High-reliability emergency response teams in the hospital: improving quality and safety using in situ simulation training

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ABSTRACT

Introduction In situ simulation training is a team-based training technique conducted on actual patient care units using equipment and resources from that unit, and involving actual members of the healthcare team. We describe our experience with in situ simulation training in a major children's medical centre.

Materials and methods In situ simulations were conducted using standardised scenarios approximately twice per month on inpatient hospital units on a rotating basis. Simulations were scheduled so that each unit participated in at least two in situ simulations per year. Simulations were conducted on a revolving schedule alternating on the day and night shifts and were unannounced. Scenarios were preselected to maximise the educational experience, and frequently involved clinical deterioration to cardiopulmonary arrest.

Results We performed 64 of the scheduled 112 (57%) in situ simulations on all shifts and all units over 21 months. We identified 134 latent safety threats and knowledge gaps during these in situ simulations, which we categorised as medication, equipment, and/or resource/system threats. Identification of these errors resulted in modification of systems to reduce the risk of error. In situ simulations also provided a method to reinforce teamwork behaviours, such as the use of assertive statements, role clarity, performance of frequent updating, development of a shared mental model, performance of independent double checks of high-risk medicines, and overcoming authority gradients between team members. Participants stated that the training programme was effective and did not disrupt patient care.

Conclusions In situ simulations can identify latent safety threats, identify knowledge gaps, and reinforce teamwork behaviours when used as part of an organisation-wide safety programme.

INTRODUCTION

The Institute of Medicine's (IOM) report entitled *To Err Is Human: Building a Safer Health System* estimated that as many as 98 000 people die in the USA each year due to medical errors—most of which are unintentional and largely preventable.[1] As a result, several international governmental and consumer-based organisations are demanding that hospitals improve patient safety. Eighteen months after the publication of *To Err is Human*, the IOM released a second, more comprehensive report entitled *Crossing the Quality Chasm* that serves as a blueprint for quality improvement and patient safety efforts.[2] Both IOM reports suggested that healthcare professionals adopt training methods currently used in the military and commercial aviation, including the use of simulation and crew resource management (CRM) training.[3–5] CRM training, when used in conjunction with simulation, demonstrates increasing promise as an effective method to reduce medical errors and improve patient safety, particularly when focused on non-technical skills, such as teamwork, leadership and communication. However, CRM training typically occurs in a simulation laboratory designed to replicate the characteristics of an operating room (OR) suite, the emergency department (ED), intensive care unit (ICU), hospital ward, or labour/delivery room.

Conversely, in situ simulation training is a team-based training technique conducted on actual patient care units using

equipment and resources from that unit and involving actual members of the healthcare team.[6–17] As such, in situ simulation training is potentially a more realistic and more effective method of training. This added realism, in our experience, offers a better evaluation of the patient care units for hidden or latent safety threats. Latent failures (also known in the literature as 'latent failures' or 'latent conditions'),[18 19] were originally defined in the aviation safety industry as conditions or threats that result from 'decisions made or by positions taken by organisations as a whole, where the damaging consequence may lie dormant for some time, only becoming evident when local triggering factors overcome the organisations' defense'.[20] Examples of latent threats include equipment design issues, optical illusions, or shortened turnaround schedules. In healthcare, Wachter has defined latent threats as 'less apparent failures of organisation or design that contributed to the occurrence of errors or allowed them to cause harm to patients—latent errors are quite literally accidents waiting to happen.[21]' Latent threats have also been defined as system-based threats to patient safety that can materialise at any time and are previously unrecognised by healthcare providers, unit directors or hospital administration.[22] These errors in design, organisation, training or maintenance may have a significant impact on patient safety and, if not recognised and mitigated, could potentially delay management in an emergency situation.[19]

Simulation-based training also provides educators the time and opportunity to formally debrief participants, something that often does not occur after actual patient encounters. One benefit of performing immediate debriefings after running simulations is that team-level discussion allows for the identification of latent threats.[23 24] We describe our experience with in situ simulation as a means to improving the quality of care delivered to children with impending respiratory or cardiopulmonary arrest at our hospital.

MATERIALS AND METHODS

Setting

Cincinnati Children's Hospital Medical Center (CCHMC) is a 523-bed academic, quaternary-care, freestanding children's hospital. It is the only paediatric hospital in the Greater Cincinnati area and serves as a primary referral centre for an eight-county area in southwestern Ohio, northern Kentucky, and southeastern Indiana. In fiscal year 2009, CCHMC had over 31 000 admissions and 114 000 ED visits, and performed nearly 6000 inpatient surgical procedures and 25 000 outpatient surgical procedures. CCHMC has targeted serious harm reduction as one of its primary quality improvement goals since 2007. As part of this effort, we have been particularly interested in improving the early recognition, resuscitation and stabilisation of children who develop impending cardiorespiratory failure on patient care units within and outside critical care areas. We developed a rapid response team, called a Medical Response Team, in 2006 which was associated with significantly decreased codes outside critical care areas and a trend towards a reduction in hospital mortality.[25] Shortly thereafter, our hospitalist group developed a modified version of the Monaghan Paediatric Early Warning Score (PEWS) and added PEWS as an additional activation trigger for our medical response team throughout the hospital in 2007.[26] Beginning in September 2008, we developed and implemented an in situ simulation training programme, based upon the success of an earlier programme in the ED.

Institutional review board approval

The study was approved by the institutional review board (IRB). The need for informed consent for participation in this study was waived, however all participants in these in situ simulations signed a confidentiality agreement and provided informed consent to be photographed and videotaped.

In situ simulation programme

We conducted initial testing of our in situ simulation training programme on all inpatient care units, including the paediatric intensive care unit (PICU) and cardiac intensive care unit (CICU), beginning in September, 2008. We were particularly interested in determining the impact of in situ simulation on the quality of care delivered to children with impending respiratory or cardiopulmonary arrest. In situ simulations were conducted using standardised scenarios approximately two times every month on inpatient hospital units, and at least once each month in the PICU and CICU. During this time, we also conducted in situ simulations in the OR. Simulations were scheduled so that each inpatient unit had the opportunity to participate in at least two in situ simulations per year. Simulations were conducted on a revolving schedule alternating on the day and night shifts and were unannounced. Scenarios were preselected to maximise the educational experience and frequently involved clinical deterioration to cardiopulmonary arrest. However, in some cases, the patient care team would activate the Medical Response Team. Many scenarios were based on actual clinical cases or on perceived latent threats and systems issues based on staff reports or near-miss and precursor event reports.

Simulations were conducted in the actual clinical environment, in real time, and included the usual staff in the clinical unit and personnel from additional areas that typically responded to a hospital-wide code alert (Code Blue Team) including: critical care physicians, critical care and ED nurses, respiratory therapist, anaesthesiologist, child life staff, hospital chaplain, resident physicians and security personnel. Simulations were conducted in an empty patient room

when available, though they were also occasionally conducted in the cafeteria, in common hallways and in outpatient clinics, including the dialysis unit. Based upon our prior experience with in situ simulations in the ED, there was a need to overschedule these simulations, as approximately 15–20% of scheduled ED in situ simulations were cancelled due to high volume and/or acuity. All in situ simulations were unannounced, in that members of the hospital-wide Code Blue Team and bedside providers were not notified beforehand. In order to avoid conducting the simulations during times of high volume and/or acuity, we did seek permission to conduct the simulation from the unit leaders, as well as the medical director of the PICU (who oversees the hospital-wide Code Blue Team) beforehand. When feasible, the cancelled simulations were rescheduled the following week.

During these simulations, we used an actual resuscitation equipment cart, which exactly replicates those used during 'true' code situations. The resuscitation equipment cart included a pharmacy tray with all standard cardiac resuscitation drugs, intravenous fluids, tracheal tubes, bags, masks, monitor leads, vascular access equipment and defibrillator. The resuscitation equipment cart that was used for these simulation training exercises was stocked, prepared and checked in accordance with the hospital policy and, therefore, could theoretically be used in an actual resuscitation. As such, an additional benefit of these in situ simulations was that we could determine if there were any issues with the preparation and use of the resuscitation equipment cart.

In situ simulations were limited to 10 min in duration, followed by a 10 min standardised debriefing in order to minimise disruption to the clinical unit. Debriefings were used to review the actual care (technical skills) and teamwork, communication and safety behaviours (non-technical skills) carried out during treatment of the 'patient.' A unique aspect of the in situ simulations conducted in this setting was a deliberate attempt to identify latent threats in the clinical environment. Debriefings were conducted in a standardised fashion by study investigators (DW, GG and MP), and resulted in a description of team-level knowledge gaps, systems issues and latent threats noted during the simulation. A standardised debriefing format assured that critical points were covered during this abbreviated debriefing session (see appendix A). In order to enhance the findings from the debriefing session, we solicited additional observations or comments from the participants via email link to an anonymous electronic survey following the simulation. Participants were surveyed on the perceived value, impact, realism and length of in situ simulations during their shifts. Deidentified, team-level and unit-level feedback was provided to the institutional safety leadership, clinical unit leadership and relevant stakeholders, including the chief medical officer, residency program director, chief safety officer, PICU medical director and team participants, regarding the latent safety threats and systems issues identified. Key stakeholders were included in these reports, so that systems issues could be quickly mitigated. The chief safety officer and PICU medical director worked with the unit leaders to remove any barriers and to assure that these issues were properly addressed. All simulations were videotaped and analysed later for quality improvement/assurance purposes and/or research. Video recordings were not available immediately, and given the constraints related to in situ simulation, these recordings were not used in the debriefing process.

Statistical analysis

Latent threats, knowledge deficits and system issues from the in situ sessions were described and categorised qualitatively; therefore, no formal statistical analysis was indicated. Coding of data was used to classify identified threats and responses by institutional leadership.

RESULTS

We performed 64 of the scheduled 112 (57%) in situ simulations on all shifts and all units (approximately 1/4 each in the PICU, CICU, OR and patient care units, respectively) between 1 January 2008 through 30 September 2009. The total number of participants from various units and their roles are listed in table 1. Due to the nature of unannounced in situ simulations, participants often arrived and departed at irregular times. It was not always possible to capture the number and/or demographics of all participants. We identified 134 latent safety threats and knowledge gaps during these in situ simulations, that is, 2.1 latent

Table 1 Participant numbers and demographics

Roles	PICU	CICU	OR	Inpatient units
Nurse	97	72	19	100
Physician	32	22	15	95
Respiratory therapist	17	22	0	25
Patient care assistant	3	6	6	5
Patient care facilitator	0	3	0	7
Pharm D	0	3	0	6
Medical student	0	2	0	0
CRNA	0	0	5	0
Surgical technician	0	0	7	0
Chaplain	1	0	0	1
Other	3	7	0	15
Total	153	137	52	254

Note: Numbers are based on providers signing in after the completion of debriefing, thus possibly, we are understating the total number of providers trained. Also, these are not individual participants, as some providers attended multiple simulations.
CICU, cardiac intensive care unit; OR, operating room; PICU, paediatric intensive are unit.

safety threats identified per simulation performed. These findings include safety threats related to the OR (accessing infrequently used equipment, OR code team roles) as well as latent threats identified in the PICU, CICU, patient care units and common areas of the hospital. We identified a large number of latent safety threats and opportunities for improvement to the Code Blue Team during the debriefing sessions (table 2). These latent safety threats can be categorised as equipment, medication and/or resource/system threats. Identification of these errors and improvement opportunities has resulted in modification of systems to reduce the risk of error.

Equipment-related latent safety threats

We identified several issues with the equipment stocked on the resuscitation equipment carts throughout the hospital. Three resuscitation equipment carts were located in non-clinical care areas, where wall oxygen and suction were not readily available. Since implementation of the in situ simulations, we have added portable suction and oxygen cylinders to the resuscitation equipment carts located in these areas. During one particular scenario involving a child with a difficult airway, the anaesthesiologist requested a laryngeal mask airway, which had to be brought from the OR area. We have since added laryngeal mask airways to all the resuscitation equipment carts throughout the hospital. In addition, we added cuffed tracheal tubes to the resuscitation equipment carts and removed several uncuffed tracheal tubes, consistent with the most current recommendations for paediatric airway management.[18 27]

Medication-related latent safety threats

Consistent with the recent updated Paediatric Advanced Life Support (PALS) guidelines,[28] amiodarone is being used more frequently in our hospital for the treatment of postoperative arrhythmias, such as junctional ectopic tachycardia, as well as during resuscitation of ventricular tachycardia and fibrillation. Amiodarone is stocked in the resuscitation equipment cart and requires dilution prior to administration. During one of the in situ simulations, a nurse incorrectly prepared the amiodarone, resulting in a significant dosing error. This was identified as a knowledge gap and a systems issue, and steps were taken to correct this latent safety threat using: different package labelling; the addition of a backup clinical pharmacist to the code team; the use of independent double-checking of all code medications; continued staff education and training. Importantly, multiple subsequent in situ simulations demonstrated correct dose preparation and administration of amiodarone. Examples of some of the types of latent threats identified are shown in table 2.

Resource- and system-related latent safety threats

In addition to identifying latent safety threats, in situ simulations provided a method to reinforce teamwork behaviours in the clinical setting. Specific behaviours, such as the use of assertive statements, role clarity, performance of frequent updating, development of a shared mental model, performance of independent double checks of high-risk medicines, and overcoming authority gradients between team members were recognised and debriefed.

Through our experience with in situ simulations, we recognised that there were no policies or guidelines in place to standardise or clarify role assignments on the Code Blue team. Rather, approximately 40 different individuals responded to the code and assumed roles as they arrived, and at the direction of the team leader (once he or she arrived). Review of several videotaped in situ simulations and feedback from participants emphasised the need to develop and standardise role assignments. We implemented the concept of a Code Blue Team nurse leader (a senior PICU nurse) to assist the Code Blue Team physician leader (PICU fellow or attending physician) and help coordinate assignments and roles. One respiratory therapist, one house-staff physician, and the responding anaesthesiologist were assigned to control the airway and provide bag-valve-mask ventilation. The hospital flow

Table 2 Examples of latent safety threats and opportunities for improvement identified by in situ simulations

Medication	Equipment	Resource/system
Lack of adenosine on code cart	No LMAs on code cart	Need for ACLS training
Amiodarone requires dilution prior to administration	Cuffed vs uncuffed ETT's availability	Crew resource management training needed
Bedside code cards not standardised	No trauma shears on code cart	Lack of standardised roles
'Look-alike' medications stored adjacent to one another (sodium bicarbonate vs dextrose)	Lack of portable oxygen in non-clinical areas	Lack of knowledge regarding roles
Vecuronium shortage	Lack of portable suction in non-clinical areas	No nurse leader assigned
	Lack of AEDs in same day surgery waiting area	No code cart brought to the code
	Non-standard mode of storage for defibrillators (test cartridge only) This had varied from unit to unit	

ACLS, Advanced Cardiac Life Support; AED, Automated External Defibrillator.

coordinator was assigned to assist with crowd control. Resident physicians were preassigned several different roles by carrying a specific code pager labelled with one particular role assignment. For instance, several resident physicians were assigned to the role of performing chest compressions, and were instructed to alternate providers for chest compressions every 2 min to prevent fatigue.[29 30] One house-staff physician was assigned to call the primary healthcare team, while another physician (with help from the hospital chaplain) was assigned to remain with any family members present at the resuscitation. Overlapping and redundant role assignments were developed so that all assignments were adequately covered. This method resulted in a marked improvement in the team's approach to code responses and the fluidity of the code response, as demonstrated on subsequent video review. Subsequent in situ simulations were used to further educate and define these roles. Some months later, we observed deterioration in the code team's simulated performance. There again seemed to be confusion regarding roles and responsibilities. During debriefing, when we inquired as to possible reasons for this, we learned that the labels on the code team pagers had 'rubbed off'. This pointed to the simplicity and effectiveness of the initial solution as well as the need to periodically examine the pager labels to assure legibility.

Another concern related to the conduct of in situ simulations is related to the impact of these simulations on the clinical staff and the patient care delivered. Table 3 demonstrates staff responses to these simulations as related to the impact on staff and patient care as well as the perceived value of these simulations to the staff. As shown in table 3, there was close agreement among personnel from various units as to the value of in situ simulations, as well as to the minimal effect of the simulations on patient care. Sample comments from staff included 'I found this mock code to be very beneficial in practicing and sharpening our skills for a real code. To me, it showed that our unit needed more education on the defibrillator,' 'It was much more realistic than doing it in the simulation lab because it was unexpected,' and 'As a new grad and new to the PICU this was so helpful. There was a real code the next day and because I was part of this simulation I felt so much more prepared and I yelled for the code sheet and was able to get it without hesitation.'

DISCUSSION

Following release of the IOM reports on patient safety and quality,[1 2] the USA Congress charged the Agency for Healthcare Research and Quality (AHRQ) to form and develop research and collaborative partnerships to promote patient safety and reduce medical errors, which resulted in the development of the AHRQ patient safety indicators (PSIs).[31] For instance, 'failure to rescue' was defined as a death resulting from a complication rather than the primary diagnosis.[31] In-hospital cardiopulmonary arrests outside of ICUs represent 'failure to rescue' events. Unfortunately, despite widespread efforts to prevent arrests and improve the care received during and after resuscitation, the outcome for children who suffer from an in-hospital cardiopulmonary arrest remains poor, with reports of survival to hospital discharge from 14% to 36%.[32 33]

Our organisation has recently embarked on a multifaceted quality improvement programme designed to improve the early recognition and management of clinical deterioration of children who are admitted to the hospital, with the ultimate goal of preventing these 'failure to rescue' events. As part of this programme, we have developed and implemented a robust rapid response system that has resulted in a significant decrease in the rate of respiratory and cardiac arrests outside our PICU.[25] Similarly, we have the use of a paediatric inpatient early warning score system to help identify patients at risk of clinical deterioration.[26] Unfortunately, these measures have not completely prevented clinical deterioration to subsequent

Table 3 Participant's evaluation of in situ simulation

Provider responses by location	All (N=160)	PICU (N=34)	CICU (N=36)	OR (N=26)	Inpatient unit (N=64)
How valuable was this type of training in the clinical setting? (1=not valuable at all, 5=extremely valuable)	4.3	4.4	4.6	3.9	4.4
How did performance of the simulation in the clinical setting impact you personally for the rest of the day?—(1=no impact, 5=major impact, I couldn't catch up the rest of the day)	2.3	2.2	2.2	2.1	2.5
How did performance of the simulation in the clinical unit impact the unit for the rest of the day? (1=no impact, 5=major delays in patient care)	2.1	2.2	2.3	1.6	2.3
How did the realism of doing this in the clinical unit compare to doing it in the simulation lab (at MERC)? (1=not realistic at all, 5=very realistic)	3.1	3.8	3.9	2.8	4.0
The length of time for this date's simulation was: (1=too short, 3=too long)	2.0	2.1	2.1	2.0	2.1

Note: N in this table is the number of providers who anonymously filled out the survey instrument, not the total number trained (see table 1 for numbers trained).
CICU, cardiac intensive care unit; OR, operating room; PICU, paediatric intensive care unit.

cardiopulmonary arrest. As such, we have also recognised the need to improve and better coordinate the resuscitation of these children in our hospital.

We believe that in situ simulation affords the best opportunity to educate and train care providers, and ultimately improve the quality of care delivered to children suffering either a respiratory or cardiopulmonary arrest. In situ simulation offers a unique form of experiential learning that has been effectively used in the labour/delivery room,[6] OR suite,[8 14 34] ED,[16] trauma resuscitation room,[7 13 17 35] PICU[36] and hospital inpatient ward.[9 11 12 15 37–39] In the current series, we report our experience with the use of in situ simulation to identify and resolve latent safety threats and improve the quality of care delivered to children suffering a cardiopulmonary arrest.

We identified a significant number of latent safety threats in each of three major categories—medication, equipment, or resource/system. Previous authors have reported problems with equipment failure or deficiencies that result in delays in initiation of advanced life support.[40–42] Similarly, medication errors can compound problems during resuscitation, potentially leading to a poor outcome.[43 44] Finally, systems issues certainly contribute to problems with resuscitation.[45 46] These findings would suggest simulating resuscitative care would be ideal for uncovering latent threats within a healthcare system. Our rate of 2.1 latent threats identified per simulation supports this suggestion. In fact, our rate was higher than we have seen in any of our prior simulation-based investigations within our institution, including training programmes for emergency medicine, neonatal ICU and Extracorporeal Membrane Oxygenation providers[20] (*unpublished data*). Only when we applied simulation to assess preparation for a new facility did we find latent threats at a higher rate.[27] This highlights the effectiveness of simulation in assessing the safety of emergency response systems, and provides opportunities to improve how the system works and potentially improve patient safety.

From a hospital leadership standpoint, there is no way to predict how much monetary savings or prevention of error in the future will result from the identification of these latent threats and subsequent improvements. However, leadership felt confident in the results of the project, and have continued the training for their providers via in situ simulation on a monthly basis since initial enrolment was completed. Since conclusion of this investigation, continued maintenance training efforts have resulted in multiple new threats being identified and continued improvements in the clinical environment.

Our investigation has several limitations that may have impacted our ability to identify latent threats in our code response system and our resuscitation of patients following cardiopulmonary arrest. First, we had a significantly higher cancellation rate than we had seen in a previous ED in situ programme. We believe that part of the reason for such a large number of cancellations was related to the high acuity of these areas as well as seasonal peaks in acuity and census. Our protocol for running the simulations included contacting the unit charge nurse and assessing the potential deleterious impact a simulation would have on patient care during that shift. The charge nurse was given the right to abort the simulation if he/she was worried about this impact. As shown in table 3, when the simulations were run, the perceived impact on clinical care during that time was low. However, this may be due to our protocol preselecting against running them at busy times. It is conceivable that if we had run simulations during these busy times, we may have been able to identify a greater number of latent resource threats. Second, due to the nature of unannounced in situ simulations, participants often arrived and departed at irregular times. We observed that some members would leave during the debriefing sessions. This may have decreased our yield and hampered team-level problem solving. We asked each participant to sign-in following the simulation, but could not guarantee full compliance, thus limiting our ability to capture the demographics of all participants. Finally, given the voluntary nature of the follow-up electronic surveys, we were not able to guarantee that all participants responded when their feedback was sought electronically.

In conclusion, we report our experience with the use of in situ simulation to identify and resolve latent safety threats and improve the quality of care provided by our hospital Code Blue team. Our experience demonstrates that the use of in situ simulation is a powerful technique to evaluate process and system weaknesses as well as a means to assess the success of potential solutions. It is certainly too soon to determine whether these improvements to the Code Blue team have improved outcome. However, we believe that our in situ simulation programme will increase the efficiency, efficacy and safety of the resuscitation of children following cardiopulmonary arrest in our hospital.

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APPENDIX. A STANDARDISED DEBRIEFING TEMPLATE

Debriefing checklist	Information shared	Source of information
Case		
Positive feedback on performance from clinical staff		
Negative feedback on performance from clinical staff		
Teamwork concepts discussed		
Additional notes on team's assessment of performance		

Identified threats	Information shared	Source of information	Suggested solutions
Medication			
Equipment			
Resources: labs, staff, radiology			
Miscellaneous			

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