SYSTEMATIC REVIEW

Surge Capacity of Hospitals in Emergencies and Disasters With a Preparedness Approach: A Systematic Review

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ABSTRACT

Objective: Surge capacity is one of the most important components of hospital preparedness for responding to emergencies and disasters. The ability to provide health and medical care during a sudden increase in the number of patients or victims of disasters is a main concern of hospitals. We aimed to perform a systematic review of hospital surge capacity in emergencies and disasters with a preparedness approach.

Methods: A systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The key words "surge," "surge capacity," "preparedness," "hospital emergency department," "hospital," "surge capability," "emergency," "hazard," "disaster," "catastrophe," "crisis," and "tragedy" were used in combination with the Boolean operators OR and AND. The Google Scholar, ISI Web of Science, Science Direct, PubMed, Scopus, Ovid, Pro Quest, and Wiley databases were searched.

Results: A total of 1008 articles were extracted and 17 articles were selected for final review of surge capacity based on the objective of the study. Seventeen studies (1 randomized controlled trial, 2 qualitative studies, and 14 cross-sectional studies) investigated the surge capacity of hospitals in emergencies and disasters to evaluate the best evidence to date. The results of selected articles indicated that there are various ways to increase the capacity of hospitals in 4 domains: staff, stuff, structure, and system.

Conclusion: Surge capacity is a basic element of disaster preparedness programs. Results of the current study could help health field managers in hospitals to prepare for capacity-building based on surge capacity components to improve and promote hospital preparedness programs. (*Disaster Med Public Health Preparedness*. 2017;11:612-620)

Key Words: preparedness, surge capacity, hospital, emergency, disaster

Emergencies and disasters can cause disorder in social and organizational activities; such disorder may be more than the capacity of the damaged area to cope with associated financial and physical damages. On other hand, effective management of these destructive and damaging events depends on predicting the problems associated with these events and planning to respond to them effectively.[1] The first and most important demand of people in these events is their health and well-being; therefore, health systems should play a key role in reducing mortalities and injuries.[1] Hospital preparedness to cope with disasters is an important part of health system programs to reduce loss and disabilities. In fact, the international slogan of preparedness for coping with emergencies and disasters, especially hospital preparedness, is the main program in disaster management at the national level, especially in disaster-prone countries.[2] The ability to provide medical and health care during a sudden increase in the number of patients or victims of emergencies and disasters is the main concern of health systems and hospitals, in particular, preparing for and improving surge capacity.[3] There are several definitions of surge capacity. According to the American College of Emergency Physicians, surge capacity is the health care system's ability for timely management of situations such as a sudden increase in the number of patients admitted to the hospital using available resources.[4] In addition to the use of available resources to manage a sudden influx of injured people or patients, several studies consider surge capacity as the ability of hospitals to increase available resources in response to disasters.[5,6] Surge capacity of hospitals has 3 main components: human resources, specialized and nonspecialized equipment, and physical space.[7] Surge capacity programs should be developed and implemented on the basis of evaluation and risk analysis. Therefore, before developing this program, risks or hazards threatening hospitals must be identified, and

hospital vulnerability characteristics must be extracted.[8] The hospital surge capacity program is dynamic and must be revised and updated constantly.[9,10] The aim of the current study was to perform a systematic review of hospital surge capacity in emergencies and disasters with a preparedness approach. The results of the current study may help health field managers in hospitals with capacity-building on the basis of surge capacity components (staff, stuff, system, structure) and may help to promote hospital preparedness for appropriate response to emergencies and disasters.

METHODS

The present study was a systematic review of publications and documents relating to hospital surge capacity in emergencies and disasters with a preparedness approach. The review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[11]

Search Strategy

This study was conducted during November 2015 to review all published articles in the field of surge capacity of hospitals in emergencies and disasters. For this purpose, we studied databases including Google Scholar (Google Inc, Mountain View, CA), ISI Web of Science (Thomson Reuters, New York, NY), Science Direct (Elsevier, Amsterdam, Netherlands), PubMed (National Library of Medicine, Bethesda, MD), Scopus (Elsevier), Ovid (New York, NY), ProQuest (Ann Arbor, MI), and Wiley (Hoboken, NJ) from January 1, 2000, to October 22, 2015. The search key words included "surge," "surge capacity," "preparedness," "hospital emergency department," "hospital," "surge capability," "emergency," "hazard," "disaster," "catastrophe," "crisis," and "tragedy." Using MeSH (Medical Subject Headings; National Library of Medicine), synonyms of these keywords were also extracted. These included "hospital communication," "hospital department," "high volume hospital," "hospital information system," "hospital planning," "hospital rapid response," "hospital material," "hospital personnel," "hospital bed capacity," "equipment," and "supplies of hospital." Using OR and AND, key words were combined and entered in the search box of the databases as follows: (surge capacity) AND (hospital OR hospital communication OR hospital department OR high volume hospital OR hospital information system OR hospital planning OR hospital rapid response OR hospital material OR hospital personnel OR bed capacity OR hospital equipment and supplies) AND (disaster OR emergency OR hazard OR crisis OR tragedy OR mass casualty incident OR catastrophe).

Selection of Articles and Documents

Independent reviewers (HS and FR) screened abstracts and titles for eligibility. When the reviewers felt that the abstract or title was potentially useful, full copies of the article were retrieved and considered for eligibility by both reviewers. If discrepancies occurred between reviewers, the reasons were identified and a final decision was made on the basis of agreement by a third reviewer (AR).

Evaluation of Selected Publications

Inclusion Criteria

The first inclusion criterion was articles or documents that investigated the surge capacity of public and private hospitals in emergencies and disasters. The second inclusion criterion was consideration of at least one of the components of hospital surge capacity in any real disaster.

Exclusion Criteria

Exclusion criteria included studies published in languages other than English. In addition, editorial studies, studies conducted before 2000, and studies that investigated the surge capacity of treatment locations other than hospitals were excluded. To obtain authoritative information, this review included only peer-reviewed journal articles. Selection bias might therefore exist in this study in terms of publication bias, especially concerning government reports that were not accessible.

RESULTS

The initial electronic database search of the literature resulted in a total of 1008 articles. At the next step, duplicate articles were eliminated and the number decreased to 802 articles. Using systematic screening, we reviewed the titles to find those related to hospital surge capacity and selected 202 articles. In the next step, abstracts of the articles were studied and 37 articles were selected to be fully reviewed. In this step, 165 articles were excluded. After that all of the selected articles were completely read and on the basis of the inclusion criteria only 17 articles (1 randomized controlled trial, 2 qualitative studies, and 14 cross-sectional studies) that reported the surge capacity of hospitals in emergencies and disasters were selected. Figure 1 shows the strategy for searching and selecting the articles in accordance with the PRISMA Guidelines.[11] All studies focused on hospital surge capacity in different types of real or potential disasters. The studies were mainly conducted in the United States, Australia, Taiwan, South Africa, and Japan. The results showed that most studies conducted on surge capacity related mainly to hospitals in different states in the United States. Of the total extracted papers, 384 different hospitals were investigated.

Details of each study and their special features regarding authors, year, sample size, study type, hospital location, type of components, and main concepts were evaluated. The summaries of each article related to hospital surge capacity in emergencies and disasters are shown in Table 1.[12-25] The study results indicated that there are various ways to increase surge capacity in 3 domains: staff, stuff, and structure. The most important way to improve surge capacity in the staff

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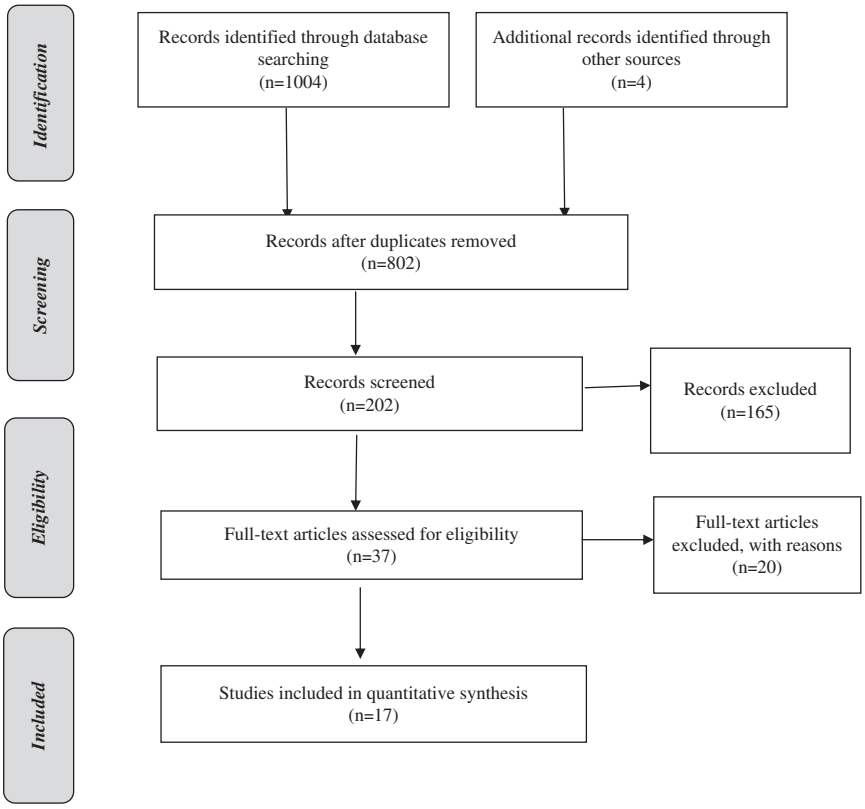
FIGURE 1

Flow Diagram Showing Selection of Articles Reviewed in Accordance With the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Guidelines.



category is to call shift workers to the hospital emergency department and alternative spaces, to request workforces from other hospitals and medical centers, and to call for volunteer and retired employees with the aim of increasing the personnel capacity of the emergency department as the first-line encounter with the disaster. In the stuff section, using existing equipment in the crisis warehouse of the hospital, transferring medical equipment from unnecessary units to key units, and providing required equipment from organizations outside the hospital with the aim of increasing the capacity of the main units in the hospital can enable appropriate responses to emergencies and disasters. In the structure section, we can increase the physical treatment space, including space for entrance and exit of the injured; categorize and discharge inpatients via reverse triage with the aim of evacuating the emergency department and evacuating patients from inpatient units whose treatments can be postponed; prepare alternative places with the aim of increasing the physical capacity for triage and emergency treatment of the patients; integrate hospital wards; cancel elective surgeries with the aim of increasing the capacity of the surgery rooms in order to be properly ready to do emergency surgeries; use spaces like parking, amphitheaters, halls, dining rooms, and other hospital areas for therapeutic spaces according to the recommendations of the hospital's crisis committee; exercise incident response operational programs with a focus on providing surge capacity for different hazards; and finally, increase capacity to transfer and displace intra- and inter-hospital victims.

DISCUSSION

Different meanings and classifications of emergencies and disasters are given in various studies.[26] Most studies have classified surge capacity concepts in 3 general sections of stuff, including supplies and equipment; staff, including all types of personnel; and structure, including facilities and programs.[18,27-31] Various other studies have also stated that hospital surge capacity should include a system component in addition to staff, stuff, and structure. These studies also stressed that all 4 concepts of surge capacity are important and that the concept of system is a main and necessary concept and that surge capacity cannot be managed appropriately without it. This concept has various components, including command and control, communication, coordination, continuity of operations, and community infrastructure.[23,32,33]

A number of studies have classified surge capacity of hospitals in other forms, including space, staffing, supplies, and

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TABLE 1

Summary of Articles on Hospital Surge Capacity in Emergencies and Disasters

Authors	Article Title	Method	No. of Hospitals	Type of Component	Hospital Location	Main Concept(s)
Delia et al (2006)[12]	Annual bed statistics give a misleading picture of hospital surge capacity	Cross-sectional	28	Stuff	United States	Assessment of hospital bed: effect on hospital surge capacity in emergencies and disasters. - Empty hospital beds that were set up according to the federal disaster planning benchmarks. - Daily and annual occupancy rates of hospital beds. - Beds stored in the hospitals' warehouses are usable in normal conditions. - Reduced bed occupancy rates could increase the hospitals' surge capacities. - Facing restriction in emergencies and disasters.
Kantar et al (2007)[13]	Hospital emergency surge capacity: an empiric New York statewide study	Cross-sectional	242	Structure	United States	Assessment of hospital structure: effect on hospital surge capacity in emergencies and disasters - Estimates of required emergency surge capacity for better response in disasters. - Provision of probable best-case scenario if wide breakup affects communication and transportation. - Provision of probable best-case scenario if wide breakup affects organizational operations. - Full knowledge of hospitals' existing capacity, including equipment and manpower. - Having a functional program including contracts with local country hospitals. - Transfer of victims in disaster conditions. - Transfer and displace the intra- and inter-hospital victims. - Increasing the physical treatment space. - Preparing alternative places.
Kelen et al (2006)[14]	Inpatient disposition classify action for the creation of hospital surge capacity	Cross-sectional	1	Structure	United States	Ways of increasing hospital capacity in emergencies and disasters: - Hospital panelists agreed on important ways of increasing hospital capacity. - Transfer and discharge of patients to other medical centers and home. - Classification of hospital patients on the basis of their disease status: a) Patients with no risk, for example, patients with antibiotics therapy for cellulitis. b) Patients with some risk of residual medical complications. c) Patients who can be discharged and transferred to other health centers or nursing home. d) Patients with substantial risk and who need acute-hospital resources. e) Patients in unstable condition or critically ill.
Bradt et al (2009)[15]	Emergency department surge capacity: recommendations of the Australasian Surge Strategy Working Group	Qualitative	No detail	Space, staff, supplies, and systems	Australasia	Concept of surge capacity is in the direction of increasing hospital capacity: - Increasing hospital capacity in terms of space before the disaster. - Discharging all selective admissions. - Identifying useable areas such as lounges and corridors, short stay, stretchers, and sitting patient areas. - Sending admitted patients to a predetermined holding area. - Allowing inpatient wards to pick patients up instead of emergency department staff doing the victim transfer. - Determining task personnel and meeting points. - Providing required equipment from organizations outside the hospital. - Distributing supplies and tools for better communication. - Notifying emergency medical system to direct flow of patients not related to the surge incident. - Conducting clinical decision-making on remaining emergency department patients during rounds. - Calling for workers from outside the hospital. - Minimizing one-on-one care to maximize space for cohort care. - Using nonclinical staff as scribes, runners, and patient transporters. - Transmitting medical equipment from unnecessary units to key units.

TABLE 1 (CONTINUED)

Authors	Article Title	Method	No. of Hospitals	Type of Component	Hospital Location	Main Concept(s)
Lee et al (2010)[16]	Barriers to surge capacity of an overcrowded emergency department for a serious foodborne disease outbreak	Cross-sectional	1	Structure, stuff	Taiwan	Barrier of hospital surge capacity in emergencies and disasters: - Shortage of alternative spaces in the emergency department. - Weak coordination between pre-hospital systems and hospitals. - Lake of clinical and nonclinical personnel. - Failure to appropriately and accurately triage patients. - Lack of biological incident response plan. - Inactivation of on-time hospital Incident Command System. - Inadequate experience and knowledge of personnel. - Not having program to inform centers, staffs, families, and patients. - Not having program for how to relocate victims and patients in hospital.
Satterthwaite et al (2012)[17]	Using 'reverse triage' to create hospital surge capacity: Royal Darwin Hospital's response to the Ashmore Reef disaster	Cross-sectional	1	Structure	Australia	Concepts of surge capacity is in the direction of increasing hospital capacity: - Programs to increase capacity are reverse triage. - Training and educational workshops for better reverse triage in order to increase knowledge and experience of staff. - Patient status and victim transfer hazard must be considered in emergencies and disasters in reverse triage method. - The places that can transfer hospitalized patients based on reverse triage must be specified.
Kaji et al (2006)[18]	Surge capacity for healthcare systems: a conceptual framework	Cross-sectional	1	Structure	United States	Surge capacity process as a concept: - Elements including stuff, supplies, and structure. - Increase capability of hospital in admissions and maximum care of victims and not only criteria for increasing the number of beds, supplies, and staff. - More research is needed in the direction of reproducible benchmark science of surge capacity. - Key issues such as convergent volunteerism, psychosocial behavioral issues, need to special expertise and supplies, and upgrading standards of care for surge capacity according to standardization of a universal metric were considered.
DeLia et al (2008)[19]	The dwindling supply of empty beds: implications for hospital surge capacity	Cross-sectional	1	Stuff, staff	United States	Surge capacity process as a concept: - Supplies and stuff, including beds that should be stored in the hospital warehouse and in responding to disasters, should be added to other hospital beds and in critical condition be rapidly available. - Providing stuff and other necessary equipment for the care of injured. - Improve the surge capacity of hospitals proportional to county population growth.
Stratton et al (2006)[20]	Characteristics of medical surge capacity demand for sudden-impact disasters	Cross-sectional	No detail	Staff, stuff, structure	United States	Surge capacity process as a concept: - Medical and nonmedical staff who have sufficient knowledge related to risk management. - Staff location so that they could be quickly recalled to hospitals. - Communities should be able to sustain medical services for 24 hours, and up to 96, before arrival of external resources and plan for an appropriate response to disasters.
Tyson et al (2010)[21]	Effect of hospital staff surge capacity on preparedness for a conventional mass casualty event	Cross-sectional	1	Staff and structure	South African	Surge capacity process as a concept: - Improve hospitals' surge capacity pre-event system including professional personnel identification, agreements with practitioner facilities, as well as large hospital groups and credentialing. - Strategies for recruitment, training, and retention and improving long-term health care worker skills. - Modified response matrix of South African medical resource model for sufficient staff to manage health care needs at mass gatherings.

Takahashi et al (2007)[22]	Assessment of medical response capacity in the time of disaster: the estimated formula of Hospital Treatment Capacity (HTC), the maximum receivable number of patients in hospital	Cross-sectional	1	Stuff, structure (space)	Japan	Estimated formula: according to Kobe University Hospital - Assess hospital treatment capacity. - Calculate maximum receivable number of patients in hospital for burn injury patients, patients with blood purification, and severe traumas, and expressed with time constraints and without time constraints. - Forecast the receivable number of patients per hour on a regional basis accurately if there were surveys on the means of transportation between hospitals and the time of transportation.
Schultz et al (2007)[10]	Improving hospital surge capacity: a new concept for emergency credentialing of volunteers	Cross-sectional	1	Staff	United States	Surge capacity challenges: - Weaknesses hospital encounter with emergencies and catastrophe such as disproportions in added beds with health care staff. - Affected staff inside and outside hospital in disaster. - Use of volunteer clinical staff including nurses, physicians, and retired staff from other hospitals. - Appropriate response programs to organize these staff and designing databases to collect essential information about them. - Requesting workforces from other hospitals and medical centers
Hick et al (2009)[6]	Refining surge capacity: conventional, contingency, and crisis capacity	Cross-sectional	1	Staff, structure	United States	Key interdependent factors affected hospital surge capacity: - System, space, staff, and supplies, although each of the 4 factors is important, the majority of experts agree that without these system components, it cannot be appropriately managed. - Command and control, communication, coordination, continuity of operations, community infrastructure. - Types of capacities including conventional capacity, contingency capacity, and crisis capacity. - In connection with concept of staff, items considered include A) conventional staff, B) contingency staff, and C) crisis staff.
Hick et al (2010)[23]	Surge capacity and infrastructure considerations for mass critical care	Qualitative	1	Staff, structure, space	United States	Improving hospitals' surge capacity includes: - Increasing their beds along with expanding wards' physical space and considering appropriate monitors for these areas. - Canceling elective surgeries. - Integrating the hospitals' wards. - Having contingency plans at the facility and government levels to provide additional supplies. - Considering sufficient staff needed to care for patients in special care wards during disaster. - Advocating for sufficient infrastructure for official implementation of critical care activities.
Kelen et al (2009)[9]	Creation of surge capacity by early discharge of hospitalized patients at low risk for untoward events	Randomized design controlling	3	Structure	United States	Planning for resource enhancement in surge capacity in emergencies and disasters: The introduction of reverse triage so that elective patients are immediately discharged to predetermined other centers.
Abir et al (2013)[24]	Design of a model to predict surge capacity bottlenecks for burn mass casualties at a large academic medical center	Cross-sectional	1	Staff, stuff	United States	Application model for time estimation and management of hospital capacity-building: - Provides enough information for decision-making in disaster management. - Model inputs for worst-case scenario include central variables, triage and inpatient disposition, space utilization and flow logic, floor and operating room resource utilization, staff utilization, and sensitivity analyses.Model findings: - Medical centers operating at high occupancy rates will quickly increase capacity to respond to a mass casualty incident. - Staffing is not a limitation for response to mass casualty incident and existing hospitals beds that can be used in mass casualty incident response. - Supply shortages are not of a great challenge considering the hospital knows the volume and type of casualties it has accommodated.

TABLE 1 (CONTINUED)

Authors	Article Title	Method	No. of Hospitals	Type of Component	Hospital Location	Main Concept(s)
Traub et al (2007)[25]	The Surge Capacity for People in Emergencies (SCOPE) study in Australasian hospitals	Cross-sectional	101	Stuff	Australia	Findings: - Resources for critical victims of mass casualty incidents did not comply with US benchmarks. - Operating rooms per 100,000 population were lowest in Western Australia and New Zealand highest for the Australian capital and the Northern Territory. - Results also showed 61% to 82% of critically injured do not have immediate access to operating rooms, and 34% to 70% do not have immediate access to intensive care unit beds. - The number of intensive care unit beds per 100,000 population was lowest in New Zealand and Western Australia and highest in Sydney and the Northern Territory. - The number of x-ray machines per 100,000 population was highest for the Northern Territory and lowest for New Zealand.

system.[15,34] There is no specified or single standard criterion for evaluating hospitals' surge capacity. In the United States, surge capacity is considered when hospitals can increase their current resources in various areas at the rate of 5% to 15%.[12] Other studies reported that surge capacity is acceptable when this rate is 20% to 35%.[10] The difference can be due to the diversity in structural, economic, facilities, and demographics of various countries. One of the studies emphasized that surge capacity is the ability of the hospital to provide necessary concepts during the occurrence of emergencies and disaster and does not include current hospital programs.[12] Considering the concept of stuff, based on the Health Resources and Services Administration, 500 beds are required and necessary in an incident per 1 million people.[19] On the other hand, the surge capacity of a hospital is not only limited to an increase in the number of beds, but these beds must be ready to provide medical and health services under normal conditions and be equipped with expertise, human resources, and sufficient facilities and be accessed quickly.[12,35,36] Studies have also shown the relationship between the surge capacity of hospitals and the occupancy rate of beds. When the occupancy rate of beds is high and unoccupied beds are low in a hospital, surge capacity is limited and this relationship can be reversed.[12,13] Hospitals require both specialized and nonspecialized equipment in a disaster, and this equipment must be available in the crisis storehouse so that it can be added to the current equipment level when needed. Various studies have reported different methods for increasing the capacity of hospitals in the structure dimension, especially physical space, and these cases include lack of admission of outpatients who are able to walk, transfer of admitted patients from the emergency department to hospital corridors, canceling of selective operations, discharge of patients with appropriate status, redesigning of physical space of departments in terms of arrangement of beds and equipment to create accessible space, expansion of portable hospitalized units, and use of physical nontreatment spaces of the hospital such as dining halls, auditoriums, and hallways to care for disaster patients.[10,14,15,21,34,37] Other strategies to increase the capacity of hospitals in the structure dimension are coordination of public and nonpublic organizations to provide resources required by hospitals in the time of disaster, having operational programs to respond to emergencies and disasters, and having performance programs such as activating the hospital response program, activating Hospital Incident Command System, practicing operational programs of response to emergencies with centrality of surge capacity for various hazards, coordinating the prehospital system with both the hospital and the emergency operations center, and systematic triage of victims at both the hospital and prehospital systems.[16,38-40] During emergencies and disasters when hospitals are faced with increased demands, one of the programs to increase capacity is reverse triage.[14,17,41] In the reverse triage method, victims' status and patients' transfer hazard must be considered in emergencies and disasters. In this regard, staff of hospitals must be trained

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and educational workshops are required for better reverse triage in order to increase knowledge and experience of staff. To increase capacity in the staff dimension, various studies have referred to several cases, including the use of all medical and nonmedical hospital staff and determining their tasks and training during disasters, issuing valid certificates to be used in disasters, preparing a list of staff and updating it, and using medical and nursing students as well as volunteer and retired forces. On the other hand, countries can use medical and nonmedical military forces such as the army to meet human resource needs.[15,17,20,21,23,41] In contrast, one study reported that using volunteer forces to increase capacity could be a factor in reducing the quality of services provided in hospitals. If use of these forces is not planned appropriately, it could be a deficient factor in establishing surge capacity in hospitals, because initial resources may be wasted in managing these volunteers.[18] It is still impossible for hospitals to determine the competence, skill, and certification of volunteers, and this factor causes increased disorder in response to disasters. Therefore, having a database for collecting information from therapeutic and nontherapeutic volunteers will be helpful for identifying these people and improving hospitals' surge capacity response.[24,25,28]

CONCLUSION

Hospital surge capacity is one of the most important hospital preparedness programs for appropriate response to emergencies and disasters. The present review revealed different classifications for surge capacity methods and concepts. We found no consensus on a unified classification. Also, studies showed that there are different ways to increase hospitals' surge capacity. Therefore, the results of the current study could help health field managers in hospitals prepare for capacity-building based on different surge capacity components. These results may also help to improve and promote hospital preparedness programs for appropriate response to emergencies and disasters according to a situational assessment of each hospital's environmental requirements.

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