Disaster Medical Education & Simulated Crisis Events: A Translational Approach

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ABSTRACT

This review addresses current educational and research efforts in disaster medical education (DME) in the United States. Since the events of 9/11, DME has received greater attention. However substantial problems remain in terms of ensuring that large numbers of medical students and residents are exposed to high quality DME – not only Emergency Medicine residents. Barriers to widespread adoption of DME include lack of performance metrics, disagreement task areas, and lack of emphasis on physician leadership. Further, such efforts must ensure retention of key information over periods that are disaster free; utilize objective training metrics that will allow for an evidence base to form; and develop low cost, scalable training approaches that offer greater fidelity to the disaster environment than classroom based instruction. To improve the state of the art, we argue that DME research must move toward a translational science model that integrates important advances in basic information science into application that improve the clinical performance of frontline medical staff who are called on to respond to individual and community needs in the aftermath of disaster. Mid-fidelity, team-in-the-loop simulations developed for disaster manager training may provide an avenue toward improved DME by exposing medical students to scenarios that fundamentally challenge their assumptions in real-time game play. This can be accomplished with lower costs and greater scalability than live exercise or mock-up training approaches.

Keywords

Disaster Medicine, Tactical Medicine, Evidence Based Physician Training, Team-in-the-Loop Simulation, Serious Gaming in Healthcare, Translational Science.

INTRODUCTION

Consensus on when, how, and how much training physicians need to deal with disaster situations remains elusive some 10 years after the events of September 11, 2001. This is in part because of a lack of objective evidence on the efficacy of training current best practices (Scott, Carson and Greenwell, 2010). Even comparatively simple training elements, such as incorporating the latest triage standards have yet to be widely incorporated into the early stages of physician training at the national level (Lerner, Scwartz, Coule, Weinstein, Cone, Hunt, Sasser, Liu, Nudell, Wedmore, Hammond, Bulger, Salomone, Sanddal, Lord, Markenson, and O'Connor, 2008; Scott et al., 2010). But perhaps more importantly, many other critical functions physicians play in the immediate phases of response and recovery – including numerous clinical, organizational, and command roles – have been under recognized in training (Bradt and Drummond, 2007).

This review paper presents four main points with the objective of gradually refining disaster medical education (DME) and encouraging movement toward evidence based training in this arena. First, we present a brief history of DME in the United States (US). Second, significant limitations with the current state of the art in DME are considered through the broader lens of disaster management studies. Third, several specific ways in which simulation systems developed for general disaster management training could be repurposed to create a more robust, scalable and cost-effective DME framework are offered – drawing on ongoing research and development efforts within the ISCRAM community. Finally, we argue that the movement toward translational science in the US offers an important approach to integrating basic ("bench") science efforts in disaster information systems to applications that have a broader clinical ("bedside" or tactical medicine in this setting) and community impact ("curbside" or community level health interventions during crisis – e.g. mass vaccination or antidote development; e.g., Buckley, Eddleston, and Dawson, 2005; Waldman and Terzic, 2010).

HISTORY OF DISASTER MEDICAL EDUCATION IN THE U.S.

While major disasters involving medical response are discussed in the literature since the Black Plague and the establishment of public health boards (Gottfried, 1983), articles specifically addressing DME have been rare until recently. Modern disaster medical research evolved with the development of emergency medical systems EMS in the 1950s, with basic emergency medical technician (EMT) training first performed in the Chicago Fire Department (Dara, Ashton, Farmer and Carlton, 2005). After a 1966 report by the National Academy of Sciences entitled "Accidental Death and Disability: The Neglected Disease of Modern Society," the Department of Transportation was entrusted with the task of improving EMS and developing EMT training.

Recommendations from education have come from case-reports of various disasters around the world (Markenson Reilly, and DiMaggio, 2005; Subarrao, Lyznicki, Hsu, Gebbie, Markenson, Barzansky, Armstrong, Cassimatis, Coule, Dallas, King, Rubinson, Sattin, Swienton, Lilliebridge, Burkle, Schwartz, and James, 2008; Waeckerle, Seamans, Whiteside, Pons, White, Burstein and Murray, 2001). In the period immediately prior to the events of 9/11, DME was focused on the development of education for chemical, biological, radiological and nuclear (CBRN) for first response agencies (Waeckerle et al., 2001), yet this was without widespread adoption in medical schools or residency (Scott et al., 2010). Given the complexity and severity of recent disasters, including 9/11, Hurricane Katrina, the Asian Tsunamis, the earthquake in Haiti, and the Fukashima nuclear disaster, shortcomings in DME have received increasing attention during the last decade (Coico, Kachur and Lima, 2004; Hsu, Thomas, Bass, Whyne, Kelen and Green 2006; Subbarao et al., 2008). Several of the milestone publications in disaster medical education note significant limitations in DME including: lack of performance-based standards (Subbarao et al., 2008); disagreement on specific content knowledge requirements (Huntington and Gavagan, 2011); disagreement on the best mechanism to disseminate information (Subbarao et al., 2008); who needs to be trained (Waeckerle et al., 2001); how often drills should be conducted (Burstein, 2006); and how to ensure retention of critical information over long periods that are disaster free (Coico et al., 2004; Hsu et al., 2006).

DISASTER MEDICAL EDUCATION AS A FRONTIER IN TRANSLATIONAL RESEARCH

The National Institutes of Health (NIH), through Clinical and Translational Science Awards[1], has established new standards for education of translational and clinical scientists. This effort recognizes that scientists must train beyond their specific discipline through exposure to and skill development in the behavioral, biomedical, public health sciences while also forging partnerships with the local community in order to address problems that are best addressed through a transdiciplinary approach (Rubio, Schoenbaum, Lee, Schteingart, Marantz, Anderson, Platt, Baez, and Esposito, 2010; Zurhouni, 2005). This movement toward translational science in the US offers an important framework for integrating basic ("bench") science efforts in disaster information systems to applications that have a broader clinical ("bedside" or tactical medicine in this setting) and community impact ("curbside" or community level health interventions during crisis – e.g. mass vaccination or antidote development, see for example, Buckley et al., 2005; Waldman and Terzic, 2010). While medical researchers typically think of "bench science" in medicine to mean experimental work done in a wet lab, or *in silico* labs working on genomics, the basic science components supporting team-in-the-loop simulation are generated in information science laboratories. To date, much of the research and development efforts around these command and control (C2) simulations has focused on the equivalent of what would be viewed as *clinical translation* – that is developing solutions that improve the performance of first responders, emergency medicine physicians, and the like. We argue that furthering this approach can also encompass *community translation* by involving a much greater number of medical trainees – some of whom may be much more directly involved in community response to disaster.

[1] See Acknowledgements

DISASTER MEDICAL EDUCATION – THE CURRENT STATE OF THE ART

Three primary approaches have been adopted to date in DME for medical students. These include standard classroom instruction, integration of basic game technology to provide low fidelity simulation of disaster events, and the use of high fidelity live exercises. Each has clear advantages and disadvantages, which are briefly articulated here.

Classroom Instruction

While a few medical schools have dedicated disaster medicine courses, this is the exception to the rule (Scott et al., 2010). More frequently, disaster medicine training is incorporated as a brief topic within specialized fields such as in a "global health" curriculum, implying its necessity is limited to physicians with an interest in disaster response or foreign aid, rather than all physicians. These brief trainings often focus on triage methods, an essential aspect for healthcare workers responding to disasters (Subbarao et al., 2008). However, it is worth noting even this important, basic DME component does not yet have nationally agreed upon methods in the US (Lerner et al., 2010) and has yet to have a strong evidence base supporting its efficacy (Jenkins, McCarthy, Sauer, Green, Stuart, Thomas and Hsu, 2008; Rothman, Hsu, Kahn, and Kelen, 2006). While familiar and relatively simple to incorporate into existing curricula, traditional educational training strategies are unlikely to improve performance in low frequency events – trainees are unlikely to recall the training, and there is little evidence content knowledge scores translate well into actual performance in complex disaster environments (Gheytanchi, Joseph, Gierlach, Kimpara, Housley, Franco and Beutler, 2007).

Low Fidelity Instructional Games

There have been some very preliminary efforts to use serious gaming techniques to augment traditional training in this arena (Franco et al., 2009). For DME, many serious games use simple, single-player interactive simulations (e.g. successive decisions in response to static prompts) such as the New York Consortium for Emergency Preparedness (NYCEP) Hospital Emergency Response Exercises (NYCEP, n.d.). Current attempts to use serious gaming interventions are typically heavily scripted, without the variability and unknowns of a real situation, and are designed to corral the student toward the "right" answer rather than deeply challenging student's assumptions (e.g. that the hospital will be left standing, etc.). These first-person games are typically turn-based, and do not simulate the tempo of an unfolding event, the pressure, and the psychological stresses of responding to a disaster with any fidelity. These are relatively inexpensive, but do not provide transformative learning experiences needed in DME. Mid-fidelity games offer a variety of advantages over low-fidelity games such as challenging player's assumptions, forcing players to improvise, and forming ad-hoc communications structures (Franco et al., 2009) without incurring the high costs of live training exercises.

Live Exercises

At the far extreme, some schools have utilized fully integrated live exercises into their DME, such as Disaster City at Texas A&M University (Parrish, Oliver, Jenkins, Ruscio, Green and Colenda, 2005). Some use pen and paper based live-action planning, and guide the experience by involving local experts who assist the students in assuming their roles in the exercise (Carney, Schilling, Frank, Biddinger, Bersch, Grace, and Finkelstein, 2011). Another approach used virtual reality simulation to train and assess medical students in triage and life-saving interventions (Vincent, Sherstyuk, Burgess, and Connelly, 2008). These approaches do provide transformative learning experiences by addressing the problems inherent to other training approaches, but at high cost. Full scale training simulation environments are expensive, and logistically intensive beyond the ability of most medical schools to support.

Improving DME – Understanding Task Areas for Physicians Responding to Disasters

Improving medical preparedness for disaster rests clearly articulating the ways in which current models fall short. These include: 1) improve retention of key information over long stretches of time when disasters do not occur; 2) integrate pedagogical techniques that are based in the transformative learning model – i.e. that are capable of challenging prior assumptions to encourage learners to gain a new level of understanding; 3) developing objective training metrics that are grounded in a performance assessment framework that will allow for an evidence base to develop; and 4) accomplishing the aforementioned tasks in a lower cost environment than live disaster exercises or disaster mock-ups that are out of the financial reach of most training institutions.

While much of the emphasis in DME remains focused on triage, physicians serve many functions in the context of disaster. Noted researchers in the field have begun to define disaster medicine as a discrete specialization in medicine that is in the process of becoming formalized and professionalized (Bradt and Drummond, 2007). This process has led to the description of disaster medicine as the nexus of clinical medicine, public health, and disaster incident management. However, while the first two areas are fairly familiar to medical personnel, the theories and practical considerations of disaster management are not as well known to most medical educators and researchers. Relevant task areas for physicians that better reflect the realities of disaster management include site security, urban search & rescue, inter-agency coordination, medical logistics, geographical information systems, public information & media relations and community recovery (Bradt and Drummond, 2007). It has also been suggested that increased physician involvement leads to better outcomes (Uddin, Barnett, Parker, Links, and Alexander, 2008) and that physician leadership and coordination is an under-researched and important aspect of medical care (Rothman et al., 2006)

While the scope of this effort precludes a detailed discussion of all the task domains a physician may be called upon to address in the context of disaster, addressing some of them in depth assists in further explicating the limitations of current training approaches and suggests important avenues for integrating approaches to training that have been more widely adopted by first responders and the emergency management field as a whole.

Role Expansion

Physicians responding to disasters are generally considered technically competent to address patient care needs in an acute disaster setting (Huntington and Gavagan, 2011), although this has been debated (Bradt and Drummond, 2007; Uddin et al., 2008; West, Lillibridge, Howard, Grabenstein, Dembek, and Dombrowki, 2010). However, just as important are administrative duties that physicians must perform during the response phase of disasters, such such as medical logistics, dynamic resource allocation, and interagency and community coordination. Because physicians are trusted with the lives of others and possess technical expertise that is unique among the professions, physicians must expand their role from acting exclusively as a clinician and act as leaders. Physicians must take these positions in order to optimize patients' care (Bradt and Drummond, 2007; Uddin, et al., 2008).

Interagency & Community Coordination

The health of a community is not only the result of access to health care, but includes infrastructure for public health and hygiene. One report from Haiti demonstrated the various public health deficits after the 2009 Haiti earthquake, including food supply, security, water, sanitation, and hygiene (Morris, 2010). Sterile water or, at the very least, clean water must be available for oral fluids and for surgical and wound washing. The personnel and patients must be physically secure from secondary disasters as well as other people. Food is also a concern, and can be a major problem after destruction of local infrastructure (Morris, 2010). In one study, over 9% of patients were malnourished as determined by a physical exam (Broach, McNamara, and Harrison, 2010). These issues apply to the medical facilities within a community, as well as the community at large (Gheytanchi et al., 2007). This makes it imperative that physicians be prepared to coordinate with local resources to ensure continued availability of these resources to communities as a way to prevent further sickness, disease, and injury and to prevent compromise the function of clinics and hospitals.

Situational Awareness – Managing Medical Logistics & Dynamic Resource Allocation

By definition, resources are a limiting factor during disasters. Judicious use of manpower, supplies, and technology is a top priority to do the most good for the most people. This is necessary because of the large amount of patients coming in, up to ten-times the normal load (Uddin et al., 2008) and because it overwhelms the hospital's surge capacity (Rothman et al., 2006). The concept of triage, "doing the most good for the most people," is of vital importance in assigning limited resources, but has yet to be widely taught to medical students or residents (Lerner, Schwartz, Coule, and Pirrallo, 2010).

However, because physician training usually takes a patient centric view, and assumes that required supplies and staff to assist patients are immediately available, but this can be a barrier to developing a broader view of the disaster and considering the interfaces between responders to facilitate medical care (e.g. coordinating between a relief center and an off-shore naval hospital ship to select appropriate patients for emergency evacuation; Auerbach, Norris, Menon, Brown, Kuah, Schwieger, Kinyon, Helderman, and Lawry, 2010). While some of these skills necessarily develop with time and experience, this process may be facilitated and accelerated by encouraging exposure to educational components that create a framework for shared situational awareness early on in medical training. Thus, the physician as an agent in coordination is needed, and can be represented as a C2 issue. Vital to this is situational awareness, which has been studied extensively with aviation (Endsley and

Robertson, 2000), a field with a low-base-rate for adverse events and has as a model for training medical personnel (operations (Baker, Gusafson, Beaubien, Salas and Barach, 2005) .

NEXT GENERATION DME: THE ROLE OF MID-FIDELITY COMMAND & CONTROL SIMULATION

In contrast to these current DME training approaches, team-in-the-loop simulation of major disaster events in the medical context may provide an important avenue toward creating compelling educational content; improving retention of key learning objectives; providing students, teachers and researchers with valuable, objective performance data. Team-based C2 simulators have been used extensively for training groups responsible for performance in other high reliability environments, including aviation operations (Baker et al., 2005), military command (Levchuk, Levchuk, Weil and Pattipati, 2006), and disaster management (Franco, Zumel, Holmen, Blau and Beutler, 2009). These systems are scalable, comparatively inexpensive, and can capitalize on existing computer lab infrastructure at medical schools rather than requiring the large capital investment needed to develop a full-scale disaster simulation such as Disaster City (Scott et al., 2010). Moreover, the team-in-the-loop approach facilitates the exposure to scenarios that require the development of shared situational awareness.

Simulation Training Strategies for DME

Simulation offers the possibility of making medical decisions based on the "most good for most people" philosophy. This is particularly promising because it can be taught and utilized by medical professionals even at the beginning of training, such as first-year students (Sapp, Brice, Myers, Hinchey, 2010). Virtual reality has also been used to perform triage (Vincent et al., 2008). Fourth-year students performed exceptionally well after an educational assessment (Scott et al., 2010). The major limitation to these would be the amount of resources required to implement them.

C2 simulation strategies have a number of advantages in terms of representing the types of activities physicians will either have to perform or remain aware of as a critical component of a larger, overall response effort. In particular, the real-time, team-in-the-loop (i.e. multiple "players" in various roles, responding to events as they unfold) provides a more realistic sense of the way in which disaster events occur and play out than individual, turn based, "choose your own adventure" simulations that have typified the field for the last few years. Further, the ability to provide unscripted changes to the event that are triggered by participant actions (e.g. failure to identify and resolve one problem cascades into a set of larger, more complex problems) sets the stage for transformative learning, may encourage longer term memory of key training concepts, and allows for objective measurement of performance (e.g. time to recognition of a problem, success in resolving it within a certain time window, loss of critical assets, and so on – for a more detailed discussion of objective measurement strategies, see Franco et al., 2008). Moreover, the ability to deploy team-in-the-loop simulations using existing client/server arrangements - for example, existing computer laboratories used for other forms of medical training minimizes cost while providing a robust training experience. Some specific examples of how these methods can be used as part of a more comprehensive DME training framework follow. The team-in-the-loop Distributed Dynamic Decision-making (DDD®) simulation software developed by Aptima, Inc. has been used for C2 training and experiments for both military (Aptima, n.d.) and disaster response (Franco et al., 2009) contexts. Examples of its use in a series of simulations for disaster response are conceptually extended to the disaster medicine training context here.

Representing Interagency Coordination

Disasters are crises that often require resources from outside of the affected community to resolve. Various agencies from local to national levels must coordinate to apply these resources in order to maximize the effectiveness of the disaster response – simply getting resources into the area is not enough, incident commanders must be aware of the resources, understand and respond to scheduling contingencies for these resources (i.e. it may be impossible to use one resource until another is brought into the operational environment). In this representation (Figure 1) The Federal Emergency Management Agency (FEMA) aircraft is landing at a local airport to provide supplies needed to resolve issues that can not immediately be addressed by assets currently in the operational theater because of a damaged highway (see overall operational picture; Figure 3).

Figure 1. Multiagency Coordination: FEMA Supply "Push" via Airlift

Representing Community Coordination

At the community level, a variety of local agencies must also coordinate. The community agencies in this diagram (Figure 2) include the community hospital, the fire department, police department, city government, and an FBI field office responsible for responding to a mass civil disturbance. Depicting an event in this way may assist medical students to anticipate different types of injuries (e.g. possible psychological injury to students at a local school, blunt force trauma in adult demonstrators, etc.), as well as the resources and communication channels available through others involved in the response effort. It is important to recognize that within the participatory model is the concept that community members will collaboratively engage with academics in the research process. Yet developing productive relationships that are capable of performing translational research at a community level remains challenging and time consuming (Hawk ET, Martisian LM, Nelson WG, Dorfman GS, Stevens L, Kwok J, Viner J, Hautala J, Grad O. 2008).

Figure 2. Community Coordination: Mass Demonstration Scenario

Representing Medical Logistics & Dynamic Resource Allocation to Improve Situational Awareness

Figure 3 shows the entire Dynamic Distributed Decision (DDD) simulator interface used in prior experiments (Franco et al., 2009). The interface allows an individual "playing" the role of various responders to interface with other responder roles, transfer assets, and dialogue with each other to develop a shared understanding of the overall operational picture, while also acting on specific tasks that they self assign or are assigned to. The specifics of medical logistics can be represented in several ways (e.g. creating contingent situations that require the transfer of medical supplies from one player to another – simulating, for example, the delivery of a shipment of vaccine into the disaster theater).

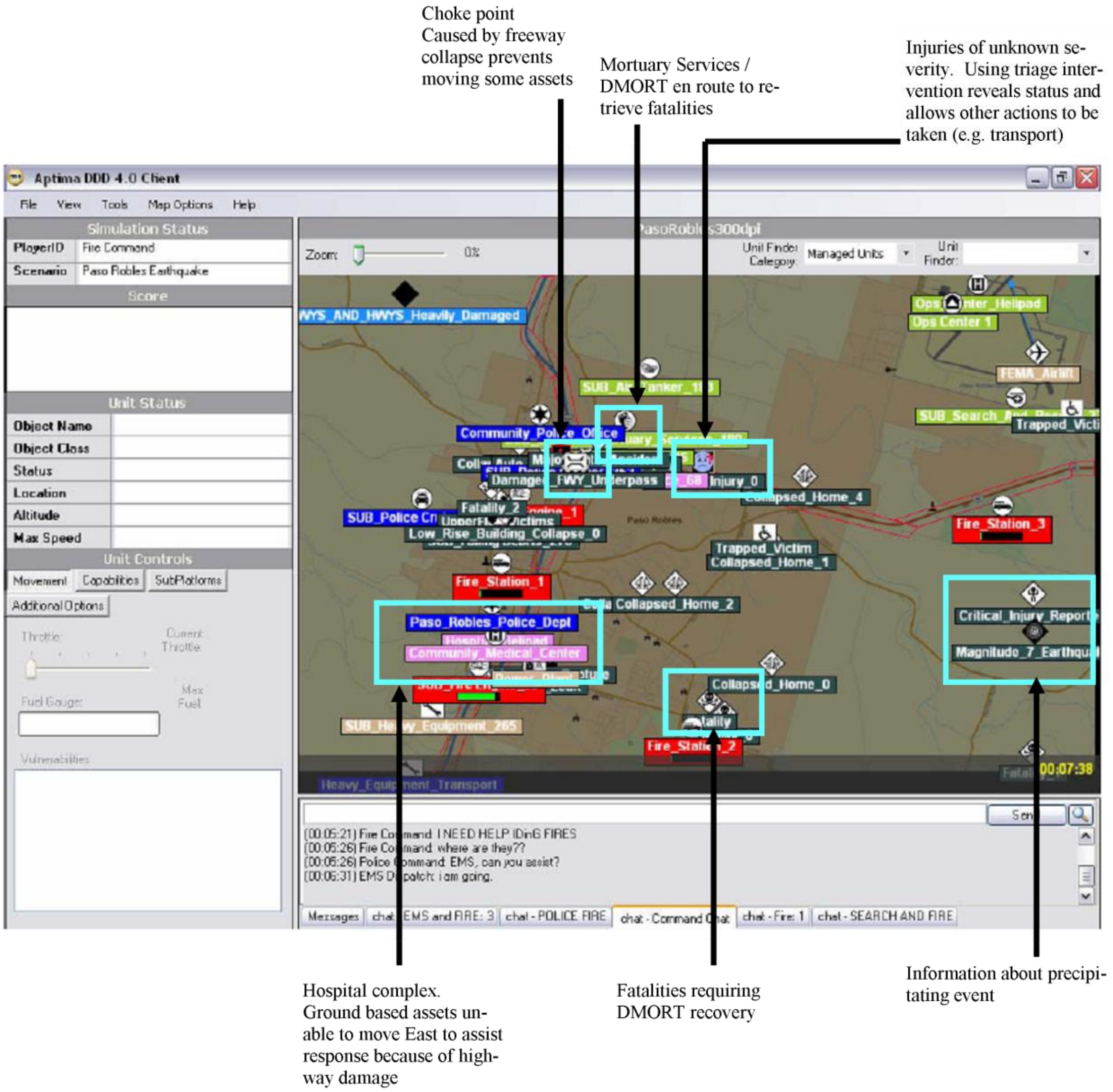

Figure 3. Developing Situational Awareness: Detecting Contingencies in a Chaotic Operational Picture

Representing Role Expansion

All of these things taken together represent the dynamic and expanded role the senior healthcare professional must take when confronted with disaster. For example, by carefully examining the overall operational picture (Figure 3), the responding physicians can become aware that some injuries have occurred outside of the city center, but that city resources are unable to reach them because of debris on roads. Thus, it becomes very important for medical responders to monitor the communication between other agencies working on clearing debris, anticipating when the choke-point will be resolved, pre-position resources in anticipation of choke-point resolution, and maintaining awareness of federal assets that are being "pushed" to the operational theater which may be able to reach the injured faster than resources that are unable to cross through the obstructed area.

CONCLUSION

Interest in Disaster Medical Education has been growing, especially since 9/11. Yet despite increased funding, organizational response, and research activity, there have been relatively few additions to the evidence base in the past ten years. Educational standards for disaster medical education have been consensus-based rather than evidence-based. There have been sporadic educational efforts, which includes classes, low-fidelity games, and live exercises, but they have had limited impact on DME training at the national level. Live exercises provide the opportunity to experience the pressure and demonstrate performance during a crisis situation, but may not address the expanded role that physicians would need to fill, such as coordinating and communicating with other agencies and the community, or allocating medical resources appropriately. A critical next step is to implement existing educational guidelines while simultaneously building an evidence base demonstrating the effectiveness of educational interventions by measuring performance of tasks identified as important for physicians responding to disasters. One particularly expeditious way to achieve this with regard to ease of implementation, cost, and scalability is medium-fidelity C2 simulations specifically designed for the delivery of disaster medical education. This work represents translational research because of its potential to improve of patient and community outcomes.

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