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Emergent Procedure Training in the 21st Century

Ernest E. Wang
NorthShore University HealthSystem,University of Chicago Pritzker School of Medicine
USA

1. Introduction

Procedural competency is a substantial part of the emergency physician's (EP) skill set. Emergency Medicine (EM) is unique in that the practicing EP must be comfortable with a wide array of procedures that have the following features: 1) They span the entire human body and cross many disciplines in medicine and surgery; 2) There are both invasive and non-invasive procedures; 3) They occur at unpredictable frequencies and never on a schedule; 4) They often need to performed under significant time-pressure; and 5) The patients they need to be performed on are often critically ill and unstable.

The Model of the Clinical Practice of Emergency Medicine (EM Model) serves as the guide for the content expertise that EPs are expected to have as active practitioners in the specialty. The EM Model was first developed in 2001 by the Core Content Task Force II and involved the collaboration of six EM organizations: the American Board of Emergency Medicine (ABEM), the American College of Emergency Physicians (ACEP), the Council of Emergency Medicine Residency Directors (CORD), the Emergency Medicine Residents' Association (EMRA), the Residency Review Committee for Emergency Medicine (RRC-EM), and the Society for Academic Emergency Medicine (SAEM).(1) It has undergone biannual revisions with the most recent revision in 2009. The EM Model specifies the types of procedures representative of the domain of emergency medicine (Table 1).(2) These include procedures such as: airway techniques, anesthetic techniques, bedside and procedural ultrasonography, obstetrics, resuscitation, head and neck procedures, thoracic procedures, skeletal procedures, vascular access, wound management, genitourinary procedures, gastrointestinal procedures, lumbar puncture, and others.

The procedures in the EM Model can be roughly divided into two groups, high and low frequency, and two types, higher and lower risk (Table 2). EPs need to be able to perform high frequency procedures precisely and reliably so as to minimize complications and morbidity. EPs need to be able to be proficient with infrequent high risk procedures so that when the situation arises (usually unpredictably and under significant time pressure), they have the greatest chance to complete the procedure successfully.

Prior to the advent of simulation-based trainers, traditional training opportunities consisted of cadaveric experience or through the apprenticeship model, succinctly described by the ubiquitous medical adage "See one, do one, teach one." These methods provided limited training opportunities due to expense and scarcity (cadavers) or due to unpredictable

Airway Techniques
- Airway adjuncts
- Cricothyrotomy
- Foreign body removal
- Intubation
- Mechanical ventilation
- Percutaneous transtracheal ventilation
- Capnometry
- Non-invasive ventilatory management

Anesthesia
- Local
- Regional nerve block
- Sedation - analgesia for procedures

Blood, Fluid, and Component Therapy Administration

Diagnostic Procedures
- Anoscopy
- Arthrocentesis
- Bedside ultrasonography
- Cystourethrogram
- Lumbar puncture
- Nasogastric tube
- Paracentesis
- Pericardiocentesis
- Slit lamp examination
- Thoracentesis
- Tonometry
- Compartment pressure measurement

Genital/Urinary
- Bladder catheterization
  - Foley catheter
  - Suprapubic
- Testicular detorsion

Head and Neck
- Control of epistaxis
- Laryngoscopy
- Drainage of peritonsillar abscess
- Removal of rust ring
- Tooth stabilization
- Lateral canthotomy

Hemodynamic Techniques
- Arterial catheter insertion
- Central venous access
- Intraosseous infusion
- Peripheral venous cutdown

Obstetrics
- Delivery of newborn

Other Techniques
- Excision of thrombosed hemorrhoids
- Foreign body removal
- Gastric lavage
- Gastrostomy tube replacement
- Incision/Drainage
- Pain management
- Violent patient management/restraint
- Sexual assault examination
- Trephination, nails
- Wound closure techniques
- Wound management
- Procedural ultrasonography
- Escharotomy

Resuscitation
- Cardiopulmonary resuscitation (CPR)
- Neonatal resuscitation

Skeletal Procedures
- Fracture/Dislocation immobilization techniques
- Fracture/Dislocation reduction techniques
- Spine immobilization techniques

Thoracic
- Cardiac pacing
  - Cutaneous
  - Transvenous
- Defibrillation/Cardioversion
- Thoracostomy
- Thoracotomy

Exposure Management
- Personal Protection (equipment and techniques)
- Decontamination

* Adapted from the 2009 Model of the Clinical Practice of Emergency Medicine

Table 1. Procedures and Skills Integral to the Practice of Emergency Medicine*.

	Higher frequency	Lower frequency
Higher risk	• Airway adjuncts (nasopharyngeal airway, oropharyngeal airway) • Intubation • Mechanical ventilation • Capnometry • Non-invasive ventilatory management • Sedation – analgesia for procedures • Blood, Fluid, and Component Therapy Administration • Lumbar puncture • Control of epistaxis (posterior) • Arterial catheter insertion • Central venous access • Cardiopulmonary resuscitation • Fracture/dislocation reduction techniques • Thoracostomy	• Cricothyrotomy • Foreign body removal (Airway) • Percutaneous transtracheal ventilation • Cystourethrogram • Pericardiocentesis • Thoracentesis • Compartment pressure measurement • Bladder catheterization (Suprapubic) • Drainage of peritonsillar abscess • Removal of rust ring • Lateral canthotomy • Peripheral venous cutdown • Delivery of newborn • Gastric lavage • Escharotomy • Neonatal resuscitation • Cutaneous cardiac pacing • Transvenous cardiac pacing • Thoracotomy
Lower risk	• Local anesthesia • Anoscopy • Arthrocentesis • Bedside Ultrasound • Procedural Ultrasound • Nasogastric tube • Slit lamp examination • Tonometry • Bladder catheterization (Foley) • Control of epistaxis (anterior) • Laryngoscopy • Intraosseous infusion • Incision and drainage • Nail trephination • Wound closure techniques • Fracture/dislocation immobilization techniques	• Regional anesthesia • Paracentesis • Tooth stabilization • Excision of thrombosed hemorrhoid • Foreign body removal (ear, nose, skin) • Gastrostomy tube replacement

** Categorization of the procedures in this table recognizes that local variations in procedural frequency exist and relative risk is dictated by patient co-morbidities and clinical presentation.

Table 2. Categorization of EM Model Procedures by frequency and risk**.

chance presentations (clinical patient care). As a result, it was not uncommon for residency-trained graduates to have little or no experience with rarely performed procedures. It also resulted in the potential for incomplete or unrefined command of the necessary steps for successful completion of complex or high stress procedures. Recent changes in residency work hour restrictions may also lead to limitations in clinical patient contact. The RRC-EM has recommended that residency graduates be exposed to a core group of procedures and resuscitations during residency training (Table 3).(3) The guidelines specify that these experiences may occur during patient care or in simulations.

Adult medical resuscitation	45
Adult trauma resuscitation	35
ED Bedside ultrasound	*
Cardiac pacing	06
Central venous access	20
Chest tubes	10
Procedural sedation	15
Cricothyrotomy	03
Disclocation reduction	10
Intubations	35
Lumbar Puncture	15
Pediatric medical resuscitation	15
Pediatric trauma resuscitation	10
Pericardiocentesis	03
Vaginal delivery	10

* Covered in separate Procedural Competency Guideline recommendations in the RRC-EM guidelines

Table 3. RRC-EM Recommended Guidelines for Procedures and Resuscitations.

2. Procedural skill acquisition

In the 21st century, the “See one, do one, teach one” model has been rendered outmoded by the several factors. The general patient public is growing intolerant of being used as a training vehicle for novices and will often decline procedures from physicians with little experience. The Institute of Medicine’s 1999 report, “To Err is Human” has propelled the patient safety movement in health care so that practitioners are have become more aware of there responsibilities to patients to first do no harm. Finally, the emergence of realistic procedural task trainers have brought simulation-based training to the forefront of medicine as a way to bridge the experiential gap between the novice and the expert.

Ziv et al. described physicians’ moral imperative to use simulation-based training as this: “The use of simulation wherever feasible conveys a critical educational and ethical message to all: patients are to be protected whenever possible and they are not commodities to be used as conveniences of training.”(4) Studies have shown that patients are more willing to have procedure performed on them by physicians who have undergone simulation training first. (5-7)

The guiding principle behind the efficacy of simulation-based procedural training is the concept of "deliberate practice" (DP). According to Dr. K Anders Ericsson, "Expert performance can be traced to active engagement in deliberate practice (DP), where training (often designed and arranged by their teachers and coaches) is focused on improving particular tasks. DP also involves the provision of immediate feedback, time for problemsolving and evaluation, and opportunities for repeated performance to refine behavior."(8) McGaghie et al. have further defined the necessary conditions for DP to be effective (Table 4).(9-10) These features are listed in order of reported frequency (percent) among the final BEME pool of 109 articles.These include immediate feedback, repetition, increasing levels of difficulty, clinical variation, simulation providing valid representation of clinical practice, and a controlled environment.(9-10)

1. Feedback is provided during learning experiences	(47%)
2. Learners engage in repetitive practice	(39%)
3. Simulation is integrated into an overall curriculum	(25%)
4. Learners practice tasks with increasing levels of difficulty	(14%)
5. Simulation is adaptable to multiple learning strategies	(10%)
6. Clinical variation is built into simulation experiences	(10%)
7. Simulation events occur in a controlled environment	(9%)
8. Individualized learning is an option	(9%)
9. Outcomes or benchmarks are clearly defined or measured	(6%)
10. The simulation is a valid representation of clinical practice	(3%)

*Adapted from McGaghie et al. Lessons for continuing medical education from simulation research in undergraduate and graduate medical education: effectiveness of continuing medical education: American College of Chest Physicians Evidence-Based Educational Guidelines. Chest. 2009 Mar;135(3 Suppl):62S-68S.

Table 4. The Ten Conditions Necessary for Effective Deliberate Practice*.

Literature across multiple medical disciplines supports the efficacy of simulation based procedural training with deliberate practice. Wong et al. demonstrated that repetitive practice of cricothyroidotomy on mannequins leads to reductions in procedural performance times and improvement in success rates.(11) Barsuk et al. demonstrated improved safety and decreased central line infections after simulation-based central venous catheter insertions.(12) Draycott et al. demonstrated improved neonatal outcomes after shoulder dystocia training.(13) Andreatta et al. reported that simulation-based mock code training significantly correlated with improved pediatric patient cardiopulmonary arrest survival rates.(14) A meta-analysis performed by McGaghie et al. reported that simulation-based training with DP is superior to traditional clinical medical education in achieving specific clinical skill acquisition goals.(15)

Additionally, Weinger argues that, in order to achieve the maximal desired effect, procedural skills acquisition and retention likely occur in a dose-response relationship, similar to drug pharmacology, with the best retention achieved using intermittent regular repetition over time rather than in single-day course training.(16) Interval simulation training over time makes intuitive sense, allowing for consolidation of training lessons and refining of muscle memory. Learners can break down procedures into their basic steps and focus on those particular steps that they have more difficulty with or feel they need to work on. These concepts are familiar to anyone who has ever learned to play a musical instrument. The argument of the dose-response relationship of simulation was supported by Conroy et al. in a recent study demonstrating competence and retention of lumbar puncture training skills using interval reinforcement.(17)

Another consideration in simulation procedural training is the "first cut" experience. Prior to simulation task trainers, procedures such as cricothytomy were performed on cadavers and the initial incision through the cricothyroid membrane could only be performed "natively" once. After that, subsequent learners could not experience the first cut sensation. With the development of procedural simulators, each learner can not only experience the first cut experience, but they can experience it over and over again.

3. Available procedural simulation

In recent years, the commercial availability of procedure specific task trainers has significantly increased. Additionally, the fidelity (or realism) has improved as well. These improvements allow medical professionals who teach using simulation modalities, otherwise known as "simulationists," to provide better procedural training for their students.

There are commercially available simulators for just about every procedure listed in Table 2. Central line simulators such as those shown in Figure 1 (Simulab Corporation, Seattle, WA. www.simulab.com; Blue Phantom, Redmond, WA. www.bluephantom.com) allow for ultrasound guided vascular access practice where the learner can repeated perform the vessel cannulation and insert the entire central line as many times as necessary until proficiency is reached. In addition to vascular access, certain models can also provide simulated regional anesthesia training (Figure 2).

Common procedures such as lumbar puncture can be practiced using task trainers such as that shown in Figures 3 (Limbs and Things, LTD, Savannah, GA. www.limbsandthings.com). These models have the added ability to simulate obese and elderly patient lumbar anatomy using "obesity" and "senior" lumbar blocks (Figure 3B). These add to the difficulty levels that can be simulated. Infant lumbar puncture simulators (Figure 4) can be used to teach the procedure on an age- and size-appropriate model (Limbs and Things, LTD, Savannah, GA. www.limbsandthings.com).

Trauma procedures such as tube thoracostomy and surgical cricothyrotomy using systems such as TraumaMan® (Simulab Corporation, Seattle, WA. www.simulab.com) have become viable alternatives to cadaver based training because the skin on the trainer can be replaced (Figure 5). This allows for the very important "first cut" visual and tactile experience that is necessary for developing the cognitive and manual skills necessary for these procedures.

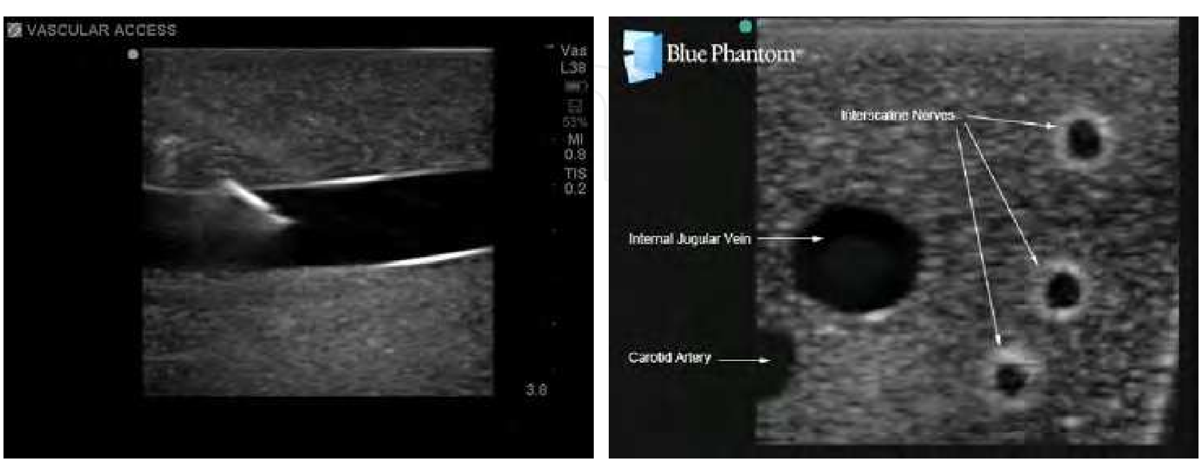
Focused Assessment with Sonography for Trauma (FAST) can be performed with varying levels of difficulty (Figure 6). The Blue Phantom FAST Exam Real Time Ultrasound Training Model (Blue Phantom, Redmond, WA. www.bluephantom.com) is one of the few ultrasound simulators that has adjustable internal bleeding levels to increase or decrease the level of difficulty. "Realistic internal bleeding in each organ space that can be adjusted by the user to simulate a wide variety of effusion states including: small, medium and large effusions or no effusions at all around the liver, spleen, heart, and bladder."

Table 5 provides a partial listing of commercially available procedural task trainers for emergency medicine relevant procedures.

http://www.simulab.com/product/ultrasound-trainers/centralineman-system

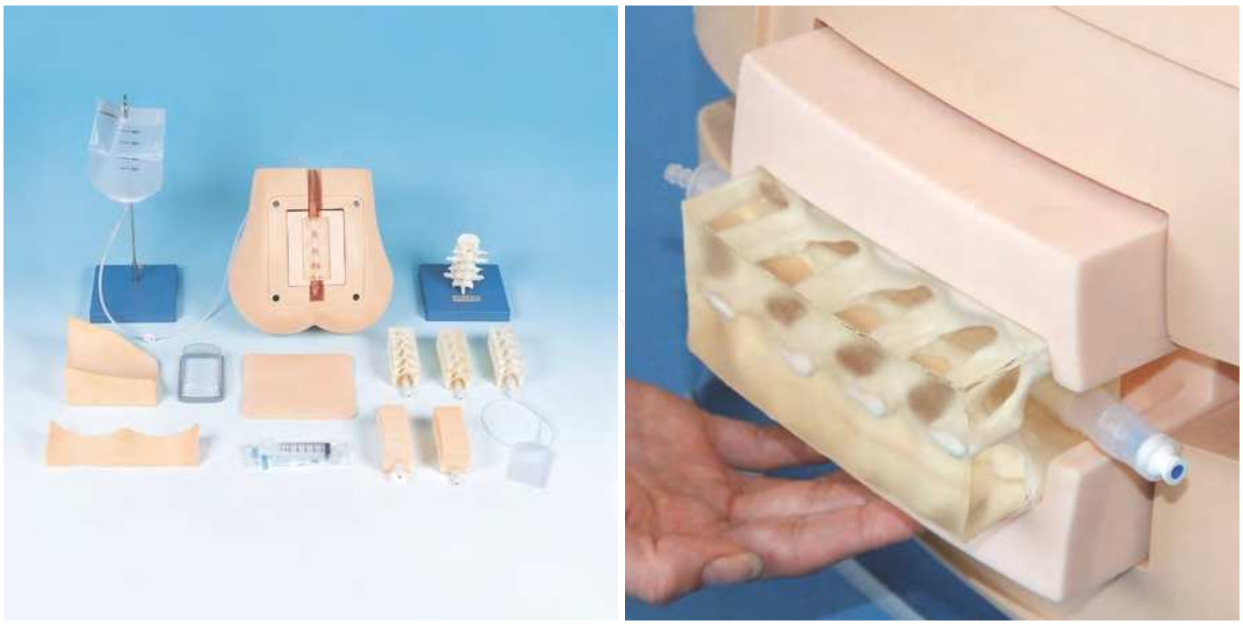
http://www.bluephantom.com/details.aspx?pid=51&cid=

Fig. 1. Central Line Trainers.



http://www.bluephantom.com/details.aspx?pid=51&cid=

Fig. 2. Ultrasound guided simulator for vascular access and regional anesthesia.



A. B.

http://limbsandthings.com/us/products/lumbar-puncture-epidural-simulator-mk-2/

Fig. 3. Adult lumbar puncture simulator.

http://limbsandthings.com/us/products/pediatric-lumbar-puncture-simulator/

Fig. 4. Pediatric lumbar puncture simulator.

http://www.simulab.com/product/surgery/open/traumaman-system

Fig. 5. TraumaMan® System for tube thoracostomy and surgical cricothyrotomy.

http://www.bluephantom.com/product/FAST-Exam-Real-Time-Ultrasound-Training-Model.aspx?cid=532

Fig. 6. FAST scan simulator.

Airway adjuncts
http://www.simulaids.com/SB32893.htm
http://www.trucorp.co.uk/sections/default.asp?secid=4&cms=
AirSim_AirSim+Advance+Crico&cmsid=4_53&id=53

Cricothyrotomy simulator
http://www.simulaids.com/LF01082U.htm

IV arm
http://www.simulaids.com/120.htm
http://www.kyotokagaku.com/products/detail01/m50b.html
http://limbsandthings.com/us/products/standard-venepuncture-arm/

Regional anesthesia
http://www.bluephantom.com/product/Femoral-Regional-Anesthesia-AND-Vascular-Access-with-DVT-Option.aspx?cid=394
http://www.bluephantom.com/product/Regional-Anesthesia-and-Central-Venous-Access-Ultrasound-Training-Model.aspx?cid=414

Joint aspiration
http://limbsandthings.com/us/products/knee-for-aspiration-mk-2/
http://limbsandthings.com/us/products/shoulder-for-joint-injection/
http://limbsandthings.com/us/products/foot-ankle-for-joint-injection/
http://limbsandthings.com/us/products/elbow-for-joint-injection/

Nasogastric tube
http://limbsandthings.com/us/products/ng-tube-tracheostomy-care/
http://www.enasco.com/product/LF01174U

Paracentesis
http://bluephantom.com/details.aspx?pid=55&cid=

Thoracentesis
http://bluephantom.com/category/Shop-By-Specialty_Emergency-Medicine_Thoracentesis.aspx

Pericardiocentesis
http://bluephantom.com/details.aspx?pid=43&cid=

Pediatric Trauma
http://www.simulab.com/product/surgery/open/traumachild-system

Tube Thoracostomy
http://www.simulab.com/product/surgery/open/traumaman-system

Wound closure
http://limbsandthings.com/us/products/wound-closure-pad-light/
http://www.simulab.com/product/packaged-savings/deluxe-boss-starter-package

Table 5. Commercially available procedural task trainers.

While these trainers are continuously improving with each model generation, most current task trainers are not yet able to provide simulated training with increasing levels of difficulty, providing significant clinical variation, and providing a valid representation of *clinical practice.* These three deficiencies with respect to the ten conditions required for deliberate practice described earlier still need to be addressed before procedural simulation will be able to adequately simulate human tissue. *Until then, there will still be a gap between simulated practice and performance in patient care.*

4. Future of procedural simulation

As we move further away from organic (cadaveric and animal) models, new areas are emerging to provide EM trainees and practitioners with alternative methods for experiential practice and maintenance of skills.

In addition to the features of current simulators, improvements to current simulators are being developed both commercially and by simulationists who desire to bridge the gap between what is currently available and what can be possible. Examples include modification of a Laerdal SimBaby to include an integrated umbilical cannulation task trainer,(18) homegrown hybrid cricothyrotomy simulators using synthetic skin and sheep larynx/trachea,(19) and homegrown epistaxis task trainer simulators.(20)

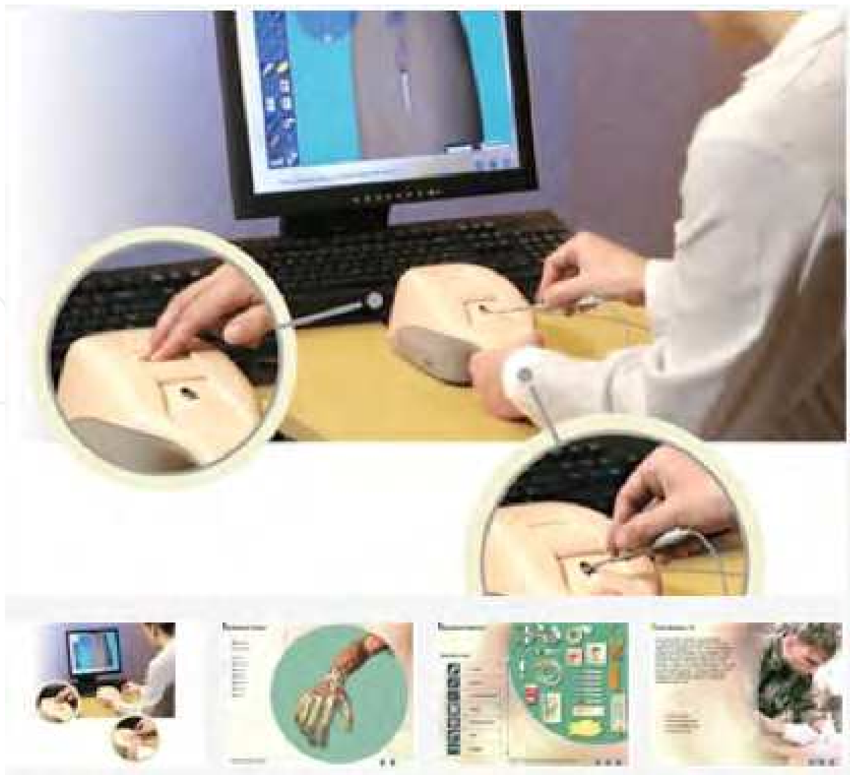
The future of procedural simulation will likely lie in the development and convergence of haptic technology and virtual reality. Haptics is a type of tactile feedback technology that allows the reporting of a learner's touch pressure forces through a virtual interface. Haptics development has been led by the surgical disciplines where its use in laparoscopy, gynecology, urology, endoscopy, ophthalmology, dentistry, ENT, and robotic surgery have advanced training and technical skills. Simbionix (Simbionix USA Corporation, Cleveland, OH. www.simbionix.com) has created a Mentor Series of VR simulators for laparoscopy, angiography, bronchoscopy, endoscopy, endourology and TURP, percutaneous access, hysteroscopy, and pelvic examination.

For EM skills, a haptic-based VR trainer is now commercially available for IV insertion (Figure 6 - Laerdal Medical, Wappingers Falls, NY. www.laerdal.com). Work by Loukas et al. reported that this simulation model enhanced the skills of inexperienced subjects significantly and that "The VR simulator demonstrated construct validity for three different levels of experience. The number of attempts over a series of equal difficulty scenarios provides a valuable alternative to the traditional measures of the learning curve."(21) Investigations in cardiology-based simulation also support the utility of a VR-enhanced experience. (22-23)

Investigational trainers are being developed for endotracheal intubation,(24) lumbar punctures,(25) and cricothyrotomy,(26) with other haptic-enhanced physical models or VR procedural trainers likely to follow. Other opportunities for enhancing EM procedural training include improved seldinger technique simulation(27) and ultrasound practice(28-9) to improve hand-eye coordination.

Virtual reality integration with remote learning opportunities will likely be available in the future as well. Alverson et al. have reported the feasibility and acceptability by students in the use of VR simulation integrated into a Problem Based Learning (PBL) session, "... as well as multipoint distance technologies that allowed interaction between students and tutors in different locations."(30) The authors believe this method of interactive experiential learning can be widely applied in a distributed network or on site.

One can imagine that, in the future, web-based VR simulation learning network will be widely available. In this type of learning system, instructors around the world, using a shared VR learning platform, upload metadata for a specific procedural task (i.e. difficulty airway scenarios using a haptic-enhanced VR intubation program) to a central server. These cases can then be accessed at any local training center for training and validation purposes.



http://www.laerdal.com/doc/245/Virtual-I-V-Simulator

Fig. 7. Virtual I.V.™ Simulator.

5. Summary

Whatever form that emergency medicine procedural training takes in the future, one thing is clear – simulated training will be the mainstay for the initial introduction to the steps and mechanics involved in performing a procedure, for accelerating the technical skill acquisition learning curve for the procedure, and for the maintenance of competency of the skills once developed. The end result will be the delivery of higher quality, more uniform, and safer care at the bedside.

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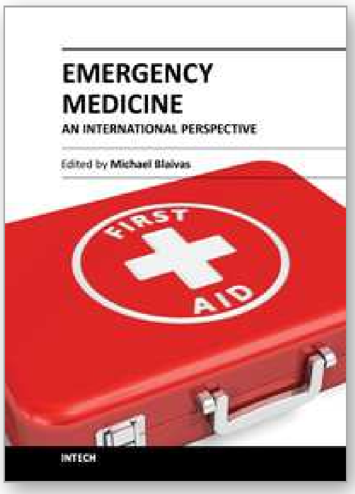

Emergency Medicine - An International Perspective

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Emergency Medicine is an expanding field that has spread beyond the shores of North America and has taken on different characteristics around the world. Although many of the struggles of emergency practitioners are similar, the field and its principles have adapted to local needs and resources. This book seeks to educate readers not only on emergency medicine theory, science and practice, but also reflects that multinational nature of emergency medicine, allowing readers to learn from experiences of others. This diverse group of authors presents a true international view of emergency medicine practice and science that will be educational for any reader.