Time for a New Paradigm in Pediatric Medical Education: Teaching Neonatal Resuscitation in a Simulated Delivery Room Environment

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ABSTRACT. ***Objectives.*** **Acquisition and maintenance of the skills necessary for successful resuscitation of the neonate are typically accomplished by a combination of completion of standardized training courses using textbooks, videotape, and manikins together with active participation in the resuscitation of human neonates in the real delivery room. We developed a simulation-based training program in neonatal resuscitation (NeoSim) to bridge the gap between textbook and real life and to assess trainee satisfaction with the elements of this program.**

Methods. **Thirty-eight subjects (physicians and nurses) participated in 1 of 9 full-day NeoSim programs combining didactic instruction with active, hands-on participation in intensive scenarios involving life-like neonatal and maternal manikins and real medical equipment. Subjects were asked to complete an extensive evaluation of all elements of the program on its conclusion.**

Results. **The subjects expressed high levels of satisfaction with nearly all aspects of this novel program. Responses to open-ended questions were especially enthusiastic in describing the realistic nature of simulation-based training. The major limitation of the program was the lack of fidelity of the neonatal manikin to a human neonate.**

Conclusion. **Realistic simulation-based training in neonatal resuscitation is possible using current technology, is well received by trainees, and offers benefits not inherent in traditional paradigms of medical education.** ***Pediatrics*** **2000;106(4). URL: http://www.pediatrics.org/cgi/content/full/106/4/e45;** ***neonatal resuscitation, simulation, medical education.***

ABBREVIATIONS. CRM, crew resource management; ACRM, Anesthesia Crisis Resource Management.

The pediatrician in attendance in the delivery room is charged with prompt recognition, resuscitation, and stabilization of the neonate in distress. To carry out this responsibility successfully the pediatrician must possess thorough knowledge of fetal and neonatal physiology, proficiency in technical skills such as endotracheal intubation and umbilical vessel catheterization, and the ability to manage all of the technologic, pharmacologic, and human resources available in the delivery room. Historically, training in neonatal resuscitation has been accomplished by assuming graduated responsibility in caring for real patients. This apprenticeship model is augmented by participation in formal courses, such as the Neonatal Resuscitation Program and the Pediatric Advanced Life Support Program of the American Heart Association and the American Academy of Pediatrics; these courses provide a standardized approach to the technical aspects of neonatal resuscitation.[1] Although this model emphasizes knowledge and technical skills, it does not formally address the behavioral skills that are essential to the performance of complex, high-risk tasks.

We sought to develop a new model of training in neonatal resuscitation embodying many of the strengths of standardized courses (which use textbooks, lectures, skill stations, and objective tests) and on-the-job training (in the real delivery room), while minimizing some of the limitations associated with these traditional training methods. In doing so we have drawn on the training models used by other professionals working in highly technical, complex, dynamic environments, where emergencies evolve rapidly and require immediate, correct responses to avoid the loss of life. Simulation-based training involves immersion of the trainee in a realistic situation (scenario) created within a physical space (simulator) that replicates the real environment with fidelity sufficient to achieve suspension of disbelief on the part of the trainee. Examples of professions that have embraced simulation-based training include aerospace (flight simulators), the military (realistic war games), and nuclear engineering (power plant simulators). Although various medical device and patient simulators have been used to teach and practice specific physical examination skills in cardiology and technical skills in laparoscopic surgery and ammniocentesis, these tools in and of themselves cannot recreate all of the visual, auditory, and tactile cues encountered when caring for real patients.[2–4] We sought to incorporate as many of these cues as possible into our training program, thereby recreating the delivery room with high fidelity.

METHODS

All NeoSim programs described in this manuscript were conducted at the Simulation Center for Crisis Management Training

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in Health Care at the Veteran Affairs Palo Alto Health Care System in Palo Alto, California. This center houses a physical space that accurately simulates a real operating room, including working medical equipment such as appropriate surgical instruments, an anesthesia machine, patient monitors, lights, wall suction, and gas sources. This space is modified to simulate an operative delivery room with the addition of a neonatal hotbed, neonatal code cart, and other equipment necessary for resuscitation of the newborn. The maternal patient is a sophisticated patient simulator (MedSim-Eagle, Inc, Binghamton, NY) that has an anatomically correct airway and palpable pulses, is capable of limited movement (including chest rise), and generates variable heart and lung sounds.[5] Both the internal physiologic and pharmacologic models and the external anatomy are modified to better simulate a pregnant female. The neonatal manikin (Medical Plastics Laboratory, Inc, Gatesville, TX) approximates a full-term newborn in size and weight. It is simpler than the maternal manikin yet it possesses a realistic airway that can be intubated, lungs that can be inflated with positive pressure ventilation, and an umbilical cord containing a single vein and 2 arteries that allow insertion of umbilical venous and arterial catheters. We have written a computer program that allows the primary cues important for accurate assessment of the neonate (heart rate and skin color) to be controlled remotely and displayed on a pulse oximeter (hemoglobin oxygen saturation is used as a surrogate for color). The initial physiologic state and the subsequent responses of the neonatal manikin to the actions of the subjects are controlled by a single observing faculty member (L.P.H.) during each NeoSim program. Although the neonatal manikin, unlike the maternal manikin, has no internal physiologic algorithms and is not automated per se, its responses are standardized for each scenario (eg, during a placental abruption scenario, heart rate and hemoglobin oxygen saturation do not improve until an umbilical venous catheter is placed and a predetermined amount of volume is delivered).

NeoSim is a full-day program combining traditional training methods, including study of the literature and didactic instruction, with realistic simulation-based experiences and video debriefings to create a safe environment for hands-on practice of neonatal resuscitation. NeoSim is unique in the world of pediatric clinical training and education research in its emphasis on the subjects' active demonstration of both technical and behavioral skills (Table 1) as they carry out neonatal resuscitation under realistic circumstances.[6] Because subjects may be unfamiliar with high-fidelity simulation-based training, an extensive introduction is conducted at the beginning of each NeoSim program. This introduction includes a lecture describing simulation-based training, videotape review of exemplars of crisis management in nonmedical and medical professions, and a detailed hands-on orientation to all of the physical components of the simulated delivery room. Once this familiarization is complete, the subjects actively participate in scenarios designed to simulate delivery room crises. We have developed a number of scenarios simulating problems with patients (meconium aspiration, perinatal depression, hemorrhage, and congenital anomalies), technology (equipment failure), interpersonal interactions among members of the delivery room team, and system failures. On entering the simulated delivery room, the trainee encounters a room staffed with all of the professionals typically present during an operative delivery: obstetrician, anesthesiologist, scrub nurse, circulating nurse, and pediatric nurse. Occasionally the father of the infant or other support person is also present. Those staffing the simulated delivery room are simulator faculty who respond to the events that occur during the scenarios, creating the complex environmental cues and stressful conditions often present within a real delivery room. The responses of the simulator faculty are standardized by instructions received in faculty briefings before the start of each scenario; however, their responses are also influenced by their professional experiences as physicians and nurses and by circumstances that arise spontaneously during the scenarios. The simulator faculty may or may not be known to the subjects before the program. During the scenarios all events are captured on time-coded videotape for playback during a formal debriefing session that immediately follows each scenario. The debriefing is conducted in a room with multiple video monitors and comfortable seating that is physically separated from the simulated delivery room. This is done to avoid any potential psychological or emotional effects that may linger from being in the simulated delivery room. As many as five scenarios and debriefings are conducted in a single course. Each delivery room scenario lasts ~15 to 20 minutes; debriefings usually require ~45 minutes for detailed analysis and discussion.

All subjects were recruited from the physicians and nurses responsible for neonatal resuscitation in the delivery rooms at Lucile Salter Packard Children's Hospital, Stanford, California. No subjects received compensation for their participation and no subjects played a role in program development. All were asked to complete an extensive evaluation at the end of the program. Subjects were asked to respond anonymously, choosing "disagree," "no opinion/neutral," or "agree" to questions designed to assess the various components of NeoSim. In addition, several open-ended questions were included to elicit both the best and worst elements of the program. This study was approved by the Panel on Nonmedical Human Subjects of the Institutional Review Board of Stanford University.

TABLE 1. Technical and Behavioral Skills in Neonatal Resuscitation

Technical skills
General physical examination
Management of thermal regulation
Positioning
Suctioning
Tactile stimulation
Treatment of meconium aspiration
Bag-mask ventilation
Intubation
Chest compressions
Delivery of medications
Umbilical vessel cannulation
Behavioral skills
Know the environment
Anticipate and plan
Assume the leadership role
Communicate effectively
Distribute workload optimally
Allocate attention wisely
Utilize all available information
Utilize all available resources
Call for help early enough
Maintain professional behavior

RESULTS

To date, 38 physicians and nurses have completed NeoSim; characteristics of the subjects are shown in Table 2. The results of the survey are listed in Table 3. Of all of the materials covered during the orientation, the videotape reviews were rated as the most helpful. With the exception of the ambient temperature, the majority of subjects deemed the physical characteristics of the simulated delivery room adequate. Only one half of the subjects described the neonatal manikin as providing a real-life experience; the majority of subjects rated the rest of the clinical equipment as adequate. The most highly rated components of NeoSim were the scenarios, debriefings, and simulator faculty; virtually all of the subjects indicated that these aspects of the program met their approval.

DISCUSSION

The results of the formal evaluations completed by the first 38 subjects to participate in NeoSim suggest

TABLE 2. Characteristics of Subjects

Number: 38
Gender: 25 females and 13 males
Age range: 25–48 y
Profession: 9 RNs and 29 MDs
Experience in clinical practice: 0–27 y

TABLE 3. The Simulated Delivery Room Training Program Evaluation

	Disagree (%)	Neutral (%)	Agree (%)
Introductory materials			
The reading materials are helpful.	5	43	52
The reading materials should be read before the course.	5	46	49
The "Introduction to CRM" lecture is helpful.	3	8	89
The aerospace videotape/debriefing is helpful.	0	5	95
The medical videotape/debriefing is helpful.	0	0	100
The orientation to the simulated delivery room is adequate.	5	13	82
Physical space			
The simulator space resembles a real delivery room.	0	3	97
The temperature in the simulator is comfortable.	8	24	68
The lighting in the simulator is adequate.	0	8	92
The acoustics in the simulator are adequate.	3	8	89
The video cameras are nonobtrusive.	3	8	89
The seating in the debriefing room is comfortable.	0	5	95
The lighting in the debriefing room is adequate.	0	0	100
The acoustics in the debriefing room are adequate.	0	0	100
Faculty			
The faculty members adequately simulate real-life roles.	0	0	100
The faculty members are enthusiastic.	0	0	100
Equipment			
The hotbed is adequate.	3	8	89
The intubation equipment is adequate	0	3	97
The umbilical cannulation equipment is adequate.	0	35	65
The neonatal code cart is adequate.	3	14	83
The medication supply is adequate.	0	14	86
The neonatal manikin provides a real-life experience.	13	37	50
The audiovisual equipment in the debriefing room is adequate.	0	11	89
Scenarios			
The scenarios recreate real-life situations.	0	3	97
The scenarios adequately test technical skills.	0	5	95
The scenarios adequately test behavioral skills.	0	0	100
The debriefings focus on crisis management skills.	0	3	97
The debriefings clarify issues raised during the scenario.	0	3	97
The debriefings allow participants to self-critique.	0	0	100
The debriefings adequately critique each scenario.	0	0	100
The debriefings enhance knowledge.	0	0	100
Other issues			
The technical skills taught in the course are valuable.	0	5	95
The behavioral skills taught in the course are valuable.	0	3	97

*What part(s) of the course did you like the best?

"Practicing taking a leadership role; great to be the leader and then see yourself on video and really think about what you were doing and why; I learn best from 'doing' and this was a great opportunity for that; debriefing sessions were helpful and positive learning experiences for all participants; real-life simulation instills a lot of confidence in starting on living patients—very good experience; the debriefings; the scenarios; video debriefing; direct, immediate feedback; personalized learning—ability to focus on individual strengths and weaknesses; feedback sessions were handled quite tactfully and positively; interaction, dynamism; the debriefing sessions—really helpful to go over the sim sessions in detail breaking them into short takes."

*What part(s) of the course did you like the least?

"The anticipation of a scenario; initial orientation; literally none; sweating, fear of the unknown; my tachycardia; no complaints at all."

*What could make the course better?

"Having more scenarios to go through; more scenarios; more often; the only thing I can think of is to improve the manikin; improve responsiveness of baby, if possible; excellent as is—I recommend it for all residents; it's great!"

*Other comments

"This was very useful to me, very useful in teaching/learning communication skills; thanks!; great experience, you did a good job making me feel comfortable in a potentially threatening environment; manikin made me realize how much I rely on sensory input in the delivery room; I don't think having a less than perfect manikin mattered—I felt this was very valuable training and will help when I'm in the NICU; it was surprisingly enjoyable and a fun way to learn; very helpful; I thought the debriefing was an excellent learning opportunity—the actors in the room help make the situation seem more realistic; will be good to repeat the course with different scenarios later; thank you!"

NICU indicates neonatal intensive care unit.

* Excerpts selected by authors.

that we have been successful in developing a simulation-based training program in neonatal resuscitation that effectively recreates conditions present in the real delivery room, is well received by trainees, and offers benefits not inherent in other educational models. The traditional paradigm of professional education and training consists of 3 primary components: 1) reading of the literature, 2) observation of others possessing more experience in the field, and 3) hands-on experience during a defined period of time in preparation for independent practice. This paradigm, although historically accepted and utilized, has numerous intrinsic limitations. Review of written literature is necessary but not sufficient to achieve competency. Research indicates that optimal acquisition and retention of knowledge and skills by adults is achieved by active participation rather than by passive observation.[7] Random observation of senior colleagues who theoretically have more experience in a particular field (learning by osmosis) assumes that those colleagues always serve as good role models, that their attributes can be incorporated into the behaviors of the trainee, and that the appropriate spectrum of situations is observed. This, however, is not universally true. Trainees may not be able to distinguish poor role models from those who are superb. Assimilation of certain professional attributes may prove a difficult task for particular trainees. The period of training or apprenticeship is limited in time and depth; therefore, the experience obtained by individual trainees may vary greatly.[8] In addition to these factors, the characteristics of the training environment itself also have an impact on the trainee. Many professionals work in dynamic domains characterized by intense time pressure, unpredictable responses, complex communication patterns involving multiple personnel, and high risk. Successful operation within dynamic domains requires the use of decision-making skills that are distinctly different from those required in relatively static domains, such as those found in clinic-based medicine.[9,10] Because many training environments lack the features associated with dynamic domains, the professionals training within these environments are not afforded the opportunity to acquire and practice these unique decision-making skills.

One of the first professions to critically assess its training methods was the aerospace industry. The cockpit of an airplane is a truly dynamic domain. Flying commercial aircraft requires both a large fund of knowledge and a set of appropriate technical skills enabling the crew to interface with and use the technology present within the cockpit. Because the crash of an airliner is associated with tremendous cost, in both irreplaceable human lives and expensive technology, the aerospace industry has long been interested in preventing such tragedies. Flying large commercial aircraft has been described as "hours and hours of boredom interspersed with moments of terror"; one might assume that these moments of terror are secondary to massive mechanical failures and the crew's inability to compensate for them. However, in two thirds of these accidents analysis of black box recordings of instrument readings and cockpit communications revealed that it was primarily poor teamwork by the crew that prevented the aircraft from landing safely.[11] The fact that highly skilled professional pilots with thousands of hours of flying experience failed to adequately manage their collective technologic and human resources in times of crisis led the aerospace industry to develop training programs in crew resource management (CRM).[12] These programs teach both the appropriate mechanical intervention to a crisis situation as well as the management of personal and collective resources (teamwork) during these adverse events. CRM programs are conducted in realistic flight simulators capable of mimicking the visual, auditory, and kinesthetic cues encountered during actual flight. Completion of CRM training is mandated annually for all flight crews working for major US airlines.

Like the cockpit of an airliner, many medical domains are similarly dynamic in nature. Although crises arise much more frequently in medicine than in aviation, some specific crisis situations may never be encountered during training, and only rarely during a career. Yet physicians and other health care personnel are expected to make rapid and correct decisions despite what may be a true lack of practical experience in managing a particular medical emergency. This was first noted by anesthesiologists—physicians charged with management of the technologic, pharmacologic, and human resources in the operating room. Recognizing the potential benefits of training in simulated medical environments, anesthesiologists and engineers developed life-like sophisticated adult patient simulators equipped with realistic physical and physiologic features and placed these devices within a physical environment containing real working medical equipment to simulate an actual operating room with high fidelity. Based in part on the CRM programs used in aerospace, a training program in Anesthesia Crisis Resource Management (ACRM) was developed in 1990.[13] This program combines training in the appropriate technical interventions with defined behavioral skills deemed vital to crisis resolution. Simulation-based ACRM training has been ongoing in anesthesiology for nearly a decade and at multiple sites around the world.[14,15]

The dynamic nature of the delivery room is similar to that of the operating room. Because many neonatal morbidities actually have their genesis in utero, the pediatrician may be faced with a patient who requires vigorous resuscitation immediately at birth. Decisions made by the pediatrician may carry lifelong consequences for both the infant and mother. Unlike the anesthesiologist, however, the pediatrician does not have the benefit of a sedated or anesthetized, well-monitored patient (as found in routine operating room cases in industrialized countries) and must rely on auditory (crying, breath sounds, and heart tones) and visual (skin color and muscle tone) cues present on physical examination, as well as on feedback from colleagues (eg, the bedside nurse) in determining the appropriate course of action.

The key to effective simulation-based training is achieving suspension of disbelief on the part of the subjects undergoing training, ie, subjects must be made to think and feel as though they are functioning within a real environment, where their actions are associated with real consequences. This is difficult to achieve in traditional training settings such as classrooms, which lack the multiple cues found in dynamic, complex, technical domains. The results of the course evaluations listed in Table 3 indicate that the subjects believed that the simulator space and medical equipment within it effectively recreate the physical aspects of the operative delivery room environment. Another component of the environment that was well received was the simulator faculty who acted as confederates in the scenarios. Our simulator faculty was rated to be both enthusiastic and highly skilled in playing multiple roles, delivering complex environmental cues, and creating stressful conditions like those encountered in the real delivery room.

The vast majority of subjects responded that the scenarios effectively recreate real-life situations and adequately test their technical and behavioral skills. During the debriefings that follow each scenario the simulator faculty members act to facilitate, not to monopolize, the discussion. They invite constructive commentary from the subject(s) involved in the scenario as well as from the confederates present in the simulated delivery room. Constructive debriefings by expert faculty in a supportive environment are likely to enhance the self-efficacy of the subjects, believed to be a key in achieving optimal human performance.[16] Virtually all of the subjects indicated that the debriefings were focused, thorough, and that they clarified important issues, allowed for self-critique, and enhanced knowledge. The positive impact of the debriefings is especially evident in the written responses to the open-ended questions listed in Table 3.

One aspect of NeoSim that was not consistently rated highly was the neonatal manikin. As mentioned earlier, it is a relatively simple device and is not capable of spontaneous respiration, generation of heart tones, movement, alteration in muscle tone, or change in skin color. Because heart rate, respiratory activity, and skin color are the major cues indicative of the need for initiation, escalation, and termination of resuscitative measures, it is difficult to compensate for the absence of all 3 of these in a newborn manikin. The bedside nurse can provide intermittent verbal cues to the subject, but this mode of information transfer is limited. The addition of the oximeter to indicate heart rate and skin color compensates for some of these deficiencies but also introduces an additional element of complexity to the scenario (oximeters are not routinely used in delivery rooms in the United States to monitor newborns in the first minutes after birth).

High-fidelity simulation-based training offers advantages over traditional training models. Simulators are controlled environments in which multiple intense clinical experiences can be provided in a relatively brief period. These clinical experiences can be scaled to fit the level of the trainee, whether he or she is a novice or veteran. Unlike the real world, the simulator offers the convenience of scheduling and the option of repetition. Because the simulator is stocked with real medical equipment and populated with interactive human colleagues, trainees must actively demonstrate appropriate technical and behavioral skills and are unable to simply talk their way through difficult scenarios. The use of videotape provides an objective, time-coded record of trainee communication and actions and creates a powerful stimulus for learning during facilitated debriefings. Because the activities in the simulator pose no risk to patients or to professional liability, trainees are allowed to witness the natural evolution of mistakes without the need for intervention by senior faculty. Finally, simulators reduce the use of hospital resources by supplanting expensive patient care arenas as the location for clinical teaching and recycling supplies and devices that normally would require disposal if used on real patients.

The use of real working medical equipment, sophisticated patient simulators, high-quality yet unobtrusive audiovisual recording and playback devices, and faculty with expertise in both the medical and educational aspects of simulation-based training is more expensive in comparison with traditional training programs. However, the experience in other high-risk domains, such as aerospace, indicates that the more realistic the simulator, the greater the suspension of disbelief on the part of trainees, and the more effective the training. Because of the expense of, and technical expertise required for, high-fidelity simulation-based training, both the aerospace industry and professionals in the field of anesthesiology use simulators as regional resources. Although cost prohibits the presence of a sophisticated simulator in every hospital, certain aspects of simulation-based training (such as recording the actions of trainees on videotape) may be easily incorporated (although in a less sophisticated fashion) on a local level.

Fanaroff[17] recently described some of the challenges facing neonatal–perinatal medicine: "We must recognize that trainees at all levels learn by doing, not by listening and observing. Medical students, residents, and fellows learn better from hands-on experience. Knowledge comes from repeating the experience. It is time to develop multimedia-based interactive training modules that provide really good simulations of possible experiences in a manner similar to the training and recertification of airline pilots." We have shown that high-fidelity simulation of neonatal resuscitation can be conducted using current technology, is well received by those experiencing it for the first time, and offers benefits not inherent in traditional medical educational models. We agree with Dr Fanaroff[17] that now is the time for a new paradigm of clinical training and medical education research, and we believe that simulation-based methodologies emphasizing both technical and behavioral skills will serve as the foundation of that paradigm.

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