Pediatric Acute Care

A Guide for Interprofessional Practice

Edited by

Karin Reuter-Rice, PhD, NP, FCCM

Assistant Professor

School of Nursing

School of Medicine, Department of Pediatrics

Duke University

Durham, North Carolina

Beth Nachtsheim Bolick, DNP, NP

Associate Professor

Department of Women, Children, & Family Nursing

College of Nursing

Rush University

Chicago, Illinois

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ONLINE CHAPTER 1

Paul N. Severin

Pediatric Simulation

"The act of imitating the behavior of some situation or some process by means of something suitably analogous (especially for the purpose of study or personnel training) is known as *simulation*" (WordNet 3.0, 2006). Often this activity employs the use of a *simulator*—that is, a device that enables the operator to reproduce or represent under test conditions phenomena likely to occur in actual performance (Merriam-Webster, 2009). Both simulation and simulators have been extensively applied in the aviation industry, military, nuclear power production, and health care. With recent advances in technology, the use of patient simulators has become an integral part of the health care environment. Numerous simulation applications are used in the health care setting, including those directed toward training and education, research and analysis, and quality assurance and safety. The complete review of medical simulation is well beyond the scope of this material, however; the reader is directed to Table 1-1 for further references. The objective of this chapter is to review pediatric simulation and its applications in the pediatric acute care environment.

PEDIATRIC DEVELOPMENTAL DIFFERENCES AND MEDICAL SIMULATION

Children are not small adults (American Academy of Pediatrics [AAP], 2006), thus, caring for the acutely ill or injured pediatric patient can be challenging. Pediatric patients are considered a specific population with unique vulnerabilities (AAP, 2006; Peck, 2008). They are estimated to account for 25% of the U.S. population (Peck, 2008; U.S. Census Bureau, 2009). The vulnerabilities associated with young patients essentially reflect pediatric developmental differences. Pediatric simulation offers a method to educate the health care professional (HCP) regarding such developmental differences (Fiedor, 2004; Fiedor et al., 2004; Nishisaki et al., 2009; Weinstock et al., 2005). These differences can be classified into four major categories: anatomy and physiology, behavior and development, psychological aspects, and therapeutic management.

TABLE 1-1

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Medical Simulation
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ANATOMY AND PHYSIOLOGY

As seen on pediatric burn assessment charts, the head accounts for a majority of the total body surface area in children. With growth of the child, the head reaches adult parameters by adolescence.

The larger body surface area-to-mass ratio noted in children increases their risk of hypothermia. The decreased ability to shiver is another disadvantage to the pediatric patient. Hypothermia can be a deadly combination with any trauma leading to coagulopathy and uncontrollable hemorrhage. When exposed to various toxins, children's larger body surface area enhances the amount of absorption and end-organ toxicity. Their normally thin, delicate skin can add to absorption, especially in the presence of abrasions or burns.

Orthopedic injuries are common in the pediatric population due to pliability of the skeleton as a result of incomplete calcification and active bone growth centers. Protected organs, such as the lungs and heart, may be injured due to overlying fractures. Cervical spine injuries may also be pronounced, as in patients with abusive head trauma (Christian et al., 2009). Spinal cord injury may even be present without any radiographic abnormalities of the spine.

Finally, vital signs vary based upon the pediatric patient's age (AAP, 2006). Younger pediatric patients (neonates) have higher metabolic rates and, therefore, higher respiratory rates and heart rates. This can be a distinct disadvantage for younger versus older pediatric patients (adolescents) when encountering similar diseases, such as inhaled toxins (carbon monoxide, nerve agents, pulmonary irritants). Neonates will suffer greater toxicity because they will inhale faster and distribute the toxin more rapidly to various end organs due to their faster metabolic rate. As the pediatric patient grows, vital signs will change, eventually approaching adult norms during middle to late adolescence.

Understanding respiratory differences is essential in the therapeutic management of an acutely ill pediatric patient (American Heart Association [AHA], 2006a). The most common etiology for cardiorespiratory arrest in children is respiratory pathology, typically of the upper airway. Most of the airway resistance in children occurs in the upper airway. Nasal obstruction due to congenital (choanal atresia) or acquired (adenoidal hypertrophy) lesions can lead to severe respiratory distress as infants are obligatory nose breathers. Their relatively large tongue and small mouth can quickly lead to airway obstruction, especially when neuromuscular tone is abnormal, such as with sedation or encephalopathy. In infants, physiologic (copious secretions) and pathologic (vomitus, blood, foreign body) factors will exaggerate this obstruction.

Securing the airway in can be challenging. Typically, the glottis is located more anterior and cephalad in infants than in older children. Appropriate visualization during laryngoscopy can be further obscured by the prominent occiput, which causes neck flexion, thereby reducing alignment of visual axes. The omega-shaped epiglottis in young infants and children is also susceptible to inflammation and swelling. In epiglottitis, for example, the glottis becomes strangulated in a circumferential manner leading to dangerous supraglottic obstruction. Children also have a natural tendency to develop laryngospasm and bronchospasm. Finally, due to weaker cartilage in infants, dynamic airway collapse can occur in states of increased resistance and high expiratory flow (bronchiolitis, asthma). Along with altered pulmonary compensation and compliance, a child may rapidly progress to respiratory failure and arrest (Dalton, 2006; De Caen et al., 2008; Perkin et al., 1996).

Cardiovascular differences are critical in the pediatric patient. Typical physiological responses tend to allow compensation to occur with a seemingly normal homeostasis (AHA, 2006a; Goodwin et al., 2004). With tachycardia and elevated systemic vascular resistance, younger pediatric patients can maintain a normal blood pressure despite decreased cardiac output and poor perfusion (compensated shock). Because children have less blood and volume reserve, they progress to this state quickly. In pediatric patients with multiple organ injury or severe gastroenteritis, these compensatory mechanisms may be exhausted. The less experienced HCP may be falsely reassured because the blood pressure is normal. All the while, however, the pediatric patient's organs are being poorly perfused. Once the compensatory mechanisms are exhausted, the patient will progress rapidly to hypotension and uncompensated shock. If not reversed expeditiously, this cascade of events may lead to irreversible shock, ischemia, multiple organ dysfunction, and death (AHA, 2006a). In addition, when managing pediatric patients with special health care needs, be aware that seemingly mild infections can lead to severe hypovolemic or septic shock (AAP, 2006).

Pediatric patients with altered mental status pose a unique challenge. The differential diagnosis may be broad in the comatose patient based on his or her stage of development alone. For example, younger pediatric patients can present with nonconvulsive status epilepticus (NCSE) instead of generalized convulsive status epilepticus (GCSE); the latter condition is more common in adults (Statler & Van Orman, 2008). Other differential diagnoses may include poisoning, inborn errors of metabolism, meningitis, and other etiologies of encephalopathy. The modified pediatric Glasgow Coma Scale (GCS) is used to evaluate the neurologic status of the preverbal pediatric patient. Unfortunately, external ocular movements and motor response may be difficult to assess in a young or developmentally delayed pediatric patient.

Pediatric traumatic brain injury may be devastating and evaluation of the neurological status of the acutely injured pediatric patient can be problematic, especially calculation of the GCS score. For this reason, some HCPs prefer to use the AVPU system (**A**lert, responds to **V**erbal commands, responds to **P**ain, **U**nresponsive) in pediatric patients.

Children's disproportionately larger head and weaker neck muscles render them especially vulnerable to acceleration–deceleration injuries. Also, the softer skull, dura structural differences, and vessel supply place the pediatric patient at increased risk for brain injury and intracranial hemorrhage. Finally, due to pediatric brain composition, the risk of diffuse axonal injury and cerebral edema is much higher in children than in adults.

Although spinal cord injury is rare in young pediatric patients, morbidity and mortality from this cause are significant. In pediatric patients younger than 9 years of age, the most commonly seen injuries involve the atlas, axis, and upper cervical vertebrae. In younger pediatric patients, spinal injuries tend to be anatomically higher (cervical) versus those observed in adolescents (thoracolumbar). Further, congenital abnormalities, such as trisomy 21 atlantoaxial instability, may predispose patients to higher rates of cervical spine injury. The clinical presentation of spinal cord injury varies in young pediatric patients due to their ongoing development. Laxity of ligaments, wedge-shaped vertebrae, and incomplete ossification centers contribute to specific patterns of injuries. Finally, *spinal cord injury without radiographic abnormality* (SCIWORA) may occur in pediatric patients. The disproportionately larger head, weaker neck muscles, and elasticity of the spine in children may lead to significant distraction and flexion injury of the spinal cord without apparent ligament or bony disruption (Tasker, 2008).

BEHAVIOR AND DEVELOPMENT

Motor skills develop from birth. Both gross and fine motor milestones are achieved in a predictable manner and must be assessed during each health care encounter. Cognitive development follows a similar pattern of maturation (Solages, 2009). The development of these skills can often predict injuries and their extent.

As an example, consider a house fire. A young infant, preschooler, school-age child, and adolescent are sleeping upstairs when the fire breaks out in the middle of the night. The smoke detectors begin to alarm. Each child is awakened by the ensuing noise and chaos. Based on the stage of development, the adolescent is most likely to make it out of the house alive. The adolescent will comprehend the threat, run down the stairs, and exit the house without delay, so smoke inhalation in this case may be minimal. In contrast, the school-age child may attempt to jump out of the window, leading to multiple blunt trauma with or without traumatic brain injury. The preschooler most likely will be too scared and not understand how to escape. Tragically, this child may hide under a bed or in a closet in an effort to make the threat "go away." When the fire fighters arrive and search the house, the preschooler may remain silent because of fear, especially of strangers in the house, therefore the preschooler will most likely succumb to burn injuries along with the effects of carbon monoxide toxicity. The infant, cannot walk, climb, crawl, or run as the smoke engulfs the room and will most likely suffer severe smoke inhalation and burn injuries, including extensive carbon monoxide toxicity.

Another aspect of development is the attainment of language skills. These skills develop over time in a predictable fashion (Solages, 2009). One of the biggest challenges in pediatric care is the inability of a young patient to verbally convey complaints. As a consequence, HCPs must often rely on a caregiver's subjective assessment of the problem. Although the caregiver's interpretation can be revealing and informative, it may not be available in an acute crisis. It will take the astute HCP to determine, for example, if an inconsolably crying infant is in pain from a corneal abrasion or has a more life-threatening condition such as meningitis, or if the seemingly lethargic adolescent is intoxicated with illicit drugs or has diabetic ketoacidosis.

Finally, the HCP must address developmental variances among pediatric patients and any comorbid features. Young pediatric patients can regress developmentally during any illness or injury. This behavior may be seen in patients with chronic medical conditions (cancer) or during prolonged hospitalization requiring rehabilitation (multisystem trauma). Further, those pediatric patients with developmental and intellectual disabilities will be difficult to evaluate because of the effects of their underlying pathology. These patients typically have unique variations in their physical examinations.

PSYCHOLOGICAL ASPECTS

Pediatric patients will often reflect the emotional state of their caregiver by taking on the adult's verbal and physical cues. At times, this behavior may also occur in the presence of an HCP. The psychological impact of an illness will vary greatly with the child's stage of development and experience. Children tend to have a greater vulnerability to post-traumatic stress disorder, especially in the context of disaster events (AAP, 2009; Brown, 2005). Further, they are highly prone to becoming psychiatric casualties despite the absence of physical injury to themselves. Younger pediatric patients tend to exhibit greater levels of anxiety, which may be evident when preparing them for invasive procedures such as phlebotomy and intravenous line (IV) placement (AAP, 2009).

THERAPEUTIC MANAGEMENT

Asymmetries are noted in the access to health care by pediatric patients, especially in the acute care setting. Although pediatric standards in emergency medical services (EMS) have improved over the past four decades, many EMTs still have limited exposure to ill or injured children. This lack of experience is not unexpected, as most emergency calls are for adult patients. Further, most hospitals that receive acutely ill patients are staffed by professionals who are primarily trained in providing care to adult patients and have a limited background in pediatrics. Additionally, the pediatric patient demands special consideration for treatment or resuscitation. Anatomically and physiologically, the pediatric patient will need different equipment (IV lines, endotracheal tubes [ETT]) and medication dosages (antibiotics, resuscitation) based on the child's size or weight. To increase their knowledge base, HCPs may attend courses such as those related to Pediatric Advanced Life Support (PALS), Advanced Pediatric Life Support (APLS), and the Neonatal Resuscitation Program (NPR) as described in text Chapter 22.

SIMULATION EDUCATIONAL THEORY AND THE ADULT LEARNER

Acute events are typically rare, but have significant and dire consequences if not identified immediately. One example is pediatric cardiopulmonary failure (Hunt et al., 2008). There are very few acutely ill pediatric patients to provide experiences for a growing number of acute care HCPs. Variability in the tools used to train learners is substantial, ranging from lectures to didactic sessions, to drills and practice. Oftentimes the methods are neither reproducible nor standardized. In addition, practicing on a live pediatric patient may not be safe or ethical. Finally, a complete evaluation of learner performance typically depends on subjective evaluation by the instructor.

Under the right conditions, high-fidelity medical simulations can facilitate learning (Issenberg et al., 2005). Pediatric simulation can allow the creation (and re-creation) of rare events. Depending on the choice of simulator, realistic responses to actions and interventions may enhance the realism of a scenario. Simulation may employ all types of learning, including those focused on the cognitive, affective, and psychomotor domains of educational objectives (Clark, 2009). Certainly, each scenario can be easily reproduced and provide repetitive practice without affecting patient safety. Because all simulations include an audio/visual recording component, feedback may be provided during debriefing. In summary, the "key benefits of simulation-based team training include efficient and scheduled use of training time and provision of a safe and structured environment to learn and practice skills that are required to manage rare or hazardous clinical events, all in the absence of risk to patients" (Weinstock & Halamek, 2008, p. 1019).

Simulation must be selected as a learning strategy based on the various needs and learning objectives of the participants (Dunn, 2004), including the need for experiential learning (Fanning & Gaba, 2007). Additional references related to adult learning theory are listed in Table 1-1.

The traditional learning model consists instructor-directed education or *pedagogy*. Adults, however, tend to learn best through *andragogy*, in which the process is learner centered and student directed. The *andragogical model* of education is based on six *core adult learning principles* (Knowles et al., 2005):

- Adult learners always *need to know* why they are learning something—in other words, they need to know the why, what, and how of the educational transaction. The facilitator, or adult educator, must raise the awareness of the adult learner so as to allow the discovery of these gaps in knowledge.
- Adults need control of their own lives and desire to be responsible. If they are to learn effectively, it needs to be their choice to do so. The *learner's self-concept* is crucial to this process. If it is not taken into account, many adults will avoid or resist new educational opportunities. The educational process must be transparent enough to aid the transition from dependent to self-directed learning.
- All too often, adult learners are requested to accept new information without taking into account their previous knowledge. The *learner's prior experiences* are filled with powerful resources from which to draw and adapt. Resistance to new concepts may occur if prior experiences are not respected or accounted for.
- The *readiness to learn* will assist in gaining acceptance of an educational opportunity by the adult learner. In many situations, the opportunity will be life related and will provide a way to cope effectively with real situations.
- Adult learners have a different *orientation toward learning* than children and adolescents. The latter have an orientation toward learning that is subject centered. In contrast, adults have an orientation that is life centered (or problem centered). For these learners, the educational material learned is viewed as necessary to negotiate obstacles encountered on a regular basis, whether at work, home, or play.
- Adults have a *motivation to learn* especially if they face internal pressures to do so. Most normal adults would like to mature and develop over time. Unfortunately, the educational process can be undermined by a negative self-concept of the adult learner (e.g., those educational opportunities that do not employ andragogical principles).

It is important to realize that pedagogy and andragogy are not always a good match to some learners based on the criterion of learner age alone. Some children and adolescents mature at faster rates than their peers of the same age. In those instances, andragogical principles may be the best method of education. Conversely, pedagogical principles may need to be employed in an adult class, especially if the topic is completely unfamiliar to the learners or does not require drawing from previous experiences.

The main objective of the facilitator during simulation is to help the learner become aware of gaps in his or her knowledge base, technical skills, and group dynamics (*need to know*). This understanding is maximized during the simulation debriefing process. Simulation helps adult educators to maximize experiential learning, in which adults are assisted in making the transition from dependent to self-directed learners (*learner's self-concept*). This quality should be present in all pediatric acute care HCPs. Simulation exercises utilize problem-solving and case methods to build on the learner's past encounters to effectively negotiate various tasks such as resuscitation or develop critical thinking skills during acute care emergencies (*learner's prior experiences*). Furthermore, simulation allows for participants to learn at their own pace (*readiness to learn*), work with new technologies and evidence-based practice strategies (*orientation to learning*), build confidence in therapeutic management, and develop team-building skills (*motivation*).

TYPES OF SIMULATORS AND SIMULATIONS

Medical simulation is not a new science. As Gary Meller (1997) recounts:

> The first medical simulators were simple models of human patients. From antiquity, these representations in clay and stone were used to demonstrate clinical features of disease states and their effects on humans. Models have been found from many cultures and continents. These models have been used in some cultures as a diagnostic instrument, allowing women to consult male physicians while maintaining social laws of modesty. (p. 194)

Today, medical simulators can be either simple or complex. Various methods have been devised to categorize simulators based on their fidelity or realism. Medical simulators, for example, have been designated as low, medium, or high fidelity, where high-fidelity simulators possess more realistic qualities than low-fidelity simulators. Simulator fidelity can be classified into three major types: equipment fidelity, environmental fidelity, and psychological fidelity (Beaubien & Baker, 2004). The relationship among the three determines the level of fidelity as experienced by the learner. Another approach is to describe the simulator by the actual design. The U.S. Department of Defense (USDOD), for example, has described simulators as including training aids, partial task simulation, standardized patient simulation, manikin-based simulations, screen-based simulation, and virtual reality (VR) simulation. Further simulation subcategories may also described, including passive (does not do anything), active (does something), and interactive (does something in response to the student) options (Wilks, 2009).

A *training aid* is any item developed or procured with the primary intent that it will assist in training and the process of learning (USDOD, 2009). Basic anatomical models, such as models of the airway, lungs, and heart, fit in this category. Aids may include various medical devices associated with patient care, such as end-tidal carbon dioxide ($ETCO_2$) detectors, pulse oximeters, cardiac monitors, pulmonary artery (PA) catheters, or suturing equipment.

Partial task simulation involves the use of products to learn or practice a specific skill. Partial task simulators are typically more complex devices, sometimes associated with a computer (Wilks, 2009). In pediatric acute care, these devices are useful in preparing the learner for various emergent procedures. For example, one study found that pediatric residents who trained on an airway simulator were more efficient at pediatric intubations using a fiber-optic scope than those without such practice (Rowe & Cohen, 2002). Another example is the use of cadaver animals as partial task simulators, although the use of live animal training is no longer common (Dunn, 2004). Additional examples of partial task simulators include intubation heads (Figure 1-1), chest tube (Figure 1-2) and central line (Figure 1-3; Figure 1-4) insertion chests, arterial line trainers (Figure 1-5), intravenous (Figure 1-6) and intraosseus (Figure 1-7) line starters, and lumbar puncture trainers (Figure 1-8).

Standardized patient simulation involves the use of individuals trained to play the roles of patients, family members, or others to allow learners to practice physical examination skills, history-taking skills, communications skills, and other exercises. This approach is used for Objective Structured Clinical Examinations (OSCE). Standardized patient simulation has also been used for invasive procedures such as learning phlebotomy techniques or performance of a pelvic examination. Other uses of this type of simulation include family interaction skills and the delivery of bad news.

Manikin-based simulations typically use high-fidelity patient simulators to represent features and behaviors of patient physiology and pharmacology in a fully interactive way. The manikin-based simulator replaces a standardized patient and provides consistent reproducibility of objective parameters. The patient simulation is set up to represent the clinical work environment (Dunn, 2004). Oftentimes, the environment can be simulated in a laboratory or simulation center. However, many educational organizations choose to perform high-fidelity patient simulations in the intensive care unit or emergency department (in situ simulation) for complete immersion of the participants in the experience (Weinstock & Halamek, 2008). High-fidelity patient

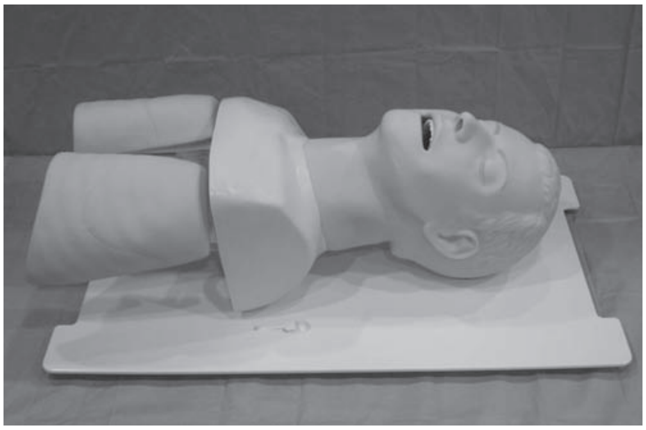

FIGURE 1-1

Intubation Trainer.

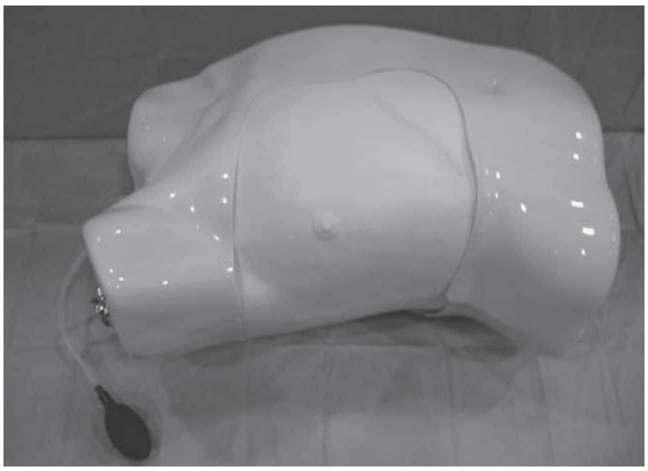

FIGURE 1-2

Chest Tube Insertion Trainer.

FIGURE 1-3

Central Line Insertion Trainer.

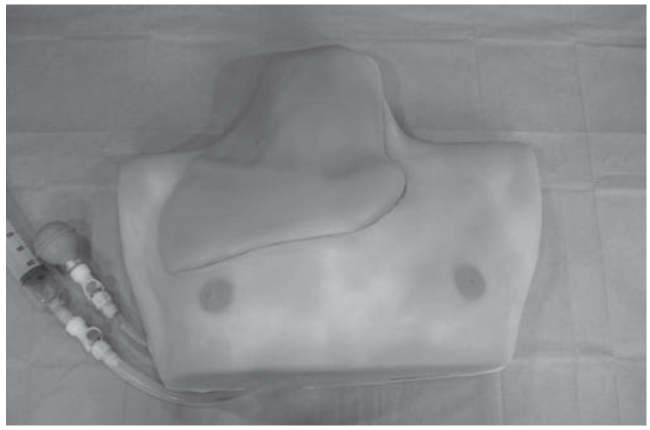

FIGURE 1-4

Central Line Insertion Trainer.

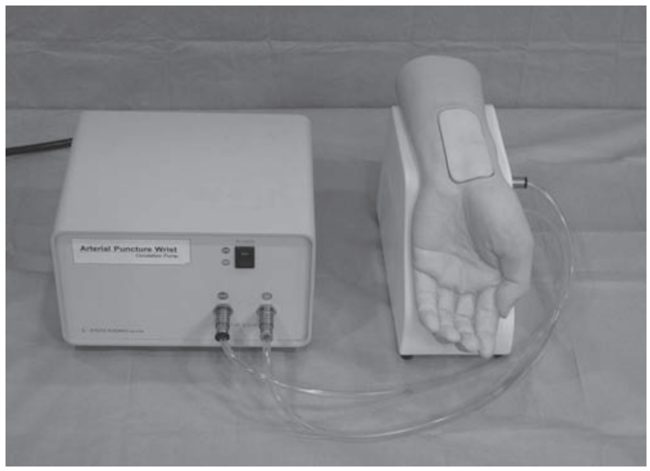

FIGURE 1-5

Arterial Line Starter Trainer.

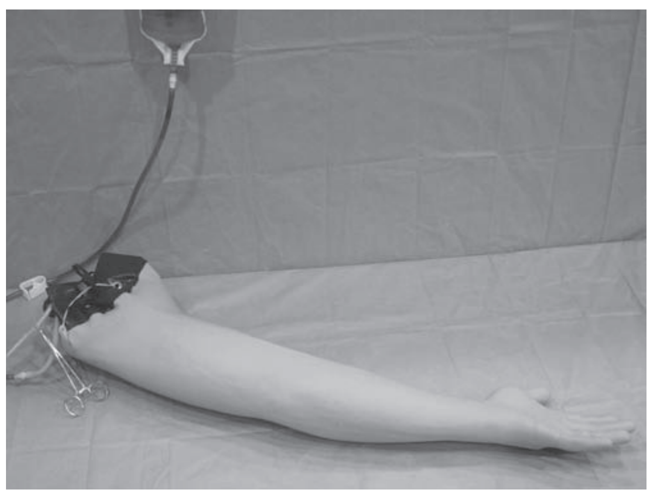

FIGURE 1-6

Intravenous Line Starter Trainer.

simulators may include adult (Figure 1-9 and Figure 1-10), pediatric (Figure 1-11), infant (Figure 1-12), neonatal, and birthing (Figure 1-13) models. Manikins may respond to the learner's action by either automatic means (bar-coded medication) or programmer manipulation. Exercises may be developed to emulate both prevalent and less common in-hospital medical scenarios. Examples of pediatric simulations include respiratory failure, status asthmaticus, cardiopulmonary arrest, ventricular fibrillation, multiple blunt trauma, diabetic ketoacidosis, seizures, and septic shock. Various procedures can be performed on the manikin, including bag-mask ventilation, intubation, cardiopulmonary resuscitation, needle thoracostomy, defibrillation, and vascular access (Medical Education Technologies Incorporated, 2005).

With *screen-based simulation*, the clinical scenario is presented graphically on a computer screen. The HCP selects diagnostic and/or therapeutic options through the user interface (Dunn, 2004). This strategy can often be used to supplement manikin-based simulations or stand-alone independent study tools. The basic features of this system allow for independent study during simulations, such as a graphical user interface, mathematical models of physiology and pharmacology, automated record keeping, built-in "Help", and automated debriefing (Dunn, 2004). Familiar examples include modules geared toward Advanced Cardiac Life Support (ACLS), PALS, and NRP courses. Other examples include hemodynamic simulators (vasoactive drugs, cardiovascular conditions), critical care emergency simulators, bioterrorism agent simulators, and sedation simulator emergencies.

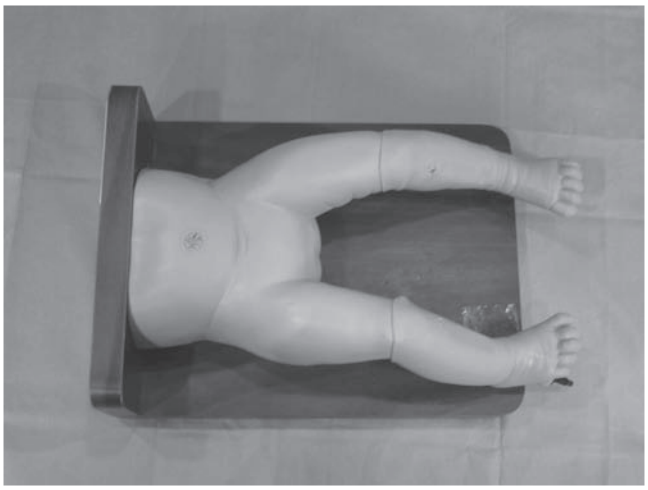

FIGURE 1-7

Intraosseus Line Starter Trainer.

FIGURE 1-8

Lumbar Puncture Trainer.

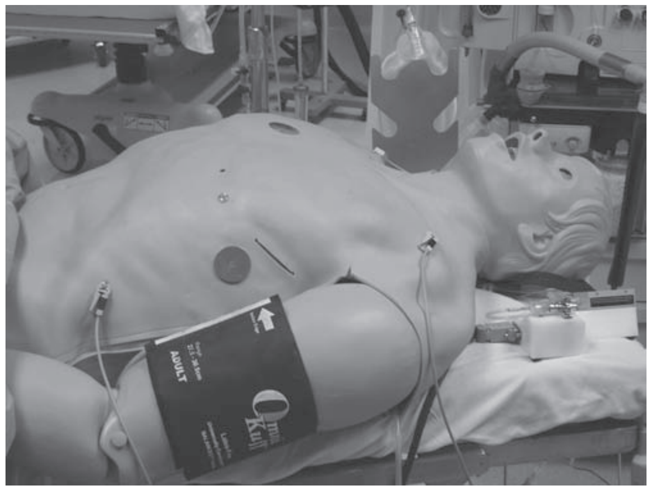

FIGURE 1-9

Adult Patient Simulator.

FIGURE 1-10

Adult Patient Trauma Simulator.

Finally, *virtual reality* (*VR*) *simulation* incorporates advanced computer technology to allow the HCP to learn or practice how to perform complex procedures. Furthermore, the technology allows learners to explore and manipulate computer-generated, three-dimensional, multimedia environments in real time. Two forms of VR environments are available: desktop VR environments and total immersion VR. The former includes the use of a computer screen, whereas the latter uses room-sized screens or a stereoscopic head-mounted display (Strangman & Hall, 2003). In medical simulation, VR simulators can be classified into three types: flat screen, augmented, and immersive (Wilks, 2009). The most familiar is the augmented VR simulator in which the equipment incorporates a simulated device, a haptic interface, and a computer monitor. Examples of augmented devices include laparoscope (Figure 1-14), endoscope/bronchoscope (Figure 1-15), and endovascular (cardiac catheterization) simulators. Of note, these examples would also be considered to be partial task trainers, as they assist in learning a specific skill. Table 1-1 provides a reference review of selected simulators for acute care training (partial task trainers, computer screen–based simulators, manikin simulators).

FIGURE 1-11

Pediatric Patient Simulator.

FIGURE 1-12

Infant Patient Simulator.

FIGURE 1-13

Birthing Patient Simulator.

FIGURE 1-14

Laparoscope Simulator.

FIGURE 1-15

Endoscope/Bronchoscope Simulator.

COMPONENTS OF THE SIMULATION FACILITY

Simulation facilities are different and similar at the same time, and may be either simple in their design or technologically sophisticated. Some provide a simple environment for the simulation, whereas others mirror an actual acute care facility such as an operating room, emergency department, or pediatric intensive care unit. Still others use former offices or spaces that rival the most elaborate movie sets and locations. Some may be a part of the college, university, or hospital, whereas others are free-standing, off-site complexes. Despite the innumerable differences among simulation facilities, all share four common components: location, rooms, layout, and equipment (Kyle, 2004).

Location is essential to the success of a simulation facility, as this site must be accessible to the users and available for use. If feasible, it should be found on-site at the educational facility or a short distance away. A separate dedicated space is not mandatory and may not be possible in certain circumstances. Using a clinical work area as the simulation facility adds realism to the simulation and allows the HCPs to perform in their usual clinical environment. Other organizations may choose to use an underused or unused clinical space for this purpose (Kyle, 2004).

Each room of the simulation facility should be dedicated to a particular function. This functionality will dictate the size of the space, which should be large enough to accommodate the number of participants and simulations performed. The *clinical action room* (*action area*) is the space where the simulation takes place (Figure 1-16). Based on the resources available, it should closely mimic the clinical environment expected by the HCP, including wall-mounted oxygen, air, and suction supply and overhead surgical lighting. Enough space should be present for all supporting equipment such as an anesthesia circuit, mechanical ventilator, or cardiac bypass circuit.

The *control room* is the nerve center for the entire simulation process (Figure 1-17). It contains the control console for the simulator itself. Depending on the facility, it may also contain display devices and recording components for the audiovisual (A/V) system used for monitoring the simulation. Ideally, the control room is situated adjacent to the action area, with the rooms separated by a one-way window. This setup allows the simulator operator (or driver) to visualize the events in the action room without the participants

FIGURE 1-16

Clinical Action Room.

FIGURE 1-17

Control Room.

feeling observed (Kyle, 2004). Further, it assists the operator in troubleshooting any issues that arise during the simulation. Oftentimes, communication among the operator and other personnel (observers, facilitators, actors) will occur via wireless headsets or similar technology.

The *observation/debriefing room*, as the name suggests, is a dual-purpose room (Figure 1-18 and Figure 1-19). During the simulation, it receives real-time A/V material of the events in the clinical action room. It allows observers to see and hear all aspects of the simulation. Further, it enhances discussion points made by the facilitator during the session. After the simulation, this room serves as a site for debriefing. The participants reconvene and the recorded simulation is reviewed by the facilitator. In addition, this room can serve a third purpose—as a classroom. Using the A/V equipment, a lecture or didactic session can be held before or after the simulation itself. Further, the availability of such a multipurpose room opens up more possibilities for users and enhances the versatility of the simulation space. Simulation areas may also be used for ACLS, PALS, and NRP courses, and virtual table-top drills for hospital disaster preparedness efforts using remote meeting capabilities (video and phone conference).

Although not considered a core room in the simulation facility, the *procedure room* is an area of the simulation space that may house smaller simulation devices such as training models and task trainers or, in some circumstances, full-size patient simulators for individual HCP training. This room can also be used for standardized patient simulations and one-on-one sessions. It can be equipped with a one-way window or A/V equipment in which faculty observe activities from the control room (Figure 1-20).

A *clinical supply room* serves as a place to store any equipment (props) used during simulations. It contains all materials to enhance the simulation. Such items include, but are not limited to, HCP clothing, resuscitation equipment, pseudo-medications and administration supplies, and various fluids including replicated blood (Kyle, 2004). The *storage room* houses everything else not in use during the simulation. If multiple patient simulators are available for use, they may also be stored there.

The efficacy of the simulation facility reflects its layout. In most circumstances, the key rooms should be located in one contiguous space. To maintain versatility, the facility should be able to support different clinical environments and users. The positions and orientations of the rooms should allow easy passage among them. Good sightlines between the action area and the control room are essential. Appropriate soundproofing provides a respectful and

FIGURE 1-18

Observation/Debriefing Room (Large-with camouflage netting for National Guard training).

FIGURE 1-19

Observation/Debriefing Room (Small).

FIGURE 1-20

Procedure Room.

protected educational environment. The patient simulator must be in clear view of the operator at all times, preferably in plain sight and on the display monitors. The feet of the patient simulator should face the operator for ease of view. The umbilical (electrical wiring) that connects the simulator to the control room should be accounted for in the layout from a realistic and safety perspective. Some facilities use underground channels to hide these components (Kyle, 2004).

The equipment used in the facility will be determined by considerations related to cost, facility space, patient simulator expense, and necessary supporting equipment. The number and types of audio and video feeds for the A/V system can be low or high end in cost (Kyle, 2004). Typically, the more sophisticated systems will be more expensive, but may be necessary for research, competency testing, or distance learning. Some facilities rely on expired clinical items to decrease the cost; however, maintaining clean and functional material is essential.

Finally, the simulation facility requires appropriate personnel to promote a safe and organized learning environment. For example, the *operator* (or *driver*) of the manikin-based simulator must be familiar with the capabilities of the device. This person must also assure proper audio and visual recording. The operator negotiates multiple obstacles during both short and lengthy sessions, so it can be advantageous if this individual has a health care background.

The facility *technician* provides equipment needed to sustain the simulator session. Oftentimes technicians will acquire, modify, or repair equipment to meet the needs of the medical specialty using the clinical action room. They work in concert with the operator or at times, serve both jobs. A creative and handy person with medical knowledge should hold this position.

Lastly, the *manager* of the facility is responsible for the business activities: scheduling, finance, purchasing, accounting, and contracts. Managers may be individuals who facilitate the financial viability of a facility and have excellent organizational skills. Familiarity with medical processes is not necessarily essential.

Other personnel may also be necessary, such as researchers, information technologists, or actors, depending on purpose of the simulation facility (Kyle & Murray, 2008).

COMPONENTS OF THE SIMULATION SESSION

INSTRUCTOR

The number of simulation facilities has increased markedly over the past few decades. From 1994 to 2005, more than 356 simulation centers were established in the United States in response to increased HCP educational demand (Cortez, 2008). Some organizations have purchased expensive simulators with the expectation that they will confer instant educational success on the learners. All too often, however, these centers have overlooked the most important component of simulation—*instructors*. The instructors develop and magnify the educational assets of the medical simulator. William Dunn said it best: "there is scientific evidence that the quality of a learner's experience affects learning outcomes in medical education. Faculty quality directly influences student performance, as has been validated in national board and medical licensing examinations within clinical curricula" (2004, p. 17). As facilitators, instructors constantly must provide an opportunity for the learner to excel during all aspects of pediatric simulation training.

CURRICULUM AND LEARNING OBJECTIVES

Pediatric simulation can provide an exceptional learning opportunity for HCPs in the field of acute care pediatrics. Curriculum development will depend on the set goals of the simulation activity. Halamek (2007) describes three skill sets to be learned by an HCP: *cognitive skills* (*content knowledge*), or "what we know in our brains"' *technical skills*, or "what we do with our hands"; and *behavioral skills*, or using the preceding skill sets "while caring for patients while working under realistic time pressure." Newly learned skill sets or those to be refined by the HCP are the intrinsic attraction of pediatric simulation.

Simulation is supported in a training model or for those in practice. Once it is determined which skill sets are to be learned, objectives are carefully constructed to meet learning goals. Although learning can extend beyond the stated objectives, minimum standards must be identified prior to the initiation of the educational opportunity. Approaches geared toward adult learners should be inherent components when designing pediatric simulation courses (Halamek, 2007). Scenarios and templates for pediatric simulations can be found on the Internet and with this text (see Table 1-1; Table 1-2; Table 1-3).

COGNITIVE AND TECHNICAL SKILLS

Numerous types of simulators and methods can be used to assist in the acquisition of cognitive and technical skills. Furthermore, scenarios can be developed to identify gaps in learners' knowledge base on technical proficiency. While developing simulation scenarios or courses, one should take into account the various domains of learning. The *taxonomy of learning domains* includes the cognitive, psychomotor, and affective domains. The *cognitive domain* refers to knowledge structure. It is often described as having six levels of increasing complexity or depth: knowledge, comprehension, application, analysis, synthesis, and evaluation. The *psychomotor domain* includes manual or physical

TABLE 1-2

Pediatric Acute Care Simulation Planning Template

I. Scenario Objectives:

1.
2.
3.

II. Simulation Milieu (Brief Summary):

III. Simulator, Equipment, and Participant Requirements:

IV. Expected Duration of Simulation Exercise:

V. Description of the Scenario:

VI. Primary Survey—Objective Data:

Across-the-room assessment
- Age/weight

Airway
- Secretions
- Airway sounds
- Obstructions

Breathing
- Rate
- Breath sounds
- Work of breathing
- Chest wall rise
- Saturation %/$ETCO_2$

Circulation
- Heart rate/rhythm
- Heart sounds
- Pulses
- Skin temperature
- Color
- Capillary refill
- Urinary output
- Blood pressure
- Skin turgor
- Mucous membranes
- Fontanel

Disability
- Pain score
- Pupillary reaction
- AVPU
- GCS

TABLE 1-2

Pediatric Acute Care Simulation Planning Template *(Continued)*

Exposure
- Body temperature
- Rashes/lesions/injuries
- Abdominal distention

Expected Impression/Differential Diagnosis:
1.
2.
3.

Expected Plan/Transitions (Brief Summary):

Diagnostic Studies
Studies may include laboratory, radiographic imaging, or bedside testing.

Therapeutic Management
Management may include initial stabilization strategies and progression to secondary survey.

VII. Data Following Initial Management:

Physical Examination Findings
- Across-the-room assessment
- Airway
  - Secretions
  - Airway sounds
  - Obstructions
- Breathing
  - Rate
  - Breath sounds
  - Work of breathing
  - Chest wall rise
  - Saturation %/$ETCO_2$
- Circulation
  - Heart rate/rhythm
  - Heart sounds
  - Pulses
  - Skin temperature
  - Color
  - Capillary refill
  - Urinary output
  - Blood pressure
  - Skin turgor
  - Mucous membranes
  - Fontanel
- Disability
  - Pain score
  - Pupillary reaction
  - AVPU
  - GCS
- Exposure
  - Body temperature
  - Rashes/lesions/injuries
  - Abdominal distention
- Additional findings from secondary survey

(Continued)

TABLE 1-2

Pediatric Acute Care Simulation Planning Template *(Continued)*

History of Present Illness/Past Medical History

Diagnostic Study Results

Describe Follow-up to Therapeutic Management/Disposition/Patient-Family **Teaching (Brief Summary)**:

Depending on scenario objectives and complexity, further series of evaluation and management may be designed.

VII. Debriefing

Review of Objectives

Evaluation of Cognitive, Technical, and Behavioral Skills

Team Dynamics
- Closed-loop communication
- Clear roles and responsibilities
- Acknowledgment of self-limitations
- Knowledge sharing
- Mutual respect

Team Leader Effectiveness
- Constructive intervention
- Reevaluation
- Summarizing
- Mutual respect

Lessons Learned
- What went well
- What did not go well

Technical/Scenario Difficulties

Quality improvement review of simulation.

Source: Courtesy of Karin Reuter-Rice and Beth Nachtsheim Bolick.

skills and has five levels of increasing complexity: imitation, manipulation, precision, articulation, and naturalization. The *affective domain* is concerned with the emotional aspects of experiences. It also has various components of increasing depth: receiving, responding, valuing, organization, and characterization (Bloom, 1956; Dave, 1975; Krathwohl et al., 1964).

BEHAVIORAL SKILLS

Simulation sessions can be completely devoted to the cognitive or technical skills of an individual learner. For example, did the learner recognize torsades de pointes? Did the learner identify hypotension due to the sedative agent? Did the learner place the central line correctly? Did the learner have difficulties intubating? Did the learner identify an enlarged heart on the chest radiograph? When a group is involved in the simulation, however, dynamics can change dramatically. Members of a team must adapt to working well with others to achieve a common goal. Using the same examples, one can easily apply them to the group. Who recognized torsades de pointes, and how was that information communicated to the group? Who identified the hypotension from the sedative agent, and was it managed effectively by the team member responsible for hemodynamic support? Did someone speak up when the subclavian artery was inadvertently cannulated by the central line operator? Was assistance called for when a difficult airway was encountered? Was the differential diagnosis of enlarged heart considered or was cardiomegaly—and not a pericardial effusion—assumed?

Crisis resource management (CRM) was developed to refine the teamwork and communication concepts (behavioral skills) that are necessary in the coordinated care of a patient emergency (Gaba et al., 1994; Murray & Foster, 2000). The hallmarks of resource management include prioritization of tasks, distribution of workload, communication, mobilization, and use of all available resources, monitoring/cross-checking, and utilization of all available data (Gaba et al., 1994). The core principles underlying CRM are leadership, role clarity, and communication (Weinstock & Halamek, 2008). Pediatric resuscitations are rare and team members may be unfamiliar with their roles and responsibilities in the face of such an emergency. CRM provides an organized process to teamwork (Cortez, 2008; Severin et al., 2008). A review by Weinstock and Halamek (2008) reported that simulation may help build the teamwork concept during pediatric resuscitation.

Interest in *in situ* simulation research is growing, as it focuses simulation education and evaluation on the concepts of effective group dynamics (Patterson et al., 2008). Some simulation centers have concentrated their efforts on specific communication and team skills, such as role clarity, communication, support, resource utilization, and global assessment (Raemer, 2004). One component of the PALS course, for instance, is directed at resuscitation team function. This component reviews the importance of team roles, behaviors of effective team leaders and members, and elements of effective resuscitation dynamics (AHA, 2006b; Weinstock & Halamek, 2008).

In the resuscitation team, the role of the *team leader* is to direct all resuscitation efforts. The leader organizes the group, monitors individual performance of team members, backs up team members, models excellent team behavior, trains and coaches, facilitates understanding, focuses on comprehensive patient care, and displays situational awareness (AHA, 2006b; Gaba et al., 1994). *Situational awareness* involves being aware of what is happening in the environment and seeking to understand how information, events, and one's own actions will affect objectives and goals. The role of the *team member* is to be proficient in resuscitation skills based on the individual's scope of practice. The team

TABLE 1-3

Pediatric Acute Care Simulation Checklist Template

Date:	
Team Leader Name:	
Team Member Names: 1. 2. 3.	
✓	**Checklist**
	Team leader clarifies roles and responsibilities of team members
	Team completes primary survey: *list key components individually based on scenario and objectives*
	Team leader states impression and differential diagnosis
	Team leader relates plan to include diagnostic studies and therapeutic management: *list key components individually based on scenario and objectives*
	Team re-evaluates patient and completes secondary survey: *list key components individually based on scenario and objectives*
	Team obtains history of present illness and past medical history: *list key components individually of these histories plus additional social/family/cultural/spiritual history based on scenario and objectives*
	Scenario objectives met
	1.
	2.
	3.
	Cognitive skills demonstrated (brief explanation)
	Technical skills performed correctly (list)
	Behavioral skills demonstrated (brief explanations)
	Team Leader
	Constructive intervention
	Re-evaluation
	Summarizing
	Mutual respect
	Team Dynamics
	Closed-loop communication
	Clear roles and responsibilities
	Acknowledge self-limitations
	Knowledge sharing
	Mutual respect

(Continued)

TABLE 1-3

Pediatric Acute Care Simulation Checklist Template *(Continued)*	
	Lessons Learned (brief explanations)
	What went well
	What did not go well
	Technical/Scenario Difficulties (brief explanation for quality improvement review)
	Additional Comments

Source: Courtesy of Karin Reuter-Rice and Beth Nachtsheim Bolick.

members must be clear about their role assignments, prepared to fulfill those role responsibilities, well practiced in resuscitation skills, knowledgeable about resuscitation algorithms, and committed to success (AHA, 2006b). Team member designations can include airway, compressor, IV/pharmacologic therapy, monitor/defibrillator, or observer/recorder/time keeper (AHA, 2006b).

Understanding the elements of effective resuscitation dynamics will enhance teamwork and promote safe, pediatric acute care (Weinstock & Halamek, 2008). The following teamwork elements can be learned and evaluated by using pediatric simulation (AHA, 2006b):

- The team leader communicates with a team member through *closed-loop communication*. This approach ensures that the request of a task has been received by the team member and that the task was completed prior to that individual's acceptance of another task. For example, the team leader states, "IV/pharmacologic therapy team member, please administer 0.3 mL of 1:10,000 epinephrine." With good eye contact, this member would reply, "Yes, I will administer 0.3 mL of 1:10,000 epinephrine." Once the task is completed, the team member, again while using good eye contact, would state to the team leader, "I have administered 0.3 mL of 1:10,000 epinephrine." Now the team leader knows the task is completed, the loop of communication is closed, and the team member is ready for the next task, order, or assignment. If eye contact is lacking or poor verbal skills are used, then the process of closed-loop communication will fail.
- *Clear messages* ensure concise communication among team members. This method appears to be effective in avoiding delays in treatment or unnecessary medication errors. Team members are to use a respectful tone without yelling or shouting. Although challenging in certain situations, only one person should speak at any given time.
- As described earlier, *clear roles and responsibilities* must be established, preferably from the beginning of the teamwork task. Many successful pediatric trauma resuscitation teams establish roles prior to the arrival of any acutely injured or burned child. All HCPs should be aware of signs of unclear team roles, such as duplication of efforts or omission of crucial tasks. It is paramount for the team leader to clearly delineate tasks to team members. Also, each team member should be encouraged to participate in the patient's care, rather than to simply follow orders blindly.
- *Knowing one's limitations* will provide optimal care for the patient. Each team member should know his or her own limitations and capabilities. Further, the team leader should be aware of the capacity and scope of practice of the team members. An attempted resuscitation is not the time to explore a new skill. Team members should voice the need for assistance and always ask for help sooner rather than later. By identifying one's own limitations, patient care and safety are optimized.
- A critical aspect of effective team performance is *knowledge sharing*. At times, team leaders can make *narrow-focus errors* (also known as *fixation errors*). Faulty reevaluation, inadequate plan adaptation, and loss of situation awareness, for example, can all result in fixation errors (Gaba et al., 1994). Gaba, Fish, and Howard (1994) identified three common fixation errors:
  - *Everything's okay:* the persistent belief that no problem is occurring despite evidence that it is
  - *This and only this:* the persistent failure to revise a diagnosis or plan despite evidence to the contrary

- *Everything but this:* the persistent failure to commit to the definitive treatment of a major problem
- During any ineffective resuscitation effort, the team leader should summarize: "We have done the following . . . what have we missed?" This will encourage the whole team to think about the process and voice any concerns or ideas.
- A team leader or team member may have to intervene with *constructive intervention* if an inappropriate intervention, order, or action is about to occur. The team leader or member should perform this intervention tactfully and with respect. Confrontation should be avoided. Optimally, a debriefing can be held if constructive criticism is needed.
- A team leader must have an overall view of the resuscitation. Constant monitoring and *reevaluation* are essential. The practice of *summarizing* aloud the patient's status, interventions that have been performed, and assessment findings will enhance team participation and critical decision making.
- The best teams are composed of members who share a *mutual respect* for one another and work together in a collegial, supportive manner (AHA, 2006b). The team leader and team members should speak in friendly, controlled voices while avoiding the urge to shout or display aggressive behavior. The PALS course reviews best practices and pitfalls to avoid for team members and the team leader. The course also provides a simulated resuscitation video demonstrating optimal team behavior (AHA, 2006b).

DEBRIEFING

The process of debriefing remains a cornerstone of simulation-based learning (Fanning & Gaba, 2007; Issenberg et al., 2005). Without earnest feedback and guided reflection, participants will be left with their own subjective interpretations of the simulation experience. A template or checklist with debriefing objectives is essential to the session and will assist in the overall educational benefit (Fanning & Gaba, 2007) (see Table 1-2 and Table 1-3).

Based on the session, debriefing usually focuses on one of the following three aspects of performance: knowledge (medical and technical knowledge), human interaction (group dynamics, CRM, conflict resolution, teamwork), or a combination of the two. In pediatric simulations, the combination of knowledge and human interaction is especially important regardless of the session objectives. Debriefing provides for a safe and educational environment in which to promote verbal feedback and constructive criticism, reflective learning, communication among participants, a culture change regarding medical errors, and positive modifications to enhance performance (Dannefer & Henson, 2004; Mort & Donahue, 2004; Sutclife et al., 2004). Learning is impaired when team members feel threatened (Fanning & Gaba, 2007). Providing verbal feedback promotes attention to detail, allows the identification of areas of improvement, and fosters a collegial relationship of trust and respect. Through this type of interaction during debriefing, participants become engaged in their own education.

It is important to remember that all pediatric simulation sessions are held for the benefit of the participants, not the facilitator. Thus faculty members should apply components of the andragogical model of adult learning previously described. Failure to put the participants' need first will be disastrous. To ensure the optimal outcome, it is useful to enlist facilitators recognized for their capabilities as educators of adult learners in the practice of clinical pediatrics.

In addition, facilitators must have experience in the debriefing process. Offering and encouraging debriefing sessions after any pediatric resuscitation or death promotes solidarity among the members of group, whether it is a single-discipline or interprofessional team (Mort & Donahue, 2004). Debriefing sessions should remain on track, but allow for flexibility. Tangential topics may induce distraction and lead to a rapid loss of focus or interest. Colleagues should respect one another's opinions and evaluate objectively to improve the learning experience for the participants. Coupled with participant evaluation, it is important to identify potential problems and remedy any learner issues immediately. See Table 1-1 for a debriefing reference.

EVALUATION

Kirkpatrick and Kirkpatrick (2006) developed an educational evaluation process based on adult learning principles using a four-step model that can be adapted for simulation:

- *Reaction evaluation* obtains data on how the participants respond to a program (positive or negative feelings). Information can be procured through end-of-meeting reaction forms, interviews (Morrison, 2003), or group discussion.
- *Learning evaluation* involves obtaining data about principles, facts, and techniques acquired by the learners. A variety of testing methods can be used to evaluate skill learning (operating machinery, reading, writing), knowledge skills (problem solving exercises, pre-tests, post-tests), or attitudinal learning (role playing, simulations, attitudinal scales).
- The next step is *behavior evaluation*, which includes observational reports of actual changes associated with the learning opportunity when compared to the learner's prior performance. This type of data includes information gleaned from observation scales, questionnaires, and diaries. Questionnaires are the

most widely used evaluation tool in health education (Morrison, 2003).
- The last step is *results evaluation* where data are collected at an institutional or organizational level. Examples include effectiveness or efficiency of a system. In essence, has the learning opportunity lead to a tangible, global improvement?

Knowles and colleagues (2005) proposed adding a final step to Kirkpatrick and Kirkpatrick's model: rediagnosis of learning needs. This step assists learners in reflecting on and reassessing their progress toward competency. This final step completes the cycle of evaluation (Knowles et al., 2005). Refer to Table 1-1 and online Chapter 2 on the role of assessment in teaching and learning for further information.

VALIDATION AND RESEARCH

Does simulation work? From an evidence-based medicine perspective, many studies support its effectiveness. Clark Aldrich (2009) reviewed 10 ways to support highly interactive virtual environments (HIVEs) in the workplace; the strategies were easily adapted to pediatric simulation. Appropriately designing a research project is challenging, however. In addition, the data collected are often more qualitative than quantitative—and research in adult learning demonstrates that it is optimal to combine both qualitative and quantitative designs (Knowles et al., 2005). Pediatric simulation projects, especially in situ studies, support use of this mixed design (Patterson et al., 2008).

Gaba (2004) suggests additional foci for health care simulation research and development:

- Integrating simulation across different dimensions of applications, purposes, and target populations
- Assessing the impact or benefit of simulation-based training across various dimensions
- Developing applications for larger systems (e.g., complete work units, entire health care organizations)
- Establishing benchmarks and criteria for competency-based performance assessment using simulation
- Investigating fundamental aspects of human performance in health care using simulation
- Employing simulation for usability testing of medical devices and patient care processes (e.g., prototypes, investigational trials)

ON THE HORIZON AND BEYOND

A longstanding limitation of high-fidelity patient simulators relates to their lack of portability; thus simulator programs needing to perform *in situ* simulation have traditionally been severely restricted. To address this shortcoming, Gaumard Scientific developed a series of "tetherless" advanced simulators. Without any external attachments by an umbilicus, the simulators are controlled by a wireless connection (up to a distance of 300 meters) and include internal components for physiologic functions such as heart beat, pulse, respiration, pupil response, and speech. These simulators are also airworthy up to 45,000 feet in altitude, allowing for their use in flight training. On the horizon is another Gaumard simulator that can be used with any medical equipment, including noninvasive blood pressure, pulse oximetry, and streaming voice devices. The voice response can be programmed into various languages and dialects (Eggert, 2009).

Computer and electronic technologies are evolving rapidly, and new advances are not limited to those mentioned in this text. Some innovations in simulation VR programs, such as HIVE, remain in their infancy. Programs such as Second Life (2009) are transforming distance learning techniques into educational approaches suitable for the adult learner. One example of simulation advancement is the Cave Automatic Virtual Environment (CAVE)—completely immersive VR environments in which projectors are directed to room-sized cubicles (DeFanti et al., 2008; Wilks, 2009). Using special three-dimensional glasses, the user enters the room and manipulates the environment. The area can be augmented with other stimuli such as sound and vibration. Entire simulation hospitals may even be built, containing virtual patient rooms and suites. Research is also under way to develop immersive virtual environments similar to a "holodeck" such as the StarCAVE and NexCAVE (Cavazza et al., 2000; DeFanti et al., 2008; Fox, 2009; Startrout et al., 2001).

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