

HOSPITAL PREPAREDNESS ASSESSMENT INSTRUMENTS IN CHEMICAL INCIDENTS: A SYSTEMATIC LITERATURE REVIEW

Fatemeh Teymouri¹, Armin Zareian*¹, Amir Hosein Pishgooie², Hasan Bagheri³

1. Department of Health in Disasters and Emergencies, Aja University of Medical Sciences, Tehran, Iran
2. Department of Critical Care Nursing, Aja University of Medical Sciences, Tehran, Iran
3. Chemical Injuries Research Center, Systems Biology and Poisonings Institute, Baqiyatallah University of Medical Sciences, Tehran, Iran

Correspondence: a.zareian@ajaums.ac.ir

ABSTRACT

BACKGROUND:

Chemical incidents are among the most frequent technological disasters that have occurred frequently in recent years. Among the organizations operating in a disaster response, hospitals, as the primary unit of care, play the greatest and most critical role. Therefore, providing appropriate measures that lead to minimizing the effects of these events is raised as one of a health system's priorities. This study was carried out with the aim of undertaking a systematic review of the literature on hospital preparedness instruments in chemical incidents.

METHODS:

This systematic review was carried out according to the Systematic Reviews and Meta-Analyses guidelines. In line with this aim, in December 2020, six electronic databases were searched in MEDLINE (PubMed, Scopus, ISI Web of Science, ProQuest, Embase, and Cochrane) with the following key words: hospital, preparedness, chemical incidents, instrument.

RESULTS:

Out of 7,794 articles that were screened, 13 articles meet the inclusion criteria for the process of final analysis. Most studies were cross-sectional, two were cohort, and three studies were conducted by a qualitative method. The result showed that none of the evaluated checklists and tools included all dimensions required for an appropriate hospital preparedness evaluation in the event of chemical incidents.

CONCLUSION:

Based on the results of this investigation, there is no comprehensive tool for assessing hospital preparedness in chemical incidents. However, the data from this survey can be employed as guidelines for policymakers and managers of medical centers for planning in dealing with potential chemical incidents.

KEYWORDS

Chemical Incidents, Hospital, Instrument, Preparedness

INTRODUCTION

Contact with hazardous material takes place in a variety of ways, including at the Industrial sites responsible for the production and storage of these materials; during the transportation of these materials through the land, rail, sea, and air ways; or as a result of deliberate release of chemicals by terrorist organizations. [1, 2] Chemical incidents are among the most frequent technological disasters that have occurred in recent years. [3] In accordance with the results of the Center for Research on the Epidemiology of Disasters, 5,143 technological disasters (accidents or unexpected and uncontrolled emissions of explosives and dangerous substances) have happened from 2000 to 2019 and has impacted approximately 1.4 million people. [4] The worst chemical disaster in history took place in Bhopal, India, in 1985, which led to the deaths of 2,500 people and injuring 150,000 people. [5] In Iran, the explosion of a train carrying sulfur, ammonium nitrate, cotton, and oil at Khayyam station in Neyshabur, led to the death of over 300 people and injuring of more than 450 people. [6] In addition, the explosion of ammonium nitrate in the port of Beirut on August 4, 2020, influenced more than 300,000 people and resulted in the death of 220 people. Moreover, it consequentially caused social unrest and a sharp drop in economic conditions in the region. [4]

Although chemical incidents may happen in a limited way, they generate numerous physical and psychological effects on people in the community [7] and cause hospitals to be faced with a large number of injured persons. [8] Injuries caused by chemical incidents need special medical care and management such as triage, decontamination, administration of antidote, attention to trauma for the injured, suitable exploitation of personal protective equipment, and prevention of secondary contamination of health care personnel. [9] Therefore, providing appropriate measures that lead to minimizing the effects of these events is raised as one of the health system's priorities. [10]

Among the organizations operating in disaster response, healthcare organizations, particularly hospitals, as the primary unit of care, play the greatest and most critical

role. [11, 12] Maintaining the functionality and performance of the hospital in times of disaster enables hospitals to have the ability to respond to the high volume of patients and injured while conducting their current duties. [13] Thus, in the preparation stage before disasters, assessing the preparedness of hospitals against all kinds of disasters is taken into account as one of the concerns of health system managers. [14, 15] The results of investigations in different countries indicate the lack of preparedness of hospitals and health-care personnel in chemical incidents. [16-18]

Assessing the hospital's preparedness for disasters is very important to understand the strengths and weaknesses of the hospital in terms of disaster management before the occurrence of events. This contributes to authorities upgrading hospital preparedness through decreasing vulnerability and increasing capacity. [19] To this end, diverse tools were designed to maintain hospital preparedness in relation to chemical incidents; however, there is still no consensus on which tools are beneficial in preserving hospital preparedness in these events. [20] Therefore, evaluating the existing tools and extracting the effective factors in hospital preparedness has a crucial role for policymakers in this field. The present study systematically reviewed the instruments available in this field. The results of this study can play an essential role as a guide in designing and developing standard instrument for hospital preparedness in chemical incidents.

METHODS

DATABASES AND SEARCH STRATEGY

This study is a systematic literature review in which investigations and data extraction were conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analysis protocol (PRISMA). [21] In this study, an extensive search was conducted to achieve articles associated with the research question in the databases of PubMed, Scopus, ISI Web of Science, ProQuest, Embase and Cochrane databases from 1970 to 2020, with the keywords in the form of MESH terms. The searching strategy of PubMed was used as a model for searching other databases while others were modified according to the requirement (Appendix 1).

INCLUSION AND EXCLUSION CRITERIA

Studies that were included in the study were those that were conducted using quantitative and qualitative methods; were relevant to the research question; focused on tools for assessing hospital preparedness in chemical incidents; enabled access to the full text of the article; and were published in the English language. Exclusion criteria applied to studies with no abstracts; where there were no full-text articles available; and duplicate articles.

Two reviewers (FT and AZ) independently assessed the eligibility of studies by screening titles and abstracts according to the inclusion criteria. After the initial selection, fulltext articles were retrieved and assessed again independently by the authors (FT, AZ, AHP and HB). Discrepancies were solved by discussion. (Figure 1)

The quality of the articles was assessed with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Checklist and Consolidated criteria for Reporting Qualitative research (COREQ) Checklist.

The data extraction form was grouped into two sections. The first section was related to the characteristics of the included studies such as the first author, year of publication, Participants, type of tool, study design/methods, evaluation dimensions, validity and reliability of the instrument (Table 1). The second section was related to the key findings of the studies (Table 2)

RESULTS

The initial search, with the specified search strategies, resulted in 8,303 documents (PubMed (1,733), ISI Web of

Science (446), Scopus (3,202), ProQuest (682), Embase (677), Cochrane (1398) Conference (69), Thesis (n=96) of which 509 were duplicated. After reviewing titles, 468 were selected for an abstract check. Then after reviewing abstracts, 136 papers were selected. Finally, 13 papers were selected through the full text of the selected articles.

The data gained from the reviewed articles are demonstrated in Table 1 and is based on the first author, date of publication, the title of the study, research units, type of instrument, evaluation method and technique, evaluation dimensions, validity and reliability of the instrument.

The majority of the articles that were included in the study were from the USA (46.1%, n = 6) and then the United Kingdom (23%, n = 3) and one article each from Italy, Canada, the Netherlands, and Israel were included in the study. Most studies were cross-sectional (61.5%, n = 8), two were cohort, and three studies were conducted by a qualitative method.

All 13 papers were subjected to qualitative content analysis of data and based on the results from the analysis of these articles, factors affecting the preparedness of hospitals in chemical incidents were identified. The assessment tools reported in this study considered various subcategories for each of the hospital preparedness elements.

Table 2 shows the factors extracted from articles regarding hospital preparedness in chemical incidents.

FIGURE 1: PRISMA FLOW DIAGRAM FOR THE SYSTEMATIC REVIEW PROCESS

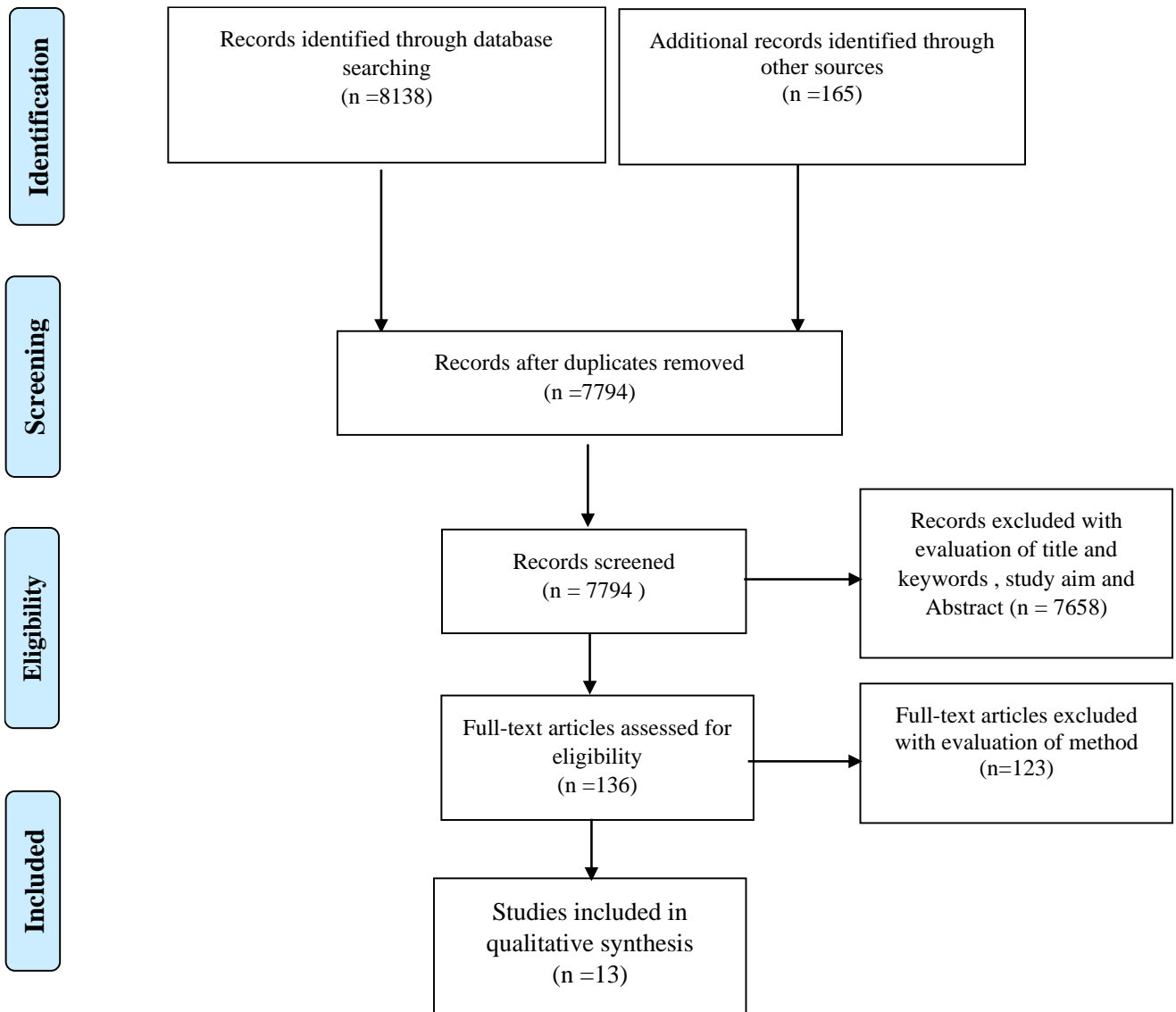


TABLE 1: AN OVERVIEW OF CHARACTERISTICS OF ARTICLES INCLUDED

Author, date of publication and place of study	Title of the study	Participants	Type of tool	Study design/Methods	Evaluation dimensions	Validity and Reliability
Burgess, 1997 USA (22)	Hospital Preparedness for Hazardous Materials Incidents and Treatment of Contaminated Patients	95 hospitals	Hospital self-assessed capability, including physical facilities and existing policies, to care for persons contaminated with hazardous materials.	Cross-sectional / A questionnaire was designed based on The Joint Commission on Accreditation of Healthcare Organizations standards and experiences gained from chemical exposures.	Three dimensions (Facilities for radioactive or chemical isolation and decontamination, A plan for evacuating the facility for sources of contamination, including spills or contaminated patients, or both, A written protocol for the treatment of patients exposed to hazardous materials)	Validity No Reliability No
Horby, 2000 United Kingdom (23)	The capability of accident and emergency departments to safely decontaminate victims of chemical incidents	154 hospitals	A questionnaire on decontamination of casualties exposed to hazardous chemicals	Cross-sectional / The questionnaire was designed by the authors and administered as a pilot	Four dimensions (chemical incident plan, staff training, decontamination equipment including personal protective equipment (PPE), and indoor and outdoor decontamination facilities)	Validity No Reliability No
Case, 2001 USA (24)	Hospital Preparedness for Biological and Chemical Terrorism in Central New Jersey	11 hospitals	Hospital preparedness Inventory to care for victims of biological and chemical terrorist incidents	Cross-sectional / A questionnaire consisting of 20-item was emailed to the hospital emergency manager and completed by those responsible for planning chemical and biological incidents	Five dimensions (training of personnel, logistical support of these patients, laboratory diagnosis, incident-control mechanisms, and pertinent information system)	Validity No Reliability No
Greenberg, 2002 USA (25)	Emergency department preparedness for the evaluation and treatment of victims of biological or chemical terrorist attack	54 hospitals	Preparation of the emergency department instrument to evaluate and treat victims of a biological or chemical terrorist attack	Cross-sectional / 38-item tool design by authors based on Domestic Preparedness Hospital provider Course Syllabus version 8.0	Five dimensions (physician training and education, antidote stocking, written policies, interagency agreements, and decontamination)	Validity No Reliability No

Author, date of publication and place of study	Title of the study	Participants	Type of tool	Study design/Methods	Evaluation dimensions	Validity and Reliability
Keim, 2003 USA (26)	Lack of hospital preparedness for chemical terrorism in a Major US City: 1996–2000	21 hospitals	Hospital preparedness for chemical terrorism	Cross-sectional questionnaire A questionnaire consisting of 7 questions was emailed to the responsible for the hospital's emergency	Four dimensions (antidote stocks, institutional response capabilities including the number of showers for decontaminating patients, the level of worker protection, and the number of staff trained to decontaminate)	Validity No Reliability No
Kollek, 2003 Canada (27)	Canadian emergency department preparedness for a nuclear, biological or chemical event	59 hospitals	Emergency preparedness against chemical, biological, nuclear, and radiological accidents	Cross-sectional / The questionnaire was designed based on a review of literature	Four dimensions (risk assessment, general disaster preparedness, preparedness for a biological event, and preparedness for a chemical or nuclear event)	Face validity Yes Reliability No
Crawford, 2004 United Kingdom (1)	Delphi based consensus study into planning for chemical incidents	39 experts from specialties involved in the management of chemical incidents	chemical incident planning and response	Qualitative study /183 statements were generated on the basis of three Delphi rounds	Preparation dimension, including three categories (planning, equipment, training) Pre-hospital response dimension, including seven categories (incident assessment, leadership, safety, communications, triage, treatment, and transfer) Hospital response dimension, including three categories (triage, treatment, and transfer)	Validity No Reliability No

Author, date of publication and place of study	Title of the study	Participants	Type of tool	Study design/Methods	Evaluation dimensions	Validity and Reliability
Bennett, 2006 USA (28)	Chemical or Biological Terrorist Attacks: An Analysis of the Preparedness of Hospitals for Managing Victims Affected by Chemical or Biological Weapons of Mass Destruction	102 Hospitals	A self-administrated questionnaire specific preparedness for managing victims of an attack involving Chemical or Biological Weapons of Mass Destruction	Cross-sectional / The questionnaire were developed based on review of literature	Six dimensions (documented and functional preparedness plans; specific preparedness education/training; decontamination facilities; surge capacity; pharmaceutical procedures and supplies; and laboratory diagnostic capability)	Validity Yes Reliability Yes
Williams, 2007 United Kingdom (29)	Preparedness of emergency departments in northwest England for managing chemical incidents: a structured interview survey	18 head nurses in the emergency department	Emergency preparedness for the management of chemical accidents	Qualitative study/ Semi-structured interview based on the analysis of interviews, a 34-item questionnaire was designed by one of the authors.	Four dimensions (Planning and training, Facilities and equipment, Water supply and disposal, Patient privacy, dignity and comfort)	Validity No Reliability No
Belsky, 2016 USA (30)	Survey of Emergency Department Chemical Hazard Preparedness in Michigan, USA: A Seven Year Comparison	120 emergency departments in 2005 and 99 emergency departments in 2012	MCEP (Michigan College of Emergency Physicians) disaster preparedness survey	longitudinal survey / The questionnaire was designed based on a review of the literature	Three dimensions (including decontamination, Supplies, Staffing)	Validity No Reliability No

Author, date of publication and place of study	Title of the study	Participants	Type of tool	Study design/Methods	Evaluation dimensions	Validity and Reliability
Oliveri, 2017 Italy (13)	Hospital preparedness and response in CBRN emergencies: TIER assessment tool	18 experts from European and non-European countries	Hospital preparedness assessment tool in CBRN emergencies	Qualitative study / Design of tool by Delphi technique and expert panel	Seven dimensions (Planning and organization, Safety and security, Standard Operation Procedures, Resources, Communication, Decontamination, Medical Management)	Validity No Reliability No
Mortelmans, 2017 Netherlands (31)	Are Dutch Hospitals Prepared for Chemical, Biological, or Radionuclear Incidents? A Survey Study	93 hospitals	Hospital preparedness of the Netherlands to deal with chemical, biological and nuclear accidents	Cross-sectional	Eight dimensions (Risk perception for CBRN incidents, hospital disaster planning, decontamination procedures and installations, availability of PPE, staff training and antidote use, availability of radio-detection equipment, isolation resources, nuclear medicine specialists, and infectiologists)	Validity No Reliability No
Siman-Tov, 2020 Israel (20)	Maintaining Preparedness to Severe Though Infrequent Threats— Can It Be Done?	24 hospitals	evaluation tool to measure readiness for toxicological/chemical events	longitudinal survey / Design of tool by Delphi technique	Four dimensions (standard operating procedures, equipment and infrastructure, knowledge of medical personnel, training and exercises)	Validity Yes Reliability No

TABLE 2: CATEGORIES AND SUBCATEGORIES OF HOSPITAL PREPAREDNESS IN CHEMICAL INCIDENTS

categories	Subcategories
Planning and organizing	A plan for evacuating the facility for sources of contamination[22], chemical incident plan (23, 31), isolation plan(26), planning(1), planning and organization(13), incident-control mechanisms(24), documented and functional preparedness plans (28), Standard operation procedures(13, 20), A written protocol for the treatment of patients exposed to hazardous materials(17, 22, 25, 28), special team for hazardous materials(20, 30, 31)
Empowerment of staff	Training of personnel(1, 23, 24, 26, 28, 30, 31), training and exercise(20, 31), Drill Experience with Regard to Biological and Chemical Scenarios(25)
Resource and facility management	Resources and equipment(1, 13, 17), logistics support(23), antidote storage (25, 27, 28, 30, 31), increase in surge capacity(28, 31), communication equipment(30)
Decontamination	Decontamination program(17, 27) planning for the exploitation of dry decontamination(30), isolation and decontamination facilities for chemical and radioactive materials(22), decontamination facility(20, 28), decontamination site(17, 23, 27, 31), decontamination shower(26, 30), internal and external decontamination equipment(23), water supply and disposal(17)
Coordination and communication	Coordination with local and regional resources (30), communications(13), Internet information systems(24)
Safety and security	Safety and security(13, 31), decontamination capability of the victims(25), personal protective equipment(20, 23, 26, 27, 30, 31), laboratory diagnosis of risk factors(24, 28, 31)

DISCUSSION

Various studies have been conducted about instruments used to identify factors affecting the readiness of hospitals in chemical incidents. Mass casualty incidents resulting from hazardous materials cause dysfunction in the activities of the emergency department, confusion, impaired communication, and lack of coordination. In the absence of immediate detection of the chemical incidents at the time of admission of victims, the incident may lead to secondary contamination of hospital personnel and infrastructure. [20] Hospital preparedness plays a vital role in the diagnosis and management of chemical victims,

and policymakers are seeking novel instruments that could promote hospital preparedness. [32]

The results of this study showed that several factors are effective in hospital readiness in chemical incidents. These factors were classified into six categories: planning and organization, empowerment of staff, resource and facilities management, decontamination, coordination and communication, safety and security.

Planning and organizing is the basis of hospital preparedness and has a great impact on the capacity of the hospital to respond to disasters. [13] Special planning for chemical incidents is needed at all levels of health services (1). An appropriate plan for this incidents includes

all essential dimensions, examination and identification of hazardous material, [23, 24, 27] isolation and prevention of secondary contamination of personnel and infrastructure, [26] decontamination facilities, [22, 25] a protocol for assessment and treatment of victims, [22, 25] emergency department evacuation program and other wards of the hospital in contamination with hazardous materials. [22]

Among the most critical dimensions of hospital preparedness to respond to chemical incidents is the empowerment of staff. Healthcare personnel should have suitable training so that they have the capability of assessing and treating chemical victims. [33] Training of personnel should be in accordance with their role and responsibilities in the disaster management program. [34] Although increasing knowledge and awareness is an important factor for performance, it is not sufficient to ensure good performance. Hence, assessment of knowledge and performance of personnel through holding various maneuvers is essential. [20] The goal of holding drills is the evaluation and improvement of hospital preparedness policies and programs and to upgrade the performance of personnel. [20] Besides, it causes the reassurance in personnel for reception and treatment of chemical victims. [24]

One of the other important factors in hospital preparedness for chemical incidents is resource and facilities management. In order to provide logistical resources and equipment, the hospital encounters challenges. Since hospitals have to bear costs despite the low occurrence of chemical incidents, including drugs required for the treatment of chemical victims, they are expensive and can only be stored for a short time, [24, 35] In this respect, experts insist that hospitals should have cooperation agreements with other hospitals and organizations, including the fire services, emergency medical services for joint use of resources and equipment at the time terrorist attacks. [25]

Decontamination is one of the contributing factors in hospital preparedness for chemical incidents. In order to prevent the contact of hospital personnel and facilities with chemical agents, all infected patients should be decontaminated before admission to the emergency department or at least at the entrance to the emergency department. [35] The decontamination process typically needs equipment, access to trained personnel as a decontamination team, and decontamination facilities such as showers and water with the appropriate

temperature. Some experts recommend dry decontamination as a first step. [13]

Coordination and Communication is considered as one of the main challenges in disasters, [36] especially in chemical incidents and these events are capable to create many psychological and physical problems for the general public as well as the medical staff exposed to the victims. [2] Each hospital should have a coordinator for mobilizing hospital resources at the time of disasters. [30] The complex and dynamic nature of disasters often generates problems in the coordination between the activities of emergency medical services and hospitals. [24] The lack of informed and timely communication between hospitals causes an increase in confusion in disaster response. Thus, the relationship between the hospital and the scene of the events should be strengthened so that hospitals could provide more resources in these circumstances. [37] During chemical events, providing detailed and reliable information is raised as a necessity for healthcare providers, firefighters, police, officials, and even victims. [13]

Safety and security is the first priority for personnel providing medical services in times of disaster. In order to ensure safe conditions, a number of procedures, personal protective equipment, pollution control, and close supervision of security officers are required. [13] Considering that the chemical incident can take place anywhere, so the chemical victims are transferred to the nearest hospital. The experience of the Tokyo incident indicates that most of the victims themselves were referred to the hospital before decontamination. [27] This causes contamination of hospital personnel and facilities. Hence, the hospital security and safety forces should not allow the victims to enter the emergency department before decontamination; in the meantime, the personnel should use suitable personal protective equipment. [5] Protection of the hospital personnel has priority over the treatment of the victims. If personnel are not safe, they quickly become injured, causing complex problems for the hospital. [24]

STRENGTHS AND LIMITATIONS OF THE STUDY

There is an extensive list of related keywords to search in several high-quality databases. Moreover, a search in the gray literature and accurate screening of studies using standard criteria are the study's strengths. One of the limitations of the research was that only articles published in English were included in the study.

CONCLUSION

In this study, 13 articles that involved both quantitative and qualitative research approaches were investigated and analyzed. The results revealed that there is no comprehensive instrument for assessing hospital preparedness in chemical incidents, and none of the studies employed the standard method of tool making and psychometrics to prepare the tool, and none of the tools had all the dimensions related to assessing the hospital preparedness for chemical incidents.

Any organization and country exploited criteria and an approach consistent with their cultural background to assess the hospital preparedness for chemical events. Tools associated with medical centers and health care personnel should be designed based on a systematic review and using the experience of experts. The data of this study could be applied as a valuable resource for planning to upgrade hospital emergency programs in chemical incidents at the regional, local, and national levels.

References

1. Crawford IW, Mackway-Jones K, Russell DR, Carley SD. Delphi based consensus study into planning for chemical incidents. *Emerg Med J.* 2004;21(1):24-8.
2. Clarke SA, Weir AGA. UK resilience to a chemical incident. *Journal of the Royal Army Medical Corps.* 2019.
3. Koenig KL, Schultz CH. Koenig and Schultz's Disaster Medicine Comprehensive Principles and Practice. 2 ed. New York: Cambridge University Press 2016.
4. EM-DAT, CRED/UCLouvain, Brussels, Belgium [Internet]. Available from: www.emdat.be (D. Guha-Sapir).
5. Chan J, Yeung R, Tang S, . Hospital preparedness for chemical and biological incidents in Hong Kong. *Hong Kong Med J.* 2002;8(6):440-6.
6. Jahangiri K, Ghodsi H, Khodadadizadeh A, Nezhad SY. Pattern and nature of Neyshabur train explosion blast injuries. *World journal of emergency surgery.* 2018;13(1):1-5.
7. Moradi Majd P, Seyedin H, Bagheri H, Tavakoli N. Hospital Preparedness Plans for Chemical Incidents and Threats: A Systematic Review. *Disaster Med Public Health Prep.* 2019:1-9.
8. Razak S, Hignett S, Barnes J. Emergency Department Response to Chemical, Biological, Radiological, Nuclear, and Explosive Events: A Systematic Review. *Prehospital and Disaster Medicine.* 2018;33(5):543-9.
9. Hasani-Sharamin P, Bagheri H, Salesi M, Dadashi F, Rouhollahei M, Poorheidary G, et al. Necessary Indicators for Developing a Hazmat Response Team of the Iranian Health System. *Advanced Journal of Emergency Medicine.* 2020.
10. Ghaedi H, Nasiripour A, Tabibi SJ. Hospital Preparedness in Radiation Crisis in Selected Countries and Developing a Conceptual Model for Iran. *ISMJ.* 2018;21(5):393-408.
11. Sharififar S, Jahangiri K, Zareiyani A, Khoshvaghti A. Factors affecting hospital response in biological disasters: A qualitative study. *Medical journal of the Islamic Republic of Iran.* 2020;34:21.
12. Azarmi S, Pishgooie AH, Sharififar S, Khankeh HR, Hejrypour SZ. Challenges of Hospital Disaster Risk Management: A Systematic Review Study. *Disaster Medicine and Public Health Preparedness.* 2021:1-8.
13. Olivieri C, Ingrassia PL, Della Corte F, Carezzo L, Sapori J-M, Gabilly L, et al. Hospital preparedness and response in CBRN emergencies: TIER assessment tool. *European Journal of Emergency Medicine.* 2017;24(5):366-70.
14. Barbera JA, Yeatts DJ, Macintyre AG. Challenge of Hospital Emergency Preparedness: Analysis and Recommendations. *Disaster Medicine and Public Health Preparedness.* 2009;3:S74-S82.
15. Aminizadeh M, Farrokhi M, Ebadi A, Masoumi GR, Kolivand P, Khankeh HR. Hospital management preparedness tools in biological events: A scoping review. *Journal of Education and Health Promotion.* 2019:8.
16. Jama TJ, Kuisma MJ. Preparedness of Finnish emergency medical services for chemical emergencies. *Prehospital and disaster medicine.* 2016;31(4):392-6.
17. Williams J, Walter D, Challen K. Preparedness of emergency departments in northwest England for managing chemical incidents: a structured interview survey. *BMC Emergency Medicine.* 2007;7(1):20.
18. Azeem AR, Sharif MW, Akhtar A, Sohail CS, Dar AA, Khan M, et al. Perception of Preparedness of Health Care Professionals in Case of a Nuclear, Chemical, Biological Attack/Emergency in a Tertiary Care Hospital. *Cureus.* 2019;11(5).
19. Heidarlanlu E, Ebadi A, Khankeh HR, Ardalan A. Hospital disaster preparedness tools: a systematic review. *PLoS currents.* 2015;7.

20. Siman-Tov M, Davidson B, Adini B. Maintaining Preparedness to Severe Though Infrequent Threats—Can It Be Done? *International Journal of Environmental Research and Public Health*. 2020;17(7):2385.
21. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic reviews*. 2015;4(1):1-9.
22. Burgess JL, Blackmon GM, Brodtkin CA, Robertson WO. Hospital preparedness for hazardous materials incidents and treatment of contaminated patients. *Western Journal of Medicine*. 1997;167(6):387-91.
23. Horby P, Murray V, Cummins A, Mackway-Jones K, Euripidou R. The capability of accident and emergency departments to safely decontaminate victims of chemical incidents. *J Accid Emerg Med*. 2000;17(5):344-7.
24. Case GG, West BM, McHugh CJ. Hospital preparedness for biological and chemical terrorism in central New Jersey. *N J Med*. 2001;98(11):23-33.
25. Greenberg MI, Jurgens SM, Gracely EJ. Emergency department preparedness for the evaluation and treatment of victims of biological or chemical terrorist attack. *J Emerg Med*. 2002;22(3):273-8.
26. Keim ME, Pesik N, Twum-Danso NAY. Lack of hospital preparedness for chemical terrorism in a major US City: 1996-2000. *Prehospital and Disaster Medicine*. 2003;18(3):193-9.
27. Kollek D. Canadian emergency department preparedness for a nuclear, biological or chemical event. *Cjem*. 2003;5(1):18-26.
28. Bennett RL. Chemical or biological terrorist attacks: An analysis of the preparedness of hospitals for managing victims affected by chemical or biological weapons of mass destruction. *International Journal of Environmental Research and Public Health*. 2006;3(1):67-75.
29. Williams J, Walter D, Challen K. Preparedness of emergency departments in northwest England for managing chemical incidents: a structured interview survey. *BMC Emerg Med*. 2007;7:20.
30. Belsky JB, Klausner HA, Karson J, Dunne RB. Survey of Emergency Department Chemical Hazard Preparedness in Michigan, USA: A Seven Year Comparison. *Prehosp Disaster Med*. 2016;31(2):224-7.
31. Mortelmans LJM, Gaakeer MI, Dieltiens G, Anseeuw K, Sabbe MB. Are Dutch Hospitals Prepared for Chemical, Biological, or Radionuclear Incidents? A Survey Study. *Prehospital and Disaster Medicine*. 2017;32(5):483-91.
32. Asch SM, Stoto M, Mendes M, Valdez RB, Gallagher ME, Halverson P, et al. A review of instruments assessing public health preparedness. *Public Health Reports*. 2005;120(5):532-42.
33. Wanner D, Gregory K, Atti M, Jasper M. *Chemical Disaster Preparedness for Hospitals and Emergency Departments*. 2019.
34. Greenberg MI, Hendrickson RG. Report of the CIMERC*/Drexel University Emergency Department Terrorism Preparedness Consensus Panel. *Academic Emergency Medicine*. 2003;10(7):783-8.
35. Mortelmans LJM, Van Boxstael S, De Cauwer HG, Sabbe MB. Preparedness of Belgian civil hospitals for chemical, biological, radiation, and nuclear incidents: are we there yet? *European Journal of Emergency Medicine*. 2014;21(4):296-300.
36. Seyedin H, Moradimajd P, Bagheri H, Nasiri A. Providing a Chemical Events and Threat's Preparedness Model for Hospitals in the Country: A Qualitative Study. *Journal Mil Med*. 2021;23(3):220-7.
37. Christensen BE, Duncan MA, King SC, Hunter C, Ruckart P, Orr MF. Challenges during a Chlorine Gas Emergency Response. *Disaster Medicine and Public Health Preparedness*. 2016;10(4):553-6.

APPENDIX 1: SEARCH STRATEGY FOR PUBMED

Database	Controlled and natural keywords
PubMed	(((((((((((((((((((((((((((((((((((Tool [Title/Abstract])) OR (Questionnaire [Title/Abstract])) OR (Checklist [Title/Abstract])) OR (Instrument [Title/Abstract])) OR (Rating Scale [Title/Abstract])) OR (Inventory [Title/Abstract])) OR (Profiles [Title/Abstract])) OR (Scale [Title/Abstract])) OR (Index [Title/Abstract])) OR (Assessment [Title/Abstract])) OR (Criteria [Title/Abstract])) OR (Standards [Title/Abstract])) OR (survey [Title/Abstract])) AND (medical facilities [Title/Abstract])) OR (Emergency room [Title/Abstract])) OR (Health officials [Title/Abstract])) OR (Health care facilities [Title/Abstract])) OR (Health care facility [Title/Abstract])) OR (medical facility [Title/Abstract])) AND (Preparedness [Title/Abstract])) OR (Readiness [Title/Abstract])) OR (Response [Title/Abstract])) OR (Appraisal [Title/Abstract])) OR (Measurement [Title/Abstract])) OR (Evaluation [Title/Abstract])) OR (Management [Title/Abstract])) AND (chemical incidents [Title/Abstract])) OR (hazardous material [Title/Abstract])) OR (chemical accident [Title/Abstract])) OR (chemical event [Title/Abstract])) OR (chemical occurrence [Title/Abstract])) OR (chemical hazard [Title/Abstract])) OR (chemical threat [Title/Abstract])) OR (chemical agent [Title/Abstract])) OR (chemical terrorism [Title/Abstract]))