SIMULATION BASED MEDICAL EDUCATION: ADVANCED DISTRIBUTED LEARNING AS A TOOL FOR THE FUTURE

Dag K.J.E. von Lubitz, Ph.D., M.D. (Sc)[1,2], Benjamin Carrasco, B.Sc.[2], Howard Levine, B.Sc.[2], Timothy Pletcher, B.Sc.[2], Francesco Gabbrielli, M.D.[3], Frederic Patricelli, Ph.D.[4], Simon Richir, Ph.D[5].

1. **To whom the correspondence should be addressed at dvlubitz@med-smart.org, tel. +1 734 527 7120**
2. **MedSMART, Inc., 220 E. Huron Street, Suite 220, Ann Arbor, MI 48114, USA, info@med- smart.org, www.med-smart.org**
3. **Department of General Surgery, University of L'Aquila, Via Vetoio, Blocco 11, 67010 Coppito, Italy**
4. **SSGRR, Via G. Falcone 25, 67100, L'Aquila, Italy**
5. **ISTIA INNOVATION, University of Angers, 62 Ave ND du Lac, 49000, Angers, France**

ABSTRACT

Several recent reports, including the major study by the Institute of Medicine of the American Academy of Sciences, indicate alarmingly high number of medical errors committed during medical operations. Among the primary sources of such errors are lack of training, lapsed knowledge and skills, and inadequate access to remedial resources. Unsurprisingly, a large number of treatment errors (both diagnostic and procedural) take place at healthcare facilities that are distant from large medical education centers, where the distance of 50 miles may indicate a very substantial deterioration of the available care. Moreover, many of these errors originate at the prehospital level where the inadequate training of the field personnel at virtually all levels of proficiency results in otherwise avoidable morbidity and mortality. Their training, while following the current regulations, is infrequent, rarely under the direction of experts available at major emergency/trauma centers, and, accordingly to our own studies (US Navy and US Coast Guard) and the work of others – largely inadequate and hampered by a severe retention loss leading to a substantially decreased level of medical readiness. One of the major issues in addressing the problem of inadequate training is that of providing efficient medical training courses to a large number of personnel dispersed at several facilities. Traditionally, education of such type is affected by a very high cost, uneven quality of instruction, and inability to provide adequate exposure in the absence of sophisticated training tools. Probably the most efficient solution to this global dilemma has been recently provided by MedSMART, Inc., whose unique approach proposes implementation of Advanced Medical Distributed Learning concepts basing them on the integration of the Internet and the remote, interactive access to the Human Patient Simulators. The concept allows, probably for the first time in the history of medicine, for the worldwide training of medical personnel that can be provided by otherwise almost entirely inaccessible leading international experts in emergency and trauma medicine. The most immediate consequence of the implementation of these concepts results in a highly unique, real time/real life exposure to the management of medical emergencies.

From the very beginning of each training session, the trainees are immersed in the process of critical decision making under stress, allowing them to develop and sustain the critical diagnostic and procedural skills whose correct application determines the nature of the subsequent outcome. In addition, almost prohibitively expensive frequent and regular instruction becomes a sustainable and practical concept, resulting in a uniformly high level of medical readiness independently of the location of the concerned facilities and their physical isolation. Apart from purely professional benefits, the new approach to distributed medical training offers significant savings by permitting simultaneous participation of a large number of trainees at located at physically dispersed sites. The released funds can be then applied directly to other aspects of medical readiness such as acquisition of better materiel, increased mobility, better communications, etc.

1. Critical inadequacies of the current approach to training in medical emergencies

The recent publication by the Institute of Medicine (IOM) of the National Academy of Science of a report demonstrating that nearly 100.000 patients in the USA die due to medical error [1] served as a stark, public reminder of facts known for many years to health care professionals: despite continuous attempts to improve delivery of medical care, errors are still rampant, their source varies from almost banal (prescription mistakes at the pharmacy level) to substantial incompetence, and the preventive efforts appear inadequate. The problems disclosed by the IOM are equally valid in other countries with advanced level of medical care [2,3,4] at an equal or even more alarming frequency [5].

The underlying sources of the majority of medical mistakes relate to the lack of training comprising both diagnostic and procedural skills and their successful application under stress, and, particularly in critical situations, less than adequate familiarity with standard guidelines developed by organizations such as the American Heart Association (AHA, [6]). While the solution to the problem appears to be a straightforward one, i.e., increased training of health care providers in all areas of demonstrated insufficiency, its implementation, particularly in widely distributed industrial or military facilities, rural and remote regions, or even in space, poses significant practical difficulties such as the ease of access, the availability of training experts, resources, etc [7,8].

Probably the most glaring example of current insufficiencies is provided by the problems of field management of sudden cardiac illness. Heart disease remains the primary killer in the Western world. Hence, the issue of sufficient level of education and training in resuscitation techniques is of paramount importance both in terms of mistake prevention, and in terms of their life-saving value [9]. Yet, a series of studies spanning over a decade [11,12,13] revealed that the compliance with BCLS (Basic Cardiac Life Support) and ACLS (Advanced Cardiac Life Suport) guidelines and the level of BCLS and ACLS training both at the pre-hospital level, and among the most senior non-specialist medical personnel, i.e., general medicine physicians, remains strikingly low. Perioperative resuscitation skills (which often amount to nothing more than excellence in ACLS) are at the equally low level, with at least one study [14] showing that only 13.7% of participants avoided making a "lethal error", while 56.3% executed at least one. Another recent study showed that, despite clear indications for defibrillation, 6% of the participants never used the defibrillator device [15]. Significantly, major deviations from the existing resuscitation guidelines appeared to be the norm rather than exception. Correspondingly, the remedial value of adequate resuscitation training has been clearly demonstrated by a number of authors [16,17,18,19,20,21] who also stressed the need for adequate frequency of refresher courses [20,21,22], and suggested a number of strategies to nurture such skills [23,24].

The issues of inadequate preparation for medical emergencies are equally, if not more, valid at the prehospital providers or even lay personnel involved in resuscitation efforts [25-31]. There is thus a pronounced lack of awareness concerning advanced resuscitation devices [32,33], less-than-efficient ability to perform triage on the site of the incident [28], faulty decision making process resulting in adverse outcomes [34-38], or deficiencies in tasks seemingly as simple as appropriate activation of the EMS (Emergency Medical System) operations [39].

The awareness of alarming deficiencies in resuscitation training and readiness is not new. Almost 25 years ago a paper in JAMA [40] described rapid deterioration of knowledge and skills following initial CPR education. Subsequent studies provided further support for the early findings showing rapid post-training decline of resuscitative ability among both very highly trained professionals as much as the lay public [41-48]. Yet, even the very recent investigations show that the overall picture has not changed [49-55]. Many trainees in conventional classroom settings cannot perform the requisite skills immediately on the completion of their training. Moreover, the mandated participation in the infrequent (12-24 months interval) resuscitation training may lead to false confidence and result in avoidable fatalities taking place at both pre- and hospital levels [56,57].

The most essential conclusion of the majority of all studies devoted to resuscitation training and retention is the unequivocal demonstration of a rapid decline of skills and knowledge with the return to the base (pre-training) level within 6 months following the original course [58]. Correspondingly, other studies clearly emphasize the need for increased frequency of adequate training or even “overtraining” [59] critical step toward improvement of the quality of the subsequent outcomes [60,61,62].

The issue of adequate training frequency and exposure is an important one. We have not been able to find adequate numerical data on the interrelationship of these three factors at the first responder level, particularly in the setting of dispersed industrial or military facilities (but see 63-67). Nonetheless, several papers clearly link the level of training of occupational medicine personnel that provide medical services at such facilities to the quality of outcome following medical emergencies [68-72]. Thus, the rarity of such events combined with infrequent training that appears to adhere to the minimum recommended frequency standards (see preceding references) are the primary factor in creating the “false positive” attitude of the providers at large industrial facilities. Such attitude has been has been observed among theoretically highly skilled independent duty corpsmen of the US Navy during our own operations at the naval facilities in Puerto Rico (von Lubitz et al., in preparation.). With the exception of personnel serving in submarines, the subsequent testing of preparedness revealed profound deficiencies in some of the most fundamental diagnostic/treatment skills required of prehospital responders at all levels of proficiency.

Equally alarming is the tendency to develop “operational reluctance” resulting from inadequate exposure and inadequate training. The latter phenomenon has been demonstrated among paramedics required to deal with the pediatric emergencies where compromised readiness related directly to limited event exposure and decreased skills and knowledge levels [73]. Unsurprisingly, it has been also shown that paramedics perceive pediatric emergencies as the most stressful [74]. A potent indicator of inadequate preparedness and confidence is the tendency to “hold back” when the encounter involves an atypical event (e.g., a pediatric emergency, see ref. 75]. Appropriate training leads, on the other hand, to a dramatic improvement of paramedic confidence [76-78]. Although there are no studies on the subject, we have no doubt that the relative rarity of emergent/life threatening situations encountered in the industrial environment produces similar attitudes, where false confidence and reluctance to provide energetic response might combine into medically unsound environment.

There is no question that all evidence points at the inadequate/infrequent training as the principal cause of all subsequent operational difficulties. The major obstacle in eliminating the problem is our current ability to provide adequate and meaningful training to large and frequently widely dispersed groups of trainees [79].

2. The need and development of new training methods: Human Patient Simulators and their advanced uses

A wide range of training tools have been proposed over the years as a remedy to the inadequacies in BLS, BCLS, ACLS, and ATLS, etc. The proposed methods span from the traditional courses [e.g., 80], through video- and multimedia-based training [81-85], to fully computerized applications [86,87]. While practically all of these tools offer some form of the level – of - training improvement, none are fully adequate to present the trainee with the urgency and stress surrounding, for example, a cardiac emergency, when several physical and intellectual resources must be rapidly brought together in order for the effort to be successful [7].

Simulation has a long and successful history in aviation, maritime operations, and in military training [88] where it has been used with a great practical success [89-91]. The very recent advent of Human Patient Simulators (HPS) promises to improve drastically the intensity and quality of medical training at all levels of proficiency [92,93]. Human Patient Simulators are computer-operated, life-size mannequins capable of physiologically faithful reproduction of human disease signs typically encountered as a part of a medical emergency. The outputs of the device provide realistic chest and heart sounds, pulses, pupillary and laryngeal reflexes, and allow monitoring all vital signs in a manner identical to the clinical setting. Fully equipped HPS permits execution of several procedures, e.g., intubation, insertion of drainage tubes and catheters, relief of pneumothorax, cricothyroidotomy. Successful implementation of appropriate procedure is immediately reflected in appropriate physiological response (e.g., relief of pneumothorax restores chest sounds and chest excursion on the affected side, normalizes ECG and blood gas status, etc.). Moreover, virtually all drugs used at the prehospital and ER/OR levels can be administered either in form of intravenous drips or as syringe-injected bolus. Drug treatment of HPS causes correct, dose dependent systemic response. Importantly, improper or delayed implementation of the required intervention may result in a “fatality”. Hence, the student is simultaneously exposed to the realism of the event (severely ill patient), the demand for instantaneous marshaling of all intellectual resources required to perform the initial diagnosis, and to the demand o execute correct intervention. Yet, just as a paramedic or a physician either in the field or at the emergency room, the student may also feel the ever-present stress of the time limit. The sophisticated nature of HPS devices, and their capability of reproducing acute disease in a highly realistic manner that offers virtually life-like challenges, led to proposals to use them both in routine training and as tools for competency testing [94-96]. Largely preliminary and, with few exceptions, primarily qualitative reports [e.g., 91,95] indicate the beneficial nature of training using HPS. Importantly, in addition to individual training, medical team training and preparation can be also executed using these devices [97,98]. Simulation has been also used to study the sources of inaccuracies in reporting critical anesthetic incidents [99,100].

The importance of simulation in biomedical education and training increases very rapidly as a substitute for "on-the-job" training and its inadequacies [7]. It is not surprising that the number of Human Patient Simulators continuously increases with over 100 units in the USA alone (nearly 170 worldwide.) However, the cost of HPS may be prohibitive (between $ 30 and 250.000 depending on the sophistication of the model) and at the present only the most affluent institutions can afford them. Moreover, the majority of the available devices are stationary and, due to their delicate nature, require considerable maintenance by skilled technical personnel [94] (the very recent HPS models developed by METI and Laerdal are fully mobile.) Hence, the machines are unavailable to the majority of those who may need simulator most, i.e., the medical personnel (EMTs, nurses, and physicians) operating in the resource austere environments, and who have the greatest practical difficulties in reaching advanced training centers in order to refresh their professional knowledge and skills.

Our preliminary studies conducted aboard a US Coast Guard cutter (USCGC FORWARD, WMEC 911) and later at the US Navy Hospital at Roosevelt Roads (an isolated facility with a difficult access to advanced training and refresher courses) indicated that even a brief exposure to HPS resulted in a measurable and significant increase of preparedness and confidence among the medical personnel participating in HPS-based refresher training [101,102]. These observations indicated the practical usefulness of HPS technology in training prehospital personnel working in technology-austere regions, e.g., non-teaching hospitals or rural and remote areas. In practice, the very high cost of acquiring multiple HPS units to be placed in such locations is prohibitive. Thus, in order to make human patient simulation accessible to a larger number of the trainees, a completely new approach to HPS-based training has been developed which incorporates extensive use of the Internet-based telepresence and remote access to- and the control of the simulating unit.

The great potential of video-based medical learning, particularly among the mature learners, has been demonstrated by Braslow and his colleagues [103-105]. Moreover, both limited studies and large-scale field operations [106-109] have shown significant value of video/teletraining methods that involve active participation and/or observation of procedures under the guidance of an expert trainer. During the past two years similar approaches to Human Patient Simulation and HPS-based training have been tested by MedSMART. As the result of these activities, the original concept of remote access to HPS developed by the precursor of MedSMART – the Medical Readiness Trainer at the University of Michigan has been broadened and significantly improved. The new capacity developed by MedSMART offers full, real time training at multiple locations and permits interaction between widely dispersed trainees, the simulator, and the expert trainer in a manner similar to that encountered in the physical classroom.

3. The new concept of Distributed Human Patient Simulation

Medical education and training of the worldwide community of health care providers is often hampered by the lack of access to the sophisticated medical training assets. The principal factors that preclude such access are either the physical distance to the advanced medical education centers or restricted financial resources that preclude acquisition of modern training technologies.

The solution to both problems may be provided by the integration of interactive medical simulation technology with the Internet. Such solution would permit projection of medical training excellence even to the most remote regions of the globe. As a result, medical simulation might become an integral part of the global healthcare concept, helping to "level the playing field" for all those whose resources forced them to be left behind.

The only company in the world that successfully implemented and tested this approach worldwide is MedSMART in Ann Arbor, MI, USA.. While MedSMART provides medical content and simulation solutions, a company specializing in telephony and Internet-based operations (Digital Realm, Inc.) provides telecommunications infrastructure. The close collaboration of both organizations proves to be essential for the success of operations that may require highly sophisticated and innovative approach to te telecommunication issues, particularly when operations are conducted in the territories characterized either by legacy or poor infrastructure. The majority of these solutions are beyond essentially layman capabilities of medical organizations and can be devised and implemented only by the highly skilled engineering personnel of commercial companies specializing in telecommunications. It is only such collaborative effort that ultimately assures the success of routine operations at the distances that often can be very substantial or even worldwide. Moreover, wide range of both medical and technical expertise is necessary in order to provide the basis for the development of "tailor-cut" approaches to the wide diversity of the training problems, as much as to the scientific analysis of the critical factors such as training outcomes, influence of human factors on medical performance, development of custom simulation tools, etc. Several recent publications (e.g., 7, 91, 94, 101, 102) demonstrate plausibility and efficacy of such solutions

Apart from purely technical issues, among the essential ingredients necessary for the success of international medical training operations (whether simulation based or not) is the necessity of very close collaboration with experts from the target countries, or even their incorporation in the infrastructure of the organization providing such training. Such approach permits operational efficiency that is unhampered by differences typical of multinational environments where local custom and culture prove the frequent a daunting obstacle, particularly to the US companies that attempt to continue their activities without acquiring adequate local expertise. Creating multinational atmosphere within the organization providing medical training was among the main reasons for the expanding global success and reputation of MedSMART. Equally important proved the fact that MedSMART is a not-for-profit company that abandoned the concept of charging the target audience for its services. While, at the company level, operational activities incur significant annual costs (about US $ 3 million) charges for these expenses are not leveled at the trainees who receive services for free but at national and international agencies responsible for the maintenance of world's health. Using such approach, MedSMART can bring even the best (and typically also the most expensive) teacher to even the poorest of classrooms permitting, arguably for the first time, sharing one of the scarcest medical resources – the expert – among a vast array of the worldwide trainees. Indisputably, this is a novel and , to some degree, controversial approach to business practices. Yet, it is precisely this novel philosophy allows exposure to the medical training expertise that would be otherwise entirely unavailable to the trainees located at the remote and, typically, severely underfinanced facilities of the world.

In summary, MedSMART offers a novel but operationally tested set of solutions to medical training of large numbers of personnel conducted under the guidance of medical experts and extensive use of simulation as the principal training tool. The solutions proposed by MedSMART involve not only training itself but simultaneous acquisition of data necessary to determine the efficacy of training, the retention levels, and the need for retraining. Importantly, MedSMART recognizes the need for highly individual approach to training staffs of large organizations with highly specific profile of operations (e.g., military, NASA, automotive industry) where the nature of typical activities is the denominator of the types of injury that require particular attention during training.

4. References

1. Kohn LT, Corrigan JM, Donaldson MS, 1999, To Err is Human: Building a Safer Health System, IOM (Natl. Acad. Press), pp. 1-312
2. Brown RW, 1997, Errors in medicine. J. Qual. Clin. Pract. 17, 21-5
3. Hart GK, 1999, Error in medicine: adverse events in intensive care. Schweiz. Med. Wochenschr. 129, 583-91
4. Smith J, 1999, Study in medical errors planned for the UK. BMJ 319, 1091
5. Medical errors: major killers in UK and USA (editorial),. Adv. Drug React. Toxicol. Rev. 19, 9-16
6. Sanders AB, 1995, The development of AHA (American Heart Association) guidelines for emergency cardiac care. Respir. Care 40, 338-44
7. MRT (von Lubitz, D.K.J.E. et al.), 1999, Immersive Virtual Reality Platform for Medical Training: a “Killer Application”, in Medicine Meets Virtual Reality 2000, J. Westwood et al. (Eds), IOS Press (Amsterdam), 207-213
8. Sherwood G, 1994, Educational outreach in rural underserved areas. Nursing Connection 7, 5-15
9. Atkins JM, 1986, Education and evaluation in emergency cardiac care programs (CPR and advanced cardiac life support): state of the art. Circulation 74 (Pt2): IV 18-22
10. Wydro GC, Cone DC, Davidson SJ, 1997, Legislative and regulatory description of EMS medical direction: a survey of states. PREHOSP. Emerg. Care. 1, 223-7
11. Hodgetts TJ, Brown T, Driscoll P, Hanson J, 1995, Pre-hospital cardiac arrest: room for improvement. Resuscitation 29, 47-54
12. Cline DM, Welch KJ, Cline LS, Brown CK, 1995, Physician compliance with advanced cardiac life support guidelines. Ann. Emerg. Med. 25, 52-7
13. Stross JK, 1983, Maintaining competency in advanced cardiac life support skills. JAMA 249, 3339-41
14. Porayko LD, Butler R, 1999, Perioperative resuscitation knowledge base. Can. J. Anaesth. 46, 529-35
15. Kurrek MM, Devitt JH, Cohen M, 1998, Cardiac arrest in the OR: how are our ACLS skills? Can. J. Anaesth. 45, 130-2
16. Dane FC, Russell-Lindgren KS, Parish DC, Durham MD, Brown TD, 2000, In-hospital resuscitation: association between ACLS training and survival to discharge. Resuscitation 47, 83-7
17. Schneider T, Mauer D. Diehl P, Eberle B, Dick W., 1995, Does standardized mega-code training improve the quality of pre-hospital advanced cardiac life support (ACLS)? Resuscitation 29, 129-34
18. Camp BN, Parish DC, Andrews RH, 1997, Effect of advanced cardiac life support training on resuscitation efforts and survival in rural hospital. Ann. Emerg. Med. 29, 529-33
19. Mann CJ, Heyworth J, 1996, Comparison of cardiopulmonary resuscitation techniques using video camera recordings. J. Accid. Emerg. Med. 13, 198-9
20. O’Steen DS, Kee CC, Minick MP, 1996, The retention of advanced cardiac life support knowledge among registered nurses. J. Nusrs. Staff. Dev. 12, 66-72
21. Brown J, Latimer-Heeter M, Marinelli A, Rex E, Reynolds L, 1995, The first 3 minutes: code preparation for the staff nurse. Orthop. Nurs. 14, 35-40

Copyright MedSMART Inc., 27th March 2002

22. Makker R., Gray-Siracusa K, Evers M, 1995, Evaluation of advanced cardiac life support in a community teaching hospital by use of actual cardiac arrests. Heat Lung 24, 116-20
23. Boudin KM, 1995, Strategies for maintaining ACLS skills in hospitals. Respir. Care 40, 550-64
24. Kaye W, 1995, Research on ACLS training – which methods improve skill and knowledge retention? Respir. Care 40, 538-9
25. Dvorkin G, 2001, Responding to aquatic facilities, Emerg. Med. Serv. 30, 78-81,88
26. Groh WJ, Newman MM, Beal PE, Finberg NS, Zipes DP, 2001, Limited response to cardiac arrest by police equipped with automated external defibrillators: lack of survival benefit in suburban and rural Indiana – the police as responder automated defibrillation evaluation, Acad. Emerg. Med. 8, 324-30
27. Seraj MA, Naguib M, 1990, Cardiopulomonary resuscitation skills of medical professionals. Resuscitation 20, 31-0
28. Schmidt T, Atcheson R, Frederiuk C, Mann NC, Pinney T, Fuller D, Colbry K, 2000, Evaluation of protocols allowing emergency medical technicians to determine need for treatment and transport, Acad. Emerg. Med. 7, 663-9
29. Swor RA, Jackson RE, Walters BI, Rivera EJ, Chu KH, 2000, Impact of lay responder actions on out-of-hospital cardiac arrest outcome, Prehosp. Emerg. Care 4, 38-42
30. Wiliamson CR, HazMat training: first responder chemical spill response team. J. Healthc. Prot. Manage. 1998-99 (Winter), 83-6
31. Thanel F, 1998, Near drowning. Rescuing patients through education as well as treatment, Postgrad. Med. 103, 141-4, 149-53
32. Mancini ME, Kaye W, 1998, In-hospital; first-responder automated external defibrillation: what critical practitioners need to know, Am. J. Crit. Care 7, 314-9
33. Ossmann EW, Bartkus EA, Olinger MI, 1997, Prehospital pearls, pitfalls, and updates, Emerg. Med. Clin. North Am. 15, 283-301
34. Hine LK, Pedone M, 1993, On-site first aid, CPR responders need to make fast, virtal decisions, Occup. Health Saf. 62, 74-8
35. Pearn, JH, 1999, Decision making in CPR, Med. J. Aust. 170, 453-4
36. Fenner PL, Leahy S, 1999, Decision making in CPR, Med. J. Aust. 170, 454
37. Mackay MJ, 1999, Decision making in CPR, Med. J. Aust. 171, 276
38. Liberman M, Lavoie A, Mulder D, Sampalis J, 1999, Cardiopulmonary resuscitation: errors made by pre-hospital emergency medical personnel, Resuscitation 42, 47-55
39. Bilger MC, Giesen BC, Wollan PC, White RD, 1997, Improved retention of the EMS activation component (EMSAC) in adult CPR education, Resuscitation 35, 219-24
40. Weaver FJ, Ramirez AG, Dorfman SB, Rainer Ae, 1979, Trineees' retention of cardiopulmonary resuscitation. How quickly the forget. JAMA 241, 901-3
41. Gass DA, Curry L, 1983, Physicians' and nurses' retention of knowledge and skill after training in cardiopulmonary resuscitation, Can. Med. Assoc. 128, 550-1
42. Mancini ME, Kaye W, 1985, The effect of time since training on house officers' retention of cardiopulmonary resuscitation skills, Am J. Emerg. Med. 3, 31-2
43. Yakel ME, 1989, Retention of cardiopulmonary resuscitation skills among nursing personnel: what makes the difference. Heart Lung 18, 520-5
44. Hammond F, Saba M, Simes T, Cross R, 2000, Advanced life support: retention of registered nurses' knowledge 18 months after initial training. Aust. Crit. Care 13, 99-104
45. Kaye W, Mancini ME, 1986, Retention of cardiopulmonary resuscitation skills by physicians, registered nurses, and the general public. Crit. Care Med. 14, 620-2
46. Martin WJ, Loomis JH Jr, Lloyd CW, 1983, CPR skills: achievement and retention under stringent and relaxed criteria, Am. J. Public Health 73, 1310-2
47. Wilson E, Brooks B, Tweed WA, 1983, CPR skills retention of lay basic rescuers, Ann. Emerg. Med. 12, 482-4

48. Chin D, Morphet J, Coady E, Davidson C, 1997, Assessment of cardiopulmonary resuscitation in the membership examination of the Royal College of Physicians, J. R. Coll. Physicians Lond. 31, 198-201
49. Nordergraaf GJ, Be WKm Sabbe M, Diets RF, Noordergraaf A, Van Hemelrijck J, Training needs and qualifications of anesthesiologists not exposed to ALS, Resuscitation 43, 79-80
50. Bell JH, Harrison DA, Carr B, 1995, Resuscitation skills of anesthetists, Anesthesia 50, 1094
51. Devlin M, An evaluative study of the basic life support skills of nurses in an independent hospital, J. Clin. Nurs. 8, 201-5
52. Wenzel V, Lehmkuhl P, Kubilis PS, Idris AH, Pichlamayr I, 1997, Poor correlation of mouth-to-mouth ventilation skills after basic life support training and 6 months later, Resuscitation 35, 129-34
53. Berden HJ, Bierns JJ, Willems FF, Hendrick JM, Pijls NH, Knape JT, 1994, Resuscitation skills of lay public after retraining, Ann. Emerg. Med. 23, 1003-8
54. Brennan RT, Braslow A, 1998, Skill mastery in public CPR classes, Am. J. Emerg. Med. 16, 653-7
55. Amith G, 1997, Revising educational requirements: challenging four hours for both basic life support and automated external defibrillators, New Horiz. 5, 167-72
56. Crunden EJ, 1991, An investigation into why qualified nurses inappropriately describe their own cardiopulmonary resuscitation skills, J. Adv. Nurs. 16, 597-605
57. Smith J, Ryan K, Phelan D, McCarroll M, 1993, Cardiopulmonary resuscitation skills in non consultant hospital – the Irish experience, Ir/ J. Med. Sci. 162, 405-7
58. Roach CL, Medina FA, 1994, Paramedic comfort level with children in medical and trauma emergencies: does the PALS course make a difference. Am. J. Emerg. Med. 12, 260-2
59. Tweed WA, Wilson E, Isfeld B, 1980, Retention of cardiopulmonary skills after initial overtraining, Crit. Care. Med. 8, 651-3
60. Pottle A, Brant S, 2000, Does resuscitation training affect outcome from cardiac arrest. Accid. Emerg. Nurs. 8, 46-51
61. Haynes BE, Pritting J, 1999, A rural emergency medical technician with selected advanced skills. Prehosp. Emerg. Care 3, 343-6
62. Pullum JD, Sanddal ND, Obinok K, 2000, Training for rural prehospital providers: a retrospective analysis from Montana. Prehosp. Emerg. Care 3, 231-238
63. Yager JW, Kelsh MA, Zhao K, Mrad R, 2001, Development of an occupational illness and injury database for the electric energy sector, Appl. Occup. Environ. Hyg. 16, 291-4
64. Piantanida NA, Knapik JJ, Brannen S, O'Connor F, 2000, Injuries during Marine Corps officer basic training, Mil. Med. 165, 515-20
65. Shaffer RA, Brodine SK, Ito SI, Le AT, 1999, Epidemiology of illness and injury among US Navy and Marine Corps female training populations, Mil. Med. 164, 17-21
66. Thornton R, Lubbock J, 1997, Survey of occupational military environment, Occup. Med. 47, 468-72
67. Lincoln AE, Smith GS, Baker SP, 2000, The use of existing military administrative and health databases for injury surveillance and research, Am. J. Prev. Med. 18 (3 Suppl.), 8-13
68. Ely EW, Moorehead B, Haponik EF, 1995, Warehouse workers' headache: emergency evaluation and management of 30 patients with carbon monoxide poisoning, Am. J. Med. 98, 145-55
69. Lim MK, 1994, Occupational heat stress, Ann. Acad. Med. Singapore 23, 719-24
70. Onuba O, 1991, Medical problems in off-shore oil drilling in Nigeria, J. Soc. Occup. Med. 41, 77-9

71. Vernon SW, Cooper SP, Morris RD, Buffler PA, Key MM, Bradley BL, 1991, Physicians' management of health effects related to industrial exposures: two case report. Tex. Med. 87, 87-7
72. Crawford SS, 1967, The emergency duties of the industrial nurse, Nurs. Clin. North Am. 2, 271-83
73. van Sprundel M, 1996, Training in first aid at the workplace, Bull. Inst. Marit. Trop. Med. Gdynia 47, 45-51
74. Su E, Schmidt TA, Mann C, Zechnich AD, 2000, A randomized controlled trial to assess decay in acquired knowledge among paramedics completing a pediatric resuscitation course, Acad. Emerg. Med. 7, 779-786
75. Frederick CS, O'Brien K, Jui S, Schmidt TA, 1993, Job satisfaction of paramedics: the effects of gender amd type of agency of employment. Ann. Emerg. Med. 22, 657-62
76. Su E, Mann NC, McCall M, Hedges JR, 1997, Use of resuscitation skills by paramedics caring for critically injured children in Oregon. Prehosp. Emerg. Care 1, 123-7
77. Losek JD, Szewcauga D, Glaeser PW, 1994, Improved prehospital pediatric ALS care after an EMT-paramedic clinical training course. Am. J. Emerg. Med. 12, 429-32
78. Spaite DW, Karriker KJ, Seng M, Conroy C, Battaglia N, Tibbits M, Meislin HW, Salik RM, Valenzuela TD, 2000, Increasing paramedics' comfort and knowledge about children with special health care needs. Am. J. Emerg. Med. 18, 747-52
79. Skelton MB, McSwain NE, 1977, A study of cognitive and technical skill deterioration among trained paramedics. JACEP 6, 436-8
80. Pullum JD, Sanddal ND, Obinok K, 2000, Training for rural prehospital providers: a retrospective analysis from Montana. Prehosp. Emerg. Care 3, 231-238
81. Kaye W, Mancini ME, Rallis SF, 1987, Advanced cardiac life support refresher course using standardized objective-based Mega Code testing. Crit. Care Med. 15, 55-60
82. Rubens AJ, Stoy W, Piane G, 1995, Using interactive videodisc to test advanced airway management skills. Prehosp. Disaster Med. 10, 251-8
83. Rubens AJ, 1991, Testing airway management skills: interactive video courseware vs. ACLS instructor. Respir. Care. 36, 849-56
84. Xie ZZ, Chen JJ, Scamell RW, Gonzales MA, 1999, An interactive multimedia training system for advanced cardiac life support. Comput. Methods Programs Biomed. 60, 117-31
85. Christenson J, Parrish K, Barabe S, Noseworthy R, Williams T, Geddes R, Chalmers A, 1998, A comparison of multimedia and standard advanced cardiac life support learning. Acad. Emerg. Med. 5, 702-8
86. Schwid HA, Rooke GA, Ross BK, Sivarajan M, 1999, Use of computerized cardiac simulator improves retention of advanced cardiac life support guidelines better than textbook review. Crit. Care Med. 27, 821-4
87. Yamamoto LG, Wiebe RA, 1989, Pediatric and adult emergency management assistance using computerized guidelines. Am J. Emerg. Med. 7, 91-6
88. Loube J, 2001, Why simulation and training. MS&T 1, 3
89. Huthmann J, 2001, Training for the silent fleet. MS&T 1, 32-33
90. von Lubitz DKJE, Beier KP, Levine H. et al., 2000, Medical Readiness Trainer: Semper Fidelis et Semper Paratus, US Army Smart Conference Proceedings, Los Angeles, January 26-28
91. von Lubitz DKJE, Montgomery JA, Russell W, 2000, Medical readiness training: just in time. Navy Med. 2, 24-27
92. Kapur PA, Steadman RH, 1998, Patient simulator competency testing: ready for take off? Anesth. Analg 89, 1157-9

93. Issenberg SB, McGaghie WC, Hart IR, Mayer JW, Felner JM, Petrusa ER, Waugh RA, Brown DD, Safford RR, Gessner IH, Gordon DL, Ewy GA, 1999, Simulation technology for health care professional skills training and assessment. JAMA 282, 861-6
94. von Lubitz DKJE, Deegan T, Beier KP, Freer JA, Levine H, Pletcher T, Treloar D, Wilkerson W, Wolf E, 2001, Simulation-based medical training: the Medical readiness trainer concept and the preparation for civilian and military medical field operations. In Proc. Laval Conf. on Virtual Reality "LavalVirtual" (Ed. S. Richir), Angers (France), May 15-18, in press
95. Morgan PJ, Cleave-Hogg D, 2000, Evaluation of medical students' performance using the anesthesia simulator. Med. Educ. 2000 34, 42-5
96. Sanders J, Haas RE, Geisler M, Lupien AE, 1998, Using the human simulator to test the efficiency of an experimental emergency percutaneous transtracheal airway. J. Mil. Med. 163, 544-51
97. O'Donnell J, Fletcher J, Dixon B, Palmer L, 1998, Planning and implementing an anesthesia crisis resource management course for student nurse anesthetists. CRNA 9, 50-8
98. Small SD, Wuertz RC, Simon R, Shapiro N, Conn A, Setnik G, 1998, Demonstration of high-fidelity simulation team training for emergency medicine. Acad. Emerg. Med. 6, 312-323
99. Byrne AJ, Jones JG, 1997, Inaccurate reporting of simulated critical anesthetic incidents. Br. J. Anesth. 78, 637-41
100. Devitt JH, Rapanos T, Kurrek M, Cohen MM, Shaw M, 1999, The anesthetic record: accuracy and completeness. Can. J. Anesth. 46, 122-8
101. Von Lubitz DKJE, Pletcher T, Treloar D, Freer JA, Levine H, Wilkerson W, Wolf E, 1999, Human Patient Simulator (HPS)-based teletraining aboard a ship in mid-Atlantic: a radical example of new emergency medicine training technology suitable for training and education in remote regions. Proc. SAEM Conf. Ann Arbor, MI, 22-24 Sept. 1999
102. Von Lubitz DKJE, French A, Montgomery J, Pletcher T, Treloar D, Freer JA, Levine H, Wilkerson W, Wolf E, 2001, Medical training at sea using human patient simulators: a new approach to the acute problem of maintenance of skills, Abstr., Intl. Meeting on Medical Simulation, STA 2001, Scottsdale, AZ, January 2001, in press
103. Todd KH, Braslow A, Brennan RT, Lowery DW, Cox RJ, Lipscomb LE, Kellerman AL, 1998, Randomized, controlled trial of video self-instruction versus traditional CPR training. Ann. Emerg. Med. 31, 364-9
104. Brennan RT, Braslow A, 2000, Video self-instruction for cardiopulmonary resuscitation. Ann. Emerg. Med. 34, 730-7
105. Batcheller AM, Brennan RT, Braslow A, Urrutia A, Kaye W, 2000, Cardiopulmonary resuscitation performance of subjects over forty is better following half-hour video self-instruction to traditional four-hour classroom training. Resuscitation 43, 101-10
106. Todd KH, Braslow A, Brennan RT, Lowery DW, Cox RJ, Lipscomb LE, Kellermann AL, 1998, Randomized, controlled trial of video self-instruction versus traditional CPR training, Ann. Emerg. Med. 31, 364-9
107. Atkinson PR, Bingham J, McNicholl BP, Loane MA, Wootton R, 1999, Telemedicine and cardiopulmonary resuscitation: the value of video-link and telephone instruction to a mock bystander, J. Telemed. Telecare 5, 242-5
108. Capone PL, Lane JC, Kerr CS, Safar P, 2000, Life supporting first aid (LSFA) teaching to Brazilians by television spots, Resuscitation 47, 259-65

Copyright MedSMART Inc., 27th March 2002

109. Morgan CL, Donnely PD, Lester CA, Assar DH, 1996, Effectiveness of the BBC's 999 training roadshows on cardiopulmonary resuscitation: video performance of cohort of unforewarned participants at home six months afterwards, BMJ 313, 912-6
110. Romano DM, Brna P, Self JA, Collaborative decision making snd presence in shared dynamic virtual environment. http://cbl.leeds.ac.uk/~daniela/Collaborative_DM_and_Presence.html
112. Xiao Y, Mackenzie CF, and the LOTAS Group, Decision making in dynamic environments: fixation errors and their causes http://www.anesthesia.umm.edu/research/HF/fixation/fixation.html

ACKNOWLEDGMENTS

MedSMART, Inc. wishes to express their gratitude to Leardal USA, Inc., particularly Mr. David Johnson and Mr. Rick Ritt, for their continuous generosity and unfailing support that made the operations described in this paper possible. Similarly, without the help and innovative approach to the daunting issues of telecommunications that faced and face MedSMART provided by the staff of DigitalRealm, Inc., Ann Arbor, USA, the world of medical training at a distance would still be faltering. Finally, Citirx, Inc. of Ft. Lauderdale, Fl. USA, provided the necessary financial resources. That too was essential!

Additional details on MedSMART, Inc. and its worldwide range of activities, please contact Ms. Yvonne Acosta Arbona, President&CEO, at info@med-smart.org