized Team*

One unique approach to biological hazards is developing special teams.<sup>57</sup> In general, multidisciplinary teams developed and organized for response should include disaster management experts, physical plant/engineering, facilities maintenance, bioengineering, occupational physicians, emergency physicians, emergency nurses, toxicologists, infectious disease physicians, epidemiologists, infection-control experts, security personals, safety officers, hospital administrators, facility engineers, mental health practitioners, volunteer services coordinators, pharmacists, and health educators.<sup>34,36,47</sup>

### *Infection Control Services and Isolation*

Effective infection control services are important in biological agent control and may operationalize victim and patient isolation needs.<sup>47,67</sup> During a biological hazard, the safety officer should collaborate with medical-technical specialists (biological/infectious disease) to determine what information and protective measures are required.<sup>41,57</sup> Major infection control practices for biological hazards include checking the availability of PPE, hand hygiene, sharps safety and disposal arrangements, removing and disposing of the PPE, arrangements for cleaning, and ensuring environmental hygiene. Also, infection control planning for biological hazards should identify and consider the extra space, such as negative airflow rooms suitable for airborne infection and respiratory systems of available isolation or single rooms.<sup>22</sup> Isolation rooms and rooms under negative pressure should be established in a suitable location and in sufficient numbers, as it should be the case for a plan to increase this capacity through portable high efficiency particulate air devices.<sup>36</sup>

## **Logistical Hospital Preparedness Measures**

### *Increase Capability*

An ability to increase capability is a major issue for hospitals in disaster and overcrowding conditions.<sup>67</sup> Increasing capability, or the ability to rapidly respond to a sudden and dramatic increase in needs, has been addressed as one of the components of preparedness so hospitals can effectively respond to disasters.<sup>55</sup> Increasing capability comprises 3 components: staff, stuff, and structure. Structure consists of both the management infrastructure as well as the physical space required to provide for infectious patients' care.<sup>40,68</sup> Hospitals must have a preparedness plan to increase capability for response to biological hazards, as the potential large number of victims requiring medical care would soon overwhelm hospital facilities. Plans to expand the hospital capability internally and then to alternate care sites can help mitigate the impact. Expansion requirements include personnel, supplies and equipment, and space.<sup>32,36</sup>

### *Hospital Personnel and Volunteer Forces*

Developing hospital personnel to meet the rapidly increasing demand for services and staff in the aftermath of a biological hazard may be one of the most challenging aspects of preparedness to respond to biological hazards. Some staff members may themselves be infected by exposure to the biological agents or may fail to come to work for a variety of reasons, such as caring for their families. A list of alternate personnel should be prepared and a recall system for mobilizing adequate on-call personnel should be developed. Sufficient numbers of hospital staff include infectious disease physicians, emergency medicine, surgeons, intensivists, nurses, pharmacists, radiology technicians, infection control, clinical laboratory experts, and respiratory therapy. These types of staff will be most useful in addressing an infectious disease outbreak.<sup>20,47</sup> Possible sources of extra personnel could include staff from other hospitals, closed clinics, or outpatient surgery departments; hospital retirees; medical, nursing, and allied healthcare students; and volunteer forces.<sup>36</sup> One solution for the shortage of specialized hospital staff could be pre-identified health care volunteers within or outside the affected community.<sup>69</sup> These individuals will require proper education and orientation and may be asked to perform beyond their levels of competency under supervision. Because it is possible that terrorists may seek to volunteer, these persons must be selected cautiously.<sup>36</sup>

### *Supplies and Equipment*

A main consideration in the preparedness for biologic hazards is stockpiling of necessary medications, supplies, and equipment.<sup>40,70</sup> Even if hospitals usually have proper and sufficient treatments and pharmaceutical procedures, during biological disasters their supplies (prophylaxis/medications) would be limited.<sup>32,36</sup> In the case of a biological hazard, casualties are likely to be widespread and medications may be in demand from multiple sources.<sup>40,71</sup> Hospitals must seek other possible sources of equipment, including neighboring medical facilities, pharmacies, medical suppliers, and veterinarians.<sup>33</sup> These plans include increasing the ability of the hospital to quickly prepare large quantities of antibiotics, vaccines, and antitoxins; equipment to provide standard precautions; PPE; disposable clothing for decontaminated patients; ventilators and biohazard bags; HEPA filters, supplies routinely required for all patients, such as bed pans, linens, and other materials in excess of anticipated demand.<sup>33,44,55</sup> Ventilators are one of type of equipment that is likely to be in short supply after a biological hazard, so purchasing portable, disposable ventilators is critical.<sup>36</sup>

### **Physical Space**

One strategy for dealing with mass casualties from biological hazards is to use alternate sites of care.<sup>20</sup> Spaces that may need early expansion include the emergency department, infectious department, inpatient units, the morgue, laundry, and possibly decontamination facilities in the case of an announced biological agent's release. Establishing a secondary emergency

department in another area of the hospital or adjacent to primary units permits increased hospital capacity. The number of active hospital beds can be increased by canceling or rescheduling of elective and unnecessary cases for surgery.<sup>36</sup> Since biological hazards last for weeks, hospitals need to plan conjointly to use available land for temporary field hospitals, and then medical facilities can transfer patients there.<sup>36</sup> Prearranged agreements for access to spaces such as hotels, care facilities, hospice, medical universities, schools, churches, mosques, public halls, and community centers may also expand the capacity of a hospital.<sup>36,47</sup>

### *Hospital Security*

Hospitals may become terrorist targets especially during disasters and when the hospitals are overcrowded.<sup>36</sup> Hence, hospital officials must improve their security personnel in an effort to provide crowd control and protection for staff and patients.<sup>32</sup> Patients should be isolated or quarantined for prevention of spread of infection. Patients must be restricted exit from isolation by security personnel. Reserve security personnel are needed at hospital entrances, triage points, emergency departments, and isolation units to prevent unauthorized access. Reporting the suspected terrorist events should begin with local law enforcement, police, and local health departments.<sup>36</sup> During biological hazards, security personnel must be in place to control the flow of human gathering inside and around the hospital. In addition, security must monitor all vehicular traffic and assure that ambulances are able to transport patients rapidly.<sup>48</sup>

## **DISCUSSION**

Preparedness refers to actions taken to prepare for and mitigate the impact and proper response of disasters. The aim of disaster preparedness is to design a practical and coordinated plan for the hospital to ensure an effective response during disasters. Hospital disaster preparedness is an ongoing process resulting from a wide range of preparation and promotional activities. It necessitates the contributions of different external related organizations and all departments of the hospital. Major elements of preparedness include planning, early warning systems, education, and exercise.<sup>72</sup> A hospital has an important and critical role in reducing mortality and morbidity due to disasters. The current systematic review synthesizes hospital preparedness measures to biological hazards. Hospital preparedness plans mainly are based on an all-hazard approach. Due to the consequences of biological hazards, having a specific plan that focuses on biological hazards for hospitals is crucial. Some studies evaluated the status of hospital preparedness during biological hazards. Based on the reported results of these studies, hospitals generally were prepared neither to manage biological hazards nor to protect the victims and personnel.<sup>23,24</sup>

The hospital preparedness plan for biological hazards should be in accordance with the comprehensive hospital disaster

management plans and policies of the health system. Various studies have reported different measures and activities to prepare hospitals against biological hazards. Based on the findings of this systematic review, preparedness measures for biological hazards include administrative, specialized, and logistical issues. A comprehensive and inclusive hospital preparedness plan for biological hazards should consider basic and essential components, such as surge capacity, risk assessment, monitoring threats and rapid identification, staff, and patient perception. From administrative and management perspectives, activities such as planning for hospital preparedness for biological hazards, establishing and development of HICS, hospital collaboration with external agencies, health risk communications, effective education, and practical exercises and risk assessments are essential for preparation for biological hazards. Specialized issues for biological hazards include early detection and surveillance systems, diagnostic laboratories, psychological and psychosocial management, infection control services and isolation, personnel and facilities protection, patient and facility decontamination, and establishment of specialized biological teams. Logistical measures include increased capability, supplies and equipment, physical space, organization hospital personnel, volunteer forces, and hospital security. If hospitals neglect preparedness for biological hazards, they will be challenged during disasters. Also, deficiency in providing the above services may lead to personnel and victims' health being threatened by a secondary contamination or infectious disease transmission.

Following a mass casualty incident (MCI), the number of patients temporarily exceeds the capability of the hospital to provide optimal care to all victims simultaneously. A sudden mass casualty incident (SMCI) may be the result of a natural disaster such as an earthquake, traffic accidents (road accident, train or plane crash), explosion, or chemical or radiological exposure to hazardous materials. MCIs occur without any warning or alert. Temporary state of insufficiency at the hospital may be due to insufficient number of personnel, space in the emergency department and intensive care unit(s), operating rooms available, drugs and medical supplies (especially ventilators), amount of supplies, and number of blood units available. A hospital plan for a SMCI should include the following:

- Strategies to prevent patients flooding the hospital
- Surge capacity (staff, space, supplies)
- Call-in of additional staff
- Organization of treatment areas
- Opening and organization of alternate treatment sites with additional equipment and supplies
- Hospital risk communication plan
- Methods for identification, registration, and tracking of patients
- Individualized plan for respiratory therapy
- Blood bank
- Laboratory

- Radiology
- Organization of a family information center
- Activation of the SMCI plan and hospital response
- Triage and principles of medical care during a SMCI
- Planning and activation of hospital decontamination<sup>73</sup>

The response phase of the SMCI includes various stages, including preparing the triage area, making space in the emergency department, and finding alternate sites of medical care and operating rooms. For response to the incident, the first priority is to prepare the triage area outside the emergency department (ED) and create space inside the ED for the incoming critical patients. Also, it is critical that a hospital has a mature identification and registration system, for multiple simultaneous patients, which could be easily accessed when tracking of patients is required by family members looking for their loved ones.<sup>73</sup>

Biologic agent MCI, such as epidemic and pandemic diseases, may occur over a long period of time, such as days, weeks, months, or even years. The enormous amount of infected patients generally do not all arrive at the hospital simultaneously.<sup>73</sup> Comprehensive preparedness plans must therefore address the following:

- Screening
- Surveillance
- Tracking of exposed individuals
- Controlled hospital access
- Prevention strategies
- Isolation and cohorting
- PPE use
- Vaccination
- Antiviral prophylaxis
- Modification of environmental controls
- Disease-specific admission criteria
- Treatment and triage algorithms
- Continuity of limited clinical operations<sup>74</sup>

A fully deployed HICS should be beneficial for the hospital during a slowly developing biological epidemic, when a disease outbreak lasts for a few days or months. In these situations, there is enough time to schedule the key personnel listed in the HICS table of organization while verifying that they are actually available.<sup>73</sup> During biological hazards, such as an outbreak of infectious disease, an infections physician, virologist, or microbiologist should be appointed as a specialist consultant in HICS framework.

## CONCLUSIONS

In general, biological hazards, such as bioterrorism and disease outbreak, have adverse consequences on human health. Hospitals have an important role in dealing with biological hazards and mitigation of their effects. Hospitals preparedness plans and activities for biological hazards are crucial, and any neglect can hurt personnel and victims during the disaster.

In this systematic review, we provided a comprehensive discussion and summarized all aspects of the hospital preparedness for biological hazards. Some hospitals have planned for emergency and disasters, but these plans are based on an all-hazards approach. In conclusion, the findings of the present study could help health managers of hospitals to be prepared. These results may also improve the hospital response to biological hazards according to a situational assessment of the hospitals.

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### Acknowledgments

This article is part of a study conducted by Iran University of Medical Sciences (IR.IUMS.SHMIS97-4-37-14382), Iran. The researchers hereby thank the School of Management & Medical Informatics, Department of Health in Disasters and Emergencies, which are supporting the study.

### Funding

Funding for this article was provided by the Iran University of Medical Sciences.

### Conflict of Interest

The authors have no conflicts of interest to declare.

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