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ORIGINAL ARTICLE

Evaluating the response of medical emergency teams to operating room code events in a children's hospital

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Abstract

Introduction: Medical emergency response teams (MET), also known as code teams, consist of health care providers who respond to life-threatening clinical changes in hospitalized patients. The study objective was to determine whether the utilization of simulation-based clinical systems testing (SbCST) and failure mode and effects analysis (FMEA) would sufficiently assess operating room (OR) MET response systems. **Methods:** A multidisciplinary team of participants and observers collaborated in the SbCST to evaluate OR MET response to a simulated intraoperative code event, followed by FMEA. The primary outcomes were latent safety threats (LSTs), with mitigation strategies resulting from pre-/post-SbCST participant surveys, and debriefing. Risk priority numbers were calculated for each LST to denote priority; resultant scores of 8–16 were deemed significant on a scale of 1–16. **Results:** Participants and observers identified 19 LSTs, 14 of which were high priority. The FMEA further subcategorized LSTs into resource, systems, facility, and clinical performance issues. Pre-/post-survey responses were not significantly different. Participants reported that the SbCST provided a realistic and immersive experience, and effectively tested current OR MET responses. **Conclusion:** SbCST adequately recreated and tested an OR code situation; a significant but infrequent medical event. The use of FMEA highlighted potential LSTs that, in turn, could be rectified to enhance performance. All 19 study LSTs were addressed via training and systems improvements. These results demonstrate that clinical systems can be evaluated and ameliorated via the use of SbCST and FMEA.

Keywords: *failure mode and effects analysis; simulation-based clinical systems testing; latent safety threat; medical emergency response team; simulation; operating room*

Introduction

The clinical status of hospitalized pediatric patients can be unpredictable and may change rapidly. In response, many US hospitals have developed specialized code teams, known as rapid response teams, or medical emergency response teams (METs). These teams consist of a multidisciplinary group of health care providers, who are trained in resuscitation and the management of acute, life-threatening events.[1,2] In some institutions, the MET is activated for emergencies in the operating room (OR) as well. However, although MET members are amply trained to respond to inpatients, some may not be as comfortable in the environment of the OR, with its distinct equipment, staff, and strict rules to ensure sterility. Given this possibility, and the fact that patient safety is at highest risk during high stakes emergencies, it is incumbent to identify and mitigate potential risk/hazards in a safe and effective way.

Simulation has proved invaluable in a number of fields, ranging from aviation to the military.[3] Its utility has also been demonstrated in health care settings. Simulation has been used in the training of ancillary staff, health care trainees, and experienced providers in fields such as emergency medicine,[4,5] obstetrics and gynecology,[6,7] and surgery.[8,9] Recently, it has been shown to be particularly beneficial for the evaluation of clinical processes and patient safety.[10–13] By replicating clinical scenarios, simulation has paved the way for more thorough and objective assessment of systems. By closely approximating real-life situations, simulation-based clinical systems testing (SbCST) enables review of current clinical workflows, and how they could be improved in the future. Moreover, this assessment can be done before staff/patient involvement to avoid patient endangerment.

Failure modes and effects analysis (FMEA), a recently developed tool, standardizes the evaluation of errors or omissions in a clinical workflow. It has been recognized and accepted by a number of prominent health care governing bodies.[14–16] The combination of both assessment tools (SbCST and FMEA) enables powerful recreation and evaluation of clinical processes. The objective of this study was to utilize SbCST and FMEA to evaluate the MET response in the OR.

Methods

Simulation setting

SbCST of the MET response to a code situation in the OR was completed in a single, free-standing, tertiary care children's hospital. The MET providers were alerted via pager of the simulated code situation in the OR by activation of the in-wall code button by OR personnel. The MET team responded from their various locations in the hospital, while the OR team performed the initial response to the code situation. The simulated case was a cardiorespiratory event that occurred during placement of a central venous catheter. The simulation was conducted in situ, in a working OR on a high-fidelity mannequin with programmable vital signs monitor. The manikin was draped, and the appropriate OR team members were scrubbed and sterile, with the anesthesia team located at the head of the bed. The MET team responded from outside the OR, replicating how an OR MET response would occur in real time.

A high-tech, interactive infant simulator, SimBaby (Laerdal, Wappingers Falls, NY; https://laerdal.com/us/products/simulation-training/obstetrics-pediatrics/simbaby/) was used in the activity. SimBaby is a teatherless simulator designed to assist health care providers to effectively recognize and respond to critically ill pediatric patients. SimBaby represents a 9-month-old infant and provides a highly realistic manikin that focuses on initial assessment and treatment. Assessments that can be performed on this manikin include assessing capillary refill time, testing pupillary light reflex, and checking bilateral pulses. In addition, this manikin allows for effective monitoring and improvement of cardiopulmonary resuscitation performance by measuring metrics such as correct compression depth, appropriate compression rate, and adequate ventilation. Interventions that can be performed include airway procedures, chest tube insertion, interosseous needle insertion, and central line placement with simulated venous blood flashback. Real medical equipment and supplies in the clinical environment were utilized in the care of the patient.

Participants and observers

Participants in the simulation included members of the surgical team and MET team (Table 1). Participants from the surgical team included a surgical technician, OR circulating nurse, anesthesiologist, certified registered nurse anesthetist, anesthesia technician, pediatric general surgeon, and pediatric general surgery fellow. The MET team comprised a pediatric intensivist (PICU; code lead), pharmacist, nursing supervisor, nurse, and radiology technician. The observers for the simulation included the OR nursing manager, OR nursing educators, anesthesiologist, pediatric surgeon, MET team leaders (pediatric intensivist, PICU nurse, PICU nurse manager, respiratory therapist lead), patient safety and quality nursing advisor, surgery performance improvement program manager (RN), and OR nurse.

Participants were chosen according to their everyday role but did not have prior knowledge of the simulation events to best be able to observe responses that would be most consistent with typical practice. The observers chosen for this simulation were a mix of senior clinical leaders who have extensive experience in the OR setting (e.g. surgeon, anesthesiologist, OR nursing manager, educator) or with the MET team (e.g. MET team physicians, nurses, and respiratory therapist) in addition to senior members of the simulation team with experience of in situ simulation and also have overlap with the patient safety and quality department. Additional observers were chosen for their specific role expertise (anesthesia technician) to evaluate for role-specific areas of opportunity. Some of the observers held dual roles, such as surgeons and MET team physicians, who were also members of the simulation team.

Survey

All front-line clinicians who provide direct patient care completed pre-/post-simulation surveys with Likert scales regarding their comfort with OR codes and the MET response to OR codes. Those who provide direct patient care were asked to complete the pre- and post-survey, whether they were a participant or an observer. Not all observers provide direct patient care so the total number of participants/observers who completed surveys are not the same. The qualitative data collection during pre- and post-simulation activity is a routine process for all simulation activity in our institution. The basic construct of the survey is adapted for the specific simulation activity but was not designed a priori to measure defined outcomes as a result of the activity. The survey results are used as benchmarks and to identify areas of opportunity that may not be

Table 1. Simulation participants

Simulation OR participants (n = 7)	Simulation MET team participants (n = 5)	Simulation observers (n = 15)
Pediatric general surgeon	PICU MD (code lead)	Pediatric general surgeon (n = 2)[a]
Pediatric general surgery fellow	Pharmacist	Anesthesiologist[a]
Anesthesiologist	Nursing supervisor	OR nursing manager
CRNA	RN	OR nursing educator (n = 2)
OR RN	Radiology technician	MET Team PICU MD[a]
OR surgical technician		MET team RN manager
Anesthesia technician		MET team RN
		MET team respiratory therapist
		PSQ, RN advisor[a]
		Surgery PIP program manager
		RN (n = 2)
		Anesthesia technician

CRNA, certified registered nurse anesthetist; OR, operating room; RN, registered nurse; PICU, pediatric intensive care unit; MD, medical doctor; MET, medical emergency team; PSQ, patient safety and quality; PIP, performance improvement program.
[a]Also a member of the simulation team.

apparent through debriefing and the FMEA tool. Descriptive statistics and paired t testing were used to compare the numerical pre-/post-simulation survey responses. Due to the small number size, direct comparison between participants and observers was not performed.

Debriefing and FMEA tool

Participants also partook in a debriefing session after the SbCST. The scripted debriefing session was led by a simulation-trained educator focused on identifying hazards and potential latent safety threats (LSTs) that occurred during the simulation. The data collected throughout the simulation and during the debriefing session were then used to complete an FMEA of the current system.

The FMEA utilized the in situ OR simulation as a tool to evaluate the OR MET response. The LSTs identified were categorized into four primary domains: resource, systems, facility, or clinical performance issues. Resource issues involved equipment, medication, personnel, or unfamiliarity with a device or medication. Systems issues consisted of procedures, policies, or processes that did not work as anticipated in the existing clinical system. Facility or space arrangement issues countered efficient, safe, effective patient care. Clinical performance issues consisted of gaps in the technical and/or cognitive skills of the clinical personnel that could be improved upon in future educational/training sessions.

A risk priority number (RPN) was calculated for each potential LST identified. The RPNs were calculated by multiplying a severity score by a probability score. Severity scores were classified as catastrophic (4 points), major (3 points), moderate (2 points), or minor (1 point), and frequency scores were frequent (4 points), occasional (3 points), uncommon (2 points), and remote (1 point) (Table 2). These scores were assigned by the simulation observers. Failure modes with high RPNs are likely the most important parts of the process on which improvement efforts should be focused. Lower RPNs are not likely to affect the overall process and are lower priorities to be addressed. The RPN score in our model ranges from 1 to 16 and RPNs between 8 and 16 were determined a priori to be considered significant and would be addressed as a result of the activity.

Results

Pre- and post-simulation surveys (n = 15)

All the pre- and post-simulation survey responses were similar, with no significant difference between their numerical scores (Table 3). The mean scores increased in six of the ten questions in the post-simulation surveys compared with the pre-simulation surveys. Most respondents reported that they were actively involved in providing safe, effective care during MET responses in the OR. After completion of the simulation, most respondents agreed or strongly agreed that they knew what processes to follow when a patient emergency occurred in the OR. Similarly, most respondents felt confident that they were ready to safely and effectively care for patients during a medical emergency in the OR.

Table 2. Failure mode and effects analysis scoring tool

	Severity categories			
	4: Catastrophic	**3: Major**	**2: Moderate**	**1: Minor**
Patient outcomes	Death or major permanent loss of function (sensory, motor, physiologic, or intellectual) Suicide Rape Hemolytic transfusion reaction Surgery/procedure on the wrong patient or wrong body part Infant abduction	Permanent lessening of bodily functioning (sensory, motor, physiologic, or intellectual) Disfigurement Surgical intervention required Increased length of stay or increased level of care for 3 or more patients	Increased length of stay or increased level of care for 1 or 2 patients	No injury, no increased length of stay or increased level of care
	4: Frequent	**3: Occasional**	**2: Uncommon**	**1: Remote**
Probability categories	Likely to occur immediately or within a short period (may happen several times in 1 year)	Probably will occur (may happen several times in 1–2 years)	Possible to occur (may happen sometime in 2–5 years)	Unlikely to occur (may happen sometime in 5–30 years)
Equipment or facility damage (US$)	> 250,000	100,000–250,000	10,000–100,000	< 10,000, or loss of utility

Risk priority number (RPN) is calculated by multiplying the severity score (1–4) by the probability score (1–4). Issues are considered significant priorities if the RPN is between 8 and 16 on a scale of 1–16.[14]

Respondents agreed or strongly agreed that the simulation scenarios were effective in providing a realistic, immersive experience for participants, except for one respondent who selected a neutral response. Nearly all of the participants believed that the OR MET SbCST identified weaknesses in hospital processes, excluding one respondent who responded neutrally after the SbCST. Most respondents agreed that the SbCST helped evaluate how effective the workflow processes were in ensuring patient safety and quality of care. All participants agreed that the in situ SbCST was effective in providing a realistic and immersive experience for participants while testing the current emergency response system in the OR.

Failure mode and effects analysis

Nineteen potential LSTs were identified in the FMEA (Table 4). Fourteen of the 19 LSTs were high priority with a score ⩾8. Of the four practical categories, three were resource issues, six were systems issues, six were facility issues, and four were clinical performance issues. Resource issues were centered around the need for additional OR team personnel, although the MET participants believed they had too many people responding. After the SbCST, these issues were addressed by streamlining the MET response process to optimize the number of responders. Systems issues involved challenges with MET team OR badge access, and available technology for the OR team to activate the MET. These access issues were addressed by the information technology department. Issues with role delineation were addressed in the debriefing, and subsequent simulation sessions were planned to ameliorate understanding of OR MET roles. Facility issues included alarm system technology (e.g. inaudible alarms throughout the OR, etc.), availability and location of medical supplies. These issues were addressed, with assistance from the information technology department, and additional supplies were relocated to the OR to facilitate use/access. Clinical performance issues focused on maintaining sterility, and the lack of familiarity with the Zoll defibrillator. These issues were addressed with additional simulation education and training.

Discussion

The goal of the MET is to quickly detect and treat patients in crisis to stabilize, mitigate, and/or reverse a life-threating critical event. Intraoperative codes are more likely to lead to mortality.[17] Therefore, MET response in the pediatric OR may be a crucial component, particularly in light of the critical nature of procedures and the potential for patients' rapid deterioration. Perioperative cardiac arrests are more frequent in children than adults (14 versus 3.7/10,000),[18] and are more likely in infants than older children.[18,19] Survival from these events is influenced by factors such as patient comorbidities, heart rhythm, delay to intervention, and the quality of life support provided.[20] Because of the

Table 3. Pre- and post-simulation survey and results

Question	Pre-survey (n = 15)		Post-survey (n = 15)		*P* value
	Mean	SD	Mean	SD	
I am confident in my ability to respond to emergencies and high-risk situations in the OR setting	3.88	0.83	3.91	0.87	0.83
I know what emergency supplies and equipment are stocked in the OR	3.27	1.08	3.36	1.05	0.68
I know what processes to follow when patient care emergencies occur in the OR	3.62	1.06	3.73	0.88	0.63
I feel confident that our workflow processes have minimized patient safety risks in the care of decompensating patients in the OR requiring activation of MET response	3.35	0.85	3.14	0.94	0.49
I am actively involved in helping my unit/department provide safe and effective care for MET responses to the OR	3.92	1.16	3.64	1.05	0.12
I feel confident that we are ready to safely and effectively care for patients during medical emergencies in the OR	3.58	0.76	3.50	0.96	0.73
I feel confident that I have received adequate orientation and training related to the new MET response or the OR process	3.44	0.87	3.48	0.87	0.62
I believe the OR/MET Code Blue Simulation-based Clinical Systems Test helped us identify potential threats to patient safety in our hospital systems	4.55	0.51	4.62	0.59	0.77
I believe the OR/MET Code Blue Simulation-based Clinical Systems Test helped us identify defects/weaknesses in our hospital processes	4.55	0.51	4.62	0.59	0.49
I believe the OR/MET Code Blue Simulation-based Clinical Systems Test helped us evaluate how effectively our workflow processes ensure patient safety and quality of care	4.55	0.51	4.52	0.68	0.80
I felt the simulation scenarios were effective in providing a realistic, immersive experience for participants	–	–	4.43	0.60	–
The Simulation Center staff provided effective support and expertise in developing and implementing this simulation activity	–	–	4.48	0.60	–
The environment and conduct of this simulation activity promoted safety and confidentiality for participants	–	–	4.52	0.60	–
I believe participation in this activity has made a difference in quality of care and patient safety in the participants' clinical setting	–	–	4.38	0.67	–

SD, standard deviation; OR, operating room; MET, medical emergency team.

necessity to provide fast, effective care, excellent working knowledge, skill, and comfort in the OR is required, and members of the MET must be appropriately trained to manage these unique situations.

OR simulation has been utilized to assess team responses to critical events.[21] In their evaluation of 263 anesthesiologists participating in two simulated perioperative crises, including cardiac arrest, Weinger et al. found gaps in participants' technical and non-technical performance.[21] In their weekly assessment of a simulated intraoperative cardiopulmonary arrest scenario using 91 multidisciplinary participants, Wongsirimeteekul et al.[22] reported that the mock code was overwhelmingly applicable to clinical practice, encouraged interprofessional learning, and promoted teamwork. Holzman et al.'s study,[23] involving 68 anesthesiologists in a 2.5-month training course, rated their performance during a simulated OR code as good, increasingly so in direct correlation with their years of practice experience. In terms of knowledge retention, over half surveyed believed the course should be taken annually; another third stated the course should be taken every other year. Caruso et al.[24] investigated the implementation of a standardized emergency response, with set respondents for intraoperative cardiac arrests. Their results demonstrated an improved code initiation process and management. In their evaluation of perioperative crisis checklists during OR code simulations, Dagey et al.[25] developed a best practice cardiac arrest checklist, and 80% of the respondents surveyed stated that they were more comfortable caring for patients experiencing cardiac arrest afterward. The opportunity to identify and address challenges related to teamwork, culture, and systems can ultimately improve patient safety and outcomes. Applying health care simulation as a patient safety tool, as opposed to solely an educational tool, has been shown to be effective in many clinical environments.[10–13] Given the unique challenges of managing emergencies in the OR,

Table 4 Potential latent safety threats (LST) identified and potential solutions

Potential LST identified	Risk priority number	Potential solutions
Resource issues		
Lack of personnel resources (OR)	16, 8	MET team activated if additional resources needed
Unneeded MET team resources	3	Extra personnel will be dismissed if not needed/redundant
Supplies	12	Added Zoll cart (× 2) in the OR area
Systems issues		
MET team badge access		Information technology provided access to OR
Communications	16, 16, 1	Electronic communication systems upgraded, back up communication systems implemented
Lack of role clarity	16	Education on MET roles for non-MET members; clarify and define roles for MET in the OR setting; ongoing simulation
Lack of closed loop communication	16, 8	Reinforce/education on closed loop communication
Delay in activating MET team	8	Empowering staff to activate MET early
SBAR format not used	12	First 5-minute training for OR staff
Facility issues		
Technology issues related to altering others to code situation	16, 16	Information technology improved internal overhead alerts, electronic communication systems upgraded
Accessibility of medical supplies	12	Reconfigure supplies to be more accessible
Code cart difficult to access due to positioning	12	Zoll carts added to help with access to code supplies
Delay in MET arrival	8	Provided easy access to PPE for MET team
Visualization of monitors	–	Determined to be limitation of simulation exercise
Difficulty tracking times	–	Determined to be limitation of simulation exercise
Clinical performance issues		
Maintaining sterility	9	Stock additional sterile gowns/gloves on Zoll cart; OR team to instruct MET team to sterile field
Lack of familiarity with Zoll defibrillator and clinical coach role	16, 8	Training in the use of the Zoll defibrillator and CPR coach role for anesthesia and OR teams
Delay in backboard placement	4	First 5-minute training
Unclear if procedural equipment should be moved	12	Clarification of roles

OR, operating room; MET, medical emergency team; SBAR, situation-background-assessment-recommendation; PPE, personal protective equipment; CPR, cardiopulmonary resuscitation.

performing SbCST to identify potential hazards, performance gaps, and opportunities for improvement is beneficial.

FMEA, promoted by the Institute for Healthcare Improvement, is a systematic, proactive method for evaluating a process to identify where and how it might fail and to assess the relative impact of different failures and identify which parts of the process are most in need of change. FMEA is used to identify and correct possible failures in a proactive manner, rather than reacting to adverse events after failures occur. This process emphasizes prevention to reduce risk and harm to both patients and health care staff. The advantages of incorporating both an SbCST and FMEA have also been reported. In their consideration of the potential benefits of combining the two tools, Nielsen et al.[26] simulated a health care process (breech delivery), then analyzed it using a multidisciplinary team, subprocess flow diagram, and a two-pronged evaluation. They reported that the application of simulation (interrupted along flow diagram substeps) and FMEA resulted in the identification of additional LSTs that were relevant for deeper analysis. Davis et al.[27] concluded that the combination of simulation and FMEA provided a more objective, comprehensive, and systematic way to identify LSTs in clinical processes.

In this current study, participants' pre-/post-survey results similarly reported that the SbCST created both an immersive and representative experience to test current OR MET responses. It was important to create as high fidelity a model as possible to represent the precise conditions MET would encounter in the OR and evaluate clinical responses.

In addition, the FMEA identified 19 LSTs, of which 14 were high priority. Most of these were systems issues, followed by facility, clinical performance, and resource issues. Stakeholder debriefing and collaboration largely addressed and resolved these matters via system amelioration. Revised OR MET protocols, roles, ancillary equipment, and accessible supplies were some of the remediation measures that were implemented. A recent systematic review concluded that simulated-based team training in emergency medicine is beneficial to teams' knowledge and attitude toward non-technical skills.[28]

Our group has used this model to test readiness as our institution transitioned to an independent pediatric trauma center. A total of 49 LST were identified, of which 9 were prioritized. The cost-benefit analysis based on the FMEA event avoidance estimated a net cost savings of up to $227,000 over the 3-month transition period (unpublished data). Future studies could involve cost-benefit analyses of MET, including their involvement in pediatric hospital ORs. The occurrence of OR code events may be low, yet the potential advantages of a specialized response team would likely prove significant. Future work from this group will entail surveying children's hospitals about their processes during intraoperative arrests. This cohort will then be compared with best practice hospitals to establish guidelines for systematic responses to these infrequent, but life-threatening events.

Potential limitations include the time of day in which the simulation training occurred, and participants' comfort level working outside of standard daytime hours (e.g. evenings and weekends). The study did not demonstrate a direct decrease in morbidity or mortality; although due to the nature of the study design (e.g. using SbCST), this would be hard to assess. Generalizability (external validity) is a potential limitation because the results were limited to one institution, however, similar results have been shown in other studies.[4,5] Lastly, long-term benefits are difficult to quantify and/or assess.

Conclusion

As technology and infrastructure evolve, so must the MET and their training. The SbCST was able to recreate a realistic, comprehensive emergency OR code scenario to assess current MET response systems. Resultant LSTs stemming from the SbCST and FMEA were identified and rectified via system mitigation and training. These results indicate the feasibility and efficacy of clinical system assessment and enhancement via SbCST and FMEA.

Conflict of interest

None declared.

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