Health Systems’ “Surge Capacity”: State of the art and priorities for future research

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Health Systems’ “Surge Capacity”: Current thinking and priorities for future research

Abstract

Context: Over the past decade a number of high-impact natural hazard events, together with increased recognition of pandemic risks, have intensified interest in health systems’ ability to prepare for, and cope with, “surges” (large-scale, sudden escalations) in treatment needs. In this review we identify key concepts and components associated with this emerging research theme. We consider the requirements for a standardised conceptual framework for future research capable of informing policy to reduce the morbidity and mortality impacts of such incidents. Here our objective is to appraise the consistency and utility of existing conceptualisations of health systems surge capacity and their components, with a view to standardising concepts and measurements to enable future research to generate a cumulative knowledge base for policy and practice.

Methods: A systematic review of the literature on concepts of health system surge capacity, with a narrative summary of key concepts relevant to the public health context.

Findings: The academic literature on surge capacity demonstrates considerable variation in its conceptualisation, terms, definitions, and applications. This, together with an absence of detailed and comparable data, has hampered efforts to develop standardised conceptual models, measurements, and metrics. Some degree of consensus is evident in relation to the components of surge capacity, but more work is needed to integrate them. The overwhelming concentration on the US context problematizes the generalizability of existing approaches and findings.

Conclusions: The concept of surge capacity is a useful addition to the study of health systems’ disaster / pandemic planning, mitigation, and response, and has far-reaching policy implications. While research in this area has grown at a striking rate, it has yet to fulfil its potential to generate knowledge to inform policy. Work is needed to generate robust conceptual and analytical frameworks, alongside innovations in data collection and methodological approaches that enhance health systems’ readiness for, and response to, unpredictable high-consequence surges in demand.
Keywords: surge capacity; disease outbreaks; disaster planning / organisation & administration; disaster medicine / manpower

Introduction

Existing evidence (ADRC, 2009; Guha-Sapir et al., 2011) suggests the frequency of recorded casualty-producing natural hazard events has increased more than four-fold on a global basis since the mid-70’s (ADRC, 2009). Whether this is a result of increases in the frequency of events- or of heightened exposure and vulnerability to hazards is unclear, with detection of patterns and trends in physical hazard frequency requiring a timeframe of millions (or hundreds of millions) of years. What is clear, however, is that demographic, social, and environmental shifts are forcing increasing numbers of people to occupy (hitherto avoided) areas (Dobbs et al., 2011; UN, 2005). Vulnerabilities to natural hazard induced disasters may in future be amplified as processes of environmental degradation, rapid urbanization, and social marginalization (themselves representing latent, serious challenges for the sustainability of health system capacity) exacerbate impacts (ADRC, 2009; Guha-Sapir et al., 2011; UNISDR, 2011). While few countries are immune to risks from natural hazard, historically it is low-income countries, particularly those in Asia, that are subject to the highest incidence, and impacts, of natural-hazard induced disasters (ADRC, 2009; Guha-Sapir et al., 2011).

A similar historical trajectory is evident in the prevalence of emerging infectious diseases (EIDs) (Jones et al., 2008). Global EID “hot-spots” (presented in figures 1a – 1d) are likewise disproportionately located in the global south, where a complex mix of societal (population density, antibiotic drug use, and agricultural systems and practices) and environmental (precipitation, temperatures and prevalence of severe weather events) factors, converge as important outbreak drivers, and where surveillance efforts and control measures are currently weakest.
These twin trends, and the threats they represent, are being taken increasingly seriously. International and national disaster mitigation initiatives now explicitly incorporate a strong proactive and pre-emptory dimension, and increasingly recognise a key role for health systems in effective planning and response (EU, 2009, 2011; UN, 2005) (WHA, 2011). The priorities laid out in the United Nations’ Hyogo Framework for Action (HFA) for 2005-2015, and within the UN International Strategy for Disaster Reduction’s (UNISDR) broader mandate (UN, 2005), are in line with this approach. So too is the EU’s announcement, in 2009, of its own commitment to disaster risk reduction both in Europe and the global south; articulated respectively in the Community Approach to the Prevention of Natural and Manmade Disasters (EU, 2009) and the EU Strategy for Supporting Disaster Risk Reduction in Developing Countries (EU, 2011). The 64th World Health Assembly resolution: Strengthening National Health Emergency and Disaster Management Capacities and Resilience of Health Systems builds on these recent global initiatives to highlight the centrality of health systems to disaster preparation, resilience, and response (WHA, 2011).

These recent initiatives emphasise that natural hazard events do not translate directly (or necessarily) into disasters (defined by their impact on society and environment) (UN, 2005), and
both the UN and EU stress that the disaster risk of natural hazards can be reduced (EU, 2011; UN, 2005). Figures 2a and 2b respectively demonstrate global exposure and global vulnerability to natural hazard risks. Comparison of the figures indicates that the two are not synonymous.

Measures can be taken to reduce population vulnerability. The challenge, as many international organisations are beginning to acknowledge (EU, 2011), lies in translating the uncoordinated ad hoc project/programme approach that persists into strategic and co-ordinated action at the global, regional, national, and local levels.

**Figure 2a: Population risk-exposure to natural hazards**

![Image of global exposure map]

Max exposure = 100%

*Classification according to the quintile method*


**Figure 2b: Population risk as a function of exposure (figure 2a) and vulnerability* **

![Image of global vulnerability map]

Max risk = 100%

*Classification according to the quintile method*


*vulnerability is a composite measure of i) susceptibility (calculated as a function of public infrastructure status, population nutritional status, income levels) ii); coping capacities (status of governance, medical care, and material security); and iii) adaptive capacities (risks projected forwards).*
This approach can be extended to a parallel stream of research focussed on the resources, procedures, and processes that need to be in place for pandemic readiness and response. In a recent comparative review (WHO, 2011) of international pandemic preparedness plans, the World Health Organisation (WHO) identified a widespread absence of sub-national planning as a serious obstacle to coordinated action in the event of pandemic. The WHO’s report recommends the revision of international plans to explicitly define responsibilities, roles, and authorisations at the various sub-national levels, a finding which is consistent with the recommendations made by various international agencies occupied with planning for natural hazard induced disaster scenarios (EU, 2009, 2011; UN, 2005) (WHA, 2011).

The concept of health systems’ surge capacity provides a potential means to capture and coordinate the commonalities between pandemic and disaster planning needs to generate a model for health system readiness and response with applicability to a wide range of scenarios. In this paper we systematically review the ways in which health systems’ surge capacity has been conceptualised since its inception as an area of research. We consider the multifaceted nature of the concept and draw out the different components that various seams in the literature have emphasised.

**Methods**

We conducted a comprehensive search of electronic databases to identify articles and records of conference proceedings which (re)conceptualise or apply a definition of health system surge capacity, or some aspect thereof. Further search inclusion criteria were (online) publication (in English) prior to 28th October 2011, and accessibility in one of the following databases: Medline (accessed via Pubmed and OVID); Web of Science; and Web of Knowledge. No limitations on country of origin or of emphasis were included as the (inter)national applicability of the concept formed an important area of interest. A number of articles applied the concept of surge capacity to day-to-day fluctuations in emergency room numbers. Those that considered this application of the concept within an extended framework that encompassed lessons for disaster or crisis scenarios were included in the analysis. Those that limited the concept’s application to operational issues surrounding ongoing emergency room overcrowding were excluded. The initial search was conducted in the listed databases using the following terms:
The breadth of the search criteria was a deliberate strategy designed to capture the
anticipated variety in the concepts’ application and avoid exclusion of relevant articles. The initial
electronic search produced 687 unique articles. The broad search strategy necessarily resulted in
the capture of a high number of irrelevant articles (these commonly related to “surges” in viral or
parasitic load in experimental laboratory or clinical settings). 508 such papers were excluded on
the basis of their title and, if necessary, abstract. In line with our objective to appraise the extent
of the concept’s recognition, all articles which were concerned with the health system implications
of “surge capacity” in a disaster (broadly defined) context were retained even if the concept was
utilised only in passing and was not defined.

These were screened for relevance, in line with the stated exclusion and inclusion criteria,
resulting in a total of 176 articles. An additional 10 further articles were identified from the
bibliographies of papers originating in the initial search; meaning a total of 186 academic, peer-
reviewed articles were reviewed. The earliest of which (Loretti et al., 2001) was published in
Summer 2001, though it was not until 2005 that the concept attained wide currency. This process
was undertaken separately and independently by the first and second authors who had agreed the
inclusion criteria prior to the search, and met to discuss their findings. Of the articles agreed to be
relevant, 167 (89.8%) related to the US context and experience. 15 (see note) related to a country
other than the US and four, (Fisher et al., 2011; Hall, 2007; Rykken et al., 2005; WHO, 2006) to a
low income country context.
Although our primary objective was a systematic review of the concept’s emergence and consolidation in the academic, peer-reviewed literature, we subsequently undertook to assess the extent of cross-over of the health systems surge capacity concept to the policy world. This entailed a search of online publications and web-resources for a number of health services and/or policy and management related agencies, organisations, and consortia with responsibility for preparing for and/or responding to disaster scenarios (including national health departments/ministries, international organisations, and allied agencies). This extension was considered valid given that the value of the health system surge capacity concept is entailed largely in its relevance (or otherwise) to real-world “surge” scenarios. Examination of government and NGO (non-governmental organisation) web resources, publications, and reports demonstrates a recent (and ongoing) cross-over of the term “surge capacity” from the academic literature.

The following sections concentrate on articulating key sites of consensus and debate within the academic literature, but draw on the “grey” literature to inform consideration of the scope for taking research and practice forward in a coordinated way.

Findings

The concept of “Surge”

Differences in conceptions of health system surge capacity begin at the level of first principles, with contention over what it is that can be said to constitute a surge event, scenario, or process. This ambiguity is, largely, a result of the term’s extension beyond its traditional application to disaster contexts to encompass daily, weekly, and seasonal fluctuations in emergency department patient numbers (historically discussed in terms of (over)crowding); a development initiated by a 2006 Academic Emergency Medicine Consensus Conference entitled ‘The Science of Surge’ (Kelen & McCarthy, 2006). Debate turns on the term’s applicability to this latter context, and of the relationship (if any) between care need escalations embedded within regular patient inflow fluctuations (widely termed “daily surge”) and those related to extraordinary events (known as “disaster surge”).

Three broad positions can be discerned in the academic literature. The first envisages these two surge contexts as a continuum of the same underlying phenomenon. The second presents
them as separate but related categories, with the potential to mutually inform one another. The third restricts the term’s use to exceptional events, deeming its application to routine fluctuations in healthcare needs inappropriate. The characteristics of each position are reported in table one. Although, in table one, the third conceptualisation appears as the least represented, it is in fact the default position of the majority of the literature on surge, wherein the concept of “daily surge” is unrecognised and the term “surge” (without the “disaster” pre-cursor) refers exclusively to severe and unanticipated escalations in health system demand.

**Table 1**: The relationship between “daily” and “disaster” surge

<table>
<thead>
<tr>
<th>Conceptualisation</th>
<th>Characteristics</th>
<th>Authors</th>
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<tr>
<td>Continuum</td>
<td>The “surge” concept is applied to any peak in patient census including those associated with day-to-day operations; the focus is on individual facilities / emergency departments</td>
<td>Jenkins et al (2006); (Jenkins et al., 2006); Asplin et al (2006); (Asplin et al., 2006); Kelen and McCarthy (2006); (Kelen &amp; McCarthy, 2006); McCarthy et al (2006); (McCarthy et al., 2006); Rothman et al (2006); (Rothman et al., 2006); Handler et al (2006); (Handler et al., 2006); Bradt et al (2009); (Bradt et al., 2009); Schull (2006a &amp; 2006b); (Schull, 2006; Schull et al., 2006)</td>
</tr>
<tr>
<td>Separate but related categories</td>
<td>The “surge” concept is applied equally to operational fluctuations and disaster contexts, but they are acknowledged as different &amp; distinct phenomena</td>
<td>Kaji et al (2006); (Kaji et al., 2006); Avery et al (2008); (Avery et al., 2008); Barbische et al (2006); (Barbisch &amp; Koenig, 2006);</td>
</tr>
<tr>
<td>Misnomer</td>
<td>The “surge” concept is reserved for scenarios occasioning departures from standard operational practices; its application to daily fluctuations is deemed inappropriate and confusing</td>
<td>Bonnett et al (2007); (Bonnett et al., 2007); Hick et al (2009); (Hick et al., 2009) Rubinson et al (2008); (Rubinson et al., 2008)</td>
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While numerous definitions of “surge” and “surge capacity” have been proposed in “daily” and “disaster” contexts, the expansion of the term’s remit to incorporate routine fluctuations in patient numbers seems to undermine, rather than enhance, the scope for clarity regarding its key components, sites of application, and wider implications. There is a tendency to conflate “daily surge” with acute periods of chronic ED overcrowding. The difficulty in this application is that such “spikes” represent a failure to accommodate routine (if growing) demands on services in a context of widespread ED closures and diminished bed numbers, rather than the large-scale, unanticipated, and sudden escalation that is implied by the term “surge”.

Attempts to invoke “surge” as an umbrella concept encompassing both “small spikes in patient volume...encountered...during routine operations” and “situation[s] where a healthcare system is overwhelmed and must expand its operations to accommodate a large influx of patients” have been criticised for misrepresenting, by conflating, the distinct nature and causes of each (Bonnett et al., 2007). The remainder of this article will restrict the use of the term “surge” to the consideration of sudden, unanticipated escalations in health system demand initiated by exceptional events (such as natural hazard induced disasters and pandemics). Our point would be that hospital overcrowding is an important issue, with substantial relevance for the concept and creation of surge capacity, but that it is qualitatively distinct phenomena.

Within this literature, recent research has sought to sub-type the concept of surge capacity (Bonnett et al., 2007; Hanfling, 2006; Potter & Brough, 2004). In practice, this has entailed differentiating natural hazard induced disaster events from communicable disease outbreaks, which ties in well with the international approach to disaster and pandemic planning detailed in the introduction. A range of terms have been proposed for distinguishing these broad event types on the basis of their injury / illness profiles; geographical coverage; oscillations and trajectories over time; and duration. Barbisch et al (2006) use the terms “sudden impact” and “obscure” events. Others have proposed: “fixed” and “extended” (Hanfling, 2006); “focal, time-limited” and “widespread, prolonged” (Potter & Brough, 2004); and “contained and “population-based” (Bonnett et al., 2007). Each is intended to frame the “surge capacity” concept in such a way as to be flexible enough to be of use for researching and planning the response needs of a range of disaster types (Bonnett et al., 2007; Hick et al., 2009; Hick et al., 2004; Hick et al., 2008b). One point to be highlighted is that, while these typologies are a useful abstract tool, “real world” scenarios will not always be neatly classifiable in these terms.
Depending on initial response, and a variety of other site and scenario specific characteristics, surges in mortality and morbidity may be phased. The proximate surge (i.e. immediate to short term direct morbidity profile) in trauma injuries following an earthquake, for example, might be followed by a phased, or latent (i.e. longer term and possibly indirect) surge in diseases associated with poor sanitation and crowding (Noji, 1992). The cholera outbreak that followed in the wake Haiti’s devastating 2010 earthquake illustrates the potential for enormous repercussions to follow from phased impacts. It highlights too, the uncertainty and unpredictability that can attend the transition from proximate to latent phases of disaster-induced healthcare demands. More work is needed to assess, record, and model the morbidity profiles and trajectories associated with disasters, an area that is recognised to be under-researched at present (Bourque et al., 2007).

The concept of surge capacity

In the absence of a standardised definition of surge capacity, authors have employed a range of meanings, with key terms at times applied inconsistently within a single article, and in many cases, not defined at all. There is a tendency to conflate the terms “surge” and “surge capacity”, whereby “surge” is utilised (Hanfling, 2006; McManus et al., 2006) to refer to both a demand-side increase in health system resources (“disaster events...generate definable surges in demand for care” (Hanfling, 2006), and the supply-side response such an event precipitates (“surge can be defined as the ability to rapidly meet increased demand for medical care” (Hanfling, 2006)). The latter application, such that “surge” describes response rather than the phenomenon necessitating the response, is widely applied (Barbisch, 2005; Barbisch & Koenig, 2006; Binns et al., 2010; Estacio, 2006; Hotchkin & Rubinson, 2008; Tadmor et al., 2006). Barbisch et al discuss “optimising outcomes in terms of optimising surge and the sub-components of surge”; employing “surge” in verb rather than noun-form, such that they describe the “health care community’s...need to surge to meet patient care needs that exceed expectations” (Barbisch, 2005)(emphasis added). Hotchkin and Rubinson (2008) similarly adopt this unwieldy verb-form to talk of “surging critical care capacity” (emphasis added). The majority position is, however, to define and / or apply the term “surge” to refer to sudden escalation and / or intensification of demand.
While at their core, most definitions of “surge capacity” denote the “the ability...to respond to a sudden increase in patient care demands” (Hick et al., 2008b), the specificity of the term’s meaning and applications varies substantially beyond this general premise. One prominent, and important, variation is in the term’s applicability to scenarios in which external assistance is required. The American College of Emergency Physicians’ definition of surge capacity as a “measurable representation of a health care system’s ability to manage a sudden or rapidly progressive influx of patients within the currently available resources at a given point in time (ACEP, 2006) (emphasis added), has been widely influential (Asplin et al., 2006; Bradt et al., 2009; Handler et al., 2006; McCarthy et al., 2006; Robertson & Cooper, 2007; Rottman et al., 2010; Schull, 2006; Schull et al., 2006; Schultz & Stratton, 2007; Welzel et al., 2010), but risks excluding consideration of potentially important mobilizable resources.

Other authors emphasise that surge capacity relates not merely to the sufficiency of currently available resources, but to the ability to effectively and rapidly expand capacity (AHRQ, 2006; Bonnett et al., 2007; Dayton et al., 2008; Hick et al., 2009; Hick et al., 2008a; Hick et al., 2010a, b; Hick et al., 2004; Hick et al., 2008b; Rodgers et al., 2006; Schultz & Koenig, 2006; Stratton & Tyler, 2006). This conceptualisation is articulated clearly by Hick et al (Hick et al., 2009; Hick et al., 2004; Hick et al., 2008b) who define surge capacity as “the ability to manage a sudden, unexpected increase in patient volume that would otherwise severely challenge or exceed the present capacity” either of an individual facility (Hick et al., 2010a) or of the wider health care system (Hick et al., 2004). This latter point demonstrates another common variation in published definitions, related to the site(s) at which “surge capacity” is deemed applicable. There is also variation in the unit of analysis employed by different studies. While some authors limit the concept to the level of individual facility vi or single department vii (most usually the emergency department or ICU), the importance of embedding facilities within the wider health system’s context is increasingly stressed viii.

Two broad applications are apparent, consistent with the priorities and objectives of the agencies involved. The first entails the concept’s increasing occurrence in international guidelines and best practice. An early example of this is the UK Department of Health’s published guidelines on pandemic management (DoH, 2009). The approach taken by this publication is consistent with that advocated by Kelen et al, discussed in some detail below. The World Health Organisation (WHO) has taken the lead in the promotion of “surge capacity” as a component of international
good practice, with its 2011 publication, *Hospital emergency response checklist: An all-hazards tool for hospital administrators and emergency managers*. The WHO draws explicitly on the 2009 pandemic guidance (DoH, 2009) issued by the UK Department of Health. The second, and more common, use of the term (shorn of its “health system’s” prefix) apparent in the grey literature is in application to the ability of humanitarian and aid agencies to scale-up their own operational capacity in response to sudden-onset needs (Emmens & Houghton, 2008; Houghton & Emmens, 2007).

The term “*surge response capability*” is a recent addition to the literature. Despite the increasing application of this term, there is little consensus on what it is; what it means; and whether (and in what ways) it differs from the concept of *surge capacity*. While the term “*capability*” is most commonly used as a synonym for “*capacity*”, another seam in the literature (Barbera & Macintyre, 2002; Binns et al., 2010; Felland et al., 2008; Hanfling, 2006; Hick et al., 2009; Hick et al., 2008a; Hick et al., 2004; Hick et al., 2008b) has attempted to define a separate identity for the “*capability*” concept. This revolves around its designation to denote the availability and adequacy of specialist resources and skills needed to meet the needs of a specific injury group, such as burns victims. While it is useful to explicitly recognise that the treatment of disaster-induced injury profiles will likely require specialist equipment and skills, the value added by defining an additional concept in this way is unclear, and in its current form, may serve to undermine attempts to develop standardised and comparable metrics.

Kelen and McCarthy (2006) have proposed an alternative approach, advocating the “*surge response capability*” concept as a means to capture “the extent to which surge capacity (...resource availability and maximized management...) can accommodate the surge (...demand for resources...)”. This then, presents surge capability as a measure of fit that enables the proportion of surge cases that resources can accommodate to be quantified. This might usefully inform mathematical modelling to estimate existing capacity and generate diagnostics of potential shortfalls. This potential remains untested, since there has been little engagement with (or application of) this proposed definition. Any future attempt to take it forward would require care to ensure it did not result in an unduly technical approach, which could lose sight of the importance of governance structures and legal frameworks for effective co-ordination, a point we expand upon below.
The components of surge capacity

Given the variability of definitions and applications of the terms “surge” and “surge capacity”, there is a striking degree of consensus over what it is that, fundamentally, comprises the ability of a health system (or an individual hospital facility within a health system) to “respond to a sudden increase in patient care demands”(Hick et al., 2008b). This consensus has emerged in recent years, largely in response to increasing dissatisfaction with prior attempts to conceptualise (and measure) surge capacity in terms of bed numbers alone. This was largely a result of initial uncritical engagements with the US Department of Homeland Security’s recommendation(HRSA, 2004) that surge capacity entail the provision of 500 beds for every one million of population for acute infectious disease scenarios, and of 50 beds for every one million of population for non-infectious disease and trauma scenarios. Other recommendations that represent surge capacity as synonymous with bed numbers suggest an ability to expand bed numbers by 25% to 30%(Schultz & Stratton, 2007).

Barbisch et al(2006) were among the first to problematise reliance on bed numbers as a proxy for surge capacity. They proposed a multi-component approach that could take into account the interactions and dependencies necessarily entailed by an effective health systems’ response to disaster / pandemic induced surge:

It is not simply beds or ventilators, but appropriately trained personnel (staff), comprehensive supplies and equipment (stuff), facilities (structure), and, of imperative importance, integrated policies and procedures (systems) to develop optimized sustainable surge capacity.

Their four component approach (staff; stuff; structure; and systems) has since proved influential, though there has been a tendency for the fourth component, that of systems, to be neglected, in favour of a concentration on “staff, stuff, and structures”(Barbisch, 2005; Barbisch & Koenig, 2006; Felland et al., 2008; Hick et al., 2008a; Hick et al., 2008b; Hota et al., 2010; Hotchkin & Rubinson, 2008; Nager & Khanna, 2009; Schultz & Koenig, 2006; Welzel et al., 2010). Some authors have appended “space” (which overlaps with other’s definitions of “structures”) to this trio of components. We consider the content of each key component in turn.
There is a wide degree of consensus regarding the central importance of maintaining sufficient staffing levels throughout a surge scenario’s duration. The integration of personnel numbers into estimates of existing capacity and diagnostics of potential shortfalls is widely understood to imply a need for analysis that goes beyond measuring available staffing levels. Kaji et al’s (Kaji et al., 2006) point that “one must plan for what people will do, rather than what one wants them to do” is represented in analyses and recommendations that seek to incorporate estimates of staff absenteeism and to develop means to intervene to reduce its extent. (Qureshi et al., 2005; Rottman et al., 2010; Steffen et al., 2004; Welzel et al., 2010). Several survey-based studies (Qureshi et al., 2005; Rottman et al., 2010; Steffen et al., 2004; Welzel et al., 2010) have attempted to discern the extent to which hospital (medical and non-medical) staff would be willing and able to report to work, and/or to remain there indefinitely, given scenarios of varying severity and risk levels. Care duties and distance between home and place of work are most commonly cited as impediments to response, with scenarios involving contagions and radiation most undermining willingness to report (Qureshi et al., 2005; Rottman et al., 2010; Steffen et al., 2004; Welzel et al., 2010).

As Iserson et al (2008) comment “no uncontroroversial way to establish a threshold at which risk acceptance becomes a duty” has, to date, been identified. The extent to which health professional’s sense of duty, understood as a matter for personal conscience, will overcome anxiety of risk represents a major source of unpredictability for surge capacity planning. An opt-out option enabling staff unwilling to work in conditions they judge too risky to personal (and family) health to instead undertake tangential, low-risk, duties has been suggested (Qureshi et al., 2005; Rottman et al., 2010; Steffen et al., 2004; Welzel et al., 2010), and was reportedly trialled in the 2003 Toronto outbreak of SARs (Iserson et al., 2008). Any planned role for reallocation must, however, rely on the expectation that take-up will be limited, so that sufficient front-line staff remain. The extent to which this expectation is credible is highly contingent on the nature of the surge event and its wider context. The mutual impact on, and of, relations between colleagues undertaking front-line and peripheral duties will likely further intervene in the practicality of any such arrangement. A further relevant point with regards to uncertainty is the extent to which healthcare professionals who do remain in post may deviate from professional, and wider social, norms of acceptable behaviour under conditions of severe strain, particularly if prolonged. While
high-profile incidents of deviation from duty of care have received disproportionate attention in the wake of disasters (Alley, 1992; Iserson et al., 2008; Kunzelman, 2010), the wider evidence (Alley, 1992; Iserson et al., 2008; Simonds & Sokol, 2009) is that the expectation that healthcare professionals will respond to patient need despite personal risks is realistic.

While a majority of studies have concentrated on the need to mobilise hospital staff, others have begun to consider roles for other medical personnel, with a greater role advised for general practitioners (Fisher et al., 2011; Nap et al., 2006; Schultz & Stratton, 2007) on the twin grounds that they can divert patients from hospitals (performing a pre-hospital triage role, the viability of which is an important avenue for future research), and may be in a position to intervene earlier to diminish the growth rate of the surge. A number of authors have suggested a role for military medical corps as a means to supplement civilian staffing levels (Bonnett et al., 2007; Hanley & Bogdan, 2008; Hick et al., 2004; Miller et al., 2008; Tadmor et al., 2006). This has been countered (Hotchkin & Rubinson, 2008; Sariego, 2006) with concerns that reliance on military medical resources (in terms of facility space and equipment as well as personnel) may prove nonviable since, in severe disaster scenarios or those implying security threats, such resources might be reserved for military support (Bonnett et al., 2007). A number of authors recommend the utilisation of existing (and creation of new) registers of medical personnel who are willing to volunteer their assistance in the event of a disaster / pandemic induced surge (Hanley & Bogdan, 2008), though difficulties are noted regarding the potential for mobilisation to be restricted in scenarios in which transport infrastructure is damaged; the ability for local commitments to over-ride more distant (but more urgent) ones in the event of a large-scale scenario; and unwillingness in the event to leave family members in hazardous situations (Hanley & Bogdan, 2008).

“Stuff”

“Stuff”, or “equipment”, typically denotes a very wide range of items, including beds, ventilators and other medical apparatus, pharmaceuticals, and a range of other essential resources. Despite concerns regarding over-reliance on bed numbers as an exclusive indicator of capacity, there remains a wide consensus that “availability of empty beds (along with requisite medical staff)” forms “a fundamental component of hospitals’ surge capacity...during the first hours and days of a disaster”(DeLia & Wood, 2008). While much of the interest in bed numbers has been centred on the level of individual facilities, the need for co-ordination among facilities is
highlighted in a recent retrospective study of the effectiveness of Asian countries’ pandemic surge capacity (Fisher et al., 2011), which found a high incidence of “hospitals with no available ICU beds...managing severe patients in emergency rooms or general wards while in nearby hospitals ICU beds were available”. This implies a need for simple updatable systems to enable resource use and depletion to be tracked over time and space. With regard to pharmaceuticals and other medical supplies, the literature’s emphasis is on the potential for low levels of stockpiling and the shift towards “just-in-time” supply-chains to detrimentally impact surge capacity. In the US system the ability of hospitals and health systems to develop and maintain emergency stock-piles is widely acknowledged (see note *) to be severely undermined by “economic pressures to run lean operations...interpreted as minimizing inventory rather than managing the costs of inventory” (Adini et al., 2006). Reliance on overseas suppliers for pharmaceuticals (as well as other essential supplies) has been highlighted as potentially exacerbating supply-chain problems in the event that imports are compromised (John G. Bartlett & Borio, 2008a).

A recent article by Hick et al (2009) proposes a series of measures that can be taken in the event of insufficiency of stockpiled pharmaceuticals and supplies, these consist of the following stages: “substitute; adapt; conserve; reuse; reallocate”. These recommendations highlight an important point regarding the standard of care that surge capacity should be aimed towards providing. Hick et al (2009) have proposed a formalised model of scalable surge capacity, composed of a three-tiered system of escalation in resource utilisation from conventional, to contingency, to (ultimately) crisis phases. Where the first two phases imply minimal disruption to normal standards of patient care, the latter implies a reallocation of priorities from maintenance of the usual standard of care to provision of the best standard of care possible in exceptional circumstances. This approach has been adopted in the US Institute of Medicine’s recommendations (Hanfling et al., 2012) on shifts in acceptable standards of care for disaster scenarios. Despite this recent intervention, this remains an issue that is rarely directly confronted in the literature, but one which provides an essential backdrop to the conceptualisation and measurement of surge capacity. It is a subject that future research should confront directly.

**Structures / Space**

Hospitals are the “structures” most commonly cited as components of surge capacity. A recent trend in the literature is to explore means to incorporate surge capacity infrastructure into plans for new hospitals, and to retro-fit existing ones (Hick et al., 2009; Joshi & Rys, 2011; Schultz
More ambitious recommendations for new “surge-proof” hospital facilities include the creation of “universal patient rooms configurable for any purpose”, modular equipment, 100% air filtration, built-in radiation protection and blast-protected walls (Romano, 2005). Such proposals involve a substantial lead-in time and can entail prohibitive expense. The widespread creation of reserve wards and the resurrection of decommissioned spaces has been proposed as a less disruptive alternative (Dayton et al., 2008), but its feasibility has also been questioned on the grounds of cost (Robertson & Cooper, 2007).

A number of means for hospitals to efficiently utilise non-medical spaces (such as canteens, waiting areas, and corridors) have also been proposed for implementation in the event of surge. This raises issues regarding the point at which measures can no longer reasonably be said to constitute “surge capacity”. A question arises over whether measures such as the use of unstaffed beds, and/or of corridors and canteens as treatment spaces, represent “surge capacity”, or, conversely are indicative of its exhaustion. This again relates what standard of care is appropriate when planning for, and implementing, surge capacity; and is an area which remains very under-theorised in the existing literature.

A series of proposals for the creation of treatment areas beyond the hospital facility have also been suggested (Dayton et al., 2008; DeLia & Wood, 2008; Hick et al., 2004; Hogg et al., 2006; Romano, 2005; Schultz & Koenig, 2006). Hogg et al (2006) suggest home-based hospital care, as a form of space creation, which might feed into widely discussed plans to incorporate a role for patient early discharge and transfer (Dayton et al., 2008; DeLia & Wood, 2008). A wide range of potential “alternate sites” (Dayton et al., 2008; DeLia & Wood, 2008; Hick et al., 2004; Hogg et al., 2006) or “sites of opportunity”(Barbisch & Koenig, 2006; Romano, 2005) have also been proposed as means to supplement hospital space. Ideally these should be located in close proximity to existing hospital facilities, and their utilisation subject to considerable pre-planning (including drills and exercises).

Plans for the construction of temporary surge facilities have also been recommended, with the experiences of Hong Kong and Canada in dealing with SARs cited as exemplars (Dayton et al., 2008). The technology exists for surge wards with airborne isolation facilities to be constructed and accessorised for inpatient care in a matter of days (Dayton et al., 2008). This has the potential to intervene in the management of prolonged surge scenarios, but is of limited applicability to short-
lived events. A proposed solution to this lead-in time is the creation of pre-fabricated modular mobile hospitals which can be transported where needed as an integrated truck trailer-bed unit. Such a model was trialled in the US in response to hurricane Katrina (Voelker, 2006). The costs of storing and maintaining the units, together with difficulties around licensing them as treatment spaces (complicated in the US scenario due to restrictions imposed by health insurance providers) are, however, cited as barriers to roll-out (Voelker, 2006).

**Systems**

Although only a minority (Barbera & Macintyre, 2002; Barbera et al., 2009; Bradt et al., 2009; Burkle, 2006; Burkle et al., 2007; Fisher et al., 2011; Hanfling, 2006; Hick et al., 2009; Hick et al., 2008b; Kelen & McCarthy, 2006; Rubinson et al., 2008) of authors retain Barbisch et al’s (2006) systems element of “surge capacity”, it is arguably the most essential of the four proposed components. In response to its widespread neglect, Hick et al (2009) emphasise the singular importance of this component, noting that the other factors “cannot be appropriately managed” in its absence. Research to assess the efficacy of surge-response in response to prior high profile events has consistently found the main limiting factor to be a lack of management systems to match resources to needs (Fisher et al., 2011; Schultz & Koenig, 2006). This has been found to lead to an under-utilisation of available resources in both the US (see endnote xii) and Asian (Fisher et al., 2011) contexts. Hick et al (2009) have developed their earlier work (Hick et al., 2004) to provide a detailed description of the systems component, subdividing it into a series of requirements for command; control; communications; co-ordination; continuity of operations; and community infrastructure. The neglect of the “systems” aspect seems to lie in its essential difference from the other constitutive aspects (staff, “stuff”, space) of surge capacity when it comes to operationalisation and measurement. One approach might therefore be to develop an independent identity for systems, perhaps through the elaboration of the capacity / capability distinction (a point returned to below).

While this provides a comprehensive and coherent account of the systems that need to be in place at the facility level, the concentration on facility level may represent a shortcoming. Other authors have made a strong case for a model of “central proactive coordination” on the grounds that “during an emergency, normal referral practices are unlikely to work” (Fisher et al., 2011). Barbisch et al (2006) propose modelling this wider health system response on the (US) National Incident Management System. Their catalogue of requirements (composed of command and control; communications systems; stress management; preventive medicine and public
health; laboratory; mortuary affairs and funeral services; personnel; logistics; transportation; and veterinary services.) does not deviate significantly from the inventory developed by Hick et al. (Hick et al., 2009), but identifies the health system rather than facility as the locus of response coordination and management. This approach is increasingly gaining ground among authors concerned to situate surge capacity in a wider health systems approach (Avery et al., 2008; Bonnett et al., 2007; Burkle, 2006; Burkle et al., 2007; Dayton et al., 2008; Estacio, 2006; Felland et al., 2008; Kaji et al., 2006; Phillips, 2006; Schultz & Koenig, 2006; Schultz & Stratton, 2007; Stratton & Tyler, 2006).

**Metrics and measurement of surge capacity**

Research to identify and conceptualise the essential components of surge capacity (and their interactions) has developed largely in isolation from empirical work to measure existing, and model optimal, capacity. The difficulty of translating the complex interdependencies inherent in the concept of surge capacity has meant that measures and metrics have tended to concentrate on the “stuff” component, and to depend on static and simplified proxies for its measurement. The challenges entailed in the operationalization of any complex phenomenon are widely acknowledged to be heightened in this instance by a widespread lack of robust and comparable data (DeLia, 2006; DeLia & Wood, 2008; Handler et al., 2006; Hick et al., 2009; Rodgers et al., 2006). A majority of the empirical studies undertaken to assess existing surge capacity have measured the availability of “staffed beds” at the facility, regional, and/or national level (DeLia & Wood, 2008), with debate around whether licensed beds or maintained beds provide the better proxy (Bagust et al., 1999; Schull, 2006; Schultz & Stratton, 2007).

Dissatisfied with bed-number proxies, others have looked at ways to use staff numbers to proxy surge capacity (Welzel et al., 2010). This introduces its own difficulties, with survey findings (Qureshi et al., 2005; Rottman et al., 2010) indicating that there is no guarantee that recorded staff levels will translate into a personnel willing to respond to disaster/pandemic induced surges. Schull (2006) has cautioned against the tendency to base predictions of “surge capacity” on analyses of existing bed and staffing numbers. He warns that “a simple count of available staffed beds, however calculated, may give a false sense of alarm” (since under surge conditions changes to operations and to standards of care will alter the relationship between staffed bed numbers and patient treatment), or of security (since facilities could become inoperable or diminished as a result of the surge inducing event). There is wide consensus (see note xii) that freeing base-line
capacity (and in particular) beds through the early discharge of inpatients, and cancellation / postponement of elective procedures and admissions would form a key first step in the event of a surge scenario. More research is needed to estimate the proportion of baseline resource utilisation that is amenable to triage in various contexts and scenarios. Attempts to simulate surge capacity have generally entailed a wider number of indicators and parameters than have survey or observational data analyses (Bagust et al., 1999; Baker et al., 2011; Balcan et al., 2009; Barthel et al., 2011; Krumkamp et al., 2010; Nap et al., 2006; Scheulen et al., 2009; Shi et al., 2008; Sobieraj et al., 2007; Ten Eyck, 2008).

Models and simulations have enabled a range of surge parameters (most frequently in relation to pandemic influenza scenarios) to be tested, factoring in the availability of equipment (including beds, key medicines, and personnel) and controlling for the anticipated age structure and treatment durations of patients together with expected levels of staff absenteeism (Bagust et al., 1999; Baker et al., 2011; Balcan et al., 2009; Barthel et al., 2011; Krumkamp et al., 2010; Nap et al., 2006; Scheulen et al., 2009; Shi et al., 2008; Sobieraj et al., 2007; Ten Eyck, 2008). Currently, capacity modelling for pandemic-induced surges in demand is at a more advanced stage than is that for natural hazard induced disasters (Anderson et al., 2003; Ercole, 2009; Krumkamp et al., 2010; Menon et al., 2005). The complexity and sophistication of such models is increasing, with more recent work exploring the potential for integrating parameterised feedback loops to account for the dynamics of resource depletion over the duration of the surge (Adisasmito et al., 2011; Krumkamp et al., 2010; Rudge et al., in press). Table two, below, summarises the findings presented in this section. We introduce the concept of “resource command”, a concept prior to “surge capacity” in order to avoid some of the conflationary tendencies identified above.

**Conclusions**

To date, a major hurdle to the development of surge capacity as a coherent sphere of research has been the absence of consensus regarding the definitions and applications of key terms. This has impeded conceptual clarity and has undermined the development of convincing measurements and metrics. Despite these difficulties, “surge capacity” is an important concept for the study of health systems’ disaster / pandemic readiness and response, and has far-reaching policy relevance for public health and health systems interventions and investments. Work is, however, needed to generate robust conceptual and analytical frameworks, alongside innovations in data collection and methodological approaches. Another key area for future research is the
addition of a temporal dimension. This would allow surge (and surge capacity) timelines to be explicitly understood to involve phased impacts. The incorporation of proximate and latent healthcare burdens can enable key sites of health system intervention to be identified.

While the development of general conceptual and analytical frameworks, together with improvements in data quality and methodological innovations for data analysis, can be of widespread applicability, there is a need to complement this with site and scenario specific findings. Despite the disproportionately high occurrence of surge generating events in low and middle-income countries, and their considerably heightened vulnerability to such events, research on surge-capacity has, to date, focused largely on high-income country contexts, principally the US. Research in other country contexts (and particularly low-income countries) is urgently required. Any general conceptual and/or analytical model will need to incorporate a role for geographical, temporal, and social contingency in outcomes, such that surge and surge capacity scenarios derive from, and inform, real-world events.

Implicit in the literature on surge capacity is the expectation that a severe, prolonged surge event, and the response it engenders, necessarily entails a diminished standard of care (Barbera et al., 2009; Bonnett et al., 2007; Bradt et al., 2009; Felland et al., 2008; Hick et al., 2009; Hick et al., 2004; Hick et al., 2008b; Kaji et al., 2006; Kaji et al., 2007; Moser et al., 2006; Phillips, 2006; Rothman et al., 2006; Welzel et al., 2010). While the three-tiered standard of care model proposed by Hick et al (2009) explicitly confronts the objectives and implications of surge capacity, the wider tendency has been to incorporate such concerns as an aside or afterthought. Future research should aim to take this work forwards, with the objective(s) of surge capacity - and the standard of care appropriate to scenario’s where needs markedly exceed resources - forming the point of departure for conceptualization and analysis.

A potential way forwards conceptually and analytically may lie in the development of the debates around the surge capacity / surge capability distinction. The Kelen and McCarthy (2006) definition of surge capability, and the wider debate over the centrality of the “systems” aspect (and concerns voiced recently regarding its neglect), brings to mind the long philosophical tradition (dating back to Aristotle’s formulation in the Nichomachean Ethics (Aristotle, 1980)) of distinguishing between capacity (as command over resources) and capability (as the ability to convert resource command into a valued, potential, outcome). Based on this distinction, surge capacity (the portion of health system resources which can be dedicated to surge needs-meeting) would be an important element, but not the only indicator (and may not be the most important of a health system’s ability to respond to disaster-induced surge(s) in demand. Systems (understood
in a broad sense) can then be understood as the conversion factors enabling surge capacity to translate into surge capability.

The development of coherent conceptual and analytical frameworks would be an important step towards creating a defined research space to enhance the development of evidence, and potentially effectively inform policy and practice. This is a move which has been called for more widely in relation to health systems research (Balabanova et al., 2010; Coker et al., 2008), and is an area that might valuably be taken forwards in future surge capacity research. Locating the health system in a wider social context will enable the systems component, widely identified as integral to surge capacity (Barbera & Macintyre, 2002; Barbera et al., 2009; Bradt et al., 2009; Burkle, 2006; Burkle et al., 2007; Fisher et al., 2011; Hanfling, 2006; Hick et al., 2009; Hick et al., 2008b; Kelen & McCarthy, 2006; Rubinson et al., 2008) to be meaningfully embedded in its wider governance, regulatory, and legislative environment.
<table>
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<th>Term</th>
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<tr>
<td>Surge</td>
<td>A sudden, unexpected escalation in health care needs induced by a public health emergency. May be (adopting Bonnet et al’s terms) geographically “contained” or widespread (“population-based”)</td>
<td>• Analysis of past hazard-event’s characteristics, duration, and phased impacts and on key event-site characteristics (demographic; geographic; and infrastructural) to inform mathematical modeling to estimate the care needs for a range of surge-scenario’s</td>
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| Health System resource command    | The total stock of resources (**staff; stuff; and structures / space**) a health system can legitimately draw upon. We propose that this be composed of five categories: “critical baseline”; “available”; “increasable”; “triagable baseline”; “mobilizable” | • Development of data sources and methods to quantify baseline health system resource stocks on a national basis, disaggregated by relevant geographical and administrative unit (province; district; facility)  
• Development of methods and data to indicate proportion of “baseline” resources amenable to triage  
• Development of user-friendly, updatable systems to enable resource use and depletion to be tracked over time and space |
| Staff                             |                                                                                                                                                                                                         | • Elaboration of the emerging literature on staff willingness (and ability) to respond to a range of event scenarios. Survey and interviews with medical and non-medical health personnel  
• Assessment of the relevance of existing research on the impacts of stress and trauma on ability to undertake and perform professional duties.  
• Assessment of the feasibility of volunteer-registers |
<p>| “Stuff”                           |                                                                                                                                                                                                         | • Identification of the key physical resources (beds, ventilators, other medical apparatus, pharmaceuticals, non-pharmaceutical equipment) that best articulate “surge capacity”. The literature indicates beds to be a necessary but not sufficient proxy, but it is impractical to incorporate every resource in estimates and models. A balance should be sought. Evaluation of the risks posed by supply-chains in the event that imports are compromised |</p>
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<th>Structures / space</th>
<th>Health System surge capacity</th>
<th>Health System surge capability</th>
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<tr>
<td>The portion of health system resources (staff; stuff; and structures / space) available to meet surge needs (excludes “critical baseline” resources committed to meeting non-surge related needs).</td>
<td>Development of a framework to assess available in-house “surge spaces”</td>
<td>What can actually be achieved with the surge capacity a health system possesses; systems (defined broadly to include governance arrangements; legal frameworks and precedents; bilateral and multilateral agreements and precedents; feasible - and practiced - procedures and plans; communications and transport logistics; staff and public response) can be thought of as the conversion factors translating capacity into capability.</td>
</tr>
<tr>
<td>Development of data sources and methods to enable baseline health system resource demand to be accurately assessed and / or modelled. Analysis should, where possible, be sensitive to temporal fluctuations in baseline demand.</td>
<td>Identification of potential legal, and bureaucratic obstacles to resource, staff, and patient mobilization across geographical and administrative boundaries</td>
<td>Case-study analysis drawing on academic literature; national and international appraisals and reports; key-informant interviews; and “survivor” surveys and interviews to identify procedural barriers to effective (and equitable) application of health system resources in past surge events.</td>
</tr>
<tr>
<td>Appraisal of past experiments with spill-over spaces (schools; sports arenas; community centres, etc)</td>
<td>Identification of feasible modifications to medical facilities to increase surge capacity</td>
<td>Analysis of written procedures and plans, and of practical exercises and “drills”, to identify potential obstacles to effective future response.</td>
</tr>
<tr>
<td>Identification of best-practice triage procedures under conditions of surge</td>
<td>Appraisal of past experiments with spill-over spaces (schools; sports arenas; community centres, etc)</td>
<td>Surveys and interviews to identify public expectations and identify potential obstacles to compliance with health advice in the event of surge</td>
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References


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\[1\] only five articles on surge capacity were published prior to 2005 (Loretti, Leus et al 2001; Shapiro 2003; Taylor 2003; Hick, Hanfling et al 2004; Higgins, Wainwright et al 2004)

\[2\] (Aharonson-Daniel et al., 2006; Anderson et al., 2003; Baker et al., 2011; Barnett et al., 2009; Downey & Hebert, 2010; Fisher et al., 2011; Hall, 2007; Menon et al., 2005; Robertson & Cooper, 2007; Rykken et al., 2005; Shi et al., 2008; Shih & Koenig, 2006; Sprung et al., 2010; Traub et al., 2007; WHO, 2006)

\[3\] WHO; UNIASC; UNOCHA; UNDP; UNICEF; ECB (Emergency Capacity Building); People in Aid; Sphere; ALNAP; InterAction; HAP; International; CARE Australia; CARE International; CARE; CRS; IFRC; Medair; Mercy Corps; MSF; NRC; Oxfam; Save the Children; WFP; World Vision International; ICRC

\[4\] Prior to the October 2010, cholera had been absent from Haiti for more than a century Piarroux et al 2011; WHO 2011b.

\[5\] (Ablah et al., 2008; Barthel et al., 2011; John G. Bartlett, 2006; Burkle, 2006; Burkle et al., 2007; Hick et al., 2008a; Hogg et al., 2006; Hotchkin & Rubinson, 2008; Kaji et al., 2008a; McManus et al., 2006; Miller et al., 2008; Nap et al., 2008; Nap et al., 2006; Romano, 2005; Satterthwaite & Atkinson, 2010; Shih & Koenig, 2006; Sprung et al., 2010)

\[6\] (Ablah et al., 2008; Adini et al., 2006; Asplin et al., 2006; Avery et al., 2008; Bar-Dayan, 2010; Barbera et al., 2009; Barnett et al., 2009; Bayram et al., 2011; Binns et al., 2010; Chaffee, 2009; D’ Arch et al., 2008; Davis et al., 2005; Delia, 2006; DeLia & Wood, 2008; Falconer & O'Neill, 2007; Farmer & Carlton, 2006; Hick et al., 2008a; Higgins et al., 2004; James G. Hodge et al., 2011; Ippolito et al., 2006; Kaji et al., 2007; Kaji et al., 2008b; Kaji & Lewis, 2006; Kanter & Moran, 2007a; Kelen et al., 2006; Kraus et al., 2007; Li et al., 2008; Lynch et al., 2008; Manley et al., 2006; Mechem, 2007; Miller et al., 2008; Peleg & Kellermann, 2009; "Reverse triage adds to surge capacity," 2009; Sandrock, 2010; Satterthwaite & Atkinson, 2010;Scarfone et al., 2010; Schull, 2006; Schull et al., 2006; Schultz & Koenig, 2006; Schultz & Stratton, 2007; Shapiro, 2003; Shi et al., 2008; Smith et al., 2011; Sobieraj et al., 2007; Sprung et al., 2010; Standards and guidelines for healthcare surge during emergencies: roles to be played by hospital security," 2009; Ten Eyck, 2008; Tran et al., 2009; Using annual bed statistics to measure hospitals’ surge capacity is misleading. Rutgers researchers report." 2006; Van Cleve et al., 2011; Voelker, 2006; Welzel et al., 2010; Yi et al., 2010; Zhang et al., 2006; Zilm et al., 2008)

\[7\] (Balcan et al., 2009; Barthel et al., 2011; Bradt et al., 2009; Christian et al., 2008; Custer et al., 2011; Daugherty & Rubinson, 2011; Fernandez et al., 2008; Griffiths et al., 2011; Joshi & Rys, 2011; Joynt et al., 2010; Kaiser et al., 2011; Kallman & Feury, 2010; Kanter & Moran, 2007b; Lee et al., 2009; Lynch et al., 2008; Markovitz, 2009; Mazowitz, 2006; Meltzer et al., 2011; Mercer et al., 2011; Nager & Khanna, 2009; Nap et al., 2010; Nap et al., 2008; NCBI, 2010a, b; Rubinson et al., 2008; Sprung et al., 2010; Tandberg & Qualls, 1994; Van Cleve et al., 2011)

\[8\] (ACEP, 2006; AHRQ, 2006; Baker et al., 2011; Balcan et al., 2009; John G. Bartlett, 2006; J. G. Bartlett & Borio, 2008b; Bonnet et al., 2007; D’Aoust et al., 2008; Eastman et al., 2007; Emery et al., 2009; Estacio, 2006; Felland et al., 2008; Fisher et al., 2011; Greenko et al., 2010; Hall, 2007; Hick et al., 2009; Hick et al., 2010b; Hick et al., 2004; Hirshberg et al., 2005; Hoard et al., 2005; J. G. Hodge et al., 2005a; J. G. Hodge, Jr. et al., 2005b; Hogg et al., 2006; Hsu et al., 2007; Kaji et al., 2008a; Kaji et al., 2006; Katz et al., 2006; Kok et al., 2006; Krumkamp et al., 2010; Langabeer et al., 2009; Levin et al., 2007; Meredith et al., 2011; Meskimen & Hicks, 2011; Monto et al., 2006; Moser et al., 2005, 2006; Planning together: community and hospital response to disasters," 2008; Potter & Brough, 2004; Robertson & Cooper, 2007; Romano, 2005; Roszak et al., 2009; Rykken et al., 2005; Scheulen et al., 2009; Sefrin & Kuhnigk, 2008; Severance, 2002; Shih & Koenig, 2006; Stratton & Tyler, 2006; Swanson et al., 2010; Tadmor et al., 2006; Taylor, 2003; Watkins et al., 2011; WHO, 2006)

\[9\] This report advocates surge capacity as one of nine “key components” of health systems disaster readiness (the remaining eight are Command and control; Communication; Safety and security; Triage; Continuity of essential
services; Human resources; Logistics and supply management; Post-disaster recovery). It breaks Surge Capacity down into thirteen key sites of action centred on calculating base-line resources, estimating surge requirements and identifying gaps to be addressed. It follows the academic literature’s emphasis on the “four S’s” of surge capacity (staff; stuff; structure; and systems), and while concentrating on the facility level notes the need to attend to the potential to mobilise extrinsic resources in line with the wider health systems approach.

(Adini et al., 2006; Avery et al., 2008; Balcan et al., 2009; John G. Bartlett, 2006; John G. Bartlett & Borio, 2008a; Bonnett et al., 2007; Burkle, 2006; Estacio, 2006; Felland et al., 2008; Fisher et al., 2011; Hanfling, 2006; Hanley & Bogdan, 2008; Hick et al., 2009; Hick et al., 2004; Hick et al., 2008b; Higgins et al., 2004; Hota et al., 2010; Hotchkin & Rubinson, 2008; Hsu et al., 2006, 2007; Kaji et al., 2006; Kaji & Lewis, 2006; Kort et al., 2005; Krumkamp et al., 2010; Miller et al., 2008; Moser et al., 2005, 2006; Nap et al., 2006; Peleg & Kellermann, 2009; Phillips, 2006; Robertson & Cooper, 2007; Romano, 2005; Rottman et al., 2010; Schull, 2006; Schultz & Koenig, 2006; Shapiro, 2003; Shih & Koenig, 2006; Sprung et al., 2010; Tadmor et al., 2006)

(Barbera & Macintyre, 2002; Barbera et al., 2009; Bradt et al., 2009; Burkle, 2006; Burkle et al., 2007; Hanfling, 2006; Hick et al., 2009; Hick et al., 2008b; Kelen & McCarthy, 2006; Rubinson et al., 2008; Schultz & Koenig, 2006)

(Avery et al., 2008; Baker et al., 2011; Dayton et al., 2008; Delia & Wood, 2008; Felland et al., 2008; Hanfling, 2006; Hanley & Bogdan, 2008; Hick et al., 2009; Hick et al., 2004; Hogg et al., 2006; Jenkins et al., 2006; Kaji et al., 2006; Kelen et al., 2006; Krumkamp et al., 2010; Miller et al., 2008; Moser et al., 2006; Peleg & Kellermann, 2009; Satterthwaite & Atkinson, 2010; Schull, 2006; Schull et al., 2006; Schultz & Stratton, 2007; Sprung et al., 2010; Welzel et al., 2010)