
Research Priorities for Surge Capacity

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Abstract

The 2006 *Academic Emergency Medicine* Consensus Conference discussed key concepts within the field of surge capacity. Within the breakout session on research priorities, experts in disaster medicine and other related fields used a structured nominal-group process to delineate five critical areas of research. Of the 14 potential areas of discovery identified by the group, the top five were the following: 1) defining criteria and methods for decision making regarding allocation of scarce resources, 2) determining effective triage protocols, 3) determining key decision makers for surge-capacity planning and means to evaluate response efficacy (e.g., incident command), 4) developing effective communication and information-sharing strategies (situational awareness) for public-health decision support, and 5) developing methods and evaluations for meeting workforce needs. Five working groups were formed to consider the above areas and to devise sample research questions that were refined further by the entire group of participants.

ACADEMIC EMERGENCY MEDICINE 2006; 13:1160–1168 © 2006 by the Society for Academic Emergency Medicine

Keywords: surge capacity, research, disaster

Surge capacity is arguably one of the most important areas of research endeavor for catastrophic events. Sound preparation and appropriate response to major events are dependent on reliable scientific underpinnings. As pointed out by Kelen and colleagues in this issue, the components of daily surge have become relatively well-known, and research techniques in the field

have evolved.¹ In contrast, the components of extraordinary surge are not well delineated, and their complex interactions remain largely unknown. This breakout session of the 2006 *Academic Emergency Medicine* Consensus Conference on the science of surge thus was charged with determining a prioritized research agenda applicable to the spectrum of daily and extraordinary surge.

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Received June 28, 2006; revision received June 30, 2006; accepted July 3, 2006.

This is a proceeding from a breakout session of the 2006 *Academic Emergency Medicine* Consensus Conference, "Establishing the Science of Surge," San Francisco, CA, May 17, 2006. Breakout session participants: Dominik Aronsky, Greg Bogdan, Clifton Callaway, Griffin Davis, Linda Degutis, J. T. Finnell, Dan France, Lewis Goldfrank, Brad Gordon, Jin Han, Steve Hargarten, Kate Heilpern, Phil Henneman, Brian Hiestand, Charlene B. Irwin, Brent King, Nancy Kwon, Richard Larson, Scott Levin, Charlie Little, Robert Lowe, Claude Lupis, John McConnell, Doug Nelson, Sally Phillips, Neils Rathlev, Carl Schultz, Boaz Tadmor, Tom Terndrup, Tammi Thomas, Prentice A. Tom, Michael Ward, Daniel Waxman, Bert Woolard, and Frank Zwemer. Address for correspondence and reprints: Richard E. Rothman, MD, PhD, Department of Emergency Medicine, The Johns Hopkins University, 5801 Smith Avenue, David Building Suite 3220, Baltimore, MD 21209. Fax: 410-735-6425; e-mail: rrothman@jhmi.edu.

METHODS

The breakout session followed a structured format. All participants who registered for the consensus conference were invited to join the Research Priority breakout session if they had an expressed interest in the topic. Participants were solicited by e-mail. Enrollment in the breakout group was limited initially to the first 15 participants. Because of strong interest at the session, an additional 15 participants were permitted to join the group on the day of the session. Stated goals of the group were to define key research-priority areas relevant to surge capacity and to define specific research objectives and questions within each of the selected priority areas that could be addressed by well-designed studies.

The session moderator (RR), assistant (EH), and scribe (CK) developed a preliminary working list of surge-capacity research topics before the session. This list was generated by first identifying relevant topics from two independent literature reviews of PubMed and Google Scholar that were performed by two of the authors (EH and CK). Search terms included combinations of *surge*, *surge capacity*, *disaster*, and *overcrowding*. The moderator also sent a request to each of the invited speakers from the surge conference to describe up to

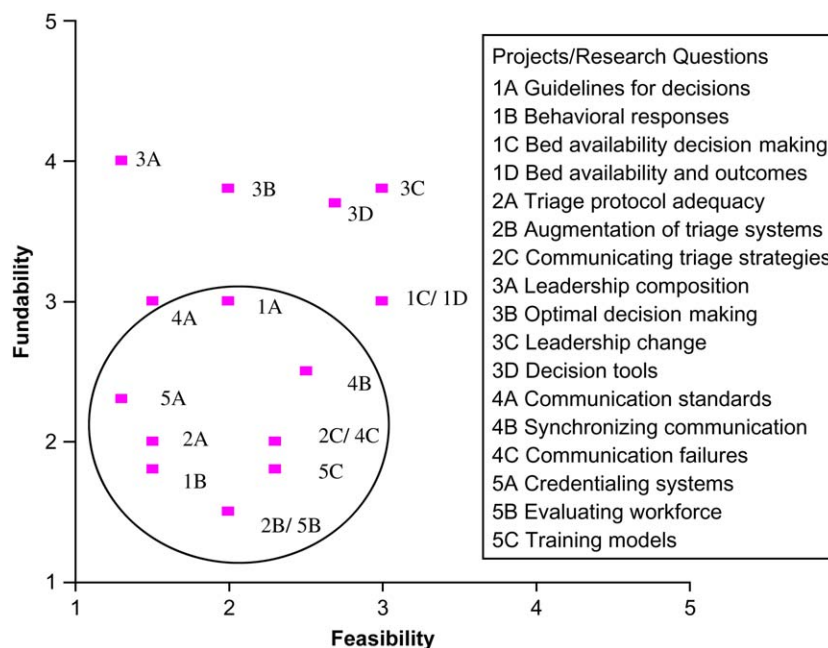


Figure 1. Feasibility and fundability of suggested research areas. A rank of 1 implies most fundable, most feasible, with the highest ranked projects highlighted by the circle.

five research topics or questions pertaining to routine surge capacity, extraordinary surge capacity, or both, that in the speaker's view were the most important priority areas for further research. A list of 25 research topics was compiled by these methods. Subsequent review by the moderator (RR) and conference chair (GK) was performed to cull and collapse redundant topics. A preliminary working list of 11 priority research topics areas thus was generated.

After ascertaining participant research expertise, the breakout session was divided into two components: group discussion and modification and ranking of a research priority list by using the nominal-group technique² to reach consensus, and development of specific research objectives and questions in each of the top five research-priority areas.

The working list of research topic areas was reviewed. The descriptive language of each topic area was modified by group discussion. Session participants were afforded the opportunity to provide additional topic areas for inclusion, which were identified through either the educational sessions or individual experience. A vote was then taken whereby participants anonymously rank-ordered, according to conceptual importance, the five highest priority topics for further research. Twenty-six members of the breakout session participated in the voting.

Voting participants were then subdivided into five working subgroups, corresponding to the five highest priority research areas. These small groups, each including a minimum of four participants, were given 30 minutes to detail up to five important research objectives or questions under the priority topic heading. Breakout groups were advised to develop specific answerable questions within the broader research priority areas as feasible.

After the conference, a brief electronic survey was sent to four leading emergency-medicine researchers (including the two co-chairs of the conference) who have estab-

lished track records of extramural funding relevant to surge. This group was asked to score each of the research topics according to two additional criteria: feasibility for directed research, and fundability, or likelihood that a project would be underwritten. Feasibility and fundability were each ranked on a scale of 1 to 5 (1 being the most feasible, and highest likelihood of attracting funding, respectively), with only whole-number responses possible. Projects ranked the highest according to these criteria were identified (Figure 1).

RESULTS

Thirty-six participants were included in the broad discussion. The majority were from academic university emergency departments (EDs), with all major geographic regions of the United States represented. Listed ranks of participants were approximately equally distributed between assistant-, associate-, and full-professor appointments. Representation also included university faculty from schools of engineering, health services, pharmaceutical services, civil and environmental engineering, medical informatics, and public health. In order of most to least frequently cited, areas of specialty expertise noted by the group included disaster management, emergency medical services (EMS) planning, operations, informatics, and infectious diseases.

Group discussion led to terminology refinement of the 11 topic areas and addition of three new topics. The final list of 14 research topic areas appears in Table 1. The group also reached consensus regarding several underlying themes that were deemed particularly important to consider in establishing a research agenda for surge. These included the need to address issues of social justice and costs when developing research and policy; the need to design and use information systems that are accessible and standardized for all users in a wide range of locations

Table 1
List of 14 Research Topic Areas, Identified and Prioritized by the Group

<ol style="list-style-type: none"> 1. Defining criteria and methods for decision making regarding allocation of scarce resources and the transition (breakpoints) from individual to population-based care, with attention to differential requirements of contained versus widespread events. 2. Developing best-practice methods and guidelines for triage protocols, with emphasis on applicability to different types of high-consequence events (e.g., pandemic influenza vs. bombing incident). 3. Determining key decision makers for surge-capacity planning and response and methods for testing their efficacy (e.g., incident command). 4. Developing effective communication and information-sharing strategies (situational awareness) for public-health decision support (e.g., interagency communications). 5. Developing methods and alternatives for meeting workforce needs, including training of personnel and evaluating or reporting performance. 6. Defining key components of surge capacity (e.g., pharmaceuticals, hospital beds, laboratories), their relative importance, and the impact of increasing investments in one area relative to others for event preparedness. 7. Applying information management and technology. 8. Determining cost-effectiveness of different surge strategies, with consideration given to payment and reimbursement methods and socioeconomic barriers to implementation. 9. Defining primary ethical issues in surge planning. 10. Applying lessons from industry. 11. Understanding crossover and linkages between daily surge and high-consequence-event surge. 12. Establishing best practices for maintaining current standards of emergency care (e.g., use of alternative treatment venues) while limiting potential impact of the event (e.g., infectious agents). 13. Defining key legal issues. 14. Operating under novel non-evidence-based scenarios and conditions.
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(e.g., academic and community hospitals, clinics, laboratories, public health departments); the need to develop methods and appropriate settings for empiric versus consensus research; and the need to continue discussion regarding whether research priorities for daily versus high-consequence surge should be considered distinct, or as part of a continuum. The majority felt that for purposes of the task at hand (ranking research priorities), it was appropriate to consider daily and high-consequence surges on a continuum.

Scores for the 14 topic areas ranged from 2–19, with a median of 8.5. The five leading scores were 19, 14, 12, 10, and 10, and appear as the first five items on Table 1. Each of the five working groups had a leader verbally present three to four research objectives or questions to the entire group. Wording of the objectives and questions was clarified by consensus (Tables 2–6). Final wording of each objective or question was modified by the authors to maintain consistency of form, without changing content. Mean scores for feasibility and fundability, as ranked by the funded experts, appear in Tables 2–6. Projects ranked the highest according to feasibility and

fundability criteria are graphically represented by the circle (nonstatistically derived) in Figure 1.

DISCUSSION

Topic 1 (Table 2)

Identification of criteria and methods for defining the breakpoints at which an ED, hospital, or medical system is overwhelmed and can no longer function under usual operating conditions, was perceived as the most important area in need of investigation. As noted by Kelen and colleagues¹ in this issue, there is a growing body of research in this arena with respect to daily ED surge, drawing largely from operational engineering, with a new set of methodologies and standards evolving.^{3–7} However, the need remains for well-defined metrics and methods for research in catastrophic surge.

We could identify no body of literature that describes a consistent approach for developing standards and processes for decision making in catastrophic surge. Most of the publications that address these issues are qualitative and are based on either expert opinion or consensus.

Table 2
Objectives and Questions Identified by the Breakout Group for Topic 1, including Feasibility and Fundability Scores*

Four Specific Objectives and Questions Identified	Feasibility (±SD)	Fundability (±SD)
A. To develop evidence-based guidelines for optimizing hospital decision making on when to ask for help. Suggested methods: simulation modeling or semistructured surveys.	2.0 (±1.2)	3.0 (±1.4)
B. To develop improved understanding of predicting behavioral responses in overcrowding and major disasters. Suggested methods: retrospective evaluation of data from international events or qualitative survey of decision makers.	1.5 (±0.6)	1.8 (±0.5)
C. To determine the impact of specific types of decisions made and the ability to open beds.	3.0 (±1.4)	3.0 (±1.4)
D. To determine whether increasing bed availability independently improves patient or health care system outcomes.	3.0 (±1.4)	3.0 (±1.6)

* Feasibility and fundability scores derived from survey of four leading funded experts, including cochairs of surge conference (mean scores provided; 1, best score; 5, worst score).

Table 3
Objectives and Questions Identified by the Breakout Group for Topic 2, including Feasibility and Fundability Scores*

Three Specific Objectives and Questions Identified	Feasibility (\pm SD)	Fundability (\pm SD)
A. To determine whether existing triage protocols are designed to adequately handle mass casualty and pandemic events (and if not, how can they be modified).	1.5 (\pm 0.6)	2.0 (\pm 0.8)
B. To determine how community resources can best be mobilized to support or augment existing triage systems.	2.0 (\pm 1.4)	1.5 (\pm 0.6)
C. To define best methods for effectively communicating alternative triage strategies to the community at large.	2.0 (\pm 2.0)	2.0 (\pm 1.2)

* Feasibility and fundability scores derived from survey of four leading funded experts, including cochairs of surge conference (mean scores provided; 1, best score; 5, worst score).

A few reports have adopted simulation or modeling methods initially used to study daily surge.^{8,9} The limited empirical research that exists includes survey analysis as well as operational modeling, such as the article by Hick and O'Laughlin proposing a concept of operations for triage of mechanical ventilation during an epidemic.¹⁰

This breakout group identified the following to create objectives and questions:

1. Research directed toward optimizing decision making has been conducted by using simulation modeling in nonmedical settings (e.g., earthquake and flood preparedness)^{11,12} and offers the advantage of flexibility and portability, because a range of variables can be manipulated and studies can be performed in different settings. Crude simulations recently have been developed for improving response preparedness to an infectious-disease outbreak (e.g., severe acute respiratory syndrome).^{13,14} As the field of simulation research evolves, potential utility for addressing decision-making issues relevant to catastrophic surge should be addressed but will require input from multidisciplinary teams of experts from a wide range of fields, including informatics, public health, and psychology. Survey studies, although having inherent limitations, also may be useful for research in decision making because they can provide data that may not be retrievable by other means (e.g., retrospective survey evaluations of Katrina)¹⁵ and can be used to provide crude assessments of the workings of complex disaster plans.¹⁶
2. The importance of understanding human behavioral response in surge is gaining increased attention. A recent study found that nearly 50% of local health department workers would not report to duty during a pandemic,¹⁷ which raises important issues for surge preparedness and demonstrates the benefit of this

line of inquiry. Similarly, postevent surveys of health-care workers in disaster settings have yielded critical data for guiding future decision making in disasters.¹⁸ Further development of these methods and lines of investigation is required.

3. Studies describing the relationships between the impact of specific types of decisions, decision making at various levels in the hospital, and bed availability have been well described. Few systematic studies were identified that evaluate whether increasing bed availability impacts individual patient or larger population outcomes, but this deserves further attention.

Topic 2 (Table 3)

Disaster triage remains a broad and ill-defined field for scientific inquiry. Review of the literature reveals several areas of ongoing discussion.¹⁹ Of particular concern, several triage protocols exist, but few have been systematically evaluated. Of those that have been tested, none have undergone outcomes-based assessment to determine whether use of the system improves patient outcomes.¹⁹⁻²⁴ Further, no specific evidence exists to demonstrate that triage, as a general concept rather than a specific model, changes patient outcomes.¹⁹ Disagreement continues regarding who should perform primary triage (e.g., physicians, nurses, out-of-hospital providers), and what the most relevant initial outcome measure should be (e.g., tagged patients, geographically separated groups of patients).²⁵⁻²⁹

Existing triage methodologies tend to be one-size-fits-all in nature, with some trauma-only methods that are based on decades of previous work but not yet proven.²⁴ Although there is controversy regarding the applicability and feasibility of population-targeted triage systems (e.g., for pediatric patients, chemical-weapons victims, or biological-weapons victims), critical review of commonly used systems demonstrates that some triage-system

Table 4
Objectives and Questions Identified by the Breakout Group for Topic 3, including Feasibility and Fundability Scores*

Four Specific Objectives and Questions Identified	Feasibility (\pm SD)	Fundability (\pm SD)
A. To define the composition of the current key leadership in planning at local, regional, state, and federal levels.	1.3 (\pm 0.5)	4.0 (\pm 2.0)
B. To determine optimal group composition and characteristics for effective leadership decision making.	2.0 (\pm 0.8)	3.8 (\pm 1.0)
C. To define whether and how decision leadership should be changed on the basis of incident and optimal methods of integrating decision makers.	3.0 (\pm 0)	3.8 (\pm 1.3)
D. To identify best tools for assessing effectiveness of decision making.	2.7 (\pm 1.5)	3.7 (\pm 1.2)

* Feasibility and fundability scores derived from survey of four leading funded experts, including cochairs of surge conference (mean scores provided; 1, best score; 5, worst score).

Table 5
Objectives and Questions Identified by the Breakout Group for Topic 4, including Feasibility and Fundability Scores*

Three Specific Objectives and Questions Identified	Feasibility (\pm SD)	Fundability (\pm SD)
A. To define required standards for communications systems and to determine which systems are most robust (within or across hospital systems).	1.5 (\pm 1.0)	3.0 (\pm 0.8)
B. To determine which methods most effectively achieve synchronization of communication content and delivery.	2.5 (\pm 1.3)	2.5 (\pm 1.3)
C. To determine which outcomes are associated with communication failures as well as which systems can be put in place to avert them.	2.3 (\pm 1.5)	2.0 (\pm 0.8)

* Feasibility and fundability scores derived from survey of four leading funded experts, including cochairs of surge conference (mean scores provided; 1, best score; 5, worst score).

components are likely to fail on the basis of differences in physiological baselines and patient presentations, which cannot be extrapolated from trauma scores.³⁰ Although it remains unclear whether a universal system should be pursued, various system components have been tested and been shown to have differential input (briefly ignoring the underlying lack of evidence that the overall triage score itself has specific value).^{22,31} Particular components that appear promising include analysis of heart-rate variance and the Glasgow Coma Scale motor component.³²⁻³⁴ Focused Assessment with Sonography for Trauma ultrasound and respiratory rate appear to be less effective in assisting with triage.³⁵

The majority of triage research studies that prioritize patient transport involve the underlying assumption that all surviving patients will eventually be taken to treatment facilities. Recently, studies have begun to emerge that take into consideration issues of scarce resources in austere conditions.^{10,36} Alternate systems of triage may be needed to work in conjunction with alternate standards of care.³⁷

Planning for triage contingencies needs to be considered across the range of patient care providers and locations, rather than just the out-of-hospital arena. Hospitals and alternative care sites need to be involved in such planning.

Finally, the literature shows that in-hospital triage systems currently have poor agreement regarding triage category definitions, evaluation methodologies, definitions of "inappropriate use" based on triage level, and outcomes criteria.³⁸⁻⁴⁰ It will remain difficult to evaluate in-hospital triage without better agreement and consistent terminology across systems.

This breakout group identified the following to create objectives and questions:

1. It remains unclear whether existing triage protocols are adequate to handle mass-casualty and pandemic events. It appears likely that modifications may be required, particularly for non-conventional (non-trauma) casualties. Research in this field is nascent.
2. Community-based resources for disaster triage and treatment often arise spontaneously in the wake of cataclysmic events. The few studies of this phenomenon appear to indicate that training and organization of community resources before disasters may prove beneficial, although outcomes-based evidence is lacking.
3. It is unclear whether the public will support and understand triage and treatment techniques that are based on alternate standards of care. Effective communication to the public relies on the underlying assumption of acceptance and support.

Topic 3 (Table 4)

Effective decision making, particularly at the leadership level, is essential to the success of any response. As defined by the Task Force on Quality Control in Disaster Medicine of the World Association for Disaster and Emergency Medicine, effectiveness "relates to how closely the output matches the specified goal."⁴¹ Thus, determining effectiveness, at its core, must address the challenge of establishing objective measures to which decision-making performance can be compared.

Defining the current key stakeholders at the local, state, and federal levels is important to determine whether additional collaborative partnerships, perspectives, or expertise (from either medical or nonmedical participants) would aid in the decision-making process. Efforts should be made to delineate ideal representation and individual leadership characteristics on surge-capacity committees.

Table 6
Objectives and Questions Identified by the Breakout Group for Topic 5, including Feasibility and Fundability Scores*

Three Specific Objectives and Questions Identified	Feasibility (\pm SD)	Fundability (\pm SD)
A. To define best methodologies for credentialing, activating, and mobilizing medical and other volunteers. Evaluate use of Emergency System for Advance Registration of Volunteer Health Professionals Plan vs. other systems.	1.3 (\pm 0.5)	2.3 (\pm 1.0)
B. To define best models for evaluating workforce preparedness. In particular, are drill exercises the best way?	2.0 (\pm 0.8)	1.5 (\pm 0.6)
C. To determine which models are best suited to educate, train, and effectively communicate with workforce to optimize responses to specific outbreaks.	2.3 (\pm 1.0)	1.8 (\pm 1.0)

* Feasibility and fundability scores derived from survey of four leading funded experts, including cochairs of surge conference (mean scores provided; 1, best score; 5, worst score).

For specific types of incidents, the disaster-management team composition and integration of decision makers should be carefully examined to enhance cooperation and coordination at all tiers.^{42,43}

Lessons learned regarding decision making through exercises and simulations are well documented.^{44,45} An evidence-based review of outcomes from scenario-based exercises and actual disaster experiences may crystallize expert consensus as to what is meant by optimal decision making. Defining this could serve as a basis for extrapolation of criterion standards to guide implementation of certain practices (e.g., quarantine) at given times.

Evaluation on the basis of objective measures is required to determine effectiveness of decision making. Several standardized tools relevant to assessment of decision making and incident command have been developed and applied, but none have been validated.^{46,47} Although measures of effectiveness for incident command and response have been proposed, direct evaluation of decision making, as reflected by incident-command system performance, remains elusive.⁴⁸⁻⁵⁰

This breakout group identified the following to create objectives and questions:

1. Key leadership for surge-capacity planning and response varies by locality and is generally not well defined. Unclear jurisdictional authority or mandates can render the decision-making process ineffective. The composition of the key leadership of decision-making groups needs to be clarified and optimized by using scientific approaches. In addition, specific roles within a unified incident-command system structure should be clearly identified.
2. Although individual decision makers must maintain the flexibility to respond to different situations, no studies have suggested how leadership should be adapted in response to various types of events. Very little evidence exists regarding best practices for integration of decision makers into the response effort.
3. Almost no objective measures or tools for evaluation of decision-making effectiveness exist. Further research should be aimed at development of validated tools and methods for assessment of decision-making effectiveness.

Topic 4 (Table 5)

The success of medical operations during disasters frequently depends on the ability of the communications infrastructure to perform under the unique conditions and stresses imposed by austere circumstances. Review of the literature reveals that the everyday communications infrastructure is subject to failure, whether through physical damage or systems overload, particularly during disasters evolving over a short period.⁵¹⁻⁵³ Redundancy of communications systems, whether through additional channels and frequencies, backup equipment, alternative modalities such as amateur radio operators, or a combination of these, can help alleviate the likelihood of communications failures.^{54,55}

Standards for disaster communications, even at basic levels such as a unified nomenclature for disaster terminology, are lacking.⁵⁶ Research into methods of disaster

communications are hampered by inconsistent terminology and variegated definitions.

Management of patient information is of critical importance during disasters. Methods for secure collecting, storing, and sharing of patient data may involve personal digital assistants, wireless Internet applications, use of preprinted bar-coded data-collection systems, deployment of global positioning system equipment, and use of geographic information systems.⁵⁷⁻⁶³

Interagency communications remain an area of concern. Joint interoperability standards may ease communications between various agencies providing mutual aid, patient-care response, and force protection. In addition, public-health departments need to be afforded a larger role in disaster preparedness and response.⁶⁴

Communications between authorities and the public are undergoing study. In particular, the timeliness, content, and delivery of health-risk communications, especially to vulnerable populations, require better understanding to assist in the mitigation of disaster effects.⁶⁵⁻⁶⁸

This breakout group identified the following to create objectives and questions:

1. Currently, no specific standards for disaster communications systems exist. Several case reports of particular systems can be found, but there is no widely accepted rubric that may be used to comparatively evaluate them.
2. Synchronization of communication content and delivery, or coordination of authoritative communication between incident command, joint operating agencies, and the public, is a fairly recent area of study. Little research exists to support particular methods and techniques of disaster health-risk communication.
3. Disaster communications failures have been reported in many disasters, but little research has been conducted to determine the underlying causes of communication failures or to evaluate preventive methods.

Topic 5 (Table 6)

A critical component of health care surge capacity is represented by the workforce that is relied upon to respond to increased system demands. Workforce requirements are complex, with issues ranging from credentialing, activation, and mobilization to education, training, and evaluation.

Standards for disaster preparedness outlined by the Health Resources Services Administration (HRSA) include a critical benchmark (standards 2-4) relating to the development of systems that enable advance registration and credentialing of volunteer health professionals during a declared emergency.⁶⁹ As defined by HRSA, the Emergency System for Advance Registration of Volunteer Health Professionals (ESAR-VHP) represents an electronic database of health care personnel who may be called upon to offer assistance in an emergency and must include registration of health volunteers, designation of resource types, and emergency verification of identity, credentials, and qualifications of the volunteers.⁷⁰ The function of such systems, as compared with other methods for registration, activation, and mobilization of volunteers, has not been studied.

Steps must be taken to ensure that the health care workforce is well trained to respond to a multitude of

threats.⁷¹ Currently, disaster drills are viewed as the criterion standard in assessing workforce preparedness. Although drills have been demonstrated as effective in enabling workers to gain familiarity with disaster procedures, identify problems in response, and apply lessons learned, the collective evidence remains sparse. A recent evidence-based report showed that although a relatively small number of studies suggest that disaster drills can be effective in training hospital staff, fewer still have addressed other training modalities, such as tabletop exercises and technologically based interventions.⁷²

Although a number of frameworks have been proposed and implemented, including competency-based⁷³⁻⁷⁹ and gaming approaches,⁸⁰ ideal models for education, training, and communication with the workforce remain to be identified. Objective evaluation is essential to gauge workforce preparedness. However, existing standardized evaluation tools have not been validated, and long-term outcomes have not been assessed.

This breakout group identified the following to create objectives and questions:

1. Although registration systems appear to facilitate deployment, research should be directed toward determining effectiveness of Emergency System for Advance Registration of Volunteer Health Professionals Plan versus other potential methodologies for credentialing, activating, and mobilizing the volunteer workforce.
 2. The effectiveness of all types of disaster-training activities, particularly alternatives to drill exercises, should be explored rigorously.
 3. Limited evidence exists regarding ways to most effectively educate, train, and communicate with the workforce in optimizing response to emergency events, including mass-casualty incidents and specific outbreaks. Further work in developing validated evaluation tools is warranted.
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CONCLUSIONS

Unlike research related to daily surge-capacity issues, research pertaining to surge capacity during extraordinary circumstances remains in its early stages. Encouraging attention has been turned to developing the scientific underpinnings of preparedness and response. Five key areas worthy of immediate attention were identified by using the nominal-group technique.² These included the following: 1) decision making in allocation of scarce resources; 2) determining effectiveness of triage techniques; 3) identifying effective decision-making paradigms; 4) developing reliable communication strategies; and 5) determining best means for preparing, training, and evaluating the workforce.

The authors thank Kuanfu Chen, MD, and Celeste Quianzon, MD, for their invaluable help, at the conference and in the preparation of the manuscript.

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