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# In situ simulation: detection of safety threats and teamwork training in a high risk emergency department

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## ABSTRACT

**Objective** Implement and demonstrate feasibility of in situ simulations to identify latent safety threats (LSTs) at a higher rate than lab-based training, and reinforce teamwork training in a paediatric emergency department (ED).

**Methods** Multidisciplinary healthcare providers responded to critical simulated patients in an urban ED during all shifts. Unannounced in situ simulations were limited to 10 min of simulation and 10 min of debriefing, and were video recorded. A standardised debriefing template was used to assess LSTs. The primary outcome measure was the number and type of LSTs identified during the simulations. Secondary measures included: participants' assessment of impact on patient care and value to participants. Blinded video review using a modified Anaesthetists Non-Technical Skills scale was used to assess team behaviours.

**Results** 218 healthcare providers responded to 90 in situ simulations conducted over 1 year. A total of 73 LSTs were identified; a rate of one every 1.2 simulations performed. In situ simulations were cancelled at a rate of 28% initially, but the cancellation rate decreased as training matured. Examples of threats identified include malfunctioning equipment and knowledge gaps concerning role responsibilities. 78% of participants rated the simulations as extremely valuable or valuable, while only 5% rated the simulation as having little or no value. Of those responding to a postsimulation survey, 77% reported little or no clinical impact. Video recordings did not indicate changes in non-technical skills during this time.

**Conclusions** In situ simulation is a practical method for the detection of LSTs and to reinforce team training behaviours. Embedding in situ simulation as a routine expectation positively affected operations and the safety climate in a high risk clinical setting.

## BACKGROUND AND CONTEXT

In situ simulation has been described as 'crash testing the dummy'.<sup>1</sup> More formally, it is a team-based training technique conducted in actual patient care units using equipment and resources from that unit and involving actual members of the healthcare team.<sup>2–5</sup> While simulation has often been used as a strategy to train individuals in both technical and non-technical (communication and teamwork) skills, in situ simulation can be used to evaluate system competence and identify latent conditions that predispose to medical error.

James Reason has described 'two approaches... to the problem of error: a person approach and a system approach.' The person approach 'focuses on the errors of individuals, blaming them for forgetfulness, inattention or moral weakness'.<sup>6</sup> This is echoed by Leonard *et al* who state: 'A large and ever present cultural barrier is the deeply embedded belief that quality of care and error free clinical performance are the result of being well trained and trying hard. In this paradigm, inevitable mistakes are viewed as episodes of personal failure with the predictable result that these events are minimized and not openly discussed'.<sup>7</sup>

The system approach examines 'the conditions under which individuals work, and tries to build defenses to avert or mitigate errors'.<sup>6</sup> Reason's 'Swiss Cheese model' of error is often cited as an example of the system approach. Despite multiple barriers and safeguards which are 'built in' to the system, when the 'holes line up', or redundancies fail, an

error can occur.<sup>8</sup> Unfortunately, in analysis of medical errors, the holes line up more often than one would anticipate. In these situations, it is often latent failures resulting in conditions such as time pressure, understaffing, fatigue, inadequate equipment and inexperience, inadequate supervision, and miscommunication 'that precipitate errors and violations'.<sup>8-11</sup>

Latent failures, originally defined in the aviation safety industry, are conditions or threats that result from 'decisions made or by positions taken by organizations as whole, where the damaging consequence may lie dormant for some time, only becoming evident when local triggering factors overcome the organisations' defense'.<sup>6</sup> In medicine, latent safety threats (LSTs) have 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'.<sup>12</sup> Operationally, we use this definition and classify LSTs identified in this project into medication, equipment, resources and miscellaneous categories (figure 1). These errors in design, organisation, training or maintenance may have a significant impact on patient safety and, if not mitigated, could have a negative impact on patient care.<sup>6</sup>

Simulation-based training provides an opportunity to formally debrief participants, something that rarely occurs after actual patient encounters. Multidisciplinary training and debriefing encourages sharing of information that while widely recognised in

one 'silo' is unrecognised in other 'silos'. In previous lab-based simulation training with emergency department (ED) providers, we recognised that multidisciplinary training provided a unique method of identifying LSTs. Many of the identified LSTs verbalised by nursing staff during debriefings were previously unrecognised by physician staff and prompted multidisciplinary problem solving. It appeared that simulation training which realistically recreates the clinical environment can inspire reflection on clinical experiences and allow the individual(s) to express concerns that relate to the actual clinical environment.<sup>13</sup> In situ simulation training, a potentially more realistic method of training, may provide a better evaluation of the patient care units in relation to hidden or LSTs.

*Our hypothesis was that the implementation of in situ simulation-based training in an actual clinical environment would promote the identification of LSTs and systems issues at a higher rate than seen in the simulation lab setting.* The purpose of the described project was twofold. First, we planned to accelerate the identification and remediation of LSTs and system issues in this high risk setting. Second, we intended to embed simulation training as part of the routine work in our environment in order to reinforce and maintain the gains in teamwork behaviours demonstrated in our previous lab-based simulation teamwork training. Ultimately, our aim was to improve the safety of the system of care for our patients.

Performance and Teamwork	Information Shared		Source of Information
<b>Scenario</b>			
Positive feedback on performance from clinical staff			
Negative feedback on performance from clinical staff			
Teamwork concepts observed/discussed			
Additional Notes on team's assessment of performance			
Identified Threats	Information Shared	Source of Information	Suggested Solutions
Medication			
Equipment			
Resources: labs, staff, radiology, etc.			
Miscellaneous			

**Figure 1** Standardised debriefing template.

## METHODS

### Setting

This project was conducted in the paediatric ED of Cincinnati Children's Hospital Medical Center. This ED is an urban Level I trauma centre and one of the busiest paediatric EDs in this country with >90 000 patient visits annually. This translates to an average of 246 unscheduled visits per day. On some days the daily census may only be 190; in busy times the census is over 300 and has reached 400 or more.

In this system, critical and unstable patients are immediately triaged to the resuscitation bay. Emergency response teams are specific to illness (medical team) or injury (trauma team) and are activated approximately 3000 times per year. The normal response to a medical team during this intervention included a faculty physician, a resident physician, a nursing team leader, a bedside nurse, a medication nurse, a respiratory therapist, a paramedic (or patient care assistant) and a child life specialist (or chaplain), all of whom are ED personnel. For trauma teams, additional personnel included a surgery resident, an intensive care unit nurse and an operating room nurse. For the highest level of trauma, these teams were augmented by a surgery Fellow (or faculty), a critical care Fellow and an anaesthesiologist. Thus, the normal care teams included between 8 and 14 personnel. The inner circle of providers, those at the bedside providing direct care, was limited to 5–6 providers. There were 3–8 providers deployed in the outer circle performing tasks such as medication and equipment preparation, phone calls and consultation. About half of these activations are subsequently determined to be stable and minimal immediate action is required. The remaining patients require immediate interventions to stabilise their physiological status. Historically, the majority of adverse events in our ED have occurred in critical patients presenting to our resuscitation bay. The volume, acuity and complexity of our patient population, in addition to the many different disciplines involved in the care, represent huge risk factors for medical error. These factors highlight the importance of teamwork training within the ED and the pursuit of a shared mental model during the care of critical patients in the resuscitation bay.

Despite direct supervision by board certified paediatric emergency physicians and surgeons, the inexperience and transient nature of the resident physicians also represent a substantial risk to our patients. As a teaching institution, we provide paediatric education to medical students, paediatric residents from our own and other institutions, family medicine residents, emergency medicine residents as well as residents from various surgical specialties. In any one month, 45–55 residents and 12 Fellows rotate through our ED.

While, this ED is busier than most paediatric EDs, it is not unique in either the kinds of patients that are

cared for or in the variety and inexperience of the residents that are trained. It is logical to believe that in order to safeguard our patients we must standardise the abilities of the 'permanent staff' to function in as safe a mode as possible and that this culture of safety is clearly expected of all non-permanent staff as well.

### Participants

We implemented the safety intervention (in situ simulation training) targeting all personnel who respond to medical or trauma team activations in the ED's resuscitation bay. The intervention was conducted with a team of frontline healthcare providers. Each group completed the intervention as a multidisciplinary team. The number of providers who participated in each simulation was determined by whether it was a medical or trauma team and the level of trauma activation.

This project was approved by the institutional review board of Cincinnati Children's Hospital Medical Center. Initially, informed consent was obtained from all participants. However, approximately half way through the project, the ED leadership felt the training had become so valuable as to require mandatory participation of all care providers in the ED. Though ED staff was not required to respond to electronic inquiries, they were required to participate in the in situ simulations. At that time, the institutional review board waived the requirement for informed consent. Video consents continued to be obtained from all participants.

### Approach

We used previously developed critical scenarios to pilot the process in the resuscitation bay and for the initial portion of the training. These scenarios were supplemented during the course of the project by scenarios related to near misses, adverse events or situations. These simulations occurred on all shifts and were presented in an unannounced fashion; the inhouse paging system was used and providers responded believing it was a 'real' resuscitation. No supplemental staffing was provided during the training. Simulations occurred at a frequency of 1–2 times a week with a goal of 90 in situ simulations in the first year.

Simulations included trauma and medical simulations and were based on high-risk clinical cases, either identified by one of the investigators (MP, GG, and RF) or referred to us by ED staff, divisional or institutional safety leadership. A number of these were based on near misses or cases that did not progress smoothly. In addition, cases that were seasonally appropriate (near drowning during summer months, bronchiolitis and hypothermia in the winter months) were used to screen for potential LSTs. Each simulation had specific goals with triggers embedded to stimulate appropriate technical and non-technical

behaviours. Scenarios that incorporated deliberate medical error and equipment malfunctions were used to allow personnel to 'trap and/or mitigate' error. Other scenarios required non-physicians or less experienced physicians to assert themselves to team leaders. An example of one scenario used is presented in online supplementary appendix A. This template demonstrates our process for developing scenarios, all which were developed by either MP or GG.

As these simulations were performed on the clinical unit during work hours, we balanced the need for the training with the current status of the ED. Parameters to cancel the simulations were developed with ED leadership and included the unit census, number of high acuity patients, shift change, presence of a critical patient in a resuscitation bay and knowledge of an incoming critical patient. We also discussed the simulation with the ED charge nurse immediately prior to its initiation in order to ensure there were no other factors, such as limited staffing, of which we were unaware.

Since the simulations were conducted in a clinical setting, the simulations and debriefings were limited to 10 min each. The simulation and debriefing were digitally recorded. Debriefing occurred immediately following the simulation. A standardised debriefing checklist was used (figure 1). GG, MP, RF and/or TL served as the facilitator for each simulation and debriefing. One to two simulation specialists attended each simulation, operated the simulator, recorded the simulation and provided technical support. Debriefing included self-assessment and group assessment of performance. Participants were asked to identify, evaluate and offer solutions to the challenges identified. A key component of the debriefing was the identification of any LSTs by the facilitator and/or team members.

#### Outcome measures, data collection and analysis

Process and outcome measures were selected in order to evaluate the effectiveness of the project's aims. The primary outcome measure was the number and types of LSTs identified during the in situ simulations. In order to facilitate the identification of LSTs, a standardised checklist to assess threats and systems issues identified during the simulation debriefing was used (figure 1). Facilitators emphasised participant identification of threats, but the facilitator also documented his/her observations and used these to prompt discussion during debriefings. Video review of the simulations was not routinely used to identify further threats; however, video was used to refine and classify these threats when needed. In addition to the identification of LSTs, we tracked solutions suggested by ED team and those that were actually implemented.

Participants were asked to complete an electronic survey following the simulation. Signed participation lists were used to generate a list of participants to whom an online, anonymous survey instrument was

electronically mailed. Reminder emails were sent to encourage completion. A typical five-level Likert scale was used to assess secondary measures such as participants' assessment of impact on clinical care, value of the training and timing of the simulations (online supplementary appendix B).

Finally, all ED in situ simulations were digitally recorded. Approximately a third of these were reviewed over the course of a year using a modified version of the Anaesthetists Non-Technical Skills (ANTS) tool as a means to evaluate the teamwork behaviours of the participating clinicians (online supplementary appendix C).<sup>14</sup> This particular scale is a behavioural marker system developed by Flin and colleagues, industrial psychologists and anaesthetists.<sup>15</sup> This scale is based on observation of four skill categories and 15 skill elements. The ANTS scale has been shown to have a high level of validity and a reasonable level of reliability when used by anaesthetists to rate non-technical skills, such as teamwork and situation awareness.<sup>16</sup> It has been adapted for use in intensive care units and the operating room.<sup>17-22</sup> Flin and Maran have also described the parallel non-technical skills required for team function in an ED setting and the use of a 'second generation' training course and ANTS tool that has been piloted with emergency providers.<sup>17</sup> Given that the ED environment requires similar levels of complex procedures, multidisciplinary teams and critical care to these environments, we believed the ANTS is an appropriate tool to use in this project.

Ratings were performed by one trained reviewer, who was blinded to debriefing results and feedback from participants. The rater was trained through the review of the ANTS online manual as well as several hours of deliberate practice of video review.<sup>14 15</sup> As only one reviewer was used, no inter-rater reliability analysis was performed.

#### Analysis

LSTs, knowledge deficits and system issues identified during the in situ sessions were described and categorised qualitatively; therefore, no formal statistical analysis for the primary outcome was performed. Data collected during the simulations were classified by the source of information and type of identified threat. Survey responses were collected electronically and results were presented as descriptive frequencies. Behaviour ratings using the ANTS scale were plotted against time and observed for trends.

#### RESULTS

A total of 218 individuals from the ED and trauma services participated in at least one of 90 in situ simulations over a 12-month period (table 1). In all, 65 of these scenarios were critical medical patients and 25 were trauma patients; this approximates the actual proportion of critical patients presenting in each

**Table 1** Individuals participating in in situ simulation training (N=218)

Discipline of participants	Percentage of total
Physician	51
Faculty	14
Fellow	24
Resident	13
Nurse	32
Paramedic	4
Respiratory therapist	3
Patient care assistant	4
Other	
Chaplain	2
Child life specialist	3
Social worker	1
Pharmacist	1

category. Approximately 10% included scripted malfunctions/omissions and 5% included scripted behavioural errors. For example, in one simulation, the faculty physician deliberately performed 'stacked' shocks, which at the time were not (and is still not) recommended on a patient in ventricular fibrillation. During debriefing, multiple team members, including a senior resident, acknowledged that they knew this was wrong, but did not intervene 'because he was the attending'. Overall, 35 other simulations were cancelled before initiation due to a critical patient in the resuscitation bay, high patient census or high overall ED patient acuity. Though this represents an overall cancellation rate of 28%, as ED personnel became accustomed to in situ simulations, the need to cancel in situ simulations decreased. In the last two quarters of the year, only 18% of in situ simulations were cancelled.

A total of 73 LSTs were identified: 22 medication threats, 26 equipment threats and 25 systems/resource threats (table 2). This resulted in an identification rate of one latent threat for every 1.2 in situ simulations performed. This was in contrast to our previous simulation lab results, where 24 LSTs were identified during 33 courses for a rate of one latent threat for approximately every seven simulations performed.<sup>13</sup> Examples of threats identified during in situ simulations included missing or malfunctioning equipment, knowledge gaps concerning availability of dilution and infusion kits of critical medications and delayed or absent response of vital team members. (A comprehensive list of LSTs identified is presented in online supplementary appendix D.) Though many of these threats were directly observed or identified by the facilitators, approximately a third were identified by simulation participants. Nurses identified half of these.

As demonstrated on the standardised debriefing template, facilitators also captured the teamwork

**Table 2** Examples of LSTs and source role for identification of threat

Latent threat category	Examples of threat	Identifying sources
Medication (N=22)	<ul style="list-style-type: none"> <li>▶ Critical medication missing from Pyxis MedStation system</li> <li>▶ Knowledge gap regarding available drips and methods to obtain them</li> <li>▶ Epinephrine concentrations confused</li> <li>▶ Similar or look-alike medications in same drawer of Pyxis MedStation system</li> </ul>	Attending physicians Nurses Pharmacist
Equipment (N=26)	<ul style="list-style-type: none"> <li>▶ Magill forceps missing</li> <li>▶ Unable to locate fans for patient cooling</li> <li>▶ Manual defibrillator 'synch' button confusing, causing delay in cardioversion</li> <li>▶ Correct BVM bag and mask sizes missing</li> </ul>	Attending physicians Resident Nurses Respiratory therapists Paramedics
Resource/system (N=25)	<ul style="list-style-type: none"> <li>▶ Inability to perform independent double check of high risk medications due to lack of staffing at medication counter</li> <li>▶ Need for PALS algorithms at the bedside</li> <li>▶ Need for equipment supply provider to attend resuscitations</li> </ul>	Nurses

BVM, bag valve mask; LST, latent safety threat; PALS, paediatric advanced life support.

concepts that were discussed by the participants. During the 90 in situ simulations, participants initiated discussion of teamwork concepts in 80 of the 104 instances that teamwork was discussed (table 3). While debriefing the 'stacked shocks' example above, one of the bedside nurses described feeling an authority gradient between herself and the faculty physician, a concept she had learned in the simulation lab. This was identified as a nurse initiated discussion of an authority gradient.

In all, 118 participants (54%) responded to the postsimulation survey. Of those responding, 92 of 118

**Table 3** Teamwork concepts discussed and source of information

Teamwork concepts discussed during debriefing	N=104	Source
Clarifying questions and assertive statements	16	Nursing 37
Target/task fixation; situation awareness	7	Attending physician 24
Sharing mental model	32	Resident/Fellow physician 10
Roles/responsibilities	17	Paramedic 4
Communication and especially closed loop communication	16	Pharmacy 2
Updating and stepbacks	15	Respiratory therapist 1
Authority gradient	1	Child life 1 Chaplain 1

(78%) rated the in situ simulation as extremely valuable or valuable, while only six of 118 (5%) rated the simulation as having little or no value. Of those responding to the question on clinical impact, 50 of 65 (77%) reported little or no clinical impact. We defined clinical impact as whether the participants felt spending 20 min training in the resuscitation bay during their shift affected the care of actual patients in the ED that day. Six participants reported a positive clinical impact and four reported the simulation was disruptive or affected the participant in a negative fashion. In all, 61 of 65 (94%) participants rated the length of the simulation as 'about right' while five rated the simulation as 'too short'. None reported it was too long. Free text feedback included 52 positive comments on the value of the simulations, eight negative comments and 19 comments that provided information or were neutral.

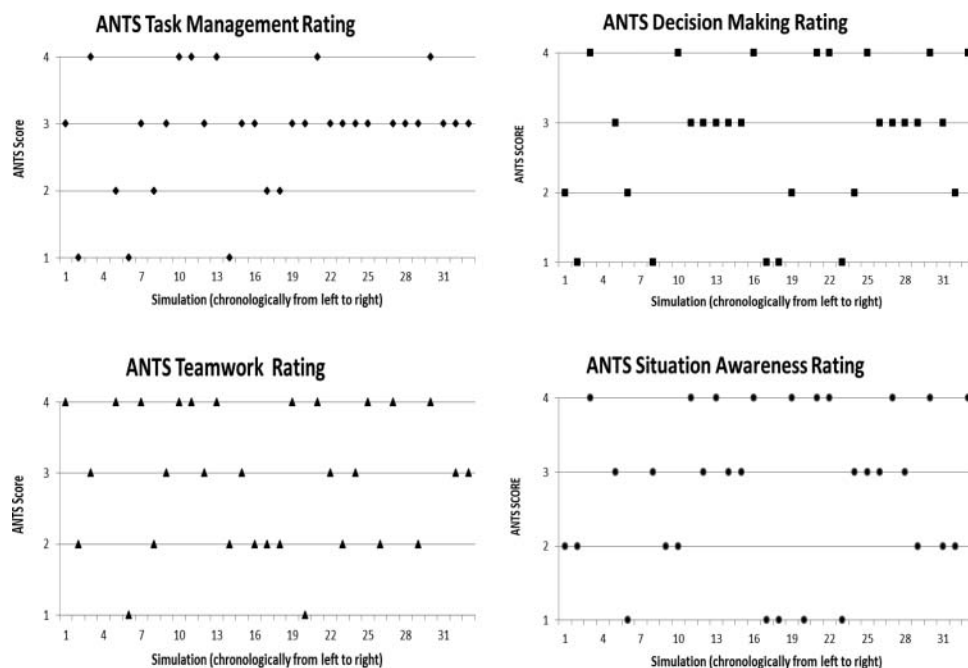
All in situ simulations were recorded and 33 (37%) of these distributed over the 12-month intervention were formally reviewed by a trained and blinded reviewer using the ANTS behavioural Scale.<sup>15</sup> The ANTS scale has four categories: Task Management, Teamwork, Situation Awareness and Decision Making. Behaviours are rated on a four point scale and those not observed in a particular simulation are not rated. Figure 2 demonstrates the ratings of the participating teams over the intervention period. A total of 121 behaviours were scored during the blinded review. Though we hoped for an improvement in the ANTS scores over time, no particular trend is observed. However, the vast majority of simulations reviewed were scored on the 'high end' of behaviours, with 35

of the scored behaviours rating a '4', 46 rating a '3', 25 rating a '2' and only 15 rating a '1'. Described another way, the majority of the teams scored a 3 or 4 (out of 4 points) (table 4).

This project also produced tangible effects on ED culture and operations. The nursing role that had previously been described as the nurse documenter became and is now described as the nursing team leader. The ED participants recognised the importance of a shared mental model. This concept accounted for almost a third of the teamwork concepts discussed during debriefings (table 3). As the physician team leader may become involved in certain critical procedures, the nursing team leader took on the crucial responsibility of maintaining a shared mental model for the team. The concept of a shared mental model was viewed as so crucial that frontline nurses insisted on adding it to the resuscitation flow sheet as an element that must be communicated with the team within the first 3–5 min of caring for a critical patient.

## DISCUSSION

This project was unique in promoting recurring in situ multidisciplinary simulation-based training as a method to improve clinical care as well as a way to discover safety threats and system issues in a high risk environment. The experiential learning afforded by this process provided the best opportunity to transfer these skills into the real life setting of a paediatric ED. Based on our previous work we expected to demonstrate that multidisciplinary simulation-based training is a valuable method of identifying safety risks in the



**Figure 2** Team Behaviours as assessed by the Anaesthetists Non-Technical Skills scale (ANTS) (Note: behaviours not observed in a particular simulation are not rated: 33 of 90 simulations were reviewed and scored using the ANTS scale).

**Table 4** ANTS scores: descriptive statistics

ANTS Elements Maximum score: 4	Task management	Teamwork	Situation awareness	Decision making
Mean (range)	2.7 (0–4)	2.6 (0–4)	2.5 (0–4)	2.4 (0–4)
Median	3	3	3	3
SD	1.1	1.1	1.2	1.2
Proportion of teams scoring 3 or 4 (N=33)	73%	64%	58%	58%

ANTS, Anaesthetists Non-Technical Skills scale.

clinical environment. In situ simulations allowed identification of a latent threat in almost every simulation performed. This is in contrast to the rate of identification we have observed in the lab setting. In our previous lab-based ED training, we conducted approximately seven simulations to identify one latent threat. Also, in lab-based training of extracorporeal membrane oxygenation providers, another high-risk environment, we identified 30 care environment LSTs during 96 simulations, or one for every 3.2 simulations performed.<sup>23</sup> We believe the in situ environment provides significant advantages over lab-based simulation for the identification of systems issues. These include a more time-pressured environment and the ability to test the actual clinical care system, including equipment, processes and staff response. If debriefing occurred immediately following clinical cases, it is likely that a number of our identified threats could be identified, albeit at the risk of harm to an actual patient. However, in our ED (and other critical care settings), immediate debriefing after actual resuscitations almost never occurs as some of the team departs with the patient, others return to care for waiting ED patients, and the remainder clean the trauma bay and restock. Thus, in situ simulation is an important strategy in identifying threats to patient safety.

This project also demonstrates the feasibility of using in situ simulation on a large scale to reinforce and sustain teamwork and communication skills. Although the ANTS results did not show any obvious improvements over time, most of the teams were scored on the high end of the scale (figure 2). These high ratings hint at maintenance of behaviours that were learned, practiced and improved upon during the simulation lab training.

In situ simulation provides a means to identify workarounds, knowledge gaps and ‘accidents waiting to happen’ in a way that few other methods are capable of matching. Combining system evaluation and teamwork training synchronously is an efficient improvement strategy for the healthcare organisation. In addition, a significant proportion of the LSTs were identified by the providers involved in the simulation.

This speaks to the necessity of including frontline care providers in the evaluation of the systems in which they work.

#### Relation to other evidence: teamwork training, simulation and safety

In situ simulation has become more common particularly in its use to evaluate new facilities and systems.<sup>5 24–26</sup> Especially related to critical conditions in obstetrics and cardiopulmonary arrest, there are deliberate efforts to use in situ simulation to detect LSTs.<sup>27 28</sup> This developing body of work speaks to the value of in situ simulation as a means to identify threats to patient safety within the system before patient harm occurs. This project is unique in that it is part of an ongoing venture to embed in situ simulation as part of the daily work of the ED and combines a deliberate effort to identify LSTs with ongoing teamwork and communication training. It is also distinctive in recognising the contribution of the frontline care providers in the identification of these LSTs. This represents another way in which ‘deference to expertise’ is a requirement in high reliability organisations.<sup>29</sup>

In our setting, in situ simulation also provides a means to continuously reinforce communication and teamwork skills. The use of in situ simulation as we have described it accomplishes the dual goals of identifying and remedying LSTs as well as providing continuous opportunities to deliberately practice technical and non-technical skills. This provides immediate benefit to the patient, the individual healthcare provider and the healthcare team. However, on a strategic level it also contributes to changing the safety culture of the system. High reliability organisations are described as those that operate in unforgiving high risk settings, but have markedly fewer than expected failures. These organisations place a high priority on (among other things) heedful interrelating, sensitivity to operations, deference to expertise and preoccupation with failure and cultivation of resilience.<sup>30</sup> In situ simulations, as part of the daily work of the ED team, address and reinforce these values. The realism and actual clinical environment of in situ simulation engage participants and drive home the need to incorporate a high reliability mind-set to improve the system and thereby patient safety as few other training methods can.

#### Challenges and limitations

The implementation of in situ simulation with working clinical teams presents challenges in terms of time pressure, acuity and patient census in a busy ED or other critical care units. Despite active participation of ED staff in training at our simulation centre for more than a year, the implementation of in situ simulation proved challenging. Performance anxiety of healthcare providers posed a significant challenge initially. Particularly in the early phase of the project,

during high census winter months, there was reluctance on the part of staff to participate in the care of simulated patients. Over time, the providers did come to understand that our goal was to understand the team process and identify LSTs as opposed to identifying individual shortcomings. The addition of the mental model to the resuscitation flow sheet and the ongoing in situ simulations in the ED speak to the value now ascribed to this process by ED staff.

ED staff also raised concerns regarding the impact of in situ simulations on patient care. As noted previously, prior to implementation 'no go' guidelines had been developed and agreed to by the project team and the ED leadership. In addition, GG met with the Patient and Family Advocacy Board to seek their input. This group, composed largely of family members of patients with complex medical problems who often seek care in the ED, offered that they were willing to spend additional time in the ED if care providers were 'practicing' to deliver safer care.

As individuals gained experience with simulation this was less of a concern. While an ED census of 35 or 40 patients would have forced cancellation in the early months of the project, by that last quarter of the intervention, we were able to conduct simulations with an ED census of 70 patients. This is important as the most likely time for LSTs to cause a problem is during high-volume, high-intensity care or when all the 'holes line up'. Thus, a limitation of, and potential bias within, our findings is that we may have missed significant LSTs by not running simulations at times when the department was very busy or by limiting a debriefing session when a critical patient arrived in the bay. Limiting cancellations is important as the simulation team invests significant time and resources in setting up the simulation which takes them away from other responsibilities. Refining our 'no go' guidelines supplemented by ongoing communication with the charge nurse prior to setting up the simulation has significantly removed the frustrations we initially experienced. The simulation team also came to recognise that approximately 20% of in situ simulations would be cancelled and that the engagement of the healthcare providers was substantially decreased when the ED census was high. There will always be a tension between patient care and in situ training and the reality is that a significant percentage of in situ simulations will be cancelled due to acuity and/or census. However, in comparison with similar work in our critical care and operating room settings, where cancellation rates are as high as 43% often due to lack of 'an open bed', in situ simulation in the ED is more feasible. As we learned, it is necessary to overschedule simulations by approximately 20% in order to achieve the target number and distribution on various shifts.

Given the time constraints of the in situ simulations, it was not possible to use video debriefing. Digital recordings of all the in situ simulations were used to

clarify issues raised during the simulations as well as for the ANTS scale analysis. We were concerned that the 10 min limit of the debriefing was a significant limitation. We partially overcame this by using a standardised electronic follow-up with in situ participants. This allowed us to seek additional (and anonymous feedback) concerning other LSTs, the perceived value of the process and impact on the participant and patients.

The postsimulation survey (online supplementary appendix B) was an internally developed instrument, so generalisation of results should be tempered. We were primarily interested in the perceived value of performing the simulations during the workday, any negative impact on actual patient care and the identification of any additional issues that participants might not have felt comfortable voicing during the debriefing. The majority of our population had previously participated in an intense lab-based simulation training course and may have been more likely to adapt to in situ simulation training and perceive its value, compared with those without previous simulation experience. This could have biased our results towards 'the positive'. Second, the response rate to the electronic surveys was 54%. Ideally, the rate would have been higher, but as response to the survey was voluntary we did not follow-up with individually targeted correspondence. The response rate may reflect the fact that participants believed that they had already provided their input during debriefing. Of note, for email-based surveys a response rate of 40% is average, 50% is considered 'good' and 60% 'very good'.<sup>31</sup>

#### Response to findings and sustainability

The identification of LSTs alone is not sufficient to promote patient safety. All but two LSTs identified during this intervention were remedied by ED staff and leadership. (The two not remedied were related to nurses' identification of issues related to a general resuscitation flow sheet and the need for a dedicated cardiac arrest flow sheet.) To address identified LSTs on an ongoing basis, the ED has partnered with the Center for Simulation to work on solutions for the identified threats and to sustain ongoing in situ simulations at a rate of 6–8 times per month on all shifts. The ED's in situ training has become a joint effort between the Center for Simulation and the ED's Medical Resuscitation Committee (MRC). This committee, developed and chaired by one of this project's investigators (GG), includes physicians, nurses and an equipment specialist who have been formally trained in simulation-based facilitation and debriefing. This group developed a reporting system for provider concerns in the resuscitation bays to augment findings from simulations. These concerns and identified threats have been combined to form 'action items' for the committee and are addressed through committee discussions, formal presentations to the division,



changes to the resuscitation bays equipment, organisation and processes, and reincorporation of these changes into in situ simulation training. As an extension of this project, a formal curriculum was developed by the MRC and the Center for Simulation involving scenarios run in monthly blocks around high-risk, low frequency medical and traumatic conditions. After completion of our study, 52 simulations were conducted in 2010 on hypertensive emergency, hypothermic arrest, smoke inhalation, foreign body airway obstruction and respiratory failure due to severe status asthmaticus. As part of this curriculum, simulations not only identified LSTs and team-level knowledge deficits, but allowed the MRC to merge published literature and local practice capabilities to refine management algorithms for these five disease states. Currently, this Committee and the Center for Simulation are using findings from 2011 in situ simulations on adult cardiac disease and rapid sequence intubation to develop similar algorithms, as well as implement a new Critical Airway Team within the ED.<sup>32</sup>

In conclusion, this project demonstrates that in situ simulation is feasible in a busy ED and provides a strategy that simultaneously allows for the identification of LSTs, deliberate practice of teamwork and communication skills and provides multiple opportunities to improve patient safety. Future efforts should focus on the implementation of ongoing in situ efforts in other critical care environments and the adaptations that may be required to create a similarly efficient use of simulation in these environments.

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**Contributors** MP, GG, TL, RF and RW made substantial contributions to conception and design of the current project and to acquisition of data and/or the interpretation and analysis of data. MP, GG, TL, RF and RW were involved in the drafting and/or revision of the article and approved the final version.

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**Competing interests** None.

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**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data sharing statement** All data are included in the manuscript.

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# ANTS System –Observation and Rating Sheet

**Consultant:** \_\_\_\_\_  
**Trainee:** \_\_\_\_\_  
**Date:** \_\_\_\_\_

<i>Categories</i>	<i>Elements</i>	<i>Observations</i>	<i>Element Rating</i>	<i>Debriefing notes and category rating</i>
<b>Task Management</b>	Planning & preparing			
	Prioritising			
	Providing & maintaining standards			
	Identifying and utilising resources			
<b>Team Working</b>	Co-ordinating activities with team			
	Exchanging information			
	Using authority & assertiveness			
	Assessing capabilities			
	Supporting others			
<b>Situation Awareness</b>	Gathering information			
	Recognising & understanding			
	Anticipating			
<b>Decision Making</b>	Identifying options			
	Balancing risks & selecting options			
	Re-evaluating			

## ANTS System –Observation and Rating Sheet

### Additional Notes

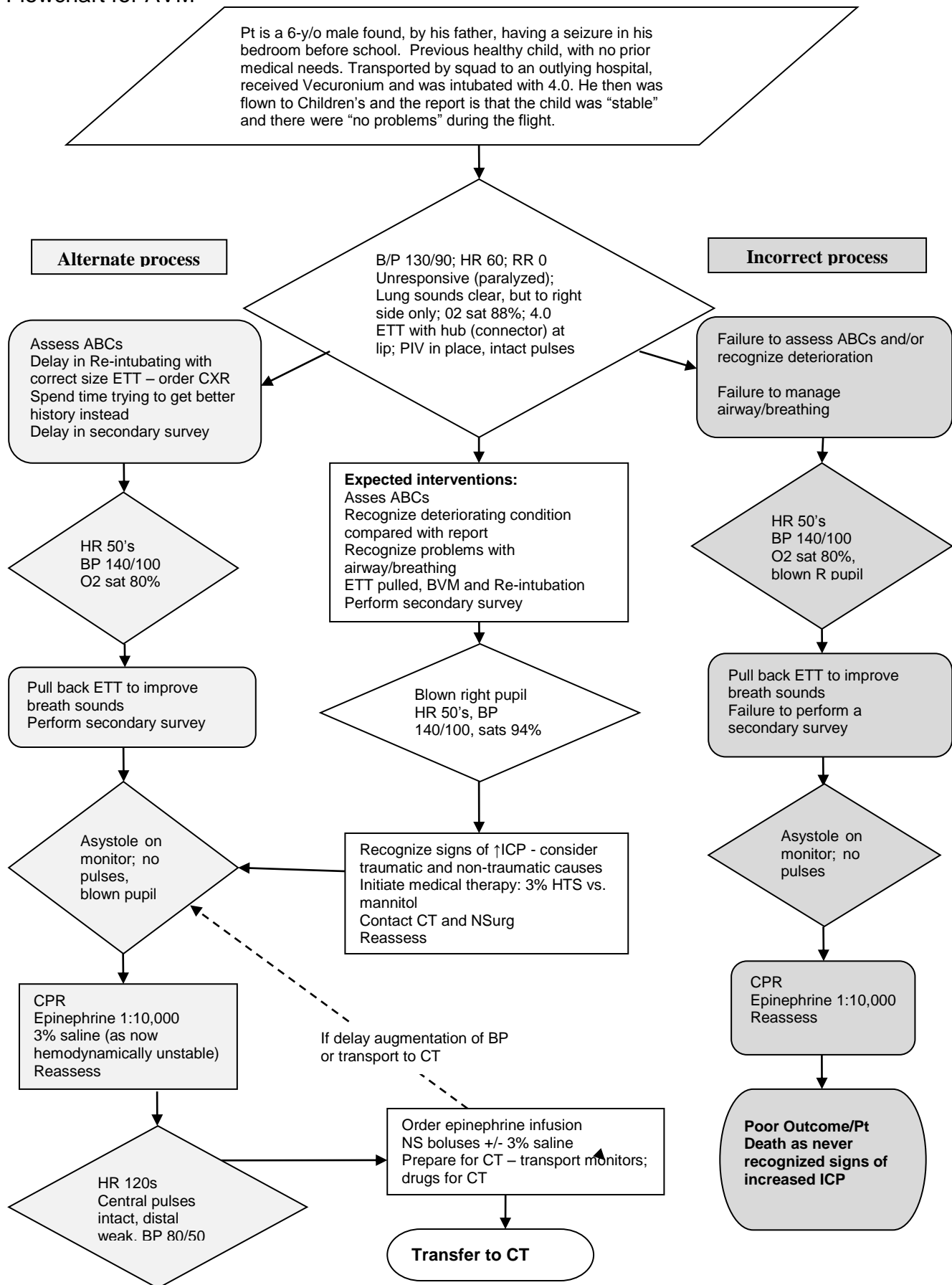
Rating Options	Descriptor
4 – Good	Performance was of a consistently high standard, enhancing patient safety; it could be used as a positive example for others
3 – Acceptable	Performance was of a satisfactory standard but could be improved
2 – Marginal	Performance indicated cause for concern, considerable improvement is needed
1 – Poor	Performance endangered or potentially endangered patient safety, serious remediation is required
<i>Not observed</i>	Skill could not be observed in this scenario

ANTS System-Observation and Rating Sheet. 2004. (Accessed May 1, 2006, at <http://www.abdn.ac.uk/iprc/papers%20reports/Ants/ANTS%20System%20Observation%20Rating%20Sheet.doc.>)

<p>Goals and objectives Technical and non-technical</p> <p>Case: <b>Spontaneous rupture cerebral AVM and right mainstem intubation at outside hospital</b></p>	<ol style="list-style-type: none"> <li>1. Recognition of airway problem: intubated patient who is presenting with hypoxia <ol style="list-style-type: none"> <li>a. What is differential diagnosis (i.e. DOPE)?</li> <li>b. What are initial management techniques?</li> </ol> </li> <li>2. Differential diagnosis of new-onset seizures and/or altered mental status</li> <li>3. Recognition of possible increased intracranial pressure <ol style="list-style-type: none"> <li>a. What are the clinical signs?</li> <li>b. What are the initial management techniques?</li> <li>c. Does recognition of increased ICP change your differential diagnosis for new-onset seizures?</li> </ol> </li> <li>4. Non-technical: <ol style="list-style-type: none"> <li>a. Establishment of team leader</li> <li>b. Establishment of shared mental model/situation awareness</li> <li>c. Closed loop communication</li> <li>d. Use of assertive statements</li> <li>e. Identification of latent threats</li> </ol> </li> </ol>
<p>Target participants (roles, specialty)</p>	<p>Emergency Department (ED) Providers</p>
<p>Clinical setting (ED, OR, patient room) sim lab or insitu</p>	<p>ED: In situ, Sim Lab</p>
<p>Basic scenario information (outline)</p>	<p>Brought to resuscitation bay as “Medical Team” by aeromedical transport from outside hospital already intubated and billed as new-onset seizures and “stable” in transport</p> <p><b>Scenario Background:</b>  <i>Past Medical History:</i> None  <i>Drug Allergies:</i> None  <i>Medications:</i> None reported  <i>Chief Complaints:</i> seizure</p> <p>Your patient is a 6-year old male, who was found, by his father, having a seizure in his bedroom before school. Previously healthy child with no prior medical needs. He was transported by squad to an outlying hospital, received Vecuronium and was intubated with 4.0 uncuffed ETT. He then was flown to Children’s and the report is that the child was “stable” and there were “no problems” during the flight.</p> <p><u>Initial exam:</u>  B/P 130/90; HR 60; RR 0; sats 88%  4.0 ETT with hub (connector) at lip (the ETT tip is currently in the right main stem)  Lung sounds clear on right side, no breath sounds on the left  PIV in place, intact pulses  Unresponsive</p> <p><u>Case progression:</u>  Move to recovery if <b>correct</b> treatment is provided, although will develop asystole despite appropriate initial care  <u>Worse</u> if appropriate care is not provided, there is a delay in care (if over 4 minutes without expected interventions) or if incorrect intervention(s) performed  Signs of deterioration: decreased HR, increasing BP, decreased distal pulses, declining saturations  If patient arrests, then go to pulseless asystole requiring CPR, epinephrine bolus(s) and medical intervention to reduce ICP</p>
<p>Simulator to be used</p>	<p>Child (Meti or Gaumard)</p>
<p>Fluids and medications</p>	<p>As in the ED setting, will have access to all the medications available in the Pyxis, as well as ability to order medications from Pharmacy (i.e. antibiotics)  IVF: NS or LR  Hyperosmolar therapy: mannitol and/or 3%NS  Epinephrine 1:10,000  Epinephrine (or other inotrope) infusion to raise MAP (to sustain CPP)</p>
<p>Equipment needed ( IV’s, ET tubes, Chest tubes,)</p>	<p><b>General:</b>  Personal protective equipment (gloves, gowns, etc)  Monitor and associated equipment (BP cuff, pulse oximetry cable, etc.)  Warming blankets/Bear Hugger  Defibrillator</p>

	<p>Backboard IVF pump, syringe pumps x 2, Rapid Infuser, Hotline</p> <p><b>IV Supplies:</b> Angiocaths, tubing, syringes, tape and IV practice arm</p> <p><b>Airway Supplies:</b> BVM, oxygen source Laryngoscope blades, ET Tubes, stylets, Tape</p>
Paperwork, labs, X rays and EKG's, photos, videos	<p>Lab Values: I-stat pH 7.10, pCO2 54, BD -7, gluc 105, Na 137, K 4.5, iCa 1.1</p> <p>X-Rays: Chest (tube placement) available, Left Lung collapse (one with ETT in right main stem and one with ETT in trachea if ETT pulled back or re-intubated)</p> <p>Head CT: diffuse intracranial bleed due to non-operable ruptured AVM</p>
Medication intervention	<p>Must initiate hyperosmolar therapy: mannitol 0.5-1 g/kg, 3% HTS at 3-8ml/kg</p> <p>Anticipate need for adrenergic support (epinephrine infusion 0.1-1mcg/kg/min, 0.05-0.1 mcg/kg/min for Norepinephrine)</p> <p>Anticonvulsants: phosphenytoin 20 mg/kg loading infusion, as prophylaxis</p>
Airway intervention (oxygen, BVM, intubation)	<p>Identify displaced/misplaced ETT: patient has right main stem intubation that has been prolonged leading to left lung collapse and hypoxia; should pull tube back until patient improves/equal breath sounds</p> <p>Correct Pre-Existing Incorrect ETT Size: patient has significant air leak - given age, a 5.0 cuffed or 5.5 uncuffed ETT is indicated; tube should be exchanged</p>
Physiologic intervention (CPR)	<p>Fluid resuscitation for maintenance of CPP and decrease of ICP</p> <p>CPR</p> <p>Assisted Ventilation and Oxygenation</p>
Procedures and other interventions	<p>Re-Intubation</p> <p>IO or central venous access in order to safely deliver inotropes</p> <p>Arterial line appropriate if delay to ICU bed or high rate of pressors required</p>
Number of and education of instructors	<p>1 facilitator</p> <p>1-2 simulation specialist</p> <p>1 AV specialist</p>
Evaluation tools and measurement points	<p>Standard Debriefing Checklist</p>
Advance organizer/pretest and how delivered	<p>Not applicable</p>
Personnel-simulation specialist, Actors/family members	<p>Consider actor as non-significant figure as no parents will be available (came by aircare)</p>
Estimated time to run simulation and debriefing	<p>Simulation 10 minutes</p> <p>Debriefing 10 minutes</p>
Need for reevaluation (time frame)	<p>Not applicable</p>

# Flowchart for AVM



Process may transition from one line to another (incorrect to desirable or vice versa), especially if team performs incorrect actions – i.e. intubation is esophageal or right main stem, incorrectly performs CPR, incorrect selection of medications, etc. It is not possible to depict/guess all expected team actions on this flowchart.

This scenario is the property of CCHMC Center for Simulation and Research. Please obtain permission prior to use.

Hello all,

Thank you to all that participated in the in situ simulation today. We want to make this a valuable part of our ongoing work to improve patient care. To that end, we are asking for your feedback. Please be honest...it really helps us to improve.

**Please try to answer the first 6 questions:**

1. How valuable is this type of training in the clinical setting from 1 (not valuable at all) to 5 (extremely valuable)? Comments?
  
2. How did performance of the simulation in the STS bay impact the ED, and you personally, for the rest of the day?
  
3. How did the realism of doing this in the STS bay of the ED compare to doing it in the simulation lab (at MERC)?
  
4. The length of time for the simulation today was : too short, too long, about right? Comments?
  
5. Our debriefing was short by design, but we would like any additional feedback you have: Specifically, was there anything you wanted to say about the simulation, communication, medications, or equipment that you didn't have an opportunity to say? Any suggestions for improvement? Any obvious or hidden safety issues that were brought to your attention?
  
6. Any other comments about today's simulation?

**If you have run one or more of these (and are now tired of filing out the same responses), please just comment here on what are the benefits of this ten minutes to you, were there any safety issues, and what could be better:**

Thanks again for your participation and your feedback,



## Appendix D – Latent Safety Threats Identified (N = 73)

Sim #	Medication Threats (N = 22)
2	Lack of communication from nurse right to medication nurse, who drew up 1:1000 epinephrine for IV use instead of 1:10,000.
5	Code book (medication and equipment book) was in the bay, but was not utilized. It was not brought to bedside.
10	Didn't use insulin dilution kit for small dose of insulin, potentially resulting in overdose.
12	Medication and Specialty Resource Unit (SRU) nurse very late. Physician was left to draw up meds - drew up epinephrine, but didn't label correctly, put tape over med line. Bedside nurse questioned it, but didn't verbalize.
12	Atropine drawn up and given, but never recorded by nurse team leader and wasn't verbalized loud enough that it was given by nurse right.
21	No one aware of insulin dilution kit's existence or where to find it.
27	Physician team leader asked for Zosyn, which was appropriate, however that medication is not in resuscitation bay Pyxis MedStation® system.
35	Team did not realize Gentamicin was available in resuscitation bay Pyxis MedStation® system for this size patient.
40	Worry for giving sedation before giving succinylcholine - medication nurses and nurse right were concerned about not giving sedation before giving succinylcholine, even though patient was unresponsive and had ketamine on board. This slowed down arrival of succinylcholine to bedside.
42	Respiratory therapist (RT) noticed medication nurse struggling with preparing albuterol. RT could have asked someone else to bag and he could have gotten medicine more quickly. RT's usually are the one who prepare albuterol in the remainder of ED, but not in resuscitation bay due to "inability to leave the head of the bed."
59	Rocephin given in penicillin allergic patient.
67	Team was planning on giving succinylcholine for rapid sequence intubation (RSI) in spite of known potassium of 8.1; potential severe adverse medical event.
72	Team had difficulty calculating burn resuscitation fluid rates. Information was eventually found in "miscellaneous calculations" page in drug and drip reference book.
74	Knowledge gap around indications for and location of glucagon. Pharmacist discussed where to locate glucagon.
77	Ativan not listed on Code book sheet; delay in preparing for patient in status epilepticus
78	Need to specify which intubation medications should be drawn up – cannot just call out for "intubation meds."
79	Team asked for intubation medication instead of being specific. Pharmacist prepared then made the nurse clarify what she wanted - must be a direct verbal order from physician.
80	Hydrocortisone – knowledge gap on how to dose for stress dosing and shock and whether to give dose based on mg/kg or meter squared.
80	Identified only 200 mg of hydrocortisone in Pyxis MedStation® system. Inadequate dose for steroid stress dose in larger patients.
81	Long interval to mix dopamine drip, due to physician asking for multiple medications at once. Need to prioritize order of medications needed.
84	Team appropriately asked for prostaglandin (PGE1) infusion, but there was obvious confusion on how to get it, knowledge gap about the continuous infusion sheet, and requirement that pharmacy requires dose/concentration/rate when ordering this.
89	1:1000 vs. 1:10,000 epinephrine confusion – located in same drawer of resuscitation bay Pyxis MedStation® system.
	<b>EQUIPMENT THREATS (N = 26)</b>
6	Endotracheal tube (ETT) too big for 8-year old.
10	Didn't synchronize for stable ventricular tachycardia, instead delivered defibrillation. Team had difficulty locating synch button due to lack of familiarity with defibrillator.
13	Clock is stopped in resuscitation bay
14	Clock still broken in resuscitation bay
15	Missing in line nebulizer device
15	Missing one liter anesthesia bag
16	Oxygen mixer not working
19	Synchronized button was not pushed before shock given, resulted in patient going from stable ventricular tachycardia to ventricular fibrillation.
21	Bag valve mask too large and was not changed to appropriate size. Potential for barotrauma
28	Lack of familiarity with T-pod (device used to secure unstable pelvis)-how to apply and indications
39	Magill forceps missing. They had been present when checked that morning. In follow up, we discovered that obstetric resident(s) was taking them from the resuscitation bay to use on the floor.
40	Endotracheal tube that was too large for patient initially chosen
43	Delay in getting ice on the patient, despite having ice machine in bays. Need bigger bags than just lab specimen bags and need way to seal them other than tape.
46	Called for fans and misting, but no one knew where or how to get fans (in patient with environmental hyperthermia).
49	Stopcocks are blowing apart when attempting to administer adenosine (new supplier)
49	Defibrillator out of paper
50	Team asked for tracheostomy box to bedside, which was appropriate. However, box was not in the Pyxis ProcedureStation™ System.
58	Confusion over T-pod use
58	Need to use rapid infuser for packed red blood cell transfusion in resuscitation bay- no one in team aware of this.
67	Team had large amount of task fixation on laryngoscope, despite equipment having been checked prior and it was working.
72	Overhead speaker does not work in triage. Needed to get extra staff in the resuscitation bays.
75	There was a need for team to put in intraosseous (IO) catheter. There was a general reluctance to do this due to lack of confidence/knowledge in performing an IO line
76	Team did not know location of Magill forceps
79	Team had knowledge gap as to how to use the defibrillator
80	EZ-IO® works well, but people forgot it was there. We need to identify specific individuals who can be responsible for bringing drill to bedside.
82	Team had confusion on how to warm resuscitation fluids using available equipment (hotline, rapid infuser).
	<b>RESOURCE/SYSTEM THREATS (N=25)</b>
5	Radiology and Neurosurgery did not call back when trauma activation paged.

6	Radiology did not attend medical team response - some in team thought they come to medical teams, whereas others said they just sometimes show up.
9	Still confusion with "who is who" in the bay, especially for non-ED staff who participate in these.
11	Nurse team leader (recorder) had to leave as "off load" team to helicopter pad in order to take different patient directly to ICU.
19	Team leader verbalized that she did not know a patient care assistant (PCA) could not set up and run an ECG, so it was delayed.
22	No one thought or verbalized to upgrade this to trauma stat when intubation/airway required. This forced ED fellow into staying at head of bed and be less available to team lead.
40	No medication nurse or SRU nurse showed up and pharmacy was not there. Lack of these providers definitely delayed care,
40	Only two providers in the room had ever taken care of a patient with an anaphylaxis before this simulation. In fact, none of the nurses or residents had managed or seen anaphylaxis. Knowledge gap for recognition and management priorities
43	RT not there at beginning of simulation, so nurse right started with bag valve mask ventilation which took her from the nurse right role. Team was missing critical nurse right role.
44	Wrong dose of epinephrine given: 1:1000 not 1:10,000. Syringe clearly labeled 1:1000 and wrong dose given twice. SRU nurse said, "I looked at the wrong line in the medication book and no one was there to do an independent double check (IDC)."
50	Absent nurse left
50	Patient requiring surgical airway. No clear algorithm of calls/management. Discuss potential use of airway page and consultation of anesthesia and ENT when patient is so sick that needs intubation and recognize possibility of surgical airway.
51	There is no nurse left is assigned to trauma evaluation (lowest of three levels of trauma patients), so the only nurse in the room was the nursing team leader. When IV fentanyl was ordered, she appropriately left the bay to find help. This meant no nurse was in the bay with the patient.
60	Started as a trauma evaluation, there was only one nurse and no RT which led to quite a few problems as no one really made up for these roles/responsibilities. Team did not upgrade to higher trauma activation to obtain more resources.
60	Staff in bay did not really know where most equipment was located. Eventually, when asked, someone was able to find it – identified need for equipment supply provider to attend resuscitations.
67	No RT showed up. Team unaware that sometimes one isn't scheduled in the ED.
71	Pharmacist re-iterated need for order of meds to come from physician, that nurse cannot call out for intubation meds.
77	Didn't know there was a second code (medication and equipment) book in resuscitation bay.
78	<b><i>Need to develop a separate documentation flowsheet for arrest patients so it's easier to read</i></b>
78	Used the incorrect arrest algorithm because only an adult size was available at the bedside
79	Team could not find ventricular tachycardia/ventricular fibrillation algorithm. It took a while and they actually brought adult algorithm to bedside, which confused them because doses were inappropriate for 7-year old.
79	Two critical patients presented simultaneously. Although team was able to recruit extra RT and RN, did not ask for more physician help. Instead, physician team leader decided which patient was sicker and sent resident to deal with "less sick" patient.
79	<b><i>Nurse team leader feels the current medical/trauma flow sheet is very difficult to use during an arrest-"too hard to jump all over the place, doesn't flow"- suggested we need to develop a separate arrest documentation flowsheet.</i></b>
81	Medication and SRU nurses cannot see vitals from medication bench.
84	There was no nurse available to help with meds/perform independent double check. Question of why so understaffed on a Monday in the winter?

**Legend:**

- Sim # - refers to the chronological order on simulations run
- ***Bolded and italicized text*** – latent threat that was NOT addressed
  - Example: Nurse team leader feels the current medical/trauma flow sheet is very difficult to use during an arrest-"too hard to jump all over the place, doesn't flow"- suggested we need to develop a separate arrest documentation flowsheet. To date, there has not been a separate "arrest flowsheet" developed, as nursing leadership has chosen to keep the current flowsheet that is used for both medical and trauma resuscitations.