Hospital surge capacity preparedness in disasters and emergencies: a systematic review

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Review Paper

Hospital surge capacity preparedness in disasters and emergencies: a systematic review

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ABSTRACT

Background: Adequate and effective emergency preparedness for hospital surge capacity is a prerequisite to ensuring standard healthcare services for disaster victims. This study aimed to identify, review, and synthesize the preparedness activities for and the barriers to hospital surge capacity in disasters and emergencies.

Methods: We systematically searched seven databases (PubMed, MEDLINE, CINAHL, Scopus, Embase, Ovid, and PsycINFO). We included all English peer-reviewed studies published in January 2016 and July 2022 on surge capacity preparedness in hospital settings. Two independent researchers screened titles and abstracts, reviewed the full texts, and conducted data extractions using CADIMA software. We assessed the rigor of the included studies using the NIH quality assessment tools for quantitative studies, the Noyes et al. guidelines for qualitative studies, and the MMAT tool for mixed methods studies and summarized findings using the narrative synthesis method. We also used PRISMA reporting guidelines.

Results: From the 2560 studies identified, we finally include 13 peer-reviewed studies: 10 quantitative, one qualitative, and two mixed methods. Five studies were done in the USA, three in Iran ($n = 3$), and the remaining in Australia, Pakistan, Sweden, Taiwan, and Tanzania. The study identified various ways to increase hospital surge capacity preparedness in all four domains (*staff*, *stuff*, *space*, and *system*); among them, the use of the *Hospital Medical Surge Preparedness Index* and the *Surge Simulation Tool* for surge planning was noteworthy. Moreover, nine studies (69%) recognized several barriers to hospital surge capacity preparedness.

Conclusion: The review provides synthesized evidence of contemporary literature on strategies for and barriers to hospital surge capacity preparedness. Despite the risk of selection bias due to the omission of gray literature, the study findings could help hospital authorities, public health workers, and policy-makers to develop effective plans and programs for improving hospital surge capacity preparedness with actions, such as enhancing coordination, new or adapted flows of patients, disaster planning implementation, or the development of specific tools for surge capacity.

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Introduction

Disaster is either a natural or human-made event that causes great losses in human lives, properties, economy, and environment and disrupts the functioning of the affected society or community to the point that it needs external aid to cope with the deteriorating

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situation.[1] As the effects of global warming and climate change begin to set in, we observe an increasing trend in the incidences of disasters.[2] The Centre for Research on the Epidemiology of Disasters (CRED) recorded an average of 357 catastrophic events occurring annually from 2001 to 2020.[3] In 2020 alone, around 100 million people were affected by natural disasters around the globe, leading to approximately 15,000 deaths and resulting in an estimated economic loss of $190 billion worldwide.[4] In addition, a total of 432 disasters occurred in 2021, claiming 10,492 lives and causing an economic loss of approximately $250 billion.[3] In this context, hospital disaster preparedness is crucial in achieving resilience to disaster.[5]

Hospital surge capacity can be defined as the capability to deal with the sudden influx of patients beyond the usual resulting from a disaster or emergency,[6] and contributes to the effort to keep mortalities and morbidities as low as possible.[7] It comprises mainly four components or domains: *staff*, *stuff*, *space*, and *system*.[8,9] *Staff* refers to all the medical personnel, such as doctors, nurses, and technicians, who are essential to the functioning of the hospital. *Stuff* refers to every piece of equipment within a hospital. Consumable supplies, such as syringes, oxygen, intravenous medications, and medicine, can also be counted as stuff. *Space* mainly indicates the number of beds in a hospital and how many extra beds can be arranged during a surge. Lastly, the policies and procedures that link the departments within a hospital or connect the hospital to other facilities and services fall within the *system* domain.[8–10]

In a New York statewide cross-sectional study comprising 242 hospitals, Kantar and Moran investigated the structural component of medical surge capacity. They suggested extending existing space and preparing new spaces for the treatment of disaster victims, as well as developing a collaboration with other facilities to transfer patients quickly when needed. In addition, prior knowledge of the hospital's existing capacity, including human resources and equipment, is essential.[11] Several studies have assessed the role of reverse triage in creating better hospital surge capacity by freeing beds for disaster victims needing immediate medical attention.[12–14] In addition, Bradt et al. recommended assigning specific tasks to specific personnel, improving communication within and without the hospital, and collecting useful resources for the surge. They also suggested hiring staff from external sources to increase the workforce.[15] A case study on Oita Prefectural Hospital in Japan strongly recommended cross-credentialing and cross-training of staff to form a better coalition of hospitals to face a catastrophe.[16] Besides conventional studies, researchers have developed novel simulations and models to improve hospital preparedness and help the system flow smother when a disaster is in the front door.[17,18] For example, the MACSIM® simulation system was used to critically examine the hospital surge capacity preparedness for mass casualty incidents (MCIs) in Sweden and found that the system can sufficiently determine the hospital's critical capacity-limiting factors to respond to MCIs.[19]

Over the years, researchers have devised strategies and procedures that could be more well-organized to enhance hospitals' surge capacity preparedness. Therefore, systematically identifying, compiling, and synthesizing those research findings is needed to critically appraise and compare similar endeavors and research in different regions. Sheikhbardsiri et al. systematically reviewed articles from January 2000 to October 2015 to compile and evaluate methods[20] that need to be updated. Besides, with the advent of the pandemic, as well as an increase in the frequency and magnitude of disasters due to climate change and conflicts, hospital surge capacity preparedness has been brought to a higher level of attention, and more information could be available. Therefore, we evaluated the existing evidence by reviewing studies from 2016 to 2022. We aimed to identify strategies adopted to strengthen the surge capacity preparedness of hospitals in emergencies and disasters and to mark their barriers or challenges by systematically reviewing and narratively synthesizing the contemporary evidence. We also attempted to determine the factors associated with hospitals' surge capacity preparedness in catastrophic events and compare between rural and urban hospitals if possible. The following research questions guided this systematic review: What preparedness activities strengthen the hospital surge capacity in emergencies and disasters? Does hospital surge capacity preparedness differ between rural and urban hospitals? If any, what are the differences? Which factors impede the hospital surge capacity preparedness in emergencies and disasters?

Methodology

Study design

We conducted this systematic review following the PRISMA guidelines.[21] Due to the heterogeneity of the studies, the narrative synthesis method was adopted to report the systematic review findings.[22] This review protocol was prepared by following the PRISMA-P statements[23] and prospectively registered in PROSPERO [CRD42022360332], published in a peer-reviewed journal.[24] No ethical approval is needed for this systematic review.

Search strategy and selection criteria

We conducted peer-reviewed literature searches on seven electronic databases: PubMed, MEDLINE, CINAHL, Scopus, Embase, Ovid, and PsycINFO, between January 1, 2016, and July 30, 2022. The previous systematic review on the surge capacity of hospitals synthesized evidence from 2000 to 2015[20]; therefore, we exclude that period from our study. We also checked the reference lists of all finally included studies to review other relevant articles, if there were any. We developed a search string using keywords and MESH terms, using the advanced search option in PubMed. Later, it was tailored to the other databases to look for potential and relevant articles. The search strategy for all databases is provided as supplementary materials (see Table S1).

The Population, Intervention, Comparison, and Outcome (PICO) framework[25] was used to define eligibility. The inclusion and exclusion criteria of the study are presented in Table 1.

Study selection and data collection

After removing duplicates using CADIMA software,[26] two independent reviewers (KH and SMN) screened the titles and abstracts of the retrieved publications based on the eligibility criteria. They independently assessed full-text articles against predefined inclusion and exclusion criteria using CADIMA. Any discrepancies at any stage were resolved through discussion with a third reviewer (AQ, PAG, or RCG).

The two reviewers (KH and SMN) independently extracted data from the eligible full-text articles using a piloted and standardized template described in detail elsewhere.[24] Data on study characteristics, such as authors, title, methods, country, surge capacity components, hospital characteristics, activities related to hospital surge capacity preparedness, and barriers to these activities, were collected. The reviewers had to reach a consensus on data extraction. A third reviewer resolved any disagreement between the two reviewers.

Table 1
Inclusion and exclusion criteria for the study.

	Inclusion criteria	Exclusion criteria
Population	Hospital	Other healthcare facilities, except for hospitals
Intervention	Actions or activities for HSCP in disasters and emergencies	Routine activities in normal time
Comparison	None	
Outcome	Measures of HSCP in disasters and emergencies	Measures of HSCP for epidemics or pandemics that are disease-related
Study	All peer-reviewed studies, including RCTs, non-RCTs, cohort, cross-sectional, and longitudinal studies. The study must consider at least one component (staff, stuff/supply, space/structure, and system) of hospital surge capacity	Protocols, editorials, letters to editors, commentaries, conference abstracts, posters, opinions, and other publications that are not peer-reviewed, including grey literature
Settings	Irrespective of location and geography	

HSCP: hospital surge capacity preparedness; RCT: randomized controlled trial.

Quality assessment

We performed the quality assessment of quantitative studies using the National Institutes of Health (NIH) quality assessment tools for cross-sectional, cohort, case–control, and intervention studies.[27] We also used the Noyes et al. guidelines to assess the quality of qualitative studies[28] and the Mixed Methods Appraisal Tool (MMAT)[29] for mixed method studies. Two independent reviewers (KH and SMN) evaluated the quality of included studies. After comparing their assessments, any discrepancy was resolved by discussing it with a senior reviewer (AQ, PAG, or RCG). Each tool had a set of questions evaluating different criteria of the articles, based on which we rated them as *Good*, *Fair*, and *Poor*. The studies rated as poor were excluded from the final list of inclusion. Notably, studies that did not fall into the above designs (data modeling studies, simulation studies, and evaluation studies) were not assessed for the presence of bias.

Data synthesis

We observed a high heterogeneity among the studies in terms of study objectives, study design, and settings; therefore, we used the narrative synthesis method to present the key characteristics and findings of the study. In addition, as the eligible studies were primarily cross-sectional, cohort, mixed methods, and qualitative studies with high heterogeneity, we did not plan for assessing meta-analysis and confidence in cumulative evidence. The narrative synthesis was done by one reviewer (KH) and crosschecked by another (SMN).

Results

Study selection

We identified 2560 records from seven electronic database searches, and after the removal of duplicates, 1043 records were retained for the title and abstract screening. After the screening, 82 full-text articles were reviewed, of which 13 were finally included for data extraction. Details of the study selection process and reasons for exclusion are provided in Fig. 1. The prime reasons for exclusion included not having eligible outcomes and population. No study was excluded for poor quality.

Characteristics of included studies

We found 13 papers: 10 quantitative studies (of which six cross-sectional in design), one qualitative study,[30] and two mixed methods studies.[31,32] The included studies were from the USA ($n = 5$),[13,17,33–35] Iran ($n = 3$),[14,30,36] Australia ($n = 1$),[37] Sweden ($n = 1$),[38] Taiwan ($n = 1$),[31] Pakistan ($n = 1$),[32] and Tanzania ($n = 1$).[39] Moreover, seven papers discussed all four components of hospital surge capacity,[17,30,31,33,34,37,39] three papers focused on the *space* component,[13,14,36] one examined the *system* component,[35] one on the *staff* component,[32] and one the *staff & stuff* component.[38] In addition, one study each discussed chemical, biological, radiological and nuclear (CBRN) disaster,[37] earthquake,[34] explosion,[31] flood,[34] and fire[31] disaster surge capacity preparedness; two studies focused on mass causality incidents,[34,38] and nine studies discussed any disasters surge capacity preparedness.[13,14,17,30,32,33,35,36,39] The key study characteristics are presented in Table 2.

Quality assessment

The overall quality assessment rating of the included studies is presented in Table 3, and the detailed assessment results are also found in the supplementary materials (Table S2). Among the six cross-sectional studies (46.2%), the overall quality rating of five studies[14,33,36,37,39] was *good*, and another[38] was *fair*. The quality of one cohort study[13] was also *good*. The remaining two mixed methods and one qualitative study were also *good* in quality. Due to the lack of suitable quality assessment tools, we could not assess the quality of three studies, which were modeling, simulation, and evaluation types.[17,34,35]

Hospital surge capacity preparedness activities

Table 3 presents the summary findings of hospital surge capacity preparedness activities of the finally included 13 articles. The findings indicated several ways to increase hospital surge capacity preparedness in four domains: staff, stuff, space, and system.

Staff

The most important way to improve surge capacity in the *staff* domain is by increasing the hospital workforce by using on-call staff, local healthcare providers and volunteers, calling in standby or off-duty staff, and hiring staff from other facilities.[30,32,37,39] In addition, develop mechanisms to maintain and recall staff during the surge, expand staff capacity by training specialized, non-specialized, trauma-competent staff, and increase the surge capacity preparedness of hospitals in disasters and emergencies.[17,30,38] Moreover, a study recommended that developing a local registry system for retired doctors, nurses, volunteers, and allied staff can be useful to call for help if the need arises.[32] Besides, hospitals should develop effective collaborative strategies and capacities to exchange their staff and patient transfer with other facilities during surge.[17,34,39]

Stuff

Several actions, such as increasing and stockpiling pharmaceutical and medical supplies, creating additional intensive care units (ICUs) and surgical theaters, reusing cleaned and sterilized supplies, and triaging or reallocating scarce supplies,[17,30,37–39] could

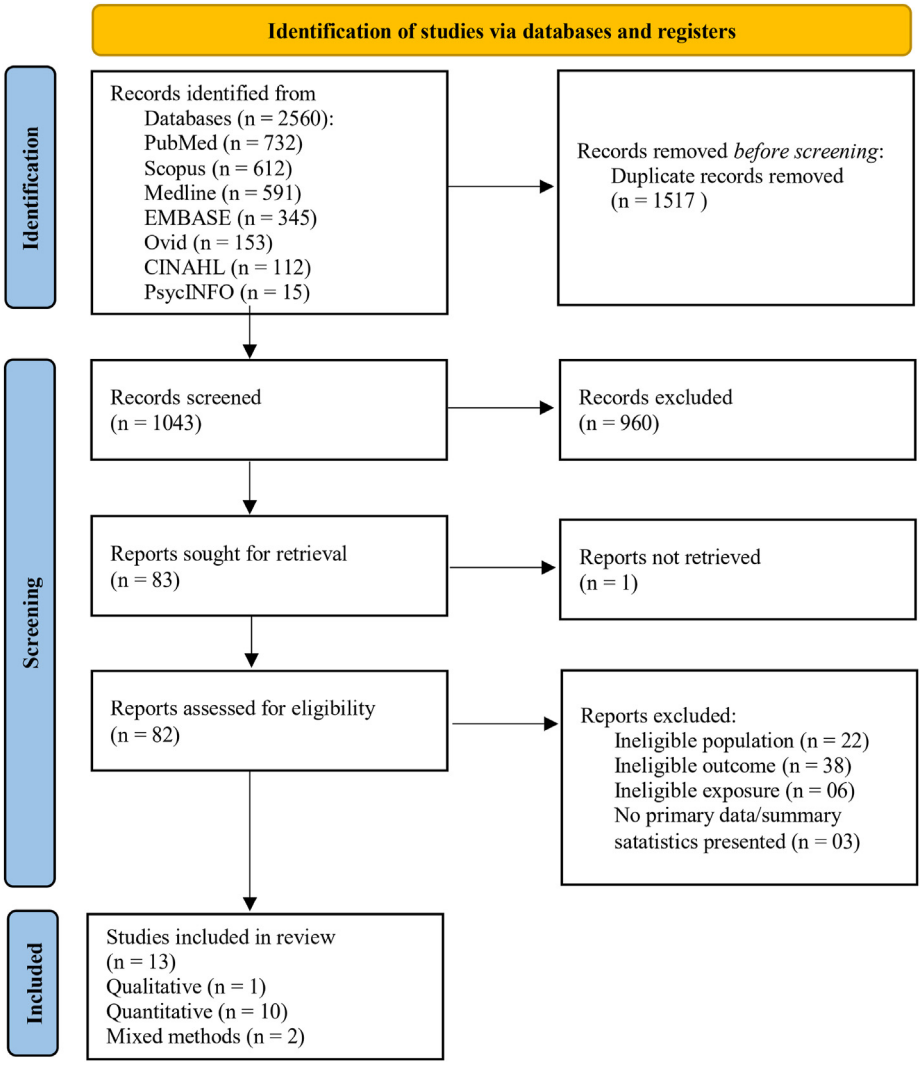

Fig. 1. Selection of included studies – PRISMA flow diagram.

improve the hospital surge capacity preparedness in the *stuff* domain. In addition, a healthcare coalition is needed in the USA to reallocate and distribute urgently needed supplies during disasters and emergencies. The study also recommended developing collaboration strategies to share supplies and equipment among healthcare facilities during the surge.[34]

Space

Increasing stockpiling areas inside the structure, opening unlicensed beds, using non-clinical areas (i.e., waiting rooms and corridors), increasing additional beds through safe early patient discharge, reverse triage, and canceling elective surgery could strengthen hospital surge capacity preparedness in the *space* domain.[14,17,30,33,36,39] Blimark et al.[38] recommended that Swedish hospitals should increase their ground-based and aeromedical prehospital transport capacity to deal with future surges.[38]

System

As the foremost steps in developing surge planning, authorities should examine the existing hospital preparedness for surge and also identify the problems and gaps in preparedness. Moreover, hospital authorities should regularly update the existing preparedness plans and evaluate results from ongoing planning to improve the surge capacity preparedness in the *system* domain.[30,31] Marcozzi et al.[33] developed a Hospital Medical Surge Preparedness Index to assess medical surge preparedness scores. This index should be used to mitigate existing gaps in surge capacity and strengthen the preparedness plan.[33] Toerper et al.[17] also proposed a web-based simulation tool that enables emergency planners to estimate the hospital surge capacity proactively.[17] In addition, Mills, Helm, and Wang[35] developed and tested an optimization model of early disposition by creating hospital surge capacity scenarios. This optimization model could help to develop effective preparedness and response plans during surges in disasters and emergencies.[35]

Rural and urban hospitals' surge capacity preparedness

We found that only four studies (30.8%) explicitly discussed urban hospitals' surge capacity,[13,14,34,39] and another four (30.8%) discussed both rural and urban hospitals' surge capacity.[17,33,37,38] The other five studies (38.5%) did not discuss any details about the location of the hospitals.[30–32,35,36] However, no study explicitly examined the rural hospitals' surge capacity. Due to the lack of location-segregated data (rural vs urban) from this systematic review, no inference could be made about the difference in surge capacity preparedness between rural and urban hospitals.

Table 2
Characteristics of included studies ($N = 13$).

Characteristics	*n* (%)	References
Year of publication		
2016–2017	2 (15.4)	13,30
2018–2019	4 (30.8)	14,17,36,39
2020–2021	5 (38.5)	31,33–35,38
2022	2 (15.4)	32,37
Country		
Australia	1 (7.7)	37
Iran	3 (23.1)	14,30,36
Pakistan	1 (7.7)	32
Sweden	1 (7.7)	38
Taiwan	1 (7.7)	31
Tanzania	1 (7.7)	39
USA	5 (38.5)	13,17,33–35
Study design		
Cross-sectional study	6 (46.2)	14,33,36–39
Retrospective cohort study	1 (7.7)	13
Qualitative study	1 (7.7)	30
Mixed methods study	2 (15.4)	31,32
Experiment and evaluation	1 (7.7)	35
Systematically designed numerical experiment	1 (7.7)	34
Systematic simulation and evaluation	1 (7.7)	17
Hospital surge capacity components		
Staff	2 (15.4)	32,38
Stuff	1 (7.7)	38
Space	3 (23.1)	13,14,36
System	1 (7.7)	35
All (4S)	7 (53.9)	17,30,31,33,34,37,39
Types of disaster/emergency (exposure)		
CBRN	1 (7.7)	37
Earthquake	1 (7.7)	34
Explosion	1 (7.7)	31
Flood	1 (7.7)	34
Fire	1 (7.7)	31
MCI	2 (15.4)	34,38
Any disaster	9 (69.2)	13,14,17,30,32,33,35,36,39
Location of hospitals studied		
Urban	4 (30.8)	13,14,34,39
Rural	0 (0.0)	
Both (urban & rural)	4 (30.8)	17,33,37,38
No detail	5 (38.5)	30–32,35,36

Note: CBRN = chemical, biological, radiological, or nuclear disasters; MCI = mass causality incidents; proportions are not 100% if studies appear in multiple categories. The supplementary material provides a complete summary of the studies (Table S3).

Barriers to surge capacity preparedness

Among the 13 studies, nine (69.2%) discussed barriers to surge capacity preparedness of hospitals in all four (staff, stuff, space, and system) domains, presented in Table 4. The barriers to hospital surge capacity preparedness mainly depend on the countries' health systems and socio-economic conditions. Lack of sufficient staff and stuff was the main obstacle to hospital surge capacity preparedness in developing countries like Pakistan, Iran, and Tanzania.[30,32,36,39] On the contrary, the lack of standardized and systematic metrics or models for assessing surge capacity, different hospital admission and discharge systems, and threats of physical damage to the infrastructure due to disasters were the main barriers to surge capacity preparedness in developed countries.[13,17,33,34]

Discussion

This study highlights various preparedness activities that can improve hospitals' surge capacity in disasters and emergencies by systematically identifying, synthesizing, and appraising peer-reviewed studies. This study also identified several gaps and barriers to surge capacity preparedness of hospitals in all domains: *staff*, *stuff*, *space*, and *system*, which need to be addressed to provide standard patient care services during surges. The study findings, particularly the use of the Hospital Surge Capacity Preparedness Index and Surge Simulation Tool, as well as other preparedness activities, would be useful to hospital administrators, healthcare providers, and policymakers in developing appropriate plans, programs, and policies for surge capacity preparedness.

Though medical surge capacity is an essential component of hospital preparedness, hospitals in underdeveloped and developing countries still face many challenges and limitations, primarily due to the lack of sufficient staff and resources.[30,32,39] Even hospitals in developed countries have several gaps in surge capacity preparedness and response to disasters and emergencies.[37,38] Besides, the absence of a universal definition and standardized measurement criteria for evaluating surge capacity makes it difficult for healthcare institutions to examine and compare their surge capacity.[10,20,40]

Surge capacity is defined in many ways[8–10,15,20] (see supplementary materials, Table S4). One general definition of surge capacity is 'the ability to obtain adequate staff, supplies and equipment, structures and systems to provide sufficient care to meet immediate needs of an influx of patients following a large-scale incident or disaster'.[10] This definition, along with others, reflects the theoretical constructs of four main domains or components of surge capacity: staff or human resources, staff or equipment and supplies, space or structure, and system,[8,10,20,33] which are widely accepted nowadays. Thus, identifying and synthesizing domain-wise hospital surge preparedness activities, including barriers and gaps, are essential to developing better plans and programs to improve the domain-wise surge capacity of hospitals.

The study findings suggested that calling stand-by or off-duty staff, hiring staff from other facilities, and using local health providers and volunteers could be effective ways to fulfill the demand for extra staff during the surge, which are supported by other studies[10,16,20] as well as previous systematic review.[20] However, hiring staff from other places is time-consuming, and integrating external staff into a surge hospital can present several technical challenges; therefore, systematic approaches, such as pre-identification and cross-training, should be taken beforehand for the hired staff to familiarize themselves with the situation and the organization.[16] Moreover, training and educating the staff[16,20] and the use of trained volunteers, medical and nursing students, and defense medical personnel can increase staff surge capacity.[20,41,42] Similarly, staff needs assessment during the surge is also crucial since factors, such as lack of transportation and family support (babysitting, meals, laundry, and accommodation), can significantly reduce staff's capacity to respond to the surge.[37] Besides, effective collaborative strategies must be in place to share staff and resources among healthcare facilities to increase their surge capacity preparedness.[17,34,39] Hospitals must develop an appropriate plan beforehand.[41]

Increasing medical supplies and stockpiling, creating more ICU and surgical theaters, and reusing and reallocating scarce medical equipment and supplies when possible were the major *stuff* preparedness activities.[17,30,37–39] A study on surge capacity in Australian hospitals shows that many victims have delayed access to operative care, ICU, and x-ray facilities during mass causality incidents.[43] The scenarios of medical supplies and equipment shortages are even more common worldwide during the COVID-19 pandemic.[44,45] Moreover, effective supply chain management, including ground-based and aeromedical transport systems, and interagency collaboration are needed to ensure adequate supplies of equipment and medicine to the hospitals during the surge.[34,38]

Table 3
Key findings of surge capacity preparedness of hospitals from selected studies with quality assessment.

Authors & country	Number and location of hospitals	Type of HSC components	Main concept(s)/SC preparedness activities	Quality assessment
Abolghasem Gorgi et al., 2017[30] Iran	18, No detail	All (staff, stuff, space, & system)	Several actions can strengthen HSC preparedness: 1) increase space inside the buildings 2) increase medication and emergency medical supplies 3) optimize general labor supply, and 4) ensure recalling and maintaining staff during the surge period.	Good
Blimark et al., 2020[38] Sweden	53, Rural & urban	Staff & stuff	1) Swedish emergency hospitals lacked operating rooms, surgical teams, or ICU beds. 2) To strengthen their HSC preparedness, hospitals should also increase their prehospital transport capacity through ground-based and aeromedical evacuation.	Fair
Chuang et al., 2021[31] Taiwan	4, No detail	All (staff, stuff, space, & system)	1) More better-trained employees are needed to provide timely and appropriate care to patients; 2) Hospitals can gain a comprehensive understanding of disaster response and interaction needs by systematically analyzing the adaptation framework and the relationships between adaptations and adaptation activities; 3) Additionally, evaluation of the outcomes of ongoing preparation is crucial to improve preparedness planning.	Good
Esmailian et al., 2018[14] Iran	1, Urban	Space	1) RT increased hospital capacity by 20% (108 beds) on average; 2) Highest potential for RT and SC is found in ENT, neurosurgery, pediatric surgery, plastic surgery, male surgical ward, and orthopedics department. 3) Patients with the highest risk of early discharge cannot be discharged earlier than necessary, including the ICU, labor, neonatal surgery, and NICU patients.	Good
Feizolahzadeh et al., 2019[36] Iran	7, No detail	Space	1) HSC during disasters can increase through the safe early discharge of suitable patients.	Good
Haroon and Thaver, 2022[32] Pakistan	8, No detail	Staff	1) Hospitals should utilize WISN to evaluate the current HR SC. 2) Hospitals must hire and manage the current strength of HCPs by allocating them according to the patient workload; 3) A provincial registry system should be created for available nurses, retired and volunteer doctors, and allied personnel to ensure staff supply during surge; 4) Before deployment, preidentified HCPs should be well educated and trained to adjust their re-definition roles during disasters to manage the initial surge of patients.	Good
Kelen et al., 2017[13] USA	1, Urban	Space	RT's contribution to the improvement of SC: 1) 10% of the patients qualified for urgent low-risk RT; 2) The psychiatry unit accounted for more than half of the RT effect, which had the most patients eligible for urgent RT; 3) The least significant effects were seen in the pediatric critical care and oncology units; 4) RT would boost SC by about 50% if it only accepted higher-risk patients.	Good
Koka et al., 2018[39] Tanzania	25, Urban	All (staff, stuff, space, & system)	Hospital preparedness for disasters in Tanzania: 1) While 68% of hospitals had a contingency plan specifying a source for these supplies, only 15% had a stockpile space with supplies (medications and consumables) on-site; 2) 80% of hospitals ensured a backup space where patients could receive care during emergencies; 3) In a surge, hospitals should be more competent to recruit employees from other facilities; 4) SC can be increased during disasters by releasing stable patients from emergency rooms and hospitals, postponing elective procedures, establishing alternative care spaces, and bringing in stand-by or off-duty staff.	Good
Mackie et al., 2022[37] Australia	6, Urban & rural	All (staff, stuff, space, & system)	1) CBRN disasters can hinder hospital staff from accessing self-care activities, commuting to work due to communication or transportation issues, or supporting their family unit; therefore, hospitals should offer additional services (babysitting, laundry, meals, and lodging) to the staff; 2) During a surge, hospitals should add more EDs, ICUs, or surgical beds by postponing elective surgery, boosting inpatient discharge rates, or using non-clinical spaces as overflow. 3) Access to more staff during disasters can be improved by using on-call staff, local providers (such as an agency), extending rosters (8–12 h), or adjusting nurse-patient ratios.	Good
Marcozzi et al., 2020[33] USA	6239, Urban & rural	All (staff, stuff, space, & system)	Application of a Hospital Medical Surge Preparedness Index: 1) Hospitals should evaluate their surge preparedness using a standard medical surge index prior to emergencies and disasters;	Good

(*continued on next page*)

Table 3 (*continued*)

Authors & country	Number and location of hospitals	Type of HSC components	Main concept(s)/SC preparedness activities	Quality assessment
			2) Hospital managers and administrations can identify and address surge preparedness gaps, encourage improvements, and mobilize resources to minimize deficiencies using the Medical Surge Preparedness Index.	
Mills, Helm and Wang, 2021[35] USA	2, No detail	System	Create and assess a model for optimizing early disposition activities that can be utilized to boost hospital capacity: 1) Managing elective demand in the inpatient units through workload smoothing during the mitigation phase, and coordination of discharge decisions between the ED and inpatient units during the reaction phase can increase SC; 2) The study suggests two critical roles for HSC: i) hospitals interested in increasing SC with little or no consideration for cost should concentrate on coordination as the primary strategy, and ii) hospitals with at least 50% elective case mix and inpatient utilization between 80% and 90% should implement smoothing and coordination, or if choosing a single strategy, may consider smoothing.	Not applicable*
Shahverdi, Tariverdi and Miller–Hooks, 2020[34] USA	5, Urban	All (staff, stuff, space, & system)	Examine the efficacy of established collaboration methods for transferring patients and sharing hospital resources (personnel, equipment, and supplies) during a surge: 1) Formal regional healthcare coalition can play a role in distributing desperately needed supplies and make effective judgments about resource reallocation during a disaster; 2) Different strategies reduce daily unmet demand across the system compared to a control scenario with no coordination; 3) Resource sharing works best in earthquake, flooding, and MCI situations, reducing system-wide unmet demand by 39%, 45%, and 23%, respectively. When collaboration methods are combined with capacity augmentation strategies, system-wide daily unmet demands are reduced by 48% in the earthquake, 53% in flooding, and 23% in MCI scenarios.	Not applicable*
Toerper et al., 2018[17] USA	3, Urban & rural	All (staff, stuff, space, & system)	Use of *Surge*—a freely accessible web-based simulation tool—to determine HSC. 1) Emergency planners can evaluate SC to facilitate disaster response using the accessible surge tool (www.pacerapps.org); 2) Providing cross-training of hospital employees before a disaster, giving just-in-time training for non-specialized employees, and adding hospital workers from other organizations can increase staff capacity; 3) Effective solutions for managing the restricted resources of hospitals during disasters include stockpiling ahead of time, reducing utilization, substituting functionally identical devices, reusing supplies that have been cleaned and sanitized, and reallocating or prioritizing constrained supply use.	Not applicable*

Note: *Unable to find any suitable quality assessment tools for these studies; CBRN = chemical, biological, radiological, or nuclear; ED = emergency department; HCP = healthcare providers; HR = human resource; HSC = hospital surge capacity; ICU = intensive care unit; MCI = mass causality incidents; NICU = neonatal intensive care unit; RT = reverse triage; WISN = workload indicators of staffing needs; SC = surge capacity.

Space or structure refers to the physical spaces for patient care, especially the bed capacity of a healthcare institute.[5,8,10] Our study found that patient transfer, safe early patient discharge, using non-clinical areas, and canceling elective surgeries could extend a hospital's space or bed capacity during a surge. Other studies supported these findings,[5,20] including the previous systematic review.[20] In addition, several studies showed that reverse triage could significantly increase surge capacity; however, only low-risk patients are eligible for reverse triage.[13,46–48] Besides, studies have shown that hospital surge capacity is limited when the bed occupancy rate is high and unoccupied beds are limited.[11,49] The Health Resources and Services Administration recommended that at least 500 beds are required per one million people to respond to mass causality incidents effectively.[50]

During a surge, the incident command system plays a central role in overseeing the management, including assessing demands and supplies. Several studies recommended that proper assessment of surge capacity preparedness and planning is crucial to deal with emergencies. Previous studies on surge capacity also showed that the lack of standardized numerical tools to measure surge capacity preparedness is a major barrier to developing effective hospital plans and programs.[20,33,51] Our study found two tools: (1) Hospital Medical Surge Preparedness Index (HMSPI) and (2) the Surge Simulation Tool (SST) that helps to measure hospital surge capacity preparedness, thus facilitating to take appropriate decisions to improve the surge capacity by the hospital authorities.[17,33] These findings were new and not identified in the previous systematic review of surge capacity preparedness.[20] The Surge Simulation Tool can measure surge capacity for any individual hospital unit or the entire hospital, which will be extremely useful for developing unit-wise plans and programs for strengthening the surge capacity of hospitals.[33]

This study also identified several barriers to preparedness for surge capacity in all domains. In general, hospitals in developing countries primarily suffered from staff and stuff shortages, whereas hospitals in developed countries, especially in the USA, had system-related barriers to hospital surge capacity preparedness.[14,17,30,32,34,37,39] However, the types of barriers depend not only on staff, stuff, space, or management of the hospitals but also on the nature and magnitude of the disaster and emergency that create the surge.

Table 4
Barriers to surge capacity preparedness of hospitals in disasters and emergencies.

Authors & country	Type of HSC components	Barriers to surge capacity preparedness
Abolghasem Gorgi et al., 2017[30] Iran	Staff, stuff, & space	The main barriers to HSC preparedness are: - lack of space, water, and electricity supplies - deficiency in providing emergency medical and essential non-medical supplies during the surge - lack of staff in hospitals during disasters, and - lack of incentives for people to stay and work in disasters.
Blimark et al., 2020[38] Sweden	Staff, stuff, & space	The main obstacles to Swedish hospitals being prepared for surge capacity are: - lack of prehospital transport capacity, including both ground-based and aeromedical evacuation - lack of pharmaceutical and medical supplies - inadequate number of hospital beds and ICU units, and - shortage of trauma-competent staff.
Feizolahzadeh et al., 2019[36] Iran	Space & system	- Even though early discharge to HSC is essential, there are no specific rules for identifying patients who can be discharged. - Furthermore, little is known about patients eligible for discharge and the rise in HSC that occurs after an early discharge.
Haroon and Thaver, 2022[32] Pakistan	Staff	The biggest obstacle to HSC readiness is the acute lack of physicians and nurses at tertiary care facilities in Pakistan.
Koka et al., 2018[39] Tanzania	Staff	Overcrowding hospital beds with critically ill patients greatly exceeds baseline provider capacity and prevents the mobilization of additional staff during a disaster.
Mackie et al., 2022[37] Australia	Staff, stuff, & system	- Surge capacity preparation could be hampered by failing to set up sufficient control lines at the hospital locations during a CBRN disaster, and not giving emergency care physicians personal dosimeters in the event of radioactive contamination.
Marcozzi et al., 2020[33] USA	System	The lack of standardized and systematic metrics hampered the capacity to assess accurately, plan, and finance optimal healthcare delivery during disasters.
Shahverdi, Tariverdi and Miller–Hooks, 2020[34] USA	Space	Increased unmet demand and hampered surge capacity can result from physical damage to hospitals and their sustaining lifelines.
Toerper et al., 2018[17] USA	System	Diverse admission systems, with discharge patterns and functions under varying operating conditions, can hamper HSC preparedness.

Note: CBRN = chemical, biological, radiological, or nuclear; HSC = hospital surge capacity; ICU = intensive care unit.

We also aimed to identify the difference in surge capacity preparedness between rural and urban hospitals; however, we could not draw any conclusion due to the lack of sufficient evidence. Therefore, more studies are needed to address this issue.

From a public health perspective, it is important to improve hospital surge capacity, particularly during disasters, because insufficient hospital capacity may lead to substandard healthcare services for the disaster victims and increase the premature discharge of vulnerable patients to the community. These conditions may burden primary care systems and displace other key routine activities, such as health promotion, disease prevention, immunization, and cancer screening program, and limit patients' access to critical care, treatment, and diagnosis, further worsening care seekers' outcomes. Our findings help to identify activities that improve hospital surge capacity, which have a direct positive effect on population health by optimizing resource utilization and decreasing the cost of opportunity. Cross-sectorial coordination and resource optimization can maintain daily healthcare services while giving a proper response to a disaster. Some considerable strengths of this systematic review are: (i) we systematically searched all vital electronic databases for peer-reviewed evidence regardless of any geographical boundary; (ii) we strictly followed the PRISMA guidelines; and (iii) we examined the quality of included studies using the NIH, MMAT, and Noyes et al. guidelines. Despite the heterogeneity of the study designs and settings, the quality of the most included studies was good. However, we could not assess the quality of the three studies due to the lack of suitable assessment tools.[17,34,35]

However, several study limitations should also be recognized. First, we only reviewed the articles written in English. Thus, we may have missed studies from other languages, a possible cause of bias. Secondly, there is a change of selection bias as we did not review any grey literature. Lastly, we only considered hospital surge capacity preparedness in disasters and emergencies, not pandemic or epidemic situations, which may provide new information about surge preparedness if included. Despite the limitations, our study highlights the practical interventions, including barriers to hospital surge capacity preparedness, which would be useful to healthcare practitioners, hospital authorities, and policymakers in developing effective surge preparedness plans, programs, and policies for hospitals.

Conclusion

This systematic review identified, reviewed, synthesized, and appraised peer-reviewed studies on preparedness activities and the barriers to hospital surge capacity in disasters and emergencies. We found several surge capacity preparedness activities, such as the Hospital Surge Capacity Preparedness Index and Surge Simulation Tool, which should be used to take proactive surge preparedness for hospitals. Moreover, cross-functional coordination and resource sharing among the hospitals should be improved to strengthen hospital surge capacity preparedness during disasters.

Author statements

Ethical approval

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Competing interests

None declared.

Author contributions

Md. Khalid Hasan: Conceptualization, Methodology, Investigation, Formal Analysis, Writing – Original Draft, Writing – Review & Editing. **Sarker Mohammad Nasrullah:** Investigation, Writing – Review & Editing. **Annalisa Quattrocchi:** Writing – Review &, Editing, Supervision. **Pedro Arcos González:** Conceptualization, Writing – Review & Editing, Supervision. **Rafael Castro Delgado:** Conceptualization, Writing – Review &Editing, Supervision.

Research data for this paper

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.09.017.

References

1. WHO. *Global assessment of national health sector emergency preparedness and response*. 2008. https://www.who.int/publications-detail-redirect/global-assessment-of-national-health-sector-emergency-preparedness-and-response.
2. Jones RL, Guha-Sapir D, Tubeuf S. Human and economic impacts of natural disasters: can we trust the global data? *Sci Data* 2022;**9**:572.
3. CRED. *Disasters in numbers 2021*. 2022. https://www.cred.be/disasters-numbers-2021.
4. Bevere L, Weigel A. *Natural catastrophes in 2020: secondary perils in the spotlight, but don't forget primary-peril risks*. 2021. https://www.swissre.com/institute/research/sigma-research/sigma-2021-01.html.
5. Anesi GL, Lynch Y, Evans L. A conceptual and adaptable approach to hospital preparedness for acute surge events due to emerging infectious diseases. *Crit Care Explor* 2020;**2**:e0110.
6. Stratton SJ, Tyler RD. Characteristics of medical surge capacity demand for sudden-impact disasters. *Acad Emerg Med* 2006;**13**:1193–7.
7. Halpern SD. ICU capacity strain and the quality and allocation of critical care. *Curr Opin Crit Care* 2011;**17**:648–57.
8. Kelen GD, McCarthy ML. The science of surge. *Acad Emerg Med* 2006;**13**:1089–94.
9. Hick JL, Barbera JA, Kelen GD. Refining surge capacity: conventional, contingency, and crisis capacity. *Disaster Med Public Health Prep* 2009;**3**:S59–67.
10. Adams LM. Exploring the concept of surge capacity. *OJIN Online J Issues Nurs* 2009;**14**.
11. Kanter RK, Moran JR. Hospital emergency surge capacity: an empiric New York statewide study. *Ann Emerg Med* 2007;**50**:314–9.
12. Kelen GD, McCarthy ML, Kraus CK, Ding R, Hsu EB, Li G, et al. Creation of surge capacity by early discharge of hospitalized patients at low risk for untoward events. *Disaster Med Public Health Prep* 2009 Jun;**3**(S1):S10–6.
13. Kelen GD, Troncoso R, Trebach J, Levin S, Cole G, Delaney CM, et al. Effect of reverse triage on creation of surge capacity in a pediatric hospital. *JAMA Pediatr* 2017 Apr;**171**(4):e164829.
14. Esmailian M, Salehnia M-H, Shirani M, Heydari F. Reverse triage to increase the hospital surge capacity in disaster response. *Front Emerg Med* 2018;**2**. e17–e17.
15. Bradt DA, Aitken P, FitzGerald G, Swift R, O'Reilly G, Bartley B. Emergency department surge capacity: recommendations of the Australasian Surge Strategy Working Group. *Acad Emerg Med* 2009;**16**(12):1350–8.
16. Kato S, Yamamoto A, Kawachi I, Sakamoto T, Kunugi C, Tarui T, et al. Pretraining and precredentialing staff for disaster: a lesson learned from the experience of the 2016 Kumamoto earthquakes. *Disaster Med Public Health Prep* 2020 Apr;**14**(2):292–4.
17. Toerper MF, Kelen GD, Sauer LM, Bayram JD, Catlett C, Levin S. Hospital surge capacity: a web-based simulation tool for emergency planners. *Disaster Med Public Health Prep* 2018 Aug;**12**(4):513–22.
18. Yamada M, Nakada T aki, Nakao S, Hira E, Shinozaki K, Kawaguchi R, et al. Novel information and communication technology system to improve surge capacity and information management in the initial hospital response to major incidents. *Am J Emerg Med* 2019 Feb 1;**37**(2):351–5.
19. Montán KL, Örtenwall P, Blimark M, Montán C, Lennquist S. A method for detailed determination of hospital surge capacity: a prerequisite for optimal preparedness for mass-casualty incidents. *Eur J Trauma Emerg Surg* 2023;**49**:619–32.
20. Sheikhbardsiri H, Raeisi AR, Nekoei-moghadam M, Rezaei F. Surge capacity of hospitals in emergencies and disasters with a preparedness approach: a systematic review. *Disaster Med Public Health Prep* 2017;**11**:612–20.
21. Page MJ, Moher D, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ* 2021 Mar 29;**372**:n160.
22. Popay J, Roberts H, Sowden A, Petticrew M, Arai L, Rodgers M, et al. *Guidance on the conduct of narrative synthesis in systematic reviews: a product from the ESRC Methods Programme*. 2006 Jan.
23. Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ* 2015 Jan 2;**349**:g7647.
24. Hasan MK, Nasrullah SM, Quattrocchi A, Arcos González P, Castro Delgado R. Hospital surge capacity preparedness in disasters and emergencies: protocol for a systematic review. *Int J Environ Res Public Health* 2022;**19**:13437.
25. Schardt C, Adams MB, Owens T, Keitz S, Fontelo P. Utilization of the PICO framework to improve searching PubMed for clinical questions. *BMC Med Inform Decis Making* 2007;**7**:16.
26. *CADIMA*. 2022. https://www.cadima.info/.
27. The National Heart, Lung, and Blood Institute. *Study quality assessment tools*. 2022. https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools.
28. Noyes J, Booth A, Moore G, Flemming K, Tunçalp Ö, Shakibazadeh E. Synthesising quantitative and qualitative evidence to inform guidelines on complex interventions: clarifying the purposes, designs and outlining some methods. *BMJ Global Health* 2019 Jan 1;**4**(Suppl 1):e000893.
29. Pluye P, Gagnon M-P, Griffiths F, Johnson-Lafleur J. A scoring system for appraising mixed methods research, and concomitantly appraising qualitative, quantitative and mixed methods primary studies in Mixed Studies Reviews. *Int J Nurs Stud* 2009;**46**:529–46.
30. Abolghasem Gorgi H, Jafari M, Shabanikiya H, Seyedin H, Rahimi A, Vafaee-Najar A. Hospital surge capacity in disasters in a developing country: challenges and strategies. *Trauma Mon [Internet]* 2017 Sep 1;**22**(5). [cited 2022 Oct 28]. Available from: http://www.traumamon.com/article_100104.html.
31. Chuang S, Woods DD, Reynolds M, Ting HW, Balkin A, Hsu CW. Rethinking preparedness planning in disaster emergency care: lessons from a beyond-surge-capacity event. *World J Emerg Surg* 2021 Nov 29;**16**(1):59.
32. Haroon MZ, Thaver IH. An assessment of existing surge capacity of tertiary healthcare system of Khyber Pakhtunkhwa Province of Pakistan using workload indicators for staffing need method. *Hum Resour Health* 2022;**19**:120.
33. Marcozzi DE, Pietrobon R, Lawler JV, French MT, Mecher C, Peffer J, et al. Development of a hospital medical surge preparedness index using a national hospital survey. *Health Serv Outcome Res Methodol* 2020 Mar 1;**20**(1):60–83.
34. Shahverdi B, Tariverdi M, Miller-Hooks E. Assessing hospital system resilience to disaster events involving physical damage and Demand Surge. *Socioecon Plann Sci* 2020;**70**:100729.
35. Mills AF, Helm JE, Wang Y. Surge capacity deployment in hospitals: effectiveness of response and mitigation strategies. *Manuf Serv Oper Manag* 2021;**23**:367–87.
36. Feizolahzadeh S, Vaezi A, Taheriniya A, Mirzaei M, Vafaeenasab M, Khorasanizavareh D. The feasibility of increasing hospital surge capacity in disasters through early patient discharge. *Bull Emerg Trauma* 2019 Apr 1;**7**(Issue 2):105–11.
37. Mackie BR, Weber S, Mitchell ML, Crilly J, Wilson B, Handy M, et al. Chemical, biological, radiological, or nuclear response in Queensland emergency services: a multisite study. *Health Secur* 2022 Jun;**20**(3):222–9.
38. Blimark M, Örtenwall P, Lönroth H, Mattsson P, Boffard KD, Robinson Y. Swedish emergency hospital surgical surge capacity to mass casualty incidents. *Scand J Trauma Resuscitation Emerg Med* 2020 Feb 12;**28**(1):12.
39. Koka PM, Sawe HR, Mbaya KR, Kilindimo SS, Mfinanga JA, Mwafongo VG, et al. Disaster preparedness and response capacity of regional hospitals in Tanzania: a descriptive cross-sectional study. *BMC Health Serv Res* 2018 Nov 6;**18**(1):835.
40. Bayram JD, Zuabi S, Subbarao I. Disaster metrics: quantitative benchmarking of hospital surge capacity in trauma-related multiple casualty events. *Disaster Med Public Health Prep* 2011;**5**:117–24.
41. Hick JL, Koenig KL, Barbisch D, Bey TA. Surge capacity concepts for health care facilities: the CO-S-TR model for initial incident assessment. *Disaster Med Public Health Prep* 2008;**2**:S51–7.
42. Pong J, Lim J, Wu S, Li A, Wong XY, Tsang L, et al. Improving emergency department surge capacity in disasters - conception of a medical student disaster volunteer corps. *Prehospital Disaster Med* 2019 May;**34**(s1). s84–s84.
43. Traub M, Bradt DA, Joseph AP. The surge capacity for people in emergencies (SCOPE) study in Australasian hospitals. *Med J Aust* 2007;**186**:394–8.
44. Cohen J, van der Meulen Rodgers Y. Contributing factors to personal protective equipment shortages during the COVID-19 pandemic. *Prev Med* 2020;**141**:106263.
45. Bown CP. How COVID-19 medical supply shortages led to extraordinary trade and industrial policy. *Asian Econ Policy Rev* 2022;**17**:114–35.

46. Satterthwaite PS, Atkinson CJ. Using 'reverse triage' to create hospital surge capacity: royal Darwin Hospital's response to the Ashmore Reef disaster. *Emerg Med J* 2012;**29**:160–2.
47. Kelen GD, Sauer L, Clattenburg E, Lewis-Newby M, Fackler J. Pediatric disposition classification (reverse triage) system to create surge capacity. *Disaster Med Public Health Prep* 2015;**9**:283–90.
48. Pollaris G, Sabbe M. Reverse triage: more than just another method. *Eur J Emerg Med* 2016;**23**:240–7.
49. DeLia D. Annual bed statistics give a misleading picture of hospital surge capacity. *Ann Emerg Med* 2006;**48**:384–388.e2.
50. DeLia D, Wood E. The dwindling supply of empty beds: implications for hospital surge capacity. *Health Aff (Millwood)* 2008;**27**:1688–94.
51. Shabanikiya H, Jafari M, Gorgi HA, Seyedin H, Rahimi A. Developing a practical toolkit for evaluating hospital preparedness for surge capacity in disasters. *Int J Disaster Risk Reduc* 2019;**34**:423–8.