Abstract:

The pediatric emergency medicine (PEM) environment is well suited for simulation-based activities, be they educational interventions for PEM learners, evaluations of the interface between health providers and the environment that they work in, or research investigations using simulation as a tool to answer specific clinical questions. As such, PEM has been among the leaders in the integration of this modality for clinical training. Traditionally, simulation has been used extensively for the dissemination of clinical training in the areas of clinical knowledge and its application, and the clinical, technical, and teamwork skills involved in PEM care. Increasingly, simulation is being used in novel applications, including breaking bad news, disclosure of error, family-centered care, quality and patient safety education, and system-level integration. The future will look to further identify, measure, and inform the integration of simulation with new and innovative adjuncts in the clinical environment, as well as to determine the optimal timing and use of simulation-based education to enhance the quality of care delivered to patients by the interprofessional and multidisciplinary team.

The Past, Present, and Future of Simulation-based Education for Pediatric Emergency Medicine

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The pediatric emergency medicine (PEM) environment is complex and dynamic. As the "front door" to the hospital for a significant number of patients, the sheer variety of possible clinical presentations that present in an unexpected manner is truly daunting. From an acute care standpoint, these presentations vary from the common (eg, asthma, seizures), to the rare (eg, penetrating thoracoabdominal trauma, organophosphate poisoning), to the novel and unexpected (eg, newly emerging infectious disease such as Middle East Respiratory Syndrome or Ebola), with uncommon or unusual presentations of everything in between. Further layered on that clinical complexity is a broad range of care providers that must function as a coordinated team. These team members range from various students, to the unit aides/clerks, residents, nurses, nurse practitioners, physician assistants, paramedics, respiratory therapists, and attending physicians whom together make up the backbone of the PEM environment. Further layered on

safety; outreach education; mobile education; systems integration

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the clinical and personnel complexity is the complex system of integration with other clinical areas within each institution, the "system" that orbits around the PEM environment (eg, critical care, diagnostic imaging, operating room). And finally, this system relies on the interplay of communication between team members, between the team and the "system" and between the team and the patients and families that we serve. Whether this communication is the handover of a patient or breaking bad news to a family, each situation is dynamic, uncertain, and potentially loaded with safety issues at each step. It is in all of these diverse ways that the experiential learning model at the foundation of simulation-based education (SBE) matches the PEM environment and thus has led to the relatively quick uptake over the past 2 decades. This article will tackle 3 essential elements of the relationship between simulation and PEM. First is a review of "where we have been," including the breadth of curriculum and integration that has been created and disseminated from the inception of simulation in the PEM environment to the present. Next is a review of "where we are now," in particular highlighting areas where PEM simulation is being creative, innovative, and setting a new bar for those who deliver SBE in any area. The final component is a compelling review of "where we are going," a provocative view of where simulation may be further expanding new boundaries in the delivery of PEM-based SBE and clinical care.

WHERE WE HAVE BEEN

Content

There is a long history of curricula developed for PEM providers that encompass the various elements that influence patient care in the clinical environment.[1–3] These include communication, clinical assessment, and procedural and nontechnical (teamwork) skills, among others. These topics are explored in greater detail throughout this edition of *Clinical Pediatric Emergency Medicine*. These curricula also include many subdomains of PEM, including cardiopulmonary resuscitation, trauma, multiple casualty incidents (MCIs), disaster management, and transport medicine.

Cardiopulmonary Resuscitation

Life-threatening events and cardiopulmonary arrests in pediatrics are rare. Therefore, the knowledge, clinical, procedural, and team skills necessary to efficiently and effectively run a pediatric resuscitation are not frequently practiced, making simulation the ideal environment to further hone these skills in order to be prepared for the real event.[4–6] The American Heart Association has advocated for the increased use of simulation as part of advanced life support training, including Pediatric Advanced Life Support (PALS). The addition of simulation to advanced life support curriculum has been shown to increase knowledge and skills in providers relative to those who did not receive simulation as part of their training.[7,8] Furthermore, high-fidelity resuscitation training has been shown to improve acquisition of clinical skills in comparison to training with low-fidelity manikins, thus supporting the American Heart Association's integration of simulation into these curriculum.[9] A longitudinally distributed PALS course with a significant simulation component has also been developed to address the issue of knowledge decay seen in students following PALS courses.[10,11]

Trauma

Pediatric trauma care was one of the earliest areas of focus within PEM regarding simulation-based training.[12–14] Because these patients are some of the more complex within the PEM environment, from both a clinical and team dynamics standpoint, simulation training is a natural fit for pediatric trauma and has been shown to improve the quality

of care provided in different studies.[15,16] Simulation has been used to identify significant gaps in knowledge, equipment, team skills, and systems related to the assessment and management of trauma patients in the rural environment,[17] although many of the areas identified as deficiencies would be relevant to trauma care in an urban PEM environment. Based on this need, established programs like the American College of Surgeons' Advanced Trauma Life Support Course[18] have increasingly used simulation as a means to practice the various clinical and procedural skills. More recently, courses like Trauma Resuscitation In Kids, [19] developed by the Royal College of Physicians and Surgeons of Canada, have heavily leveraged the use of simulation in terms of the practical application of the concepts taught within the course. Trauma Resuscitation In Kids has also tried to maximize the use of interprofessional teams and a focus on team training in further driving the realism and pertinence of this experiential learning.

MCIs/Disaster Management

Multiple simultaneous patients presenting to an emergency department (ED) are relatively rare, but practicing these events can help an institution prepare for the possibility. Multiple casualty incidents and disasters can be a result of a natural event (eg, tornado, earthquake), human accident/error (eg, school bus crash, radioactivity leak, house fire), infectious disease (eg, Middle East Respiratory Syndrome, influenza pandemic), and intentional events (eg, mass shooting, terrorism). The specific etiology of the MCI dictates the types and numbers of patients to be expected. There are several cognitive, emotional, and physical vulnerabilities that make the pediatric application of MCI training unique, including plans for patient reunification

with family members.[20,21] Depending on the magnitude of the event, the goal of the PEM team changes to doing the most good for the most patients, within the limitation of available resources.[22,23] Because this affects the initial triage, stabilization and disposition of patients, simulated disaster codes can be an excellent way of practicing these specialized skills.[24–28]

Transport Medicine

In many institutions, responsibility for the transport of acutely ill or injured pediatric patients also falls under the care of PEM. Similar to other clinical aspects of PEM, the transport of pediatric patients is a dynamic and complex problem that involves the interplay of an individual within a team working within a defined system and environment. The physical transport of patients most often occurs in an environment that is not ideal for the provision of pediatric emergency and critical care (eg, helicopter, ambulance, fixed-wing aircraft), but necessary based on the long distance required for the provision of definitive care. All of the elements of this dynamic environment can be simulated: tight spaces, noise, vibration, specialized equipment, and extreme conditions that impact the rapid evaluation and management of patients being transported. The physical ability to mimic these conditions has been aided by the portability of the new generation of wireless portable mannequins. ✚

Process

Longitudinal Curricula

Several PEM simulation curricula have been published in the literature (Table 1). They were all developed for use within residency and postresidency

TABLE 1. Comparison of published PEM curriculum.

Learner Group	Design	Methodology (base content)	Instructional Scenarios	Evaluation Scenarios
PEM Fellows[29]	Longitudinal	Delphi reduction (ABP/RCPSC)	48 scenarios/2 years	No
PEM Fellows[3]	Longitudinal	Expert opinion (ABP/RCPSC)	43 scenarios/2 years	No
Pediatrics Residents[30]	Longitudinal	Delphi reduction (PALS/ACGME)	9 scenarios/1 year	No
Emergency Medicine Residents[31]	Single Day	Expert opinion (PALS)	6 scenarios/1 day	3 scenarios at 1 month

Abbreviations: ABP, American Board of Pediatrics; RCPSC, Royal College of Physicians and Surgeons of Canada; PALS, Pediatric Advanced Life Support; ACGME, Accreditation Council for Graduate Medical Education

fellowship programs, with a defined number of scenarios being covered over a defined period. Four main curricula have been developed to date. The most robust of the group was developed using a Delphi reduction method that resulted in 48 key curriculum topics to be covered during a 2-year PEM fellowship, averaging out to 2 per month.[29] A second PEM fellowship curriculum was created by identifying key topic areas and then choosing key presentations within each of those topic areas. This curriculum was designed to run on a weekly basis while PEM fellows rotate through the ED. The topic areas are divided into first- and second-year and the scenarios chosen from a total of 43.[3] A longitudinal curriculum designed to teach PEM content to pediatric residents used content mapping targeting various core resuscitation skills (eg, airway and breathing, circulation, teamwork, etc) divided among multiple scenarios.[30] Finally, a longitudinal curriculum designed to teach PEM content to emergency medicine residents resulted in a curriculum of scenarios designed to parallel the systematic approach to airway, breathing, circulation, disability and exposure/environment that is taught in the PALS course. The curriculum consisted of 6 formative cases and 3 evaluation cases performed at a later date. There was a correlation found between performance and year of training, but no direct improvement as a result of the educational intervention.[31]

Boot Camps

As opposed to longitudinal curricula that are designed to be delivered over the span of a training program, boot camps have been developed for a short but intensive experience with core training in PEM. They are often delivered at the beginning of a training program to rapidly develop the key knowledge and skills required to function well within the discipline. Other boot camps have been developed to help with the transition between years in training (ie, from year 1 to year 2 of PEM fellowship training). Some programs have even used this learning modality to link up with other programs and maximize time, space, equipment, and human resources (ie, facilitators). A combination of procedural skills, clinical skills, and team training (crisis resource management) are often covered. Their popularity stems in part due the practicality of scheduling; some programs can cover new fellows or interns for a day or two of dedicated training vs routine longitudinal attendance at a weekly simulation event. Depending on the scale of boot camps, the availability of a large simulation center may be required to handle the number of leaners in the time allotted both with space and simulation equipment.

In Situ Training

Simulation-based education delivered directly in the clinical environment has the advantages of training individuals and teams in their own clinical space with their own equipment. As such, the team members will be using the same equipment, and located in the same space they would use in a real clinical situation. The other advantage of this approach is that latent errors in the space, equipment, and clinical systems can be identified without harm to real patients. In situ simulation in the PEM environment offers learners who may not have a chance to lead the care of ill children to experience this role in the ED setting and with the usual care team, an important opportunity for fellows and residents.

The disadvantage tends to be the availability of clinical space for education in otherwise busy EDs.[32,33] However, learners do not have to travel to a simulation laboratory that might not be close by. Asking learners to travel even short distances can lead to attrition in attendance. Faced with the choice between in situ and off-site locations, in situ or a mix of both approaches may benefit attendance overall.

Just-in-Time Training

More programs are starting to include just-in-time (JIT)–style training within PEM. The primary objective of JIT is to choose the patient or procedure ahead of time and to rehearse performance prior to managing the patient or performing the procedure in real life. Although the prediction of clinical presentations to the ED is impossible, certain thematic topics can be predicted in a JIT fashion: assessment of a polytrauma patient, approach to a poisoned patient, mass-casualty incident, cardiac arrest, and so on. This is an obvious difference with JIT sessions traditionally seen in intensive care units and inpatient units, where a specific patient is chosen based on the potential for deterioration. As opposed to scenario-based clinical presentations for knowledge and team training, JIT in the ED is well suited to procedural skill training. There have been several successful examples of this published in the literature related to lumber puncture, cardiopulmonary resuscitation (chest compressions), and airway management.[34,35] ✚

WHERE WE ARE NOW

Initially, simulation in PEM consisted of training in high-stakes, time-sensitive events, such as resuscitations and procedures, that were difficult to train exclusively in real-life scenarios due to the infrequent nature and the life or death consequences associated with management of these events. As

discussed above, these skills remain the predominant focus of simulation training in fellowship programs. However, current applications have expanded to include nontechnical skills such as communication and management of psychosocial issues.[36] This has occurred in part in response to changes in the health care environment that have placed an increased emphasis on providing high quality, safe, and family-centered care.[37,38] In addition, there has been increased appreciation of the essential role communication plays in patient outcomes and satisfaction.

These behaviors and skills have traditionally been taught through modeling and mentorship. There is now recognition that formal training in communication skills, professionalism, and leadership is necessary and has been proven to improve overall outcomes. The recent publication of the Entrustable Professional Activities (EPAs) for PEM fellows reflected this emphasis by including the competency domains of interpersonal and communication skills in all of the required EPAs.[39] The domain of communication encompasses multiple exchanges of information between physicians, patients and families, and other health care providers, as well as the many more interactions with learners, organizations, and the public. As such, it is a broad and complex competency that is difficult to teach and assess without experiential learning. Simulation has emerged as an ideal teaching modality for these competency domains because of the ability to practice both frequent (eg, patient counseling) and infrequent (eg, breaking bad news) learning tasks. When done well, this approach can create in a realistic yet safe, nonthreatening environment that fosters learning. We will explore ways that PEM educational efforts are incorporating simulation for training in these competencies through the examples of providing family-centered care, leading difficult conversations, and practicing patient safety.

Patient and Family-Centered Care

Patients and families are integral members of the health care team. In recognition of this, there is increased emphasis on patient and family-centered care (PFCC). Many of the 8 dimensions of PFCC in PEM (emotional support, team coordination, patient and family involvement in care decisions, timely care, education, pain management, child-focused environment, and seamless transitions) are amenable to SBE.[40] To improve the health care providers' role in practicing PFCC, health care providers can participate in simulations that focus on team coordination, timely care, pain management, and

seamless transitions. Standardized patients or trained patient and family volunteers can be used in practice encounters focusing on emotional support, patient and family involvement, and patient education.

Simulation is also being used to promote PFCC via simulation for patients and families as the target learners. Just as health care providers can learn and practice technical skills, cognitive reasoning, and behavioral tasks, so too can patients and family members, empowering them to fully participate in their care.[41,42] Cognitive skills relevant for families in the ED may include recognition of anaphylaxis, a prolonged seizure, or respiratory distress. Technical skills relevant for families of patients in the ED include administering an intramuscular injection of epinephrine, antiepileptic rescue medication, or administration of albuterol metered dose inhaler with spacer and facemask. Behavioral objectives may include effective communication with emergency medical services or effective workload distribution with another home caregiver. Simulation can also be used to assess a parent's competency at performing essential care giving at home. For example, it may be used to assess if a family member can properly administer antibiotics through a central line in a sterile fashion. Although the principles of PFCC of respect and dignity, information sharing, participation, and collaboration should always be guiding principles in SBE, this is particularly important when involving patients and families.[43]

Breaking Bad News

Pediatric emergency medicine physicians frequently have to deliver difficult news to patients and families within the context of a busy ED. This may include notification of the death of a loved one or a new diagnosis of a chronic or terminal illness. Although the content will differ with each patient, there is a nearly universal experience of distress for PEM providers delivering difficult news. This distress is further compounded by the uncertainty of how the family will respond given that PEM providers usually do not have long-term relationships with patients and families. Appropriate preparation and education can make difficult conversations less stressful for the PEM physician, and in cases of death notification, it may help decrease the development of pathologic grief in the surviving family members that can occur when death is unexpected. There are a few different models for delivering bad news suggested in the literature, including GRIEV_ING and SPIKES.[44,45] Regardless of which model is selected for education, the objectives can be achieved through the use of role play,

simulation, and standardized patient encounters that focus on this complex skill. An important way to simulate the experience in its entirety is to perform a simulation in which the patient dies and then team members are immediately tasked with talking to the family, with a standardized patient acting as a family member.[45]

Medical Error Disclosure

Medical error disclosure is one specific scenario for the delivery of difficult news. This could be an error in diagnosis, interpretation of results, therapeutic choice, or miscalculation, among many others. Simulation presents an ideal opportunity to engage in these challenging conversations so that PEM providers are better able to handle this delicate and stressful situation in clinical practice.[46] Standardized patients are often used for to represent the family member(s) to which the error us being disclosed.

Patient Safety

The ultimate role of SBE is to improve patient safety and outcomes. This can be done at the level of the individual provider (knowledge, skills, and attitudes), the team (communication, shared mental models), and the health care system.[47] Traditionally, this is done by simulating rare but important outcomes and through trialing new procedures and equipment with task trainers. Recently, simulations have focused more intentionally on patient safety through the use of simulated patient care handoffs, assessing adherence to care bundles, simulation-informed root cause analysis, and in situ simulation to identify latent patient safety threats.[48–51]

Extension of Simulation Beyond Academic Centers

Traditionally, simulation has been available exclusively to large medical and academic centers due to the high cost and expertise required to use SBE. However, given that most children receive ED care outside academic centers and free-standing children's hospitals, there has been an increased recognition of the need to provide education to health care professionals practicing outside large medical centers. Simulation can be provided in these settings in a variety of ways. Distance education using screen-based simulation offers the opportunity to enhance cognitive skills relative to PEM clinical presentations, yet requiring minimal resources compared with the use of high-technology manikins. However, screen-based simulation is not suited to address procedural skills, team-based

training, or systems issues inherent in PEM clinical practice. There is still a need to provide in situ experiential learning using mobile simulation programs, where simulation equipment and educators are transported to participants in these environments. This may involve bringing manikins and clinical equipment to run the in situ simulation in the rural ED or the use of a mobile simulation center.[51] Yet another option is for a simulation educator to run a simulation virtually through the use of videoconferencing akin to telemedicine.

Systems Integration

The pediatric ED is a part of a complex health care system comprised of many interrelated components. Given the multiple interconnected relationships between the components and the whole system, these systems must work in concert to achieve optimal care. It is often not known how these systems will interact until a problem occurs that adversely affects patient care. Simulation can be used prospectively to understand the systems factors that affect health care delivery. By performing simulation with real teams in real settings, potential problems can be identified before they occur. For example, a simulation may uncover lack of child-sized equipment or mislabeled equipment.[17] Simulation can also be used to evaluate new clinical equipment and care environments, including the identification of latent safety threats. ✚

WHERE WE ARE GOING

Simulation-based education offers a useful tool for provision of instruction and feedback within the PEM environment, particularly related to the skills, teamwork and systems testing reviewed above. It offers particular advantages to the PEM educator faced with interprofessional trainees spanning the range of training from student to experienced practitioner. Looking forward, where do we go next to address unmet needs, improve existing programs, and develop a broader group of educators?

One definition of simulation describes this method as the artificial replication of sufficient elements of a real-world domain to achieve a stated goal.[52] This conceptualization encourages the avoidance of unnecessary complexity. While tempting, the use of flashy technology does not always equal better education. We accept some degree of artificiality or "close enough" because it leads to the important outcome of actually getting simulation education done. In the future, we should ask the hard question of how we "get the work done", while expanding to

incorporate more facets of clinical PEM practice, as well as identifying new ways to achieving our various educational goals while staying within our (time, and fiscal) means. In this section, we propose some areas that are well suited for future exploration with SBE.

Electronic Medical Record

One of the more commonly neglected or "simulated" features in PEM simulations is the need to interface with a functional or clinically realistic electronic medical record (EMR) system. In our busy clinical setting, the EMR introduces substantive human factors concerns such as loss of eye contact/attention of the provider at the computer, the need for a (additional) provider working at the EMR, who is perhaps outside the room leading to opportunities for error. While some centers can either simulate or provide this feature, this ability currently comes with both a time and monetary cost to maintain. The absence of EMR interaction creates the potential for negative learning as team leaders/members may forget, for example, to close the loop regarding order placement when the EMR is omitted. Further, EMRs can be part of important system barriers that may go unrecognized without their inclusion during simulation. Our local experience with ordering emergent blood products has illustrated how challenging this can be and forms an important take home for learners (ie, to learn how to order blood before the crisis). Further work needs to identify methods to allow use of existing EMR systems in simulation. At the same time, hospitals should be encouraged to invest in workable test systems that can be used for more than the mundane technical testing needs. At the same time, commercial or open-source simulated EMRs could be used to help address this need in part.

Large System-Level Integrated Simulation

While likely to remain a costly endeavor, simulations that create meaningful interactions between the PEM providers and the local "micro" system (operating room, wards, blood bank, pharmacy, administration) and the larger "macro" system (emergency medical services, nearby and regional hospitals, public health services) are truly valuable learning and testing opportunities. While tabletop exercises and other more modest simulations are often performed, these less robust tests cannot uncover all barriers unless all components of the system are fully tested. An example of an "incomplete" system test would be a multiple casualty trauma simulation in which the blood bank,

operating room and senior surgeons are not available to participate. Simulations could range from the more obvious (mass casualty, Ebola-type illness) to the more mundane (influenza surge) to the truly terrifying (live shooter in building, evacuation due to fire). It is in these situations that both unexpected issues (which phones work when there is no power given the availability of voice-over-internet phones) and expected although none-the-less challenging (who is in charge, who is deciding when my patient can go to CT?) may arise, impacting care delivery. It is clear that these events are time, resource and staff intensive events that must be designed in a way to produce meaningful training and/or system level data. While these events exist today, the future challenge is to translate the "occasional" event at a few sites to the "regular" event at most/all institutions.

Mastery-Based Training Models

The usefulness of mastery-based training[53] has been established to both be effective in improving performance and leading to clinically relevant translational outcomes.[54,55] This approach, which is not specifically simulation-dependent but often linked in practice, will likely grow in the future. The approach also aligns well with the EPA model described above – if we directly train learners until they can do a task reliably then we can more easily answer the question to what extent we trust them (in the EPA sense). The question facing the PEM educational community is which tasks and skills will be addressed with this approach given finite resources and the inherent additional remediation required for a portion of learners in a mastery learning model. Lumbar puncture, airway and CPR/resuscitation skills[56] are clear targets, with teamwork and communication skills an evolving target area. The challenge will be how to use this data – are there resources to continue remediation as needed for all learners? How do we manage the 'stragglers'? PEM simulation educators should be aware of this approach as it becomes more mainstream and impacts the demand on available resources.

Regional and Rural Simulation

As discussed above, many PEM programs have a defined relationship with community institutions. There is a clear role for the PEM simulation programs to extend their SBE offerings to these sites, with the approach tailored for local needs. For programs in which there are on-site faculty available, one marker of success is the training, to the extent possible, of simulation champions or leaders who can take on part or all of the responsibility of

providing simulation at the community site. It is less of a challenge overall to get simulation equipment to the community site, as compared to providing qualified simulation educators. Future opportunities include linked simulation that starts at the community site, and is then handed off to a "transport team" and transported to the referral hospital. This approach provides a method to practice remote communication and transport medical control within an integrated simulation. It is also a venue in which the community and regional providers can develop a common understanding of the often very different practice constraints and conditions between the 2 sites and possible identify opportunities for common practice (eg, sepsis management). As noted above, remote tele-education is also an opportunity for simulation delivery if the technical equipment and expertise are developed.

Long-Form (Longitudinal) Simulation

Healthcare teams provide care in the ED over hours and not minutes. Simulations generally occur over minutes and not hours, due to the obvious time and resource constraints. However, important safety events often occur around slower declines in patient status and the success or failure of the team in recognizing and acting on patient deterioration. Scenarios involving an evolving case of sepsis or a decline in mental status are typical case targets for the topic. The general simulation approach has been to use "time skips" to forward the case to another key transition (ie, "it is now 2-hours later"). This expediency precludes the team's chance to identify their own patterns or trends, which may be the key learning tasks for certain clinical presentations. Future work on how one feasibly implements long-form simulation would target a key patient safety and teamwork domain not currently well addressed. ✚

SUMMARY

It is clear that over the past 20 years, SBE has become engrained in the educational fabric and culture of PEM for both traditional clinical and procedural areas, as well as non-traditional areas such as communication and teamwork, breaking bad news, and identification of latent safety threats. The possibility of exploring new ideas at the interface of technology and clinical care, larger and longer system-based educational events over a more distributed and interconnected system, new ways of exploring the patient and family experience and safer care, and innovative models of delivering

simulation to the end user (learner), will all keep the PEM environment at the cutting edge of SBE. ✚

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