HIGH FIDELITY HUMAN PATIENT SIMLATION TRAINING IN TRAUMA AND EMERGENCY MEDICINE – DISTRIBUTED MULTIPLATFORM ENVIRONMENTS IN A DISTANCE LEARNING SETTING

Dag K.J.E. von Lubitz, MedSMART, Ann Arbor, MI 48114, USA; Benjamin Carrasco, MedSMART, Ann Arbor, MI 48114, USA; Howard Levine, MedSMART, Ann Arbor, MI 48114, USA; Tim McClelland, Medical Plastics Laboratory, Inc., Gatesville, TX 76528; Caleb Poirier, MedSMART, Ann Arbor, MI 48114, USA; Simon Richir, ISTIA Innovation, University of Angers, F 4900, France

ABSTRACT

Simulation devices represent the latest and unquestionably the most efficient adjunct in the complex process of education and subsequent "refresher" training of medical personnel. It allows safe of diagnostic and manual skills in a setting that is not affected by ethical dilemmas, it does not endanger the patient, allows non-punitive "learning from mistakes", and, finally, helps in the development of cohesive multidisciplinary medical teams. However, both simulation devices and the facilities in which they are housed are expensive, require dedicated personnel, and space. Primarily for these reasons, but also because of the distance from the training centers, many medical professionals, particularly those working in rural and remote regions have practically no access to simulation-based training. The fiscal and logistic barriers can be overcome by the implementation of the already existing distance simulation methods. However, whenever High Fidelity Patient Simulators are used in a multi-unit training environment (e.g., mass casualties) the problems of simulator incompatibility may introduce major problems in the orchestration and control of the simulated events. The paper discusses the issues involved in simulation-based training in which multiple simulators are involved and where ultra-long distances separate the trainees from the simulator facilities.

Key words: medical simulation, medical readiness, medical education, distance learning, simulation, EMS, Internet, high fidelity patient simulators

Simulation and medical training

In similarity to aviation, large-scale introduction of simulation-based training [1,2] may result in significant progress towards reduction of diagnostic and procedural errors, improvement of confidence and preparedness, and enhanced medical readiness [3,4,5,6]. Thus, even if detailed studies are needed to prove the point, systematic introduction of simulation as a standard educational tool may have a substantial and positive impact on the quality of both training and subsequent professional performance of both individuals [7,8,9,10,11,12] and medical teams [13,14] with improvement of patient safety to follow [15,16,17,18].

Our previous publications [18,19,20,21] have extensively discussed the need for simulation-based training of medical personnel and the problems associated with such training. The conceptual incompatibility of the existing training platforms ("solid" simulation devices such as High Fidelity Patient Simulators versus VR-based devices) has been successfully overcome by the creation of a "medical flight simulator" [18,19,20,22] in which High Fidelity Patient Simulator (METI) has been incorporated as a centerpiece of a dynamic VR-rendered environment (CAVE) of a busy emergency room – the Medical Readiness Trainer (MRT, Fig. 1). While MRT served only as a concept demonstrator, other investigators using procedure training devices provided convincing evidence of the efficacy of training performed in VR environments [23,24,25]. Even more importantly, highly complex "total VR" surgical training systems have been developed and tested during the past few years [26] indicating the direction of the training trend at large centers of academic medicine. The other, and just as useful end of the medical simulation spectrum is represented by the increasingly very sophisticated High Fidelity Patient Simulators (HFPS) and less complex single-procedure simulators. HFPS units (Fig. 2) are preeminently suitable to train medical personnel at all levels of expertise [27] in rapid diagnosis and management of complex emergency and trauma events. The machines provide a highly realistic output that is largely similar to that seen in a real-life setting, allow use of the identical instruments to those used in the clinical environment, and even allow administration of drugs with the physiological responses changing appropriately. While significantly simpler and cheaper both in setting up and use compared to VR-based systems, HFPS units are nonetheless sufficiently complex to require dedicated support personnel. Like VR-based training devices, efficient operation of HFPS requires dedicated space. Finally, despite decreasing acquisition price (the phenomenon that also characterizes VR environments) the purchasing costs are considerable. Combined, the operating expenses and the complexity of a training center may be significant [28,29] and, typically, put its creation beyond the means of smaller organizations [30]. Expanded use of simulating devices in teaching pre-clinical subjects, use in non-traditional setting e.g., training of veterinarians [31], physiology education [32] or pharmacology [unpublished] will significantly broaden their applicability across several disciplines and may spread the expenditure more evenly. Highly innovative operational framework of training centers [27] may help to reduce the immediate costs even further. Nonetheless, the obstacles of not only cost but also broad-based accessibility indicated above remain and significantly limit the reach of simulation-based education [27]. During the past 4 years we have proposed, developed and tested under routine operational conditions a new approach intended to breach the tradition of stationary simulation centers and make simulation-based medical training available to essentially anyone with an Internet connection [30,33,34]. The concept is based on a free access to the central simulation facility and its HFPS machines from a remote site located anywhere in the world, and the ability to train under the guidance of a centrally located expert teacher. The HFPS are under the local control of the teaching expert that can be relinquished and passed over to the remote trainees who then assume completely interactive remote control of the device. Despite its demonstrable usefulness [33,34], the operational usefulness of the concept was limited due to the problems in operating successfully more than a single HFPS unit. The capability of operating several HFPS becomes essential when training involves mass casualties, and when the machines used as the constituents of the training federation [35] are the product of more than one manufacturer.

Multi-platform environment

When several dispersed HFPS units are controlled from a central training facility Fig. 3] or accessed by the remote learners, the only means to ensure uniformity of training is to make it independent of both physical and operational characteristics of the simulation devices. This is particularly important when the training center has the overriding remote control of all distributed HPFS units, or when it serves as the "expertise center" [34,36,37] during simultaneous training of large numbers of learners isolated by geographical distances, e.g., in multi-simulator training of dispersed medical intervention teams (e.g., just-in-time preparation for mass casualties caused by the acts of terrorism, natural disasters, etc., see ref. 16)**.**

While the two principal HFPS systems in existence (Laerdal and METI, Fig. 2) have practically identical anatomical features and generate very similar profile of training-relevant output, the conceptual basis of their software/hardware interaction differs significantly. As a result of these differences, combining both systems into a unified, remotely accessible training environment poses practical difficulties. In the simplest setting of multiple simulators produced by the same manufacturer, all devices can be easily slaved to the same high speed CPU/high RAM control computer located at the central training facility allowing simultaneous or individual remote operation of the federated HFPS units. However, central simultaneous remote control of dispersed, collaborating simulators built by different manufactures is severely impeded by software incompatibility of the machines. From the medical point of view, voice commands given by the remote trainee to the personnel at the simulator host site (e.g., the central training facility) are the most realistic. The procedure approximates the routine approach of medical team personnel during real-life activities. The use of separate computers dedicated solely to the control of the identical brand federation of HFPS units provides another simple solution. Yet, it must be also remembered that in a fast-paced environment of a multi-patient scenario, such control, particularly if remotely executed by the trainees with little or no background in computer operations, may become very cumbersome. Consequently, trainees' attention may rapidly shift from the main subject (medical training) to the frantic attempts at mastering unfamiliar technology that will, in turn, significantly erode the realism and deteriorate effectiveness of training. Simulator-bridging software that automatically translates commands given from the control interface of one system into the commands that are understood by the simulator of a different and otherwise incompatible brand is the most effective solution. It is also technically the most complex since, in the absence of commercially available products, the software bridge must be developed as a private venture of the competent staff at the user's facility. It becomes readily apparent that, from the technical and fiscal point of view, the most suitable placement of the software bridge is at the central (hub) control facility at which all signal processing takes place. The solution is identical to the concept of Medical Application Software Provider (Med-ASP) that we proposed in one of our earlier publications [27]. Implementation of the ASP concept simplifies signal traffic and, by providing its more effective processing, and eliminates the annoying time lags that may render distance-based simulation training exceedingly unrealistic. Med-ASP concept assures that only the meaningful commands are passed within the simulator federation and also that exchange occurs at the maximum speed allowed by the available bandwidth.

Access and remote simulator control

Access from the periphery to the central facility and vice versa can be obtained either by using point-to-point connectivity, with each remote site having its own IP address and an allocated fast Internet connection, dedicated ISDN lines, or through a Web-based portal hosted at the central training facility. The Internet-based access without Quality of Service (QOS), although the simplest one, may become unreliable during extended (more than 1 hr) continuous transmission due to frequent connection interruptions and slow-downs, or up- and down-load loss of transmission speed. These problems are particularly annoying during long- or very long distance operations (e.g., transcontinental. or global.) Work in which ISDN-lines are routinely used is also the most expensive. Access through a Web portal necessitates its creation – a matter of technical complexity that is best accomplished by the technical personnel at the central simulation facility serving as a Med-ASP organization. However, with the portal located at the servers of the training facility, and with the significant part of the operational software necessary for the efficient training (HFPS control/translation software; remote camera control software, training scenario programs, etc.) accessible through such portal, multi-site activities become greatly facilitated. The peripheral sites are provided with a simple, intuitively understood simulator control interface displayed at the remote computer monitor and the operation of the simulator is performed either via point-and-click mouse interaction or, at a more sophisticated level, by touching appropriate controls on the touch-sensitive screen.

In summary, one of the principal roles of the central training facility is that of a broad-concept ASP that, in addition to standard training activities aimed at a large number of distributed learners, provides simulation-centered software, supplies supporting electronic training elements, e.g., access to more traditional didactic tools, archives of previous simulation-based courses, testing materials, etc. In such configuration, prior experience indicates that transmission speeds of 128 Kbs are adequate to fulfill all the required tasks without any deterioration in the quality of image/voice/data elements.

Practical operations

For practical purposes, testing of the distributed multi-simulator training concept was conducted using two simulators. During operations between Ann Arbor, MI, USA and Laval, France two SimMan (Laerdal) HFPS units were used. One HFPS was located at the training center of MedSMART, Inc. in Ann Arbor while the second simulator was placed at the city exposition hall in Laval, France. The participants in Ann Arbor could interact with the conference participants (trainees) in Laval over a two-way real-time interactive video-conference, with full screen, full motion video and high-quality audio. The same principles were used during subsequent series of training exercises performed at the Alpena (MI, USA) Medical Readiness Training Center of the Air National Guard (Fig. 4). In the latter case two HFPS units manufactured by Laerdal, Inc. and METI, Inc. were used. Also, during the activities in Alpena, due to the concerns posed by opening of military network to civilian traffic, training was performed using a dedicated high-speed LAN as the telecommunications link between two simulators placed at physically separated locations. In either case, real-time interactivity and simulator control were accomplished by using high-end video conferencing systems at each location, with an ADSL Internet connection bridging the French and the US sites. In the latter case ADSL Internet connection was selected based on the intention to test the performance of the relatively unsophisticated telecommunication link that would be relatively common at technically less advanced locations but offered both the simplicity of set-up and an acceptable stability during the transatlantic operations. These considerations notwithstanding, it must be remembered that HFPS remote control can be implemented over any type of wide area link, including a standard telephone connection [33], dedicated private line [33,34], or via the Internet [36, and in preparation; and the section on training for First Responders at www.med-smart.org].

During Internet-based operations, one of the critical factors was the dependence of the overall quality of the sound and image on the bandwidth (speed) and latency (delay) of the Internet connection. A minimum of 128 kilobits per second sustained transfer rate is required for real-time video conferencing. If the round-trip latency exceeds 200 milliseconds, then the conference participants will notice a delay in the conversation, similar to the delay encountered over a satellite telephone call. Constant measurement of latencies and bandwidth variation between Laval and Ann Arbor indicated a relatively low average latency (below 100 milliseconds round trip), while sufficient average bandwidth (sustained >300 Kb/sec.) As a result, we were able to conduct contiguous, uninterrupted sessions lasting up to 4 hrs each assuring, at the same time, that the remote trainees had a very high quality learning experience based on a fully interactive simulation technology.

Each HFPS was under both local and full remote control from either site, i.e., the technician in Ann Arbor could manipulate the HPS in France, and vise-versa. Multi-site remote control of the machines was made possible through the implementation of a proprietary process developed by MedSMART. Proprietary software based on digitized physiological outputs of one simulator as the controlling element of driving the other unit was loaded into the memory of the computers controlling HFPS mannequin at either location. The machines were then programmed to allow either concerted or independent action with the operational control seamlessly transferable between the operator stations in Ann Arbor and Laval. The approach allowed a significant degree of flexibility permitting the introduction of unpredictable and confounding events. The latter were used to enforce upon the trainees the sense of medical realism and urgency demanding immediate action, significant modification of the original patient management plan, or even the need for complete diagnostic reevaluation. In order to facilitate generation of such events, the vital signs and all other pertinent patient data were projected both the local and the remote computer screen. With all pertinent information displayed on the control monitors, the remote technician was able to manipulate both HFPS units, interrupt their pre-programmed routines and insert ad-hoc events (e.g., noise in EEG leads, failure of a monitoring device, abnormal drug response, etc.) in a physiologically correct manner, or let the pre-programmed scenarios run their full course without any intervention at all.

Conclusions

The experiments described in this paper show that a successful HFPS network can be created with a moderate ease, and that the network can perform effectively at very large distances (over 7000 km between Laval and Ann Arbor.) While less sophisticated than pure VR-based medical training systems, HFPS networks utilizing concepts of Advanced Distributed Learning (ADL) are significantly cheaper to operate and maintain than VR-based federations. Hence, they are also much more readily available to the medical personnel operating in the environments with limited access to fiscal and intellectual resources that highly advanced VR technology requires. In similarity to VR-based medical training devices [23,24,25,38], both individual HFPS units and ADL networks utilizing them offer sufficiently high level of versatility and the associated "suspension of disbelief" to create highly efficient training tools [34,38,39,40]. Both VR and HFPS approaches to medical simulation have their advantages and disadvantages. Combining both may lead to a significant enhancement of both the efficacy and intensity of training [19,37] and convert the present, largely explorative arena of medical simulation into an indispensable tool that simulation provides today in practically all aspects of aviation and maritime education and training.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Laerdal USA and MPL, Inc., particularly of Mr. David Johnson and Mr. Rick Ritt whose assistance made our work possible. We are grateful to the Mayor of the City of Laval and the Organizing Committee of Laval Virtuel for supporting our experiments and operations in France. Finally, our gratitude to MAJ. J. Kirk, USAF and his staff at Alpena ANG Station who were instrumental in allowing us to conduct the "impossible" at their training facilities.

Correspondence to: DvL, MedSMART, Inc. Suite 260, 220 E. Huron Street, Ann Arbor, MI 48114, USA; info@med-smart.org

References

1. Isenberg SB, Gordon MS, Safford RE, Hart IR, 2001, Simulation and new learning technologies, Med.Tech. 23,16-23
2. Karnath B, Frye AW, Holden MD, 2002, Incorporating simulators in a standardized patient exam, Acad. Med.77, 754-5

3. Morgan PJ, Cleave-Hogg D, 2002, Comparison between medical students' experience and competence, Med. Educ. 36, 534-9

4. Hammond J, Bermann M, Chen B, Kushins L, 2002, Incorporation of a computerized human patient simulator in a critical care training: a preliminary report, J. Trauma 53, 1064-7

5. 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

6. Marshall RI, Smith JS, Gorman PJ, Krummel TM, Haluck RS, Conney RN, 2001, Use of human patient simulator in the development of resident trauma management skills, J. Trauma 51, 17-21

7. King PH, Pierce D, Higgins M, Beattie C, Waltman LB, 2000, A proposed method for the measurement of anesthetist care variability, J. Clin. Monit. Comput. 16, 121-5

8. Weller JM, Bloch M, Young S, Maze M, Oyesola S, Wyner J, Dob D, Haire K, Durbridge J, Walker T, Newble D, 2003, Evaluation of high fidelity human patient simulator in assessment of performance of anaesthetists, Br. J. Anaesth. 90, 43-7

9. Forrest FC, Taylor MA, Postlethwaite K, Aspinall R, 2002, Use if high fidelity simulator to develop testing of the technical performance of novice anaesthetists, Br. J. Anaesth. 88, 338-44

10. Block EF, Lottenberg L, Flint L, Jakobsen J, Liebnitzky D, 2002, Use of human patient simulator for the advanced trauma life support course, Am. Surg. 68, 648-51

11. Watterson L, Flanagan B, Donovan B, Robinson B, 2000, Anaesthetic simulators: training for the broader care health-care proession, Aust. N.Z. J .Surg. 70, 735-7

12. Rosenblatt MA, Abrams KJ, NY State Soc. Annesthesiol. Inc, Comm. Contd. Med. Educ. And Remed., Remed. Sub-Comm, 2002, The use of a human patient simulator in the evaluation and development of a remedial prescription for an anesthesiologist with lapsed medicalskills, Anesth. Analg. 94, 149-53

13. Holcomb JB, Dumire RD, Crommett JW, Stamateris CE, Fagert MA, Cleveland JA, Dorlac GR, Dorlac WC, Bonar JP, Hira K, Aoki N, Mattox KL, 2002, Evaluation of trauma team performance using an advanced human patient simulator for resuscitation training, J. Trauma 52, 1078-85

14. Murray WB, Foster PA, Crisis resource management among strangers: principles of organizing a multidisciplinary group for crisis resource management, J. Clin. Anest. 12, 633-8

15. Gordon JA, Wilkerson WM, Shaffer DW, Armstrong EG, 2001, "Practicing" medicine without risk: students' and educators' responses to high-fidelity patient simulation, Acad. Med. 76, 469-72

16. Murray D, Boulet J, Ziv A, Woodhouse J, Kras J, McAllister J, 2002, An acute care skills evaluation for graduating medical students: a pilot study using clinical simulation, Med. Educ. 36, 833-41

17. Rall M, Schaedle B, Zieger J, Naef W, Weinlich M, Innovative training for enhancing patient safety. Safety culture and integrated concepts, Unfallchirurg 105, 1033-42

18. Fellander-Tsai L, Stahre C, Anderberg B, Barle H, Bringman S, Kjellin A, Ramel S, Strinnlund B, Carlson C, Wredmark T, 2001, Simulator training in medicine and health care: a new pedagogic model for good patient safety, Laekertidn. 98, 3772-6

19. von Lubitz DKJE.and the MRT Team, 2000, Medicine in the Village: technology, health, and the world. In IEEE Proc. "Conf. on Extra skills for Young Engineers" Symposium, B. Vlasovic, A. Cesar, R. Meolic, F.S. Balan (Eds), Maribor Univ. Press., pp. 27-33

20. Von Lubitz DKJE, Pletcher T, Treloar D, Wilkerson W, Wolf E, 2000, Immersive virtual reality platform for medical training: a "killer application", in Medicine Meets Virtual Reality 2000 ((ed. Williams, J., et al), IOS Press, Amesterdam

21. von Lubitz DKJE, Freer J, French A, Hawayek J, Montgomery J, Levine H, Wolf E., 2001, Autostereoscopy in medical telepresence: the Medical Readiness Trainer experience. Procedings of HEALTHCOM 2001, 3rd Intl. Workshop on Enterprise, Networking, and Computing in Healthcare Industry (Eds. F. Patricelli, P.K. Ray), Scuola Superiore G. Reiss Romoli, L'Aquila, Italy, June 29 – July 2001, 61- 76, ISBN 88-85280-53-6

22. von Lubitz DKJE, 2002, EMERGENCY! Medicine and Modern Education Technology, Proceedings Intl Conf. on Internet, Business, Science, and Medicine, L'Aquila, August 2002, CD-ROM, SSGRR (L'Aquila), ISBN 88-85280-63-3

23. Agazio JB, Pavlides CC, Lasome CE, Flaherty NJ, Torance RJ, 2002, Evaluation of a virtual reality simulatorin sustainment training, Mil. Med. 167, 893-7

24. Seymour NE, Gallagher AG, Roman SA, O'Brien VK, Bansal VK, Andersen DK, Satava RM, 2002, Virtual reality training improves operating room performance: results of a randomized, double-blinded study, Ann. Surg. 236, 458-63

25. Gallagher AG, Satava RM, 2002, Virtual reality as a metric for the assessment of laparoscopic skills> Learning curves and reliability measures, Surg.Endosc. 16, 1746-52

26. Caudell TP, Summers KL, Holten J 4th, Hakamata T, Mowafi M, Jacobs J, Lozanoff BK, Lozanoff S,Wilks D, Keep MF, Saiki S, Alverson D, 2003, Virtual patient simulator for distributed collaborative medical education, Anat. Res. 270B, 23-9

27. Lary MJ, Pletcher T, von Lubitz, DKJE, 2003, Distance-based mass medical readiness training for prehospital providers, SSGRR Internet Conference, L'Aquila, Italy
http://www.ssgrr.it/en/ssgrr2003s/panel.htm

28. Morgan PJ, Cleave-Hogg DM, 2001, Cost and resource implications of undergraduate simulator-based education, Can. J. Anaesth. 48, 827-8

29. Schaefer JJ 3rd, Grenvik A, 2001, Simulation-based training at the University of Pittsburgh, Ann. Acad. Med. Singapore 30, 274-80

30. Von Lubitz DKJE, Levine H, Wolf E. 2002, The Goose, the Gander, or the Strasbourg Paté for All: Medical Education, World, and the Internet. In Electronic Business and Education: recent Advances in Internet Infrastructures (W, Chin, F. Poatricelli, V. Milutinovic, Eds.), Kluwer Acad. Publ. (Boston), pp. 189-210

31. Modell JH, Cantwell S, Hardcastle J, Robertson S, Pablo L, 2002, Using human patient simulator to educate students of veterinary medicine,J.Vet.Med. Educ. 29, 111-6

32. Tan GM,Ti LK,Suresh S, Ho BS, Lee TL, Teaching first-year medical students physiology: does human patient simulator allow more effective teaching? Singapore Med.J. 43, 238-42

33. Treloar, D, K.P. Beier, J. Freer, H. Levine, D.K.J.E. von Lubitz, W. Wilkerson, E. Wolf, 2001, On site and distance education of emergency medicine personnel with a human patient simulator, J. Mil. Med, 166, 1003-6

34. von Lubitz DKJE, Carrasco B, Gabbrielli F, Levine H, Levine R, Ludwig T, Poirier C, 2003, Transatlantic medical education: preliminary data on distance-based high fidelity human patient simulation training. Medicine Meets Virtual Reality 2003 (J. Westwood, ED), IOS Press (Amsterdam), pp. 379-85

35. Proctor MD, Creech GS, 2001, 2001, Object-oriented modeling of patients in a medical federation, IEEE Trans. Inf. Technol. Biomed. 5, 244-7

36. von Lubitz DKJE, Montgomery J, Russell W, 2000, Just in time training: emergency medicine training aboard a ship. Navy Medicine 3-4, 24-28

37. von Lubitz DKJE, 2002, EMERGENCY! Medicine and Modern Education Technology, Proceedings Intl Conf. on Internet, Business, Science, and Medicine, L'Aquila, August 2002, CD-ROM, SSGRR (L'Aquila), ISBN 88-85280-63-3

38. Myjak MD,Rosen J, 2001, MEDNET: a medical simulation network grand challenge, Stud. Health. Technol. Inform. 81, 341-7

39. Bloom MB, Rawn CL,Saltzberg AD, Krummel TM, 2003,Vrtual reality applied to procedural training, Ann. Surg. 237, 442-8

40. Pittini R,Oepkes D, Macrury K, Reznick R, Beyene R, Windrim R, 2002, Teaching invasive perinatal procedures: assessment of a high fidelity simulator-based curriculum, Ultrasound Obstet. Gynecol.19, 478-83