DEVELOPING MASS MEDICAL READINESS, I: SIMULATION-BASED, DISRIBUTED TRAINING OF GEOGRAPHICALLY DISPERSED EMS AND PREHOSPITAL PERSONNEL

Marvis J. Lary[1], Benjamin Carrasco[2], Howard Levine[2], Richard Levine[2], Timothy A. Pletcher[3], Dag K.J.E. von Lubitz[2,4]

"To Mara who started it all"
A naval officer

1. Office of the Dean
College of Health Professions
Central Michigan University
Power Hall 104
Mount Pleasant, MI 48859
USA
lary1mj@cmich.edu

2. MedSMART, Inc.
City Center Building
Suite 260
220 E. Huron Street
Ann Arbor, MI 48104
USA
info@med-smart.org

3. Center for Advanced Research and Technology
Central Michigan University
Mount Pleasant, MI 48859
Tim.Pletcher@cmich.edu

4. To whom all correspondence should be addressed at:
MedSMART, Inc.
City Center Building
Suite 260
220 E. Huron Street
Ann Arbor, MI 48104
USA
dvlubitz@med-smart.org

ABSTRACT

Medical errors involving either misdiagnosis or mismanagement of patients continue to influence the quality of healthcare delivery. Despite ongoing efforts at the improvement of diagnostic and manual skills through continuous medical education (CME) programs, problems affecting the efficiency of such training are easily perceptible. Thus, despite the existing guidelines, inter-institutional and intersystem variations in the quality of CME programs may influence subsequent quality of care delivered by the affected organizations. Currently, CME training is delivered either as standard didactic lectures or, more rarely, as a combination of bedside instruction and hands-on practical exposure. Contrary to the prevalent claims of "interactivity" of the Web-based training modules, many appear to be nothing but electronic books with the process of learning supported by quizzes and case reports. Hands-on training, performed most commonly at large institutions of medical training, is both costly and invariably affects only a comparatively small number of personnel. Hence, its impact on medical activities within a large geographical area is, of necessity, limited and its value rests primarily with the education of in-hospital staffs and the personnel in the immediate vicinity of the training center. The advent of High Fidelity Patient Simulators opened new avenues of hands-on medical training whose realism can closely approximate that of the real life clinical environment but is free from the ethical concerns imposed by the "teach or treat" dilemma. Mistakes, which often serve as the highly powerful source of learning, can be made without fear of consequences, management of often very complex medical events can be practiced, and stress elements that often accompany the practice of medicine can be freely introduced, conditioning the trainee to the rigorous demands of dealing with medical emergencies.

Widespread use of simulators is complicated by their relative scarcity consequent to their continuously high price and the resources necessary for their effective operation. However, integration of the Medical Application Software Provider (MedASP) concept with the principles of the Advanced Distributed Learning (ADL) and Distributed Interactive Simulation (DIS) overcomes these obstacles. This highly unique approach that we have developed and tested offers significant interactivity yet permits simultaneous, highly realistic training a large number of widely dispersed learners. It is, therefore, of particular relevance in the context of providing sustained learning to EMS and prehospital personnel in rural and geographically remote areas. The approach also offers realistic means of "just-in-time" training in situations of mass casualty threats, e.g., chem/bioterrorism, natural disasters, industrial disasters, humanitarian relief activities, etc.

Key words: medical readiness, medical education, distance learning, simulation, EMS, bioterrorism, Internet, high fidelity patient simulators, just-in-time training, medical simulation, medicallearning

1. The "new" medical world and the growing need for training

The past 50 years witnessed probably the most explosive growth of medical knowledge in the history of medicine imposing dramatic changes on the practice of healthcare [1,2]. Unsurprisingly, the issue of lifelong medical learning rose to the unprecedented prominence and intensifying exploration of the means to improve efficiency of medical education and postgraduate training that often involves very sophisticated technologies [3-5]. Yet, while most advanced training is routinely practiced at the major medical training centers [6 - 8], the access to even relatively simple the continuous medical education (CME) is often difficult in rural and remote regions of the globe [9 - 12]. Isolation, inadequate funds, inconsistent quality of training programs, and variation in the allocation of training resources have been often described as the principal issues that need to be addressed to produce measurable changes [reviewed in ref. 13].

The emergence of new medical threats such as bioterrorism [14] introduced a new challenge in educating large numbers of prehospital and emergency room personnel necessary to ensure maximum level of readiness [14 - 17]. Medical professionals who typically do not participate in EMS operations may have an active role in interventions associated or following an act of bioterrorism [18], clearly indicating that the required training must account for the existing differences in the baseline knowledge. Moreover, the required training programs must be highly standardized and conducted at a consistently high quality level if it is expected to develop and sustain adequate preparedness against emerging threats of bioterrorism or mass casualty events [19 - 23]. In summary, even a perfunctory review of the existing literature clearly indicates the persistent and rapidly growing need for continuous education and training of both preand hospital personnel [24 - 26], and the significant role of federal, state, local, and non-governmental agencies in developing robust tools and systems that will be sufficient to provide both continuous and “just-in-time” medical training [27 - 29].

2. The nature of the training need

Changes in medical practice, increasing specialization, and multi- or cross-disciplinary approach to the treatment of disease [30 - 37] require a very wide range of sophisticated postgraduate education programs at both pre- and in-hospital levels of medical operations. Problems ranging from communication and definition of professional identities and roles within the medical management team [38-41], through procedure difficulties [42-44], missed or wrong diagnoses [45-48], to errors in medical command of EMS operations or even fundamental inadequacies in training of prehospital and in-hospital healthcare providers [44,46,49-53] have been described. One of the unifying trends that emerge from several studies is that of inadequate training of non-specialist healthcare workers in adult and pediatric emergency and trauma medicine [52 – 62] and in surgery [63 – 67] that is particularly pronounced in rural and remote regions worldwide.

Clinical and procedural errors resulting from training deficiencies at the first responder/paramedic level [68,69] are as common as those at to the higher echelons of care providers, and pose similar major concerns. The adverse effects of less than optimal teamwork caused by poor team training [70], substandard mastery of essential (even basic) diagnostic skills and resuscitation procedures [71-75], and unreliability in the delivery of commonly encountered services as advanced cardiac life support [76] have been well documented. Even more problematic are the substantial inadequacies in pediatric resuscitation skills resulting from both inadequate initial training and infrequent refresher education that combine with a relatively rare exposure to pediatric emergencies [77 – 80]. The intense need for continuous education and training is emphasized even more strongly by the recently reported lack of reliability in performance rating during EMT licensing examinations [81] – a failure that allows operational entry of personnel with less-than-optimal knowledge and skills. Cumulatively, the inadequate entry-level preparation combined with the demonstrated skills decay [79, 80, 82] are not only the source of major concerns, but provide further argument for the vigorous maintenance of clinical competence through the process of lifelong learning among all healthcare professionals [83 – 92].

Trivial in comparison to often life/death repercussions of medical errors, the costs that accompany each incident of faulty patient management constitute another significant motive for sustained training of medical personnel. It is estimated that the average price of a resuscitation attempt vary between $ 3.000 and $10.000 depending whether its initiation started as an in-hospital or pre-hospital event [94, 95]. Clearly, any error resulting in a serious aggravation of the presenting complaint will automatically increase the final cost of care by making it more complex and more resource-demanding [96]. Thus, while the argument of “I am certified” may still be heard, the wealth of existing data on errors indicate that the presence of certification alone may offer very false security in one’s own medical prowess. The real cost of such (possibly unwarranted) certitude may, indeed, be quite extreme both in terms of the medical outcomes and in the associated costs expenditure.

3. The existing training methods

Presently, medical education at all levels of expertise is conducted in a manner that, despite a host of advances in technology, has not changed significantly during the recorded history of medicine [1]. In the broadest terms, training of healthcare professionals is conducted either as a totally passive assimilation of the existing body of knowledge such as books [97,98] or lectures [99,100], or through an active, bedside-based approach. The latter may involve either the combination of passive and active methods or the hands-on methods alone [101-103]. Significantly, while it is often claimed that electronic dissemination of medical knowledge provides "interactivity", many existing platforms represent nothing but technologically advanced forms of traditional (essentially passive) training based on traditional didactic principles [e.g. 104 – 106]. The primary advantage of information technology in the didactic e-training packages rests with the ease of access to the appropriate sources of latest information, rapid cross-referencing of information and the supporting data, and the ability to organize information derived from various resources into easily catalogued logical units that assist in assimilation and solidification/retention of the acquired knowledge.

Rapid growth of Internet connectivity in the technologically advanced countries is associated with the most important attribute of electronic healthcare knowledge dissemination – erosion of distance as the main obstacle in accessing postgraduate professional education among healthcare personnel in rural and remote regions of the world [reviewed in ref. 107]. The existing Internet/Web-based medical training and/or consultation programs cover a wide range of topics, satisfy almost every need for specialized knowledge, and, with the increasing sophistication of the existing protocols, may involve a large variety of approaches spanning from e-mail exchange to videoconferencing and multimedia offerings [e.g., 108-120]. The main disadvantage of didactic distance learning is its essentially static nature that fails to reflect the dynamism of medical specialties such as emergency/trauma medicine, military medicine, or surgery [121]. The existence of inaccurate, obsolete, or incomplete content of many medical information sites provides another major problem that affects the overall quality of many Internet-based learning resources [107, 122].

Hands-on training based on the trainee-patient contact, while highly effective in the development of the necessary clinical skills [123, 124], is associated with a number of challenges [125 – 129] and risks [130]. Facing equally daunting issues of hands-on training, the aviation community, where both training and operations are associated with many characteristics similar to the high-paced tempo of medical specialties such as emergency medicine, trauma medicine, or perioperative care), used in the past 80 years [131] simulation devices that both to increase the efficiency of training and minimize the associated dangers [132 - 135]. Although the history of simulation in medicine is significantly shorter, both its role in education and training, and its level of sophistication increase very rapidly [136 –140]. Presently, High Fidelity Patient Simulators (HFPS, previously known as Human Patient Simulators) serve as highly complex “medical flight simulators” in a wide variety of training tasks. The use of HFPS units in hands-on training eliminates all risk factors associated with similar training on living patients, permits improvement of diagnostic skills by allowing practical understanding of the involved steps, hones interactions of medical teams, and promotes punishment-free learning based on one’s own errors [121, 141 -147]. Training based on or in virtual reality environments [107, 121, 148 – 151] represents technologically the most sophisticated level of medical simulation that proved to be particularly suitable in surgery and emergency medicine [107, 151].

4. Simulation training – good but inaccessible

A rapidly increasing number of publications describe preeminent applicability of medical simulation in training of healthcare personnel in a variety of medical specialties [152 – 163]. However, in the majority of cases, studies of simulation efficacy have been performed in the setting of large training institutions that can easily supply the required significant fiscal resources for the acquisition of the simulation equipment, and provide both space and personnel necessary for the successful operation of a simulation center [164, 165]. Unsurprisingly then, the target audience of simulation-based training consists typically of students and residents associated with the institution that already has its own simulation center, i.e. the trainees who are also exposed to the essentially maximal concentration of the traditional educational resources. In contrast, both pre- and in-hospital healthcare professionals, particularly in rural and remote regions, are largely excluded from the benefits of simulation-based training predominantly conducted at the large academic medical education centers. The cost of attending and of the training itself, the ease of accessing the training site, and the difficulty in fitting training into professional schedules appear to be the predominant obstacles [121 and in preparation]. Thus, it is paradoxical that the economical and logistic issues may prevent simulation technology from reaching the audiences where it may have a far greater impact than at the established centers of medical learning.

5. Simulation-based distributed medical training

In order to circumvent the obstacles preventing large-scale access to simulation-based training, we have developed and operationally tested a model for distributed simulation-based training targeted at widely dispersed, large numbers of medical personnel (Fig. 1). The model combines the principles of Distributed Interactive Simulation (DIS) and of the Application Service Provider (ASP), and facilitates utilization of a sophisticated simulation facility by the remote learners (Fig 2, and references. 121, 165, 166, 167, 168). Practical implementation of the concept allows execution of highly realistic training in often complex and stress-filled environment of field emergency and trauma medicine and obviates the need for the trainees to leave their physical location that may be separated by thousands of miles from the simulation facility [169]. The additional advantage of the model is its preeminent suitability for real-time dissemination of world-class medical training expertise in the form of practical "patient demonstrations" rather than the commonly encountered didactic format of a theoretical lecture [169]. Consequently, prehospital learner audiences in rural and remote regions who, hitherto, had significant difficulties in accessing arguably the most sophisticated form of medical learning can now benefit from both advanced training technology and expertise, and the customized services may be provided essentially on demand.

We have performed numerous operations that utilized and validated the concept of distance-based simulation training at all levels of medical expertise. Courses in ACLS, ATLS, and CTLS were given to US and NATO military personnel [165,166,167, and in preparation], medical students and physicians [169], and First Responders [in preparation] with the distance between the simulation facility in Ann Arbor and the trainees from 140 to nearly 8.000 miles (transatlantic training in France and Italy, Fig. 3). In two instances of transatlantic training, highly innovative peri- and intraoperative decision-making and team training were the main subject of the courses [169]. Finally, crew responses to a chemical warfare threat were practiced aboard a US Coast Guard vessel (USCGC FORWARD) during its operational deployment in South Atlantic [165]. The demonstrated efficacy ease of such training combined with the high level of interactivity, and the ease of access to the advanced simulation facility and world-class training expertise independent of the distance separating the students from the central simulation center [166, 167, 168, 169] is of special significance for EMS and military healthcare providers, particularly in situations of increased need for “just-in-time” training of a large number of personnel deployed to several geographically dispersed sites [121] as seen during bioterrorist threats, military conflicts, or large scale rescue operations [166].

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Fig. 1

The concept of Medical Application Software Provider (Med-ASP). The central training facility provides high-level training expertise, and remotely accessible High Fidelity Patient Simulators. The central facility has also the capacity of real-time, on demand, remote control of satellite simulators (client machines) providing remote customers who already have access to their own simulation devices with customized training expertise at a distance. Implementation of the concept results in improved access to the costly simulation devices and other forms of advanced medical training technology, optimization of operations, and significant cost reduction for the users. Med-ASP concept allows maximum flexibility in the effective use of the scarce resources whose availability is limited in the rural and remote regions, i.e., simulation facilities and advanced training expertise.

Fig. 2a

Laerdal SimMan HFPS configured to operate as a platform for training management of severe trauma. The simulator is moulaged to represent significant burns to the chest and arm, facial penetrating injuries and avulsions, and open abdominal injuries with avulsed intestines. Patients of this type would be encountered following major traffic accidents, industrial explosions, or combat. Training in the field management of grave traumatic injuries at the prehospital level is greatly facilitated when HFPS units are used. Importantly, appropriately conducted simulation introduces the realism and stress of complex medical environments that cannot be reproduced in more traditional training settings. The figure clearly emphasizes the pre-eminent suitability of simulation for just-in-time training.

Fig. 2b

Multi-site, multi-simulator control station. The operating engineer has the view of all distant sites, controls operation of the cameras, voice inputs and sound levels, and is in full control of communication back-up systems, allowing an immediate switch to another line/IP address if the currently active connection fails. As shown, multiple site/multiple simulator technical control is a complex operation that requires highly skilled telecommunication personnel with expertise in TV activities, and who are capable of coordination of several sources of input and output while correlating these with the training taking place in the studio. It is the creation of effective and sophisticated control centers rather than the arrangements at the remote sites that poses the major difficulty in distributed simulation-based learning.

Fig. 3

Simulation-based distance training in the performance of complex medical procedures. The upper figure shows the training expert at the central simulation facility in Ann Arbor, MI instructing a group of junior physicians (lower picture) in Italy (L'Aquila) in the execution of fiberoptic intubation. The expert is in real time sound/video contact with his student allowing him not only to demonstrate the procedure itself, but also make a "running commentary" and either query the trainees or answer their questions. The expert sees the trainees as they are shown in the lower picture. The inset view in the lower provides the expert with the scene as seen full scale by his students in Italy, i.e., the process of guiding the fiberscope toward the patient's trachea, and the fiberscope view of the inside of the trachea. The fiberscope view allows students to become familiar with the characteristic landmarks, recognize faulty placement of the device, assist in guiding the tip of the device, and – eventually – perform the entire procedure remotely simply by directing an untrained technician. This type of training is particularly suitable for telemedical consultation and guidance.