Early experience with simulated trauma resuscitation

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Although trauma resuscitation is best taught through direct exposure with hands-on experience, the opportunities for this type of teaching in Canada are limited by the relatively low incidence of serious injury and the consolidation of trauma care to a small number of centres. Simulators have been used extensively outside the health care environment and more recently have been used by anesthetists to simulate intraoperative crises. In this paper early experience using a realistic mannequin, controlled by a remote computer, that simulates a variety of physiologic and injury specific variables is presented. The resource implications of simulated resuscitation are reviewed, including one-time and operating costs. Simulated trauma resuscitation may be an educational alternative to "real-life" trauma resuscitation, but careful evaluation of the benefits and resource implications of this type of teaching through well-designed research studies will be important.

Même si l'exposition directe et l'expérience pratique constituent la meilleure façon d'enseigner la réanimation de patients traumatisés, les possibilités de dispenser une telle formation au Canada sont limitées par l'incidence relativement faible des traumatismes graves et le regroupement des soins aux patients traumatisés dans un petit nombre de centres. On utilise beaucoup les simulateurs en dehors du contexte des soins de santé et les anesthésistes s'en servent depuis quelque temps pour simuler des situations d'urgence pendant une intervention. On décrit dans ce document les premières expériences d'utilisation d'un mannequin réaliste, contrôlé à distance par ordinateur, qui simule toutes sortes de variables physiologiques et spécifiques à une lésion. On passe en revue les répercussions de la réanimation simulée sur les ressources, y compris les coûts ponctuels et les coûts d'utilisation. En réanimation de traumatisés, la simulation peut constituer un autre moyen de formation pour remplacer la réanimation de traumatisés «en temps réel», mais il importera d'évaluer attentivement les avantages de ce type d'enseignement et ses répercussions sur les ressources au moyen d'études de recherche bien conçues.

It is generally accepted that the principles and practice of trauma resuscitation are best learned through direct observation at, and participation in, real-life resuscitations. However, this creates a dilemma in a country like Canada where serious injury remains relatively infrequent (even in large tertiary care trauma centres) and the number of health care providers wanting hands-on exposure is high.[1] Currently, there are only 7 trauma centres in Canada that annually assess more than 300 trauma patients having an Injury Severity Score of 16 or greater, so exposure to resuscitation from serious injury is limited.[1,2]

Penetrating injury accounts for less than 15% of all trauma admissions, even in large urban centres, limiting exposure to this unique patient population.[3] Most trauma patients are now appropriately triaged to 1 or 2 centres in most Canadian cities, so only those practitioners working in such centres or trainees who rotate through these centres are exposed to a significant number of seriously injured patients.[1] Health care professionals from a variety of disciplines are therefore in a dif-

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ficult position: they are expected to be competent to care for a hemodynamically unstable, seriously injured patient should one present to their institution when they have had limited hands-on recent exposure to trauma resuscitation.

It is incumbent upon academic trauma centres to educate postgraduate trainees in trauma resuscitation and to provide continuing education for practising physicians and surgeons who may have limited exposure to trauma resuscitation in their day-to-day practice. This educational role is also extended to allied health professionals including nurses, paramedics, radiology technicians and respiratory therapists. Many trauma centres have difficulty ensuring that trainees in their own university-based educational programs (as well as other local programs) receive adequate exposure to resuscitation, and it is often impossible to accept the many requests received for electives from outside centres and for continuing medical education.

Strategies

A number of strategies have been developed to deal with this educational challenge. The most successful program to date has been the Advanced Trauma Life Support (ATLS) program as offered through the American College of Surgeons.[3] The 1997–1998 ATLS course focuses more on simulated patient assessment, and the moulage educational and testing station continue to be the highlight of the course for most students. For many practising physicians and surgeons, the ATLS course may be their only opportunity to refresh their skills for trauma resuscitation, as many will see fewer than 1 seriously injured trauma patient per year.[3,4]

Another strategy, recently introduced, is simulated trauma resuscitation using a realistic mannequin that is controlled by a remote computer (e.g., the METI; Eagle Simulation Inc., Binghampton, NY) that simulates a variety of physiologic and injury-specific variables. The simulator attempts to reproduce or represent exact or nearly exact phenomena likely to occur in the real world. Simulators have been used extensively outside the health care environment by NASA and for commercial aviation, military applications and the nuclear industry.[5–8]

Introducing a simulator

The first specialty to use a simulator for medical purposes was anesthesia. In 1995, the Sunnybrook Health Science Centre (now the Sunnybrook and Women's College Health Sciences Centre) purchased an Eagle simulator and opened a simulation centre for human performance and crisis management training. The simulator has subsequently been used extensively at the centre for simulating intraoperative crises, with a primary focus on training and evaluating anesthetists.[5] A number of studies have been conducted that document the value of simulators for assessing the skills (including the crisis management skills) of an anesthetist in an operating-room setting.[6–8]

It became evident that patient simulators had applications outside the operating room and could be used for simulating trauma resuscitation. In conjunction with surgeons at St. Michael's Hospital in Toronto, Eagle Simulation Inc. has developed upgrades to the original mannequin (designed for operating-room crises) that are specific to the assessment and resuscitation of the trauma patient. The characteristics of the mannequin (including trauma upgrades) that are important for creating a realistic and interactive resuscitation are outlined in Table I.

Table I

Features of the Mannequin Simulator

Physical examination, physiologic and procedural features
Eyelids open and close
Pupillary reaction to light
Unilateral or bilateral movement of arms (flexion, extension)
Breath sounds (normal, reduced or absent, unilateral or bilateral)
Heart sounds
Palpable pulses
Simulated femoral fracture (absent distal pulse becomes normal after reduction)
Voice (through control room)
Intubation (can be made more difficult)
Cricothyroidotomy
Chest tube insertion
Diagnostic peritoneal lavage (percutaneous through port)
Monitoring features
Electrocardiography
Measurement of arterial pressure — invasive and noninvasive
Pulse oximetry
Measurement of end-tidal carbon dioxide

Designing a simulation centre

Early experience with the anesthesia simulator emphasized the importance of realistically reproducing the environment of an operating room and developing clinically relevant and reproducible operating-room scenarios. As a result there are significant space and resource issues that must be considered when operating a simulator.[5–8] The space allocated for the simulating centre at the Sunnybrook and Women's College Health Sciences Centre is shown in Fig. 1. As noted, it is not only necessary to allocate a simulation room (to be set up as an operating room, trauma resuscitation room or emergency department resuscitation area) but also to have a control room and office for the computer equipment necessary to control simulator functions. Optimally, there should be a storage room for the many supplies needed to simulate the various situations and seminar rooms for planning, briefing and debriefing. Fixed video equipment is extremely valuable for taping the "resuscitations" for debriefing and educational purposes. Optionally, the video and audio signals from the cameras are mixed with the output from the physiologic monitor processed through a digital to analog converter. This allows for the overlay of tracings and values from the monitors onto the real-time video of the simulation; this is useful for correlating the hemodynamic status of the patient with the assessment and resuscitation performed.[5]

The simulation room at the centre was originally outfitted as an operating room, including an operating-room table and the standard physiologic monitoring equipment and gas machine used in the actual operating rooms. This simulation room can, however, be rearranged to appear like a trauma resuscitation room or a resuscitation bay in an emergency department. The monitoring and resuscitation equipment used in the trauma room (portable ventilator, monitor, resuscitation trays, portable x-ray equipment and view boxes) can be set up in the simulation room to approximate the environment of a trauma resuscitation room. A wall-mounted telephone in the room allows for direct communication with the operating room, consultants or a receiving physician. Figs 2 and 3 show the trauma team assessing the simulated patient in the specially recreated trauma room.

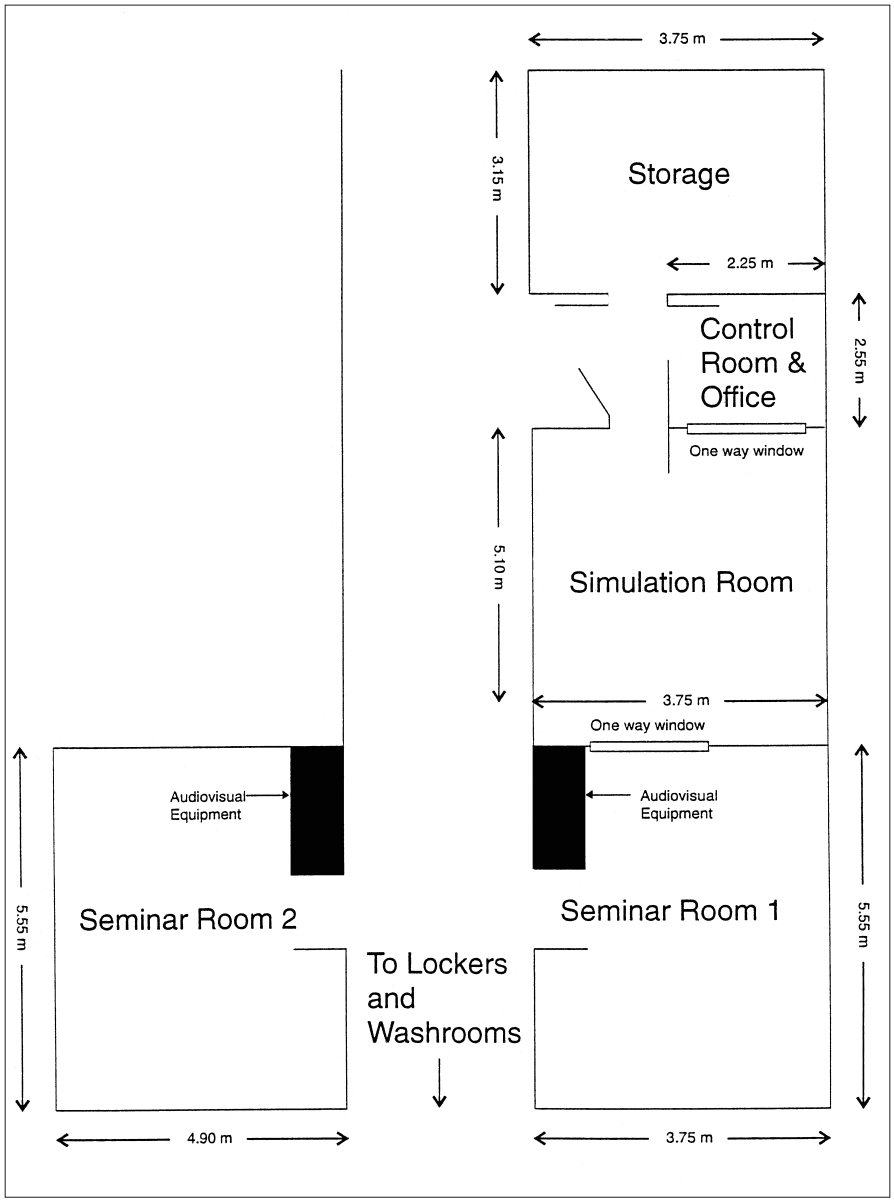

FIG. 1. Floor plan of the simulation centre. The simulation room can be designed to look like an operating room or a trauma resuscitation room. The individual working in the control room can view the resuscitation through a one-way window and through computer guidance can alter the mamnnequin's responses and physiologic variables in response to the assessment and resuscitation. The seminar rooms are used for planning scenarios and briefing and debriefing sessions.

Models of trauma resuscitation in Toronto

The first 2 models of simulated trauma resuscitation that we are aware of were developed at the Sunnybrook Health Science Centre and St. Michael's Hospital in Toronto. At St. Michael's Hospital the focus has been on a "lone resuscitator" model, with a physician working with 1 nurse, very similar to the scenarios used in the ATLS moulage training and testing stations.[3] At Sunnybrook the early focus was on trauma team functions, whereby a simulated patient is assessed and resuscitated by a trauma team, including a trauma team leader, residents from general surgery, orthopedic surgery, neurosurgery and anesthesia, as well as nurses, a respiratory therapist and a radiology technician. These 2 models focus on different but equally important needs. The lone resuscitator model is necessary to educate practitioners who most commonly work in smaller centres where they are expected to resuscitate and stabilize the seriously injured person before transfer to a trauma centre. The trauma team model is important for larger centres where teams are the standard and allows for the additional review of leadership skills and team dynamics.

FIG. 2. A simulated trauma resuscitation. The trauma team leader (white coat) is talking to the anesthesia resident. A surgical resident is performing a percutaneous peritoneal lavage. The x-ray machine is positioned to take a chest film.

FIG. 3. A second trauma resuscitation. The chest is being auscultated. The anesthesia resident is preparing to intubate the patient.

Regardless of whether a lone resuscitator or trauma-team scenario is being developed, there is a significant investment of time and energy in designing and implementing the resuscitation scenarios. It is important first to identify which specific components of the resuscitation are critical and what the desired and acceptable approaches are, as with ATLS scenarios.[3] The scenarios are written up in advance, including changes in vital signs and potential responses of the patient to a variety of different treatment or resuscitation options that may be chosen by the individual participating in the simulation. This allows the person working in the control room to appropriately change the mannequin responses (movement of upper extremities, pupillary reacivity, etc.) and the physiologic variables (i.e., heart rate, blood pressure, oxygen saturation) in response to different treatment choices. The scenarios are complete with radiographs and results of investigations that may be performed. All equipment that may be re-

quested for resuscitation must be available in the event it is needed during the resuscitation. All other members of the team (nurses, other physicians) are scripted so that they can respond to the resuscitation in a predictable fashion; this allows for a standardized assessment of the lone resuscitator or the trauma team member being assessed. Development of a scenario requires approximately 10 hours and team members require 1 to 2 hours of preparation and rehearsal time before the scenario is available for general use. Once this initial time has been invested, the scenario can be used repeatedly. Each scenario is approximately 15 to 20 minutes long, and a training session in the simulator environment could be composed of 2 to 4 scenarios, each emphasizing a different aspect of trauma resuscitation.

The person who works in the control room and who operates the simulator must be skilled in the computer applications and be able to adapt quickly to changes in the resuscitation. Training is available for these operators, focusing on technical and computer skills as well as on the design and evaluation of scenarios. Voice can be projected through the mannequin from the control room and provides an opportunity for the awake "patient" to interact verbally with the trauma team leader or assessing team members throughout the resuscitation.

Early experience using the simulator for trauma resuscitation at both hospitals has been favourable. Those who have been assessed have described the environment as quite realistic. The ability to hear breath sounds, assess pupillary reactivity and feel pulses (in all cases both normal and abnormal) mandates a hands-on approach to assessment. The continuous sounds (including alarm bells) and visual display associated with monitoring of heart rate, blood pressure and oxygen saturation are very important in creating a resuscitation-room environment. The ability to perform procedures such as intubation and chest tube insertion and to splint injured extremities (with return of absent pulses) make the assessment and resuscitation more realistic. Within the limits of scripting the other members of the team it is possible to standardize the case and the responses to resuscitation; one of the real benefits of the simulator is that it allows for a standardized scenario, which potentially can then be used as an evaluation tool. The ability of the trauma team or person being assessed to perform procedures appears to have advantages over the objected structured clinical examination (OSCE) using live volunteers.[5–9]

There have been no formal studies to date to objectively demonstrate that performance improves after subjects have participated in the trauma simulation. This, unfortunately, is consistent with many of the other methods of educating health professionals in trauma resuscitation. Chopra and associates[10] demonstrated an improvement in performance when anesthetists were exposed to anaphylactic shock scenarios on an anesthesia simulator; there is, however, no evidence that this improved performance can be generalized to other clinical situations, including trauma resuscitation. It will be important to objectively demonstrate benefits from simulated trauma resuscitation through well designed research studies, especially considering the cost of the simulator and the significant investment of time and energy to operate a simulator.

Costs of establishing a simulation centre

Limitations or disadvantages of simulated resuscitation include the up-front costs of the simulator, the space requirements and the investment of time and energy on the part of personnel who run the simulator and design the scenarios. The cost of the simulator, including the upgrades for the trauma resuscitation, is approximately $300 000. Dedicated equipment for the room for trauma resuscitation (not critical, but desirable) can cost up to $50 000 (stretcher, monitor, view boxes). Room renovation and office equipment for the seminar space at Sunnybrook and Women's College Health Sciences Centre cost $50 000 and dedicated audiovisual equipment for taping the resuscitations cost an additional $25 000. Ongoing operating costs are primarily attributable to the time investment of the control room operator, those who design scenarios, other participants (team members), and the person who runs the briefing and debriefing sessions.

Comment

There will never a perfect substitute for direct exposure to real-life resuscitation, but it is important that we consider new models of teaching early trauma care. Through programs such as ATLS and new strategies such as the simulator we will be able to expose as many professionals as possible to the principles and practice of trauma resuscitation. The ability to "schedule" resuscitations is a clear advantage, especially in centres where the volume of cases is low and the number of persons seeking exposure is high.

Simulators will likely have an increasing role in health care education. Five years ago there were only 4 simulators in North America; there are currently 4 in Canada with many other centres now planning purchases. Plans are already under way to improve trauma simulation to include ultrasonography for free intraperitoneal fluid or pericardial fluid. Trauma sim-

ulation has many potential applications beyond the operating room and the trauma room, including emergency department and critical care unit resuscitation scenarios. Early experience with trauma simulation suggests that the simulator is a useful additional modality for teaching resuscitation and thereby improving the quality of early trauma care.

References

1. McLellan BA. Mergers, acquisitions and trauma care in the 1990s. *J Trauma* 1998;44(4):575-9.
2. Baker SP, O'Neill B, Haddon W, Long WB. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma* 1974;14:187-96.
3. American College of Surgeons, Committee on Trauma. *Advanced trauma life support program for physicians.* Chicago: The College; 1997.
4. Canadian Institute for Health Information. *Ontario trauma registry annual report.* Toronto: Ontario Ministry of Health; 1996.
5. Kurrek MM, Devitt JH. The cost for construction and operation of a simulation centre. *Can J Anaesth* 1997;44:1191-5.
6. Howard SK, Gaba DM, Fish KJ, Yang G, Sarnquist FH. Anesthesia crisis resource management training: teaching anesthesiologists to handle critical incidents. *Aviat Space Environ Med* 1992;63(9):763-70.
7. Devitt JH, Kurrek MM, Cohen MM, Fish K, Fish P, Murphy PM, et al. Testing the raters: inter-rater reliability of standardized anaesthesia simulator performance. *Can J Anaesth* 1997;44:924-8.
8. Holzman RS, Cooper JB, Gaba DM, Philip JH, Small SD, Feinstein D. Anesthesia crisis resource management: real-life simulation training in operating room crises. *J Clin Anesth* 1995;7(8):675-87.
9. Hart IR. The OSCE — objective yes, but how useful? In: Hart IR, Harden RM, Walton HJ, editors. *Newer developments in assessing clinical competence.* Montreal: Heal Publications; 1986. p. 22-8.
10. Chopra V, Gesink BJ, de Jong J, Bovil JG, Spierdijk J, Brand R. Does training on an anaesthesia simulator lead to improvement in performance? *Br J Anaesth* 1994;73:293-9.

Notices
Avis

American Society for Surgery of the Hand

The American Society for Surgery (ASSH) of the Hand will be presenting the following courses: internal fixation, to be held in Vail, Colo., from July 22 to 25, 1999; the 1999 comprehensive review course in hand surgery, to be held in Dallas, Tex., in August 1999. For further information on these courses contact the ASSH central office at 847 384-8300.

Interventional ultrasonography

The 8th International Congress on Interventional Ultrasound will be held from Aug. 31 to Sept. 3, 1999, at Herlev Hospital, University of Copenhagen, Copenhagen, Denmark. The deadline for abstracts is May 1, 1999. Registration is DKK 3400 before July 1 and DKK 3700 thereafter. Further information may be obtained by contacting the Department of Ultrasound — Herlev Hospital, University of Copenhagen, DK-2730 Denmark; tel +45 44 88 32 40, fax +45 44 94 80 09, ultrasound@herlevhosp.dk22

Techniques in advanced laparoscopic and gynecologic surgery

From Nov. 4 to 6, 1999, the Mayo Clinic Scottsdale will hold the "12th annual techniques in advanced laparoscopic and gynecologic surgery" course at Marriott's Camelback Inn Resort, Golf Club and Spa, 5402 East Lincoln Dr., Scottsdale, Ariz., under the direction of Dr. Javier F. Magrina. The course will provide an in-depth review of laparoscopic techniques, complications and instrumentation. Approximately 4 hours of live surgery from Atlanta, Chattanooga, Tenn., and Scottsdale will be performed via satellite. Other course highlights include: interactive case presentations, laparoscopic skills practice with pelvic trainers and a video festival, which will include a variety of laparoscopic procedures with an interactive discussion by each author. Credits: AMA Category I, ACOG. For more information contact Kristen Eberhard, CME Department, Mayo Clinic Scottsdale, 13400 East Shea Blvd., Scottsdale AZ 85259, USA; tel. 602 301-7552, fax 602 301-8323.

Pediatric ECMO techniques and technology

The Ege University Faculty of Medicine is sponsoring an international conference on pediatric ECMO techniques and technology on Nov. 5 and 6, 1999, in Izmir, Turkey. For further information contact Prof. Oktay Mutaf, The Thoracic Unit, Department of Pediatric Surgery, Ege University Faculty of Medicine, Bornova 35 100, Izmir, Turkey; fax +90 232 375 12 88, omutaf@med.ege.edu.tr