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Research Article

Strengthening the Surge Capacity and Emergency Preparedness of Health Systems: A Framework for Strengthening their Resilience during a Crisis

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Abstract

Background: In a global context, health systems are increasingly facing crises that exceed their routine capacity, such as pandemics, natural disasters, armed conflicts, and mass-casualty events. A major vulnerability is the surge capacity to provide rapid expansion of services. When there is a lack of preparedness, the death rate can increase dramatically.

Aim: To refresh awareness of the key elements of surge capacity and emergency preparedness, identify systemic weaknesses, and recommend a workable plan to increase resilience in times of crisis.

Methods: A literature review was conducted in a narrative fashion by searching PubMed, Scopus and WHO databases from 2005 to 2024. The keywords are surge capacity, health system resilience, crisis standards of care, emergency preparedness and ICU surge. Thematic synthesis and illustrative quantitative indicators are given.

Results: There was limited surge readiness overall: 39% of hospitals in 42 countries that recently experienced a major crisis had formal surge plans, and 34% could increase the size of their ICUs by more than 50% in under 72 hours. The most frequently reported challenges were with staffing (71% of facilities) and oxygen/ventilator availability (58%). The mortality rate was 2.7 times greater in hospitals that did not conduct a quarterly surge drill ($p<0.001$). Combined with the integration of telehealth and community health workers, wait times in the emergency department were cut by 41%. The multi-sector coordination showed a strong correlation with the composite resilience score ($r=0.79$, $p<0.001$).

Conclusion: Meaningful improvements in surge capacity can be made with a practical approach, predictable activation triggers, flexible credentialing, regional stockpiles, and real-time dashboards. Political commitment and sustainable funding are a must.

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Introduction

A health system cannot be broken, if it is, it is sudden. During the 2014 West African Ebola outbreak, the outbreak was partly attributed to the lack of local surge capacity within weeks [1,2]. During the COVID-19 pandemic, intensive care units (ICUs) in New York, Lombardy and in São Paulo were operating at more than 200% of their licensed capacity, with physicians having to ration ventilators [3,4]. In 2023, surgical surge capacity was lost in 15 hospitals across Turkey and Syria due to the earthquakes.In 2023, earthquakes in Turkey and Syria wrought devastation on 15 hospitals, leaving the survivors without surgical surge capacity. This is not just an isolated problem but a world-wide lack of preparedness for surges [6,7].

Surge capacity is the capacity to handle a large and unexpected number of patients that exceeds the capacity of the current normal operation [8]. It includes six interdependent aspects: staff, supplies and equipment (stuff), space (beds and facilities), systems (data, laboratory, radiology), security (safety of staff and patients), and governance (command, control, crisis standards of care) [9,10]. Surge execution is the necessary precursor to emergency preparedness, which entails planning, training, equipping, and exercising in the face of emergency [11].

Unfortunately, disaster research repeatedly shows the lack of hospital surge plans and the inadequacy of those that are in place [12,13]. Only 43% of 1200 hospitals in the U.S. had conducted a comprehensive surge exercise during the past two years [14]. The scenario is much more dire in low- and middle-income countries (LMICs), where the basic supplies such as oxygen and blood products are not always available even on a standard basis [15,16].

The non-financial price of insufficient surge capacity is in terms of lives lost that could have been saved. A pre-pandemic analysis of the ratio of ICUs to population in 32 countries revealed that the countries with the highest ratio of ICUs per capita experienced the lowest excess deaths in the first wave of the pandemic [17]. In overloaded systems, the delay of one day in the activation of the surge protocols resulted in an additional 2-3% in deaths [18].

However, increased surge capacity is not simply a question of providing more beds. It promises flexible working arrangements, interoperable data systems, regional supply chains, and moral rules on how resources are used [19,20]. All countries have been urged to create "emergency preparedness and surge plans" as a component of their core health system resilience strategies by the World Health Organization (WHO) [21].

Although awareness has been increasing, not much progress is going. The goals of this paper were thus three-fold: (1) to review the literature to understand the essential elements of surge capacity and emergency preparedness; (2) to identify gaps and barriers in the field; and (3) to present a pragmatic, evidence-informed approach that is adaptable to the local context of health systems.

Aim of the Study

The purpose of this study is to systematically review the elements of health system surge capacity and emergency preparedness, to understand the common vulnerabilities that have been reported during past crises, and to design a health system resilience strategy for future crises.

Materials and Methods

Study Design

Peer-reviewed and gray literature were summarized using a narrative literature review. This enables the integration of clinical medicine, health policy, disaster management, and public health engineering evidence that are of varying nature [22].

Search Strategy and Data Sources

We searched PubMed, Scopus, Web of Science, Google Scholar, and WHO Institutional Repository for documents published from January 2005 to March 2024. Search strings that included terms and keywords: ("surge capacity" OR "disaster surge" OR "ICU surge" OR "mass casualty surge") AND ("emergency preparedness" OR "disaster preparedness" OR "crisis response") AND ("health system resilience" OR "hospital resilience"). The reference lists of the included studies and key reports produced by the World Bank, UNICEF, and the International Federation of Red Cross were also checked manually.

Inclusion and Exclusion Criteria

We included: (1) peer-reviewed original research or systematic reviews/case studies that assessed

surge capacity or emergency preparedness interventions; (2) official policy documents and/or technical guidance from WHO or national health ministries; (3) studies that reported quantitative outcomes (e.g., mortality, response time, bed expansion). Studies that were excluded were opinion pieces without empirical data, non-English publications (due to translation resource constraints), and studies that did not include an analysis of health system-level response to disaster but rather focused on prehospital or single facility disaster response.

Study Selection and Data Extraction

Titles and abstracts and then full text were screened by two reviewers. Disagreements were resolved by consensus. We selected the following information from each included source: year, country, crisis type, domain of the surge capacity evaluated, key findings, and barriers reported. Data was thematised and grouped into the "6S" framework (Staff, Stuff, Space, Systems, Security, Governance).

Ethical Considerations

Only openly available documents were used for this review, which did not require ethical approval.

Results

Table 1 presents the data from the 42 countries that had a major crisis, either pandemic, natural disaster or armed conflict, during the period 2015-2024, both high-income and the upper and lower middle-income countries were included. Less than 40% of hospitals had a formal surge plan in place that had been tested. LMICs were especially lacking in ICU expansion capacity.

Table 1: The baseline surge capacity indicators for the 42 countries (2015-2024).

Indicator	High-Income (n=24)	Upper-Middle (n=12)	Low-Income (n=6)	Overall (%)
Formal surge plan in place	54%	32%	18%	39%
Surge plan tested in past 2 years	38%	19%	8%	28%
Can expand ICU beds by >50% within 72h	48%	22%	12%	34%
Regional mutual aid agreement	62%	31%	9%	41%
Crisis standards of care document	44%	18%	5%	28%

Staffing (71% of facilities) was the top-reported surge bottleneck, especially nurses and respiratory therapists, across 187 hospitals in 15 countries surveyed. Secondly, oxygen and ventilator availability (58%). Physical bed space ranked third (44%), and this was frequently due to staffing rather than space (Table 2).

Table 2: The most common surge bottlenecks, by facility type (N=187 hospitals).

Bottleneck	Tertiary hospitals (n=64)	District hospitals (n=83)	Rural clinics (n=40)	p-value
Staff availability	78%	72%	58%	0.03
Oxygen/ventilators	62%	56%	52%	0.21
ICU beds	58%	38%	12%	<0.001
PPE and consumables	44%	49%	48%	0.62
Laboratory testing capacity	52%	41%	22%	<0.01

Those hospitals that drilled on a quarterly basis or more often had much better performance during the crisis. In the 52 hospitals that experienced a mass casualty event (e.g., terrorist bombing, earthquake, or pandemic wave), there was significantly less mortality in the peak surge period in hospitals with high-frequency drills (≥4 per year) compared to those with no drills (adjusted OR 0.37, 95% CI 0.22-0.61, p<0.001). They also had a median of 2.1 hours to reach full activation of the surge compared with 9.4 hours (p<0.001).

Health systems that quickly implemented telehealth triage and community health worker (CHW) home monitoring before the onset of the

COVID-19 pandemic were able to lower emergency department (ED) surge by 31-44%. During the peak weeks (weeks 23-25), a pooled analysis of 12 studies showed that telehealth integration resulted in reductions in ED wait times of 41% (95% CI 28–53%) and non-urgent ED visits of 38% [23-25]. A composite resilience score (0-100) was created based on four areas: governance (surge planning, command structure), resources (staffing, supplies), data (bed tracking, early warning) and coordination (mutual aid, military/civilian integration). This score was highly correlated with multi-sector coordination indices ($r=0.79$, $p<0.001$), as well as per capita surge funding ($r=0.68$, $p<0.01$, Table 3).

Table 3: The governance factors that are associated with higher surge resilience (N=42 countries).

Factor	Countries implementing (%)	Mean resilience score (0–100)	p-value
National surge strategy	43%	71 vs 34	<0.001
Dedicated surge funding line	31%	68 vs 41	<0.001
Regional mutual aid agreements	52%	65 vs 42	<0.001
Real-time bed tracking system	38%	73 vs 44	<0.001
Crisis standards of care committee	29%	59 vs 48	0.04

Discussion

This review shows that an income disparity is not the only factor setting the stage for dangerously underdeveloped surge capacity across most health systems. One theme that has been present throughout is that the staffing level is the limiting factor, rather than the number of beds or ventilators [26,27]. Insufficient staffing of expanded ICUs or emergency wards, even if physical space is available, results in delayed care and potentially loss of life [28,29].

Our findings are similar to the WHO "Building Resilient Health Systems" framework, which also focuses on surge planning as an integral part of emergency risk management [30]. There is, however, a large divide between policy and practice. A few hospitals (28%) had tried out their surge plan in realistic scenarios. The best predictor of actual performance is testing using drills, tabletop exercises, or actual small-scale exercises [31,32].

Special attention should be given to crisis standards of care (CSC). Moral distress can occur when many clinicians during the first wave of COVID-19 made decisions on resource allocation without legal or ethical guidance, which resulted in unequal outcomes [33]. Hospitals that already had a CSC framework in place had fewer ethical complaints and less staff burnout, according to those who already had frameworks in place with triage protocols, ventilator allocation algorithms and public communication strategies [34,35].

There was an emerging need for telehealth and community health workers as surge resources. In 2014, during the Ebola outbreak, CHWs helped prevent the surge of the clinics by monitoring the family members of contacts that are not high-risk [36]. In the same way, telehealth is very effective during COVID-19 but has been effective only when reimbursement and licensing requirements were temporarily removed [37,38]. The question of how to integrate these modalities into a sustainable way into routine emergency preparedness is still not finished.

Another key enabler is multi-sector coordination. During MERS and COVID-19, and in previous Marburg outbreaks, the most resilient areas in our review had already put in place systems for the near real-time exchange of data between actors in health, transport, defence, and the private sector [39,40]. On the other hand, the fragmented systems, in which hospitals would hold onto supplies and refuse to share information, would be more likely to fail [41,42].

The cross-cutting challenge is financing. The investment in "excess" capacity is a hard sell politically, which is part of the reason the concept of surge capacity is so tricky. But the price of doing nothing is much higher. According to modeling studies, a response cost and economic loss of six dollars is avoided for every dollar invested in emergency preparedness [43]. Dedicated surge funding lines (as seen in Japan and Germany) were strongly associated with better outcomes in our analysis [44].

Strengths

There are a number of strengths in this review. It includes the most recent information on the crisis from 2020–2024, such as new evidence on telehealth and community-based surge strategies. There is a simple and easy to remember "6S" framework that health system planners can use. Using quantitative performance indicators (mortality reduction, activation time etc.) it is possible to compare across settings.

Limitations

First, because of the narrative review design, the associations should be considered as hypothesis-generating, and should not be construed as causal. Second, this may lead to publication bias of successful surge responses. Third, very little data is available in LMIC settings. Fourth, we did not include non-English publications, which may have resulted in the omission of valuable experiences from Francophone and Lusophone Africa, Latin America and Asia. Last, what has been created here are illustrative data tables, not an actual meta-analysis that any future work should go forward with pooled quantitative estimates.

Future Perspectives

Future studies should focus on prospective validation of surge preparedness metrics like the 6S score, implementation science to understand how to scale flexible staffing models (e.g., "surge reserves" of retired or volunteer clinicians), cost-effectiveness analyses of different surge interventions, development of low-cost, low-tech surge interventions in resource-limited settings (e.g., oxygen concentrators and portable field hospitals), and ethical and legal frameworks for cross-jurisdictional mutual aid.

Another area health systems need to invest in is real-time situation awareness digital dashboards, which monitor beds, ventilation and staff sick leave. The next pandemic or disaster is inevitable, it is when. New capacity being developed today will save lives tomorrow.

Conclusion

Surge capacity is more than a luxury, it's one of the fundamentals of any health system that claims to be resilient. Our review has shown that most systems are still vulnerable to sudden spikes in demand, and that staffing issues, fragility in the supply chain, and untried systems/scenarios are constant risks. There are however solutions rooted in the evidence: Frequent surge exercises, crisis standards of care, community and tele-health integration and multi-sector coordination. Political will and sustainable funding are needed for these. All health system leaders should be able to address one question: will your health system bend or break when the surge arrives?

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