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## Simulation-based training delivered directly to the pediatric cardiac intensive care unit engenders preparedness, comfort, and decreased anxiety among multidisciplinary resuscitation teams

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**Objectives:** Resuscitation of pediatric cardiac patients involves unique and complex physiology, requiring multidisciplinary collaboration and teamwork. To optimize team performance, we created a multidisciplinary Crisis Resource Management training course that addressed both teamwork and technical skill needs for the pediatric cardiac intensive care unit. We sought to determine whether participation improved caregiver comfort and confidence levels regarding future resuscitation events.

**Methods:** We developed a simulation-based, in situ Crisis Resource Management curriculum using pediatric cardiac intensive care unit scenarios and unit-specific resuscitation equipment, including an extracorporeal membrane oxygenation circuit. Participants replicated the composition of a clinical team. Extensive video-based debriefing followed each scenario, focusing on teamwork principles and technical resuscitation skills. Pre- and postparticipation questionnaires were used to determine the effects on participants' comfort and confidence regarding participation in future resuscitations.

**Results:** A total of 182 providers (127 nurses, 50 physicians, 2 respiratory therapists, 3 nurse practitioners) participated in the course. All participants scored the usefulness of the program and scenarios as 4 of 5 or higher (5 = most useful). There was significant improvement in participants' perceived ability to function as a code team member and confidence in a code ( $P < .001$ ). Participants reported they were significantly more likely to raise concerns about inappropriate management to the code leader ( $P < .001$ ).

**Conclusions:** We developed a Crisis Resource Management training program in a pediatric cardiac intensive care unit to teach technical resuscitation skills and improve team function. Participants found the experience useful and reported improved ability to function in a code. Further work is needed to determine whether participation in the Crisis Resource Management program objectively improves team function during real resuscitations. (*J Thorac Cardiovasc Surg* 2010;140:646-52)

High-risk enterprises such as the aviation and nuclear power industries have long recognized the contribution of human error to accidents and catastrophic events.<sup>1,2</sup> Training in teamwork and communication, known as Crew Resource

Management training, has been implemented in the aviation industry to reduce the potential for such errors.<sup>1</sup> In the 1990s, Gaba, Fish, and Howard<sup>3</sup> at Stanford adapted core concepts from Crew Resource Management to anesthesia and renamed the process "Crisis Resource Management" (CRM). From this initial application, CRM is now used broadly to train health care teams across clinical specialties and expertise gradients—from undergraduate to postgraduate and continuing medical education.<sup>4,5</sup> CRM training aims to improve team functioning, particularly communication, in an attempt to reduce or mitigate the potential for human error that may lead to patient harm.

Most commonly, traditional CRM courses have been carried out in dedicated simulation centers, attended by participants during nonclinical time. Members of our group have previously published on the benefits of hospital-based on-site simulation and, more recently, in situ simulation at the point of care for multidisciplinary CRM training.<sup>6,7</sup> Benefits of these modalities include ease of integration into regular clinical schedules and therefore increased opportunities to

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### Abbreviations and Acronyms

CPR	= cardiopulmonary resuscitation
CRM	= Crisis Resource Management
ECMO	= extracorporeal membrane oxygenation
pCICU	= pediatric cardiac intensive care unit

successfully train full multidisciplinary teams. In situ simulation has also been described by us and others as a robust tool to identify potential threats within hospital systems and procedures.<sup>8,9</sup>

We describe here the application of in situ simulation to the highly specialized care environment of the pediatric cardiac intensive care unit (pCICU). Emergencies in the pCICU involve complex physiology and require interaction among multiple care providers, including cardiologists, cardiac surgeons, cardiac intensivists, nurses, respiratory therapists, and extracorporeal membrane oxygenation (ECMO) specialists. To optimize patient outcomes, providers must be able to perform specific technical and cognitive skills as well as share in efficient coordination and communication. Recent studies from both pediatric cardiac surgery<sup>10</sup> and general pediatrics<sup>9</sup> have demonstrated that deficiencies in teamwork and communication are significant among providers and that these contribute to important medical errors.

To facilitate and promote excellence in teamwork and communication while reinforcing cognitive and technical skills specific to pCICU resuscitations, we have implemented a multidisciplinary simulation-based educational program within a busy 24-bed dedicated pCICU. We hypothesized that the program would have positive effects on comfort and confidence levels among participants involved in resuscitation events.

## MATERIALS AND METHODS

### Course Design

The pCICU-CRM training course is a monthly multidisciplinary training program that teaches teamwork and practice-specific resuscitation skills to nurses, cardiology and critical care fellows, cardiothoracic surgery trainees, and allied health professionals working in the pCICU. Founded on widely established adult learning principles, the course targets the 4 major types of learners<sup>10</sup> through a combination of (1) game play, (2) didactics, (3) video review, and (4) hands-on high-fidelity simulation-based training. Simulations are followed by structured reflection via video-based debriefing, all within a 4.5-hour course embedded within the work day. pCICU nurses are required to participate every 2 years, and fellows participate a minimum of 2 times during their 3-year training program. The program is nonevaluative.

**Game play.** Before engagement in full-scale high-fidelity simulation, game play is used to allow participants to explore CRM principles within a nonmedical, safe and low-stakes setting.<sup>11</sup> Participants are asked to read aloud a word written on a tennis ball after which the ball is thrown to a colleague within a 3-second time period. With each successive ball that enters the field, the participants begin to engage in and experience the chaos and disorder common to crises in general. The game is then “debriefed” to

highlight key contributors to poor crisis management (eg, disorganization, chaos, lack of identifiers/names) followed by a discussion of mechanisms of improvement (eg, communication, role clarity, event manager), which serves as introduction to the didactic CRM lecture.

**Didactics.** The didactic session, a 45-minute interactive lecture, reviews the 5 major principles of CRM—role clarity, communication, personnel support, resource use, and global assessment—with emphasis placed on practical applications of these principles in the pCICU environment. For example, in discussions of resource use, specific information is included about how to mobilize the necessary equipment and personnel for initiation of ECMO during CPR. This also allows the course to introduce and reinforce institution and unit-specific patient safety standards, programs, policies, and initiatives.

**Video review.** Within the didactic, participants watch 2 videos of high-performance teams in a crisis situation and comment on CRM principles. Specifically, we use a clip of the NOVA film “Why Planes Crash,”<sup>12</sup> a recreation of the 1972 crash of Eastern Airlines flight L-1011 over the Florida Everglades. In this incident, crewmembers became fixated on the failure of the landing gear indicator light, failing to monitor flight equipment and notice that the autopilot had become disengaged. The plane ultimately crashes after gradual, unrecognized loss of altitude. The second film, “First, Do No Harm Part 1: A Case Study of Systems Failure”<sup>13</sup> depicts a re-enactment of an obstetrical emergency where poor team behaviors lead to poor outcomes. Both videos serve as “trigger tapes” for discussion of errors of fixation, communication, and loss of situational awareness and reinforce the importance of these principles for high-stakes teams.

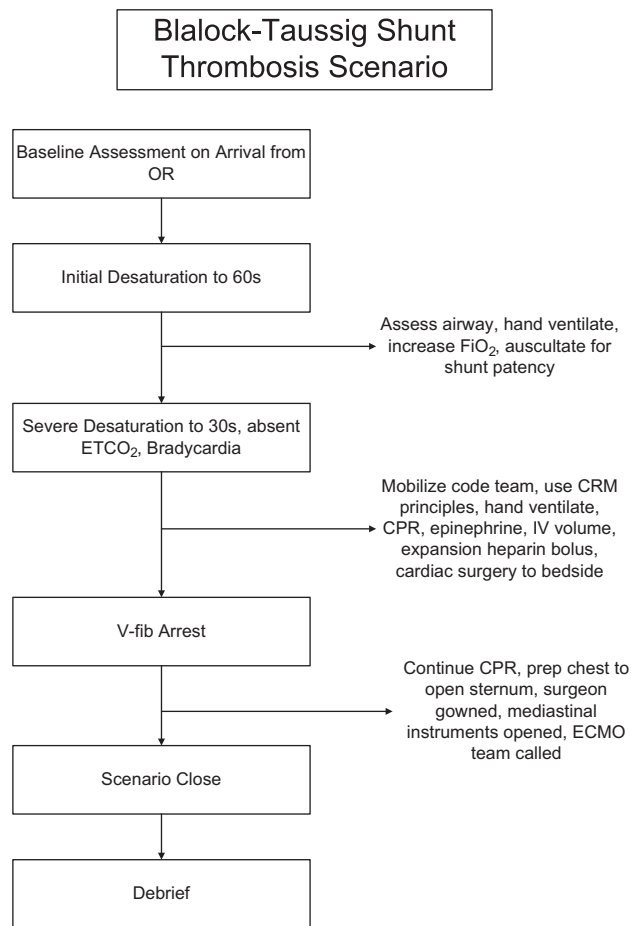
**Simulation scenarios and debriefing.** To both optimize authenticity as well as ensure clinical relevance for participants, we derive scenarios from real cases from the pCICU. This “animates” the morbidity and mortality process allowing large portions of staff to experience, reflect on, and suggest improvements related to specific patient events. Cases include acute thrombosis of a modified Blalock-Taussig shunt, pericardial tamponade, pulmonary hypertensive crisis, and obstructed endotracheal tube in a patient with palliated single ventricle. Scenarios are designed to include specific training goals and objectives including introduction to new equipment as well as intensive care unit policies and procedures. Each scenario is designed to address specific predominantly CRM objectives (80% of total course time). Technical and medical learning objectives are also covered (20% of total course time).

All course scenarios are implemented in situ at the point of care within an actual pCICU bed space using the same equipment (defibrillators, ventilators, surgical instrument trays), and supplies (code cart, medications) used for real patients. The in situ approach facilitates (1) participation of the complete complement of caregivers, (2) authentic high-fidelity simulations, and (3) opportunities for risk-free deliberative practice with resuscitation equipment.

Simulations are carried out using a high-fidelity patient simulator mannequin (SimMan or SimBaby, Laerdal Medical, Inc, Stavanger, NY), which is set up in a pCICU bed space. Basic vital signs as well as physiologic data, including intracardiac pressure tracings, end-tidal carbon dioxide tracing, and electrocardiogram, are displayed on a bedside monitor as appropriate for a given scenario. The team must incorporate and act on physiologic data from the monitor and from examination of the mannequin. Progression of the clinical scenario can be controlled by course facilitators in real time to correspond to interventions made by the care team.

Participants are expected to provide care within the context of a scenario in the same way that they would in a clinical encounter within the limitations of the specific mannequin. This includes drawing up and administration of medications, airway management, cardiopulmonary resuscitation (CPR), and some procedures, such as chest tube or central line placement and thoracentesis. All procedures are performed with participants using sterile barrier precautions to enhance the realism of the experience.

As an example, Figure 1 outlines the clinical progression of a scenario used in our training program in which a patient with single ventricle has



**FIGURE 1.** Flow diagram of clinical sequence for sample simulation scenario. *Boxed text* depicts the clinical progression. Text in the *right hand column* depicts expected actions by participants. *OR*, Operating room; *ETCO<sub>2</sub>*, end-tidal carbon dioxide; *V-fib*, ventricular fibrillation; *F<sub>IO<sub>2</sub></sub>*, inspired oxygen fraction; *CRM*, Crisis Resource Management; *CPR*, cardiopulmonary resuscitation; *IV*, intravenous; *ECMO*, extracorporeal circulation.

acute thrombosis of a Blalock–Taussig shunt postoperatively. Learning objectives for this scenario include the following: (1) recognition of the physiology of shunt thrombosis, (2) early declaration of a crisis and recruitment of emergency team, in particular surgeon, to the bedside, (3) recognition of need to reopen the sternum on an emergency basis and knowledge of steps required to do so, and (4) application of excellent CRM principles, in particular, use of closed loop communication and maintenance of situational awareness. The pCICU bed space and mannequin are prepared to replicate the immediate postoperative setting. In particular, the mannequin is intubated and ventilated. Vascular access includes internal jugular, common atrial, and arterial lines, as well as peripheral intravenous lines. A sternal dressing and chest drains are present as would be in an acute postoperative patient. These details enhance authenticity and realism experienced by participants.

All simulation scenarios are videotaped with a tripod-mounted video recorder as part of a mobile simulation setup as previously described in an article by Weinstock and associates.<sup>7</sup> Scenarios are then immediately followed by structured video-based debriefings using widely established industry-based methodologies<sup>14</sup> performed by trained physician and nurse facilitators. The overarching goals of the debriefings include (1) exploration of efficacy of teamwork and adherence to CRM during the simulated resus-

citations balanced with (2) discussion of medical management. Significant errors in medical management are directly addressed, even though the focus of our training is teamwork-based. The debriefing is carried out in 3 phases as follows: (1) a reactions phase in which participants are given an opportunity to raise issues they encountered during the crisis scenario, (2) an understanding phase, in which issues surrounding teamwork raised either by the facilitators or by the participants are probed to uncover system faults or cognitive processes leading to suboptimal teamwork, and (3) a summary phase, in which medical and teamwork principles addressed during the debriefing are summarized. Attempts are made by the facilitators to let the group problem-solve teamwork deficiencies, rather than prescribe corrective actions for the future.

**Program evaluation/assessment.** For quality assurance and improvement purposes, all participants completed precourse and postcourse questionnaires using a 5-point Likert scale. Measures included comfort level participating in and leading a code and anxiety regarding participating in a code event. Questionnaires also assessed perceived utility of key didactic components, particularly with regard to communication. Specifically, inasmuch as the didactic curriculum emphasized speaking up against inappropriate management and speaking against an authority gradient, the questionnaire elicited participants self-reported comfort level with these behaviors. Realism and usefulness of the individual simulation scenarios as well as the course as a whole were also queried.

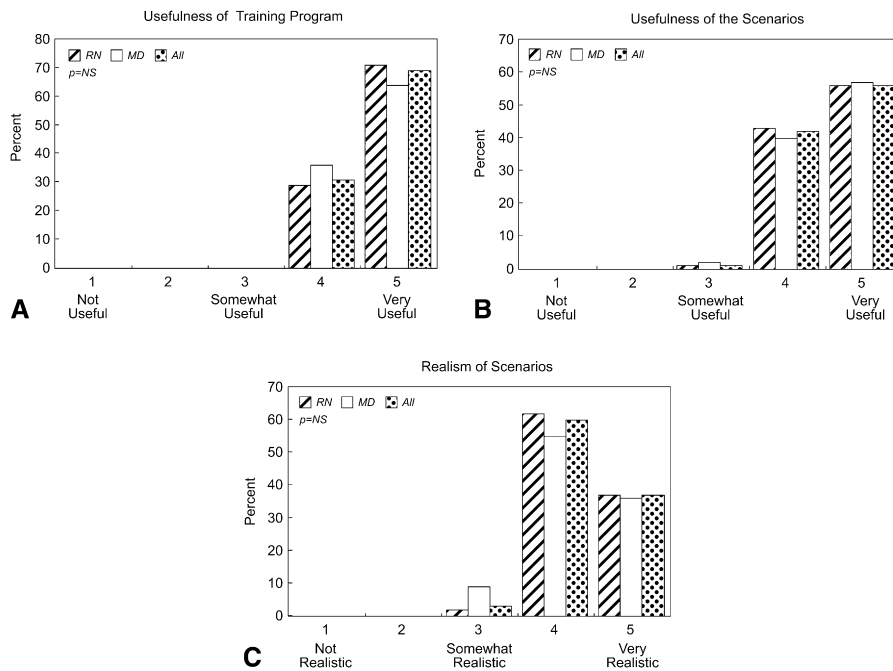
**Statistical analysis.** Pretest and post-test evaluations were compared using the Wilcoxon signed ranks test. Subgroup analyses were performed to evaluate changes before and after the course for physician and nursing participants. The Mann–Whitney *U* test was used to compare responses between nurses and physicians regarding post-course overall program evaluation. Because only a small number of allied health care providers (eg, respiratory therapists) participated in the course, the subgroup analysis only compared responses between physician and nurse participants.

**RESULTS**

A total of 182 pCICU providers participated in 27 courses over a 33-month period. Participants included nurses (*n* = 127), cardiology, cardiac surgery, and critical care fellows (*n* = 44), pCICU attending physicians (*n* = 6), respiratory therapists (*n* = 2), and nurse practitioners (*n* = 3). This was the initial exposure to simulation-based training for 61% of participants, with no difference between nurses and physicians in prior exposure (61% and 57%, respectively; *P* = not significant).

Postcourse questionnaires demonstrated that the majority of participants found the course to be “very useful” (median score 5 on a 5-point Likert scale) (Figure 2, A). Similarly, scenarios were rated highly regarding both usefulness (median score 5) and realism (median score 4) (Figure 2, B and C). Subgroup analysis of both physician and nursing respondents demonstrated that these groups found the scenarios equally realistic and useful and the course as a whole equally useful (Figure 2).

Overall, course participants perceived themselves to be better prepared both to participate in and to lead future resuscitation events after participation in the pCICU–CRM program (*P* < .001; Figure 3, A and B). In addition, after the course, participants reported feeling a higher degree of confidence and a lower anxiety level with regard to participating in future pCICU code event (*P* < .001; Figure 3, C and D).

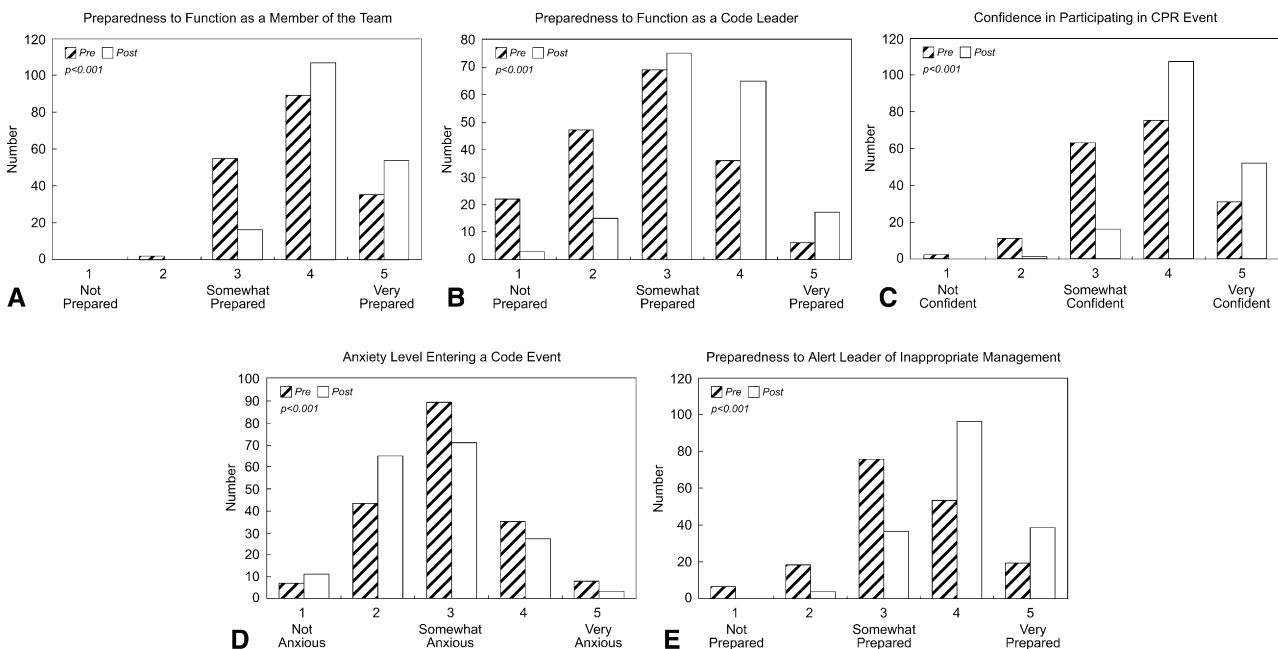


**FIGURE 2.** Overall evaluation of the training program by physicians, nurses, and participants as a whole. RN, Registered nurse; MD, physician; NS, not significant.

Participants also reported increased likelihood of alerting the team leader if they perceived the management of the resuscitation event to be inappropriate ( $P < .001$ ; Figure 3, E).

Subgroup analysis demonstrated that both nurses and physicians perceived an improvement in preparedness to

participate in or lead future code events as well as improved confidence regarding participation in future code events (all  $P < .001$ ). Both groups also reported an increased likelihood of speaking up in the case of perceived inappropriate management ( $P < .001$ ). A difference was detected between



**FIGURE 3.** Precourse and postcourse assessment by participants of their confidence, preparedness, and anxiety entering a future resuscitation event. CPR, Cardiopulmonary resuscitation.





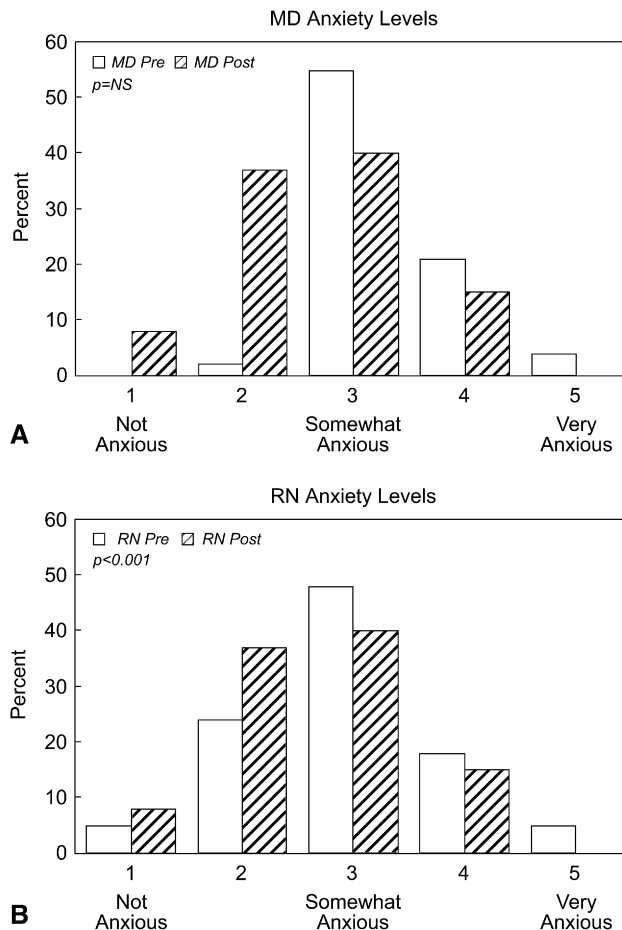
physicians and nurses in anxiety regarding participation in a future code event, with nurses noting a decrease ( $P < .001$ ) and physicians noting no significant change in anxiety (Figure 4, A and B). Reporting of change in anxiety did not differ for those who had prior simulation training experience versus those who did not.

**DISCUSSION**

Simulation-based training in CRM has long been thought to improve team function in high acuity clinical situations.<sup>12</sup> We report here successful implementation of a multidisciplinary in situ CRM training program taught at the point of care within the highly specialized environment of the pCICU. We show that participation in the course led to improved self-perception of confidence and preparedness among multidisciplinary team members with regard to managing future real crisis events. Although others have reported on implementation of simulation-based training programs directed at resuscitation of postoperative pediatric cardiac patients, these programs have focused primarily on technical and resuscitation skills.<sup>13</sup> To our knowledge, this is the first report of the implementation of a CRM program delivered within the highly specialized environment of the pCICU at the point of clinical care with a substantial focus on both technical and nontechnical (teamwork) resuscitation skills. Although technical skills are essential to achieving a successful resuscitation, an in situ simulation-based training program includes and interweaves critical team CRM training with practice-specific medical objectives within a single educational experience and setting.

Emergencies in the pCICU frequently involve complex physiology, and the resuscitation of these patients often falls outside the scope of Pediatric Advanced Life Support guidelines. Knowledge of Pediatric Advanced Life Support guidelines may be necessary but not sufficient to resuscitate patients in this environment, particularly when advanced technologies such as ECMO to aid CPR<sup>14</sup> are used. Our course reinforces optimum application of these content- and context-specific skills and thus meets the needs of a wide array of practitioners working in a unique practice environment. Delivering the complete package of simulation, debriefing, and associated didactic training in situ allows us to easily incorporate a full team of care providers across disciplines (nursing, physicians, respiratory therapists) in the training, and this is more difficult in an off-site simulation center.

Evaluations after pCICU-CRM courses among participants reflected a high degree of scenario authenticity. It is hypothesized that authentic experiential learning via high-fidelity simulation leads to increased emotionality and subsequently improved transfer of learned skills and behaviors.<sup>15</sup> Flight simulators take advantage of this principle by providing environments that strictly adhere to and reproduce the cockpit as well as the full flying team. Likewise, highly



**FIGURE 4.** Nurses’ and physicians’ assessment of their anxiety regarding participation in a future cardiopulmonary resuscitation event before and after participation in pCICU-CRM training program. pCICU, Pediatric cardiac intensive care unit; CRM, Crisis Resource Management.

specialized high-performance pCICU teams likely experience the same benefits from training in their own environment using their own equipment.<sup>16</sup> We have found that the in situ approach facilitates the achievement of realism at all important levels—technical, conceptual and emotional, full team—as reported by Diekmann, Gaba, and Rall.<sup>17</sup>

The importance of the realism of the technical component is emphasized in the pCICU environment and is achieved easily via the in situ training approach. Easy access to unit-specific equipment such as monitors, resuscitation carts, and defibrillators, as well as ECMO circuits and surgical instrument trays, ensures that, in addition to meeting CRM goals, our program offers robust opportunities for deliberative practice around procedures that are specific and relevant to our teams. For instance, during crisis events in the pCICU, complex arrangement of multiple pieces of equipment necessary for patient care (ECMO circuit, surgical instrument cart, code cart, echocardiography machine) may complicate caregiver access to the patient,

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communication, and team function. This is prompted during the simulation scenarios, thus allowing teams to practice, reflect, and provide solutions to possible barriers to rapid delivery of care. In addition, practice within the actual pCICU using unit-specific equipment has also uncovered important latent safety threats within the system.<sup>9</sup>

Postcourse evaluations demonstrated equal efficacy among physicians and nurses regarding overall course utility. Both groups noted a significant improvement in sense of preparedness and confidence regarding participation in future pCICU crisis events. This is likely in part due to the multidisciplinary nature of the course from design through implementation. In close collaboration with medical simulation specialists, the pCICU–CRM course was designed and implemented by physician and nurse content experts in pediatric cardiac intensive care also trained in high-fidelity simulation and debriefing. This structure serves several important purposes. First, multidisciplinary involvement from course design through implementation ensures that scenarios and materials are true and relevant to clinical practice and of adequate physiologic complexity. Second, multidisciplinary involvement during course implementation, specifically debriefing, serves 3 important roles: (1) pays attention to the educational needs of all learners (physicians and registered nurses), (2) models the benefit of interdisciplinary instruction and education, and (3) models teamwork and collaborative practice to be applied to the patient care setting.

Interestingly, after course participation, nurses reported a decrease in anxiety regarding participation in future CPR events, whereas physicians noted no change. Factors such as shorter duration of time in clinical practice or lack of prior exposure to simulation training could be hypothesized to play a role in the benefit of anxiety reduction gained through participation in the pCICU–CRM course for nurses but not physicians. However, our data do not support this. Nurses participating in this course reported significantly more years in clinical practice than physicians. A similar proportion of both nurses and physicians had previous exposure to simulation. In addition, those participants with prior simulation experience and those without both reported a decrease in anxiety after course participation. Alternatively, the difference in decrement in anxiety between physicians and nurses could be explained by a core concept taught in the pCICU–CRM course, namely, an emphasis on all team members as active contributors to all aspects of the resuscitation as compared with limited responsibility implicit within the traditional hierarchy in medicine. This approach deliberately expands the traditional task-oriented roles of nurses during a pCICU code event, empowers nurses to contribute to medical decision-making, and may contribute to the decrease in anxiety toward participation in future code events reported by nurses. The efficacy of this approach is supported by the fact that both physicians and nurses reported an in-

creased likelihood to speak out in the face of medical management they perceived as inappropriate

There are several limitations to our study. First, the fact that course facilitators worked closely with course participants on a daily basis may have introduced bias into the course evaluation process, as participants may have felt compelled to give the course favorable reviews. We attempted to reduce this bias through the use of de-identified evaluations. Future studies might eliminate this bias by partnering content experts with trained facilitators from other clinical specialties. We are beginning to use such a model of “cross-debriefing” at our institution with favorable results. An additional limitation is the inherent subjectivity of participant evaluations. Finally, although simulation-based CRM training continues to be widely adopted in medicine, implementation of CRM training programs has not been definitively linked to decreased number or severity of adverse events or improved patient outcomes.<sup>18</sup> Likewise, this study focused on development, implementation of a novel pCICU–CRM course and did not attempt to evaluate changes in use of CRM principles either in the simulator setting or in the clinical environment after course participation.

In summary, we describe here an effective multidisciplinary in situ simulation-based team and skills training course delivered at the point-of-care within the highly specialized practice environment of the pCICU. Nurses and physicians identify course content to be realistic, relevant, and useful and report increased perceived comfort and decreased anxiety regarding participation in future crisis events. Highly specialized in situ simulation courses, such as that described here, demonstrate feasibility for unique, accessible opportunities for whole clinical teams to practice the full gamut of complex cases on-demand within ultracomplex clinical environments, all without risk or harm to patients. This concept is particularly important in the complex, multidisciplinary environment of the pCICU, where simulation stands to become a standard in both pregraduate and postgraduate training in the care of pediatric cardiovascular disease.

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