Simulation-Based Training of Medical Teams to Manage Chemical Warfare Casualties

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Abstract

With chemical warfare becoming an imminent threat, medical systems need to be prepared to treat the resultant mass casualties. Medical preparedness should not be limited to the triage and logistics of mass casualties and first-line treatment, but should include knowledge and training covering the whole medical spectrum. In view of the unique characteristics of chemical warfare casualties the use of simulation-assisted medical training is highly appropriate. Our objective was to explore the potential of simulator-based teaching to train medical teams in the treatment of chemical warfare casualties. The training concept integrates several types of skill-training simulators, including high tech and low tech simulators as well as standardized simulated patients in a specialized simulated setting. The combined use of multi-simulation modalities makes this maverick program an excellent solution for the challenge of multidisciplinary training in the face of the looming chemical warfare threat.

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To study medicine without books is to sail an uncharted sea,
while to study medicine only from books is not to go to sea at all.

William Osler

The use of nuclear, biologic and chemical warfare agents as acts of terror is an imminent threat to the civilian population. It is essential that the medical community concentrate their efforts both on understanding chemical warfare-related medical conditions and being prepared to treat the resultant casualties. Accordingly, aspects like etiology, presenting signs and symptoms, diagnosis and differential diagnosis, immediate and long-term treatment, complications, and adverse effects of treatment should become an integral part of the current medical education [1,2].

Training of medical teams to treat mass casualties of non-conventional warfare agents has thus far focused on two main aspects: a) medical and logistic preparation for the situation of imbalance between sudden temporary demand and availability of medical resources, and b) simple and uniform guidelines for first-line treatment and triage. The teaching and training in all other aspects of this unique medical situation must rely on advanced and sophisticated teaching techniques.

Simulation in medicine

Simulation has been used in medical education in an unsystematic manner since the early days of medicine. As early as the sixteenth century, mannequins, or "phantoms" as they were called then, were developed to teach obstetric skills in order to reduce the perceived high maternal/infant mortality rates [3].

Health professionals intuitively engage in simulation activities as part of their training, as they attempt to improve their own or their students' readiness to deal with "real patients." It is common to practice injections on an orange, to practice suturing on pieces of cloth, to rehearse medical interviews with the help of role playing, or to practice physical examination on simulated (standardized) patient-actors. Increasingly sophisticated techniques for diagnosis and management require ongoing training in highly technical procedures, and the growing complexity of interactions between members of healthcare teams during technical procedures requires better interactive training techniques. Simulation can help to fill the gap between the need to train clinicians for sophisticated technical and interpersonal skills and the dependence of training on the availability and accessibility of live patients [4,5].

Modern medical simulation can be divided into four main categories [6]:

- Low tech simulators such as simple models or mannequins used as task trainers for the practice of simple physical maneuvers or procedures
- Simulated/standardized patients [7] or actors trained to role-play patients, used mostly for the training and assessment of history-taking, physical examination and communication skills
- Screen-based simulators [8] or computer programs specially designed to train and assess clinical knowledge and decision-making through a simulated clinical environment presented on the screen
- Realistic simulators [8–10] – a new generation of highly sophisticated computer-driven simulators that model human anatomy and physiology realistically and allow trainees to manage complex and high risk clinical situations in a life-like setting. This generation includes both sophisticated mannequin platforms with the tactile and visual appearance of a living person, as well as virtual reality devices and simulators that replicate a clinical setting and enable trainees to practice certain clinical procedures.

Simulation setting

The Israel Center for Medical Simulation is used by our team as a training site. The center, located at the Sheba Medical Center, was established in the year 2000 with a vision towards collaborative national efforts focused on improving training and assessment of healthcare professionals. The center offers a comprehensive approach for utilizing simulation-based medical education in order to address Israel's specific needs and advance health professionals' ability to provide excellent medical treatment to Israeli society. Unlike most current models of medical simulator facilities that focus on a single specialty or limited simulation modalities (and are often underutilized), the center. is designed to include the whole spectrum of medical simulation modalities mentioned above, including simulated patients, screen-based simulation, advanced task trainers and advanced cutting-edge interactive patient simulators. Its goal is to provide training for all healthcare professionals (physicians, nurses and paramedics) at all levels – from students to accomplished professionals, and from all schools and medical centers in the country as well as the Israeli emergency medical system and armed forces.

The training concept adopted by our team was to integrate several types of skill-training simulators, including high tech and low tech simulators as well as standardized simulated patients in a specialized simulated setting.

Hi tech medical simulators

"SimMan," "AirMan" and "HeartSim 4000" (Laerdal Medical AS, Stavanger, Norway) are computer-driven, full-body male/female mannequins that allow the simulation of advanced life support skills. The simulators can be pre-programmed to simulate different pathophysiology situations and play the patient role in interactive instructor-led training.

The Human Patient Simulator (Medical Education Technologies Inc., Sarasota, Florida, USA) represents the latest in state-of-the-art simulation technology for training clinicians at all levels of medical education. This simulator is a sophisticated high tech computer-driven interactive, life-like mannequin. It simulates clinical and anatomic parameters such as palpable pulses, reactive eyes, self-regulating control of breathing, heart and breath sounds, and cardiac vascular and pulmonary physiology. The mannequin can also be made to respond verbally by means of a microphone used by an instructor in the adjacent control room. Physiologic and pharmacologic models control the patient-simulator responses (both normal and pathologic) to drugs, mechanical ventilation and other medical interventions. Sophisticated mathematic models of human physiology and pharmacology determine automatically the patient's response to the user's actions and interventions.

With dynamic coupling of the cardiovascular, pulmonary and pharmacologic models along with physical embodiment of the mannequin, the two human patient simulators allow for the complete characterization of real adult and pediatric patients.

Low tech advanced task trainers

The FCS-3000 (Female Complete Care doll; Medical Plastics Laboratory, Inc., Gatesville, Texas, USA) is a full-body mannequin designed to teach all skills ranging from basic patient handling to advanced nursing and medical care. This mannequin enables monitoring and care of non-invasive blood pressure, auscultation, recognition of normal and abnormal heart, lung and bowel sounds, injections, endotracheal intubation, nasogastric tube placement, and enema simulation.

The ALS baby trainer (Laerdal Medical AS, Stavanger, Norway) is a 3 month old 5 kg baby simulator designed to provide airway management, vascular access and electrocardiographic monitoring and arrhythmia recognition.

Training medical teams to treat chemical warfare casualties – current status

Training medical teams, which include doctors, nurses and emergency medical technicians, to treat chemical warfare casualties is a national task. Preparing such a training system is complicated not only because the scenario is one of mass casualties but also because of the unfamiliar medical situation and physical conditions [9,11]. The medical information on nerve gas intoxication, for example, is limited since most information comes from few reports in the medical literature, data from the terrorist attack using the nerve gas sarin in a Tokyo subway [12], descriptions of war casualties from the Iran-Iraq war, and information obtained from animal studies. Some information is also gained from toxicologic disasters, like the Union Carbide incident in Bophal, India [6]. The need to physically protect medical teams from secondary contamination and the need for patients' decontamination before definitive medical treatment further complicate the scenario and influence the preparations of the medical system and the training of medical teams.

There are two main challenges in a chemical warfare scenario: treating the casualties and organizing the scene.

Treating the casualties

The general characteristic of such an event is a mass casualty situation with unique clinical signs. Decontamination of the casualties is mandatory, and the medical care principles include termination of exposure, administration of specific medical treatment and palliative treatment, especially maintaining ventilation when necessary. The medical team should have basic trauma skills combined with a basic knowledge on medical assistance in a mass casualty event on the one hand, and knowledge on the specific medical treatment protocols relevant to a chemical warfare scenario on the other. Prompt antidote therapy is life saving, therefore it should be administered as soon as possible.

In a chemical warfare attack, three distinct groups of patients warrant special consideration: those who have clinical signs of poisoning, those who present in a panic state, and those who may present after an unjustified administration of antidote. The skills of the medical team should include not only recognizing a chemical warfare casualty and acting according to a specific treatment protocol, but also discriminating between a "true" casualty and a person who received an antidote without being exposed to any chemical agent. Another aspect is the relative independence with which the caregiver should work. In a scenario with relatively uniform clinical presentations, especially when dealing with organophosphate victims, it is important that nurses and medics have extended authorities; for example, they should have the ability to treat casualties (using intramuscular and intravenous injections) without need for a doctor's approval at each and every step.

Organizing the scene

The mass casualty scenario has unique characteristics, including the need to decontaminate casualties using protective gear at the decontamination area, and the need for a triage area. We have to train the teams how to organize the scene so they will be able to implement their medical skills in the most efficient way. The scene requires meticulous preparations as well as timely cooperated action in order to save lives.

It is important to differentiate between two main educational programs: one is geared toward the military medical personnel dealing at the field level, and the other toward the civilian medical personnel. Those programs can be distinguished by the personnel, the casualties, the equipment and the organization of the event, although both should be able to deal with the same clinical presentation of the victim.

The hospital area should be divided into a "contaminated" area (preferably outside the hospital itself) and a "clean" area inside the hospital. All staff in the contaminated area must be protected.

The triage has to be simple in order to treat as many casualties as possible in a short time and to give them the best medical treatment possible by using simple treatment protocols. The criteria should be chemical (contaminated/decontaminated), age-related (children/adults), and medical (mild/moderate/severe/combined injury). The triage is based on the likelihood of survival in order to save as many casualties as possible.

At present, the Israel Defense Forces medical corps and the home front command are conducting a nationwide educational program in Israeli hospitals on the prevention, decontamination and treatment of chemical warfare casualties. Drills are exercised frequently to prepare medical teams (both civilian and military) for such an event. The program's aim is to teach and train medical teams (consisting of doctors, nurses, paramedics and other emergency medical system personnel) to treat victims of chemical warfare, particularly nerve gas intoxication [13]. Lectures and films on the medical aspects of nerve gas intoxication and treatment of nerve gas casualties are part of the curriculum of emergency medical technicians, nursing and medical schools. Medical teams at hospitals as well as pre-hospital medical teams are routinely trained for this task. The training includes not only frontal lectures and films, but also hands-on training using simulated patients with an attached note describing their medical condition. These simulated patients undergo decontamination and treatment, with the medical personnel wearing full protective gear.

Unfortunately, most doctrines and educational programs are not published in the medical literature for reasons of confidentiality. Shapira et al. [13] have presented an outline of hospital organization for chemical warfare attack, while Poles [14] examined the contingency of a national hospitalization system for peacetime emergencies.

The problem with the setting described here is that there is no real interaction between the casualty and the medical personnel and there is no way to confirm that the casualty is receiving the correct treatment. Training sessions depended on the availability, cooperation, good will and acting skills of the simulated patients (non-professional actors). This led to the use of medical technicians and medical doctors to simulate some of the casualties, enabling the training to be more realistic and to simulate the injuries, as well as to give professional feedback on the function of the medical teams.

Safety poses another problem in the current training courses. The performance of intrusive measures under the challenging conditions of a chemical warfare event is part of the training program (intravenous line insertion, endotracheal intubation, chest compressions, intra-osseous line insertion). These invasive procedures are problematic when human volunteers are used as simulated patients.

Simulation in training medical teams to treat chemical warfare casualties

Rationale

Complementing the traditional knowledge-based training for chemical warfare casualties with actual hands-on training of medical teams has always been a challenge. Similar to the teaching of trauma teams, chemical warfare teams may benefit from simulation-based training. Experience acquired from civilian trauma team training [15,16] as well as from the U.S. Navy and the Australian Defense Force demonstrates the advantages of simulation-based training in enhancing trauma management skills.

There are important advantages to the use of sophisticated and expensive technologies over the traditional training methods. Disaster drills, even when carefully planned, fail to manifest the complexity of such a medical situation [17]. The integration of sophisticated simulated patients partly overcomes this problem. Simulation-based training enables continuous evaluation of the casualty as clinical presentations change over time. Actual changes in respiratory, hemodynamic and other physiologic parameters can be observed, evaluated and measured rather than reported to the trainee by the instructor [18]. Scenarios that in reality would be dangerous for the casualty and/or the trainee can be simulated in a risk-free realistic learning environment [18,19]. Thus, difficult airway management training includes learning from fatal mistakes. The sophisticated human patient simulator simulates deterioration to death.

Chemical warfare scenarios are rarely encountered during peacetime. The non-availability of clinical material combined with restrictions on animal use and the cost of conducting mass casualty exercises render quality training very difficult to achieve [19–21]. Repeating the practice is another feature that can be achieved using interactive simulation. Repetition can be useful not only for enhancing individual expertise but also for establishing teamwork and evaluating team performance in a stress situation [18]. The unique medical situation of treating chemical warfare casualties has several characteristics that make it a natural choice for the use of simulation-assisted medical training: First, chemical warfare casualties are not common and the clinical presentation might be complex and confusing, including combined trauma and toxicologic injuries. By using various simulation techniques medical teams can learn about these rare and complex situations. Moreover, treatment protocols as well as the response to medical treatment can be learned and trained. For treating contaminated victims in a mass casualty scenario, medical teams can be trained while wearing personal protective gear that potentially limits cognitive function in this situation. Another important factor in training is the aspect of team management and interaction within the team and between teams – a key factor of quality care in such scenarios. Realistic simulation-based training has been shown to be an effective team-training tool [4].

Assessing the chemical warfare competencies of medical personnel in a simulated environment may serve as a basis for policy makers' decisions regarding future training for treatment of chemical warfare casualties [22]. Simulator-assisted training overcomes the above-mentioned difficulties and is, in our opinion, a breakthrough in this area of medical training.

Implementation

- ***Research and development***

Our team configures both the high tech and low tech mannequins to simulate chemical warfare casualties by changing the physiologic parameters of the respiratory, cardiovascular and neurologic systems. In addition, features of muscle fasciculation, tremor, seizure activity, loss of sphincter control, airway secretions and vomiting will be added to the simulators with the assistance of the Sheba Medical Center's Department of Biomedical Engineering. A sound system of different body sounds has already been added.

- ***Role-playing actors***

Standardized simulated patients (professional theater actors trained for the role) are used. A library of possible scenarios was compiled and includes patients in extreme anxiety, panic reaction, false injection of antidotes, and chemical warfare casualties who penetrate the clear zone prior to decontamination.

The architectural plan of the Israel Center for Medical Simulation permits spacious state-of-the-art training and performance assessment utilizing novel audiovisual equipment, one-way mirrors and debriefing facilities, which provide an ideal setting for trauma and chemical warfare-simulated training on the field, as well as in emergency room, operating room, and intensive care unit conditions in both multi-casualty and single patient scenarios. For the purpose of training, the center was designed as a virtual hospital divided into a contaminated and a decontaminated area, with designated areas set for triage of both the severely injured and the mild casualties.

- ***The training day***

Medical teams (doctors, nurses, medics and paramedics) exercise the treatment of a single casualty. Following several trials and after reaching a learning curve, they are tested in a multiple chemical warfare casualty scenario. We test both their medical skills and their teamwork capabilities. Testing is repeated following training sessions. The simulation program provides medical teams with the opportunity to practice on active and responsive chemical warfare casualties and thus improve their personal skills and teamwork. Most of the medical teams consist of doctors and nurses or doctors and medics, which we consider as the basic medical teams.

Conclusion

We believe that the Israel Center for Medical Simulation training program combined with ongoing hospital drills provides an optimal solution for the treatment challenge and answers the practicing needs of the training medical teams. Further studies are required to assess the cost-effectiveness of simulation-based training [23]. This complicated question is beyond the scope of this article.

As nuclear, biologic and chemical warfare becomes an imminent threat, medical systems need to be ready to treat the casualties of such a mass casualty event. Medical preparedness should not be limited to the triage and logistics of mass casualties and first-line treatment, but should include the whole spectrum of medical knowledge and training [24,25]. Tragically, the need for such training has never been so great. The special characteristics of this medical situation make the use of medical simulator training a natural choice. The Israel Center for Medical Simulation has developed a unique training program for that purpose. The combined use of multi-simulation modalities such as standardized/simulated patients, low tech and high tech simulators, novel developments of clinical presentations of simulated chemical warfare, multimedia-assisted simulated settings, and built-in debriefing capabilities make this maverick program the ultimate solution for the challenge of training in the face of the looming nuclear, biologic and chemical threat.

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There is a great man who makes every man feel small. But the real great man is the man who makes every man feel great

C.K. Chesterton (1874–1936), British writer