Utilizing Technology Based Learning for Disaster Preparedness

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ABSTRACT

Preparing for disasters can be a grueling, although necessary, exercise for those involved in emergency response. The large scale nature of disaster response poses many obstacles to executing an effective disaster preparedness drill that incorporates hospitals, fire and rescue personnel, and police. Cooperation and effective communication during these incidents is imperative. Simulation technology is a realistic alternative to a large, multi-disciplinary, one- time effort. Each discipline may be able to practice and reinforce their roles in a disaster with the aid of various emerging technologies. This paper examines some of the technologies already being implemented in the area of disaster preparedness. Technology based learning (TBL) strategies are analyzed for consistency with accepted principles of adult education.

Keywords: *Disaster, Drill, Human Patient Simulators (HPS), Preparedness, Simulation, Technology Based Learning, Virtual*

INTRODUCTION

Traditionally, public safety agencies that charged with emergency response have prepared for multiple casualty incidents (MCIs) and disaster through structured participation in disaster drills. Disaster drills pose several challenges for emergency medical responders. These mock exercises require an inordinate amount of pre-planning, seamless interagency communication, and the investment of additional time and resources. The identification of efficient, cost effective, and realistic training methods would theoretically enhance communication between hospitals, fire rescue departments, and other organizations charged with protecting public health. There is a paucity of data about what strategies constitute the most effective training for mass casualty occurrences. Recent developments in high fidelity simulation, virtual reality, and internet based training strategies have revolutionized public safety's approach to disaster preparedness and response. This paper will examine currently available literature and describe how a technology based learning (TBL) strategy may complement readiness efforts.

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Rationale/State of the Art

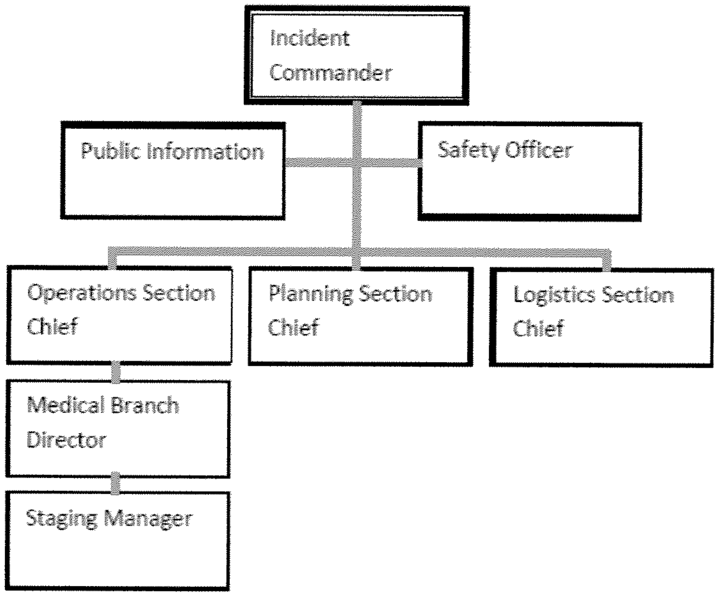
Though disaster training seems like a prudent undertaking, the practice of system wide drills is actually mandated through several regulatory agencies. The Joint Commission (formerly the Joint Commission on the Accreditation of Health Care Organizations) requires hospitals to interface with the surrounding community and conduct a mass-scale event at least yearly (The Joint Commission, 2008). The Centers for Disease Control and Prevention have issued a variety of guidelines on disaster preparation (Centers for Disease Control). Finally, the National Incident Management System (NIMS), a component of the Federal Emergency Management Agency (FEMA), has integrated the hospital structure into a universal algorithm known as the Hospital Incident Command System, or HICS. Figure 1 contains a visual depiction of an incident management structure for healthcare organizations with the basic components of the modularized and scalable hierarchy of command and control highlighted. Hospitals participating in disaster drills must conform to existing guidelines so that every emergency medical responder, from the first firefighter on scene, to the hospital logistics officer, speaks the same language with regard to the triage, treatment, and eventual disposition of mass casualties.

The imperative of preparation has been borne out by historical events. In addition, the continued confusion surrounding the response to large scale incidents is demonstrated in the literature. In 2006, Bartley, Stella, and Walsh, (2006) examined the utility of simulated disaster exercises. The paper, aptly titled, "What a Disaster?!" suggested that traditional training methods failed to address persistent deficiencies. Hospital personnel likely to participate in an MCI incident were asked to complete a pre-event survey. Results demonstrated a significant amount of confusion with regard to roles and command structure. The "pass rate" for the emergency management test prior to formalized training was 18% (9/50). Though participants indicated an increase in their knowledge base, "post intervention knowledge. . . remained suboptimal" (Bartley, Stella, & Walsh, 2006). The majority of participants described the exercise as having some benefit, but the authors were unequivocal in emphasizing the need for more intensive preparation, training, and a system-wide review of emergency response.

A 2003 review of literature conducted by the Agency for Healthcare Research and Quality further clarified the need for improvement in disaster training. The overall evidence of the efficacy of traditionally managed disaster drills was classified as, "inefficient." In addition, the wide range of studies, methods of evaluation, and declared objectives obviated the AHRQ from drawing any meaningful conclusions from available data (Thomas, Hsu, Kim, & Colli, 2004). In light of imminent threats to public health and safety in the forms of bioterrorism and natural disasters, the need to optimize emergency preparedness is present and clear. Significant challenges to system wide implementation disrupt comprehensive disaster planning efforts. Traditional drills often require the presence of a large number of volunteers in addition to paid agency employees. Normal operations cannot be suspended during a drill, and public safety agencies incur overtime expenses in the planning and execution of such an event. Organizations like the Joint Commission mandate disaster exercises on a yearly basis. The idea that knowledge about emergency preparedness and response can persist despite a relative infrequency of planned events runs contrary to principles of adult learning.

Technology based learning may enhance preparatory efforts. Internet based case scenarios computer generated simulation models can factor in a wide variety of detail that traditional drills fail to replicate. In addition, the utilization of newer technologies can facilitate outreach to distant sites and theoretically introduce more personnel to an incident management curriculum.

Figure 1. Sample hospital incident command chart



Emerging Trends

Disaster drill planning and implementation is extremely demanding on human resources. Aside from those involved in the planning and organization of the drill, there are the participants and patients. In most cases, additional staffing needs to be in place to allow day to day operations to remain intact without being disrupted by training. Depending on the number of patients and types of injuries required to be portrayed, a significant number of volunteers will need to be moulaged.

There are pros and cons to using live, moulaged actors vs. high fidelity human patient simulators (HPS). Conveying realism regarding patient presentations has its limitations. Gillet et al. (2008) pointed out that "[actors'] medical knowledge, enthusiasm, and time devoted to training for the drill can vary significantly, resulting in disparity of effective suspension of disbelief" (p. 1145). An inaccurate representation of an injury or condition may mislead a provider to the wrong diagnosis and subsequently the wrong treatment.

This segues into the limitations of the realism of treatment with regards to using actors. It is not feasible to perform invasive procedures on live actors, despite a diagnosis which may necessitate such an intervention. Part of performing a disaster drill is to give the participants the perception of the chaotic environment, the strain on resources and the "congestion of patient flow typical of an actual resuscitation" (Gillet et al., 2008, p. 1148). If the interventions identified as appropriate are unable to be performed, "this creates an under-representation of the true time and resource utilization required to manage the patient" (Gillet et al., 2008, p. 1148).

Human Patient Simulators (HPS)

Human patient simulators (HPS) offer many benefits that help overcome challenges associated with the use of live actors. The HPS are attached to a computer where a simulator operator is able to input data for the simulator to display. Some scenarios are pre-programmed but can be altered based on the path the participant takes. The operator is responsible for entering medications, and their doses administered by the participant. Based on the data entered, the HPS will respond to the intervention and the participant is to identify the outcome. These high fidelity simulators are designed to accommodate the performance of invasive interventions, thus eliminating the limitations experienced by live actors. Live actors are only able to verbalize anticipated exam findings of certain conditions. They cannot present signs they do not exhibit and thus "physical exam findings and implementation of care can only be articulated by providers rather than performed" (Gillet et al., 2008, p. 1148). It is details such as these that can be incorporated into scenarios with the use of HPS. As previously mentioned, it is important to give an accurate representation of the time, space, and human resources required to handle a scenario typical of a disaster.

Disasters often present providers with conditions and injuries not readily seen or that providers may have little or no experience in treating. HPS allows providers to treat these rare conditions and perform interventions without the risk of causing harm to a patient in the event an error is made: "The use of HPS in health education allows healthcare providers to practice skills without risk to patients/subjects, providing a natural framework for the integration of basic and clinical science. Simulations are ideal for allowing learners to make mistakes safely in lieu of real-life situations, to learn from these mistakes and ultimately improve their performance by subsequent avoidance of those mistakes" (Vincent, Berg, & Ikegami, 2009, p. 207). Disaster drills are designed to identify gaps in knowledge, areas in need of improvement, and communication breakdowns. Being able to incorporate as many details as possible into the training only increases the chances of identifying those gaps. Another advantage of using simulators as opposed to live actors is the ability to have one simulator that represents several patients over the course of one exercise increasing the participant's exposure to different patient presentations. Using HPS can expose several learners to a number of different scenarios in a reasonable amount of time. Studies have shown that after only two iterations with the HPS, time to triage, identification and treatment of life threatening injuries of multiple "patients" is significantly improved (Vincent et al., 2008, 2009).One question to consider, which dictates the need for further research regarding the use of high fidelity HPS, is determining whether or not the performance improvement is due to the increased comfort level of interacting with the simulators or due to a actual increase in knowledge and in confidence with skills.

The cost of purchasing HPS can be considerable. The HPS alone can range anywhere from $50K to $100K. Most purchasing entities purchase more than one and require someone who is trained to operate the HPS. In some cases, having someone on staff who is dedicated to maintenance and repairs may be necessary. Lastly, it is ideal to have an environment within which scenarios can be facilitated. These additional upfront and ongoing costs represent a sizeable financial commitment. As mentioned previously, there are significant costs related to disaster drills regardless of the approach. Depending on the number of participants and agencies involved, as well as the additional resources that may be required for a particular drill, a cost analysis should be performed.

In many cases, disaster preparedness drills are not given the attention they demand or deserve. Many organizations believe that it is a waste of valuable time, money, and resources to prepare for an event that may never happen. It is the opinion of Gordon et al. (2001) that "Given recent reports on the magnitude and cost of medical errors in the United States- to both patients and institutions—individual centers may very well consider [HPS] a worthwhile investment" (p. 472). When are errors more likely to occur? When resources are overwhelmed and facilities are unprepared to manage the circumstances, such as during a disaster.

An invaluable benefit of using HPS is the ability to more easily repeat training sessions to different groups at different times. This is essential because the organizations that will be responding to a disaster are 24 hour a day, 365 day a year operations. When taking this fact into consideration, the more opportunities offered to participants to prepare for a high risk, low frequency event, the more likely gaps in knowledge and areas in need of improvement will be identified.

Repeat exposure to disaster scenarios also aids in long term knowledge. In a study of internal medicine residents that had a simulation-based bio-defense and disaster preparedness curriculum incorporated into their program, residents "significantly improved both objective and subjective ability to respond to a disaster… [this] preparedness did not appear to be maintained one year after training. Thus it appears that re-exposure to the didactic material and/or experiential portion of the training is necessary to maintain this increased level of expertise over time" (Summerhill et al., 2008, p. 150).

Immersive Virtual Reality

There are several versions of the immersive virtual reality technology. Some require the participants to wear a head-mounted display (HMD) and utilize a gesture command system to indicate task performance. This technology generally takes place in an empty room where there are no obstacles and the participant may move about freely.

In a study conducted by the University of Hawaii, John A. Burns Schools of Medicine, 20 medical students with no triage training or virtual reality experience were placed in three virtual reality mass casualty scenarios each with five victims with varying degrees of acuity. It was mentioned previously that scores improved after two iterations; however, it would be essential to determine the nature of that improvement; increase in knowledge or familiarity of technology. Nonetheless, the participants felt that they improved their confidence in prioritizing and identifying critical patients (Vincent et al., 2008, p. 1163).

A dynamic adaptation of immersive virtual reality technology is the Cave Automatic Virtual Environment (CAVE). This technology creates a three-dimensional setting by projecting images in stereo from several angles in a single room. The software is capable of duplicating any site from multiple photographs and can overlay with computer generated effects such as disaster components. The participants are able to visualize their environment by wearing liquid crystal display (LCD) shutter glasses. These glasses will alternate the right and left eye visual path "in synchronization with the projection sequence" (Wilkerson et al., 2008, p. 1153).

In a study done at the University of Michigan, 15 paramedics were placed in the CAVE environment. They were instructed to participate in the study wearing full turnout gear, as they would on a real incident. HPS were incorporated into the immersive VR environment to allow each paramedic to have the opportunity to perform interventions. The simulation software is able to overlay injuries on the HPS so that the injuries are realistic without having to moulage the simulators. Background noises such as sirens and screaming are incorporated into the scenario in order to more effectively replicate the chaotic environment:. "… Immersive training in a cave environment has the potential to provide a previously unavailable realism and level of involvement, while simultaneously allowing for individual feedback and rehearsal necessary for learning retention" (Wilkerson et al., 2008, p. 1157).

One of the advantages of immersive VR rather than traditional classroom and skills training is the ability to simulate the stress levels during a disaster. First responders "… [usually] know what should be done and can readily identify appropriate actions in a classroom or other relatively less stressful exercise, once immersed in the chaos of a high-fidelity disaster scenario, errors typically identified during post event analysis of disaster events occurred" (Wilkerson et al., 2008, p. 1158).

There is very little research involving virtual reality (VR) secondary to its paucity. In addition, virtual reality systems are few and extremely costly. As this technology becomes more readily available and program costs become more competitive, it will become an effective way to prepare health care providers and first responders for a disaster. "High fidelity simulation has the potential to overcome many of the limitations of disaster drills. Simulation technology currently plays a major role in the training of pilots and military personnel. In these settings, simulation has successfully been used to train individuals for a wide range of situations, including potential catastrophes" (Wilkerson et al., 2008, p. 1153).

Computer Based Training

The Johns Hopkins University Center for Event Preparedness and Response (CEPAR) collaborated with the Department of Homeland Security to develop computerized models for large scale incidents. The program, known as the Electronic Mass Casualty and Planning Scenarios (EMCAPS), includes nine simulated disaster scenarios ranging from a dirty bomb explosion to a chlorine gas leak. The scenarios are customizable and permit municipalities to integrate demographics into each event. Because the EMCAPS model is scalable, it is suitable for use with prehospital and hospital based providers. The computerized scenarios are designed to comply with Joint Commission readiness standards since they permit local officials to estimate the "surge" of casualties likely to occur following any significant event (Scheulen, Thanner, Hsu, & Latimer, 2009). The EMCAPS program remains available for download, free of charge. The program's accessibility lends itself to distance learning opportunities as hospitals across the country can engage in a mutually agreed upon scenario. Public health agencies, municipal emergency responders, and law enforcement officials can tailor casualty estimates according to local demographics and therefore achieve a more realistic assessment of impact. Hopkins researchers claim that the program's ability to integrate "local or regional data" distinguishes EMCAPS from other computerized models (Scheulen, Thanner, Hsu, & Latimer, 2009). The unpredictable nature of natural and manufactured disasters makes it difficult to validate scenarios, but that should not deter emergency responders from preparedness efforts.

Indeed, EMCAPS is not the only program designed to assist regional emergency planners. The Bioterrorism and Epidemic Outbreak Response Model (BERM) is funded by the Agency for Healthcare Research and Quality. It is similar to EMCAPS in that it is federally funded, available for download, and available free of charge (Agency for Healthcare Research and Quality). BERM is slightly narrower in scope in that it estimates the casualty impact from a large scale bioterrorism event. The program permits hospitals, public health agencies, and clinic personnel to estimate needs related to core and support staff: "Such a model provides numerical estimates and forces critical examination of assumptions about prophylaxis clinic design and about the availability of human and material resources" (Agency for Healthcare Research and Quality). Certainly, this program can complement other traditional and computerized disaster planning events.

Computerized programs do not represent the total emergency preparedness solution. The transition to a simulated casualty model risks compliance on behalf of emergency personnel. As part of a comprehensive strategy, models like EMCAPS and BERM have the potential to inform future decisions about resources required in light of a high impact scenario. Indeed, the data from these programs can be modified to construct an event that more accurately reflects local demographics and capability.

DISCUSSION

Emerging Trends and Adult Learning

Technology-based learning is transforming the way adults learn. TBL offers the adult learner several environments which stimulate self-discovery and encourage learners to ask more questions. "If properly designed, technology-based instruction easily allows learners to tailor the learning to real-world problems" (Knowles, Holton, & Swanson, 2005, p. 237). In the setting of disaster preparedness, there may not be enough time or money to invest in a training program that fails to adequately prepare emergency responders. It is essential that any training program geared towards adult learners supply relevant and immediately applicable information. In an era of budget shortfalls and economic uncertainty, professionals are being asked to accomplish more and take on more responsibility with fewer resources. Accordingly, professionals appreciate and benefit from "learning activities [that] address problems.., skills, competencies, and/or knowledge required to solve problems" (Gilley, 2004, p. 371). TBL also enables educators to deliver a curriculum that acknowledges the time constraints of adult learners. Flexible schedules and internet-based educational methods permit full time employees to learn at a customized pace.

EVALUATION

The AHRQ in conjunction with Johns Hopkins University Evidence-based Practice Center (JHU EPC) developed a module-based evaluation tool for hospital disaster drills. Although this tool is designed for hospital evaluation, many of the modules could be easily adapted to other disciplines.

"The Department of Homeland Security (DHS) developed [a] Training and Exercise Plan Workshop (T&EPW) User's Handbook, which provides the necessary information and documentation to each state or urban area in conducting an annual T&EPW." The Homeland Security Exercise and Evaluation Program (HSEEP) was developed to standardize exercise planning, design, development, conduct and evaluation (T&EPW User's Handbook).

In terms of evaluating whether or not technologically enhanced drills are efficacious and cost effective remain research priorities. The studies using immersion virtual reality, HPS are few and small scale. However, computer based training has been utilized and found to be effective with the most common obstacle being participants resistant to or uncomfortable with the two dimensional environment. In a 2009 study conducted by Heinrichs, Youngblood, Harter, Kusumoto, and Dev, the results identified that an online simulation program can be an effective solution for training in hospital preparedness. This study, in which an almost exact two dimensional depiction of the Stanford University Medical Center Emergency Department was created online, allowed participants to respond to a chemical, biological, radioactive, nuclear or explosives (CBRNE) incident simultaneously from multiple locations. Each participant was represented online by an avatar, and was able to communicate with team members using voice over internet protocol (VoIP). Despite the unfamiliarity with the technology, 82% of the participants and 95% of the participants felt that this was an effective tool for clinical skills training and team skills training respectively.

Serious gaming, as used by the military, offers an "innovative, low-cost, technology based solution that can rapidly fill critical training gaps and increase the impact and effectiveness of training for our soldiers in a time of war" (Ratwani, Orvis, & Knerr, 2010). Ratwani et al. (2010) point out that "design and evaluation research focusing on game-based training is in its infancy." The aviation industry has been using flight simulators successfully for decades. Flight simulators offer the same benefits that have been achieved in healthcare simulation and in disaster response. Safety is a key factor in the consideration of a virtual environment. Just as pilots can suffer a horrendous landing or a fatal crash and still walk away having had the experience without deadly consequences, disaster drills that are simulated offer a learning experience in decision making, triage, incident command, proper decontamination procedures, all without the concern that poor judgment or knowledge gaps resulted in human casualties. In terms of measurability, simulation programs are capable of gathering data throughout an exercise and compiling it for evaluation.

Another extremely valuable component of a preparedness exercise, which is difficult to replicate with live actors, is the element of reproducibility. The same exercise, consisting of all the same details and conditions, could have multiple iterations with different participants.

That kind of consistency in a testing environment is impossible to achieve with traditional drills (Boosman & Szczerba, 2010).

CONCLUSION

Disaster preparedness is a vital part of public health planning and response. Citizens, emergency health providers, hospitals, and municipalities all have a vested interest in maintaining a state of readiness. Traditionally, planning for high consequence events has been limited by costs and personnel availability. Emergency response planning is conducted at regular and infrequent intervals. Current literature reveals that knowledge retention remains a significant barrier to the implementation of effective training. Though drills are conducted yearly, event planners nevertheless confront the challenges of staff turnover and interdepartmental communication. Recent advances in technology have targeted these problems and provide public health planners with additional resources. Human patient simulation has progressed enough to permit simulators to "respond" to their environment and provide rescuers with feedback in real time. Currently available computer algorithms feature disaster scenarios that are scalable to a specific locale. Finally, virtual reality technologies immerse the learner within an environment that mimics the actual conditions of mass casualty response. Emergency management personnel can utilize these technological options to supplement current activities and satisfy government readiness mandates. Other challenges for public personnel include how to effectively deliver incident management knowledge across a wide range of expertise. Today's emergency managers must therefore remain well versed in the incident command principles as well as adult learning techniques.

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