

# Neonatal Cardiac Emergencies: A Multidisciplinary Simulation Curriculum for Neonatology and Pediatric Cardiology Fellows

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## Abstract

**Introduction:** Although care for neonates with cardiac disease is frequently provided by neonatologists and pediatric cardiologists, training in the multidisciplinary management of neonatal cardiac emergencies is not often included in fellowship training. We created a multidisciplinary simulation curriculum to address the skills needed for neonatal cardiac care. **Methods:** Neonatology and pediatric cardiology fellows participated in 1-hour simulations on 3 different days. They managed a neonate with: (1) cyanosis, (2) cardiogenic shock, and (3) an unstable arrhythmia. Using both remote consultation and bedside evaluation, the participants diagnosed and jointly established a management plan for the infant. During the debrief, facilitators reviewed the clinical decisions and multidisciplinary management skills of the participants. Participants completed pre- and postparticipation surveys to evaluate the curriculum's effect on their confidence in the management of neonatal cardiac disease. **Results:** Thirty-three paired survey responses from 20 participants (11 neonatology and 9 pediatric cardiology) reported a mean overall satisfaction score of 4.6 ( $SD = 0.7$ ) based on a 5-point Likert scale. Postparticipation confidence scores improved significantly in: (1) the recognition of the signs of congenital heart disease (pre = 4.1, post = 4.5,  $p = .01$ ), (2) differentiation of cardiac cyanosis from noncardiac cyanosis (pre = 3.9, post = 4.2,  $p = .05$ ), and (3) confidence in discussing cardiac concerns with consultants (pre = 3.3, post = 4.1,  $p = .02$ ). **Discussion:** This multidisciplinary simulation improved fellows' confidence in the management of neonates with cardiac disease and provided an opportunity to practice team work, remote consultation, and cross-disciplinary communication.

## Keywords

Neonatal Cyanosis, Neonatal Cardiogenic Shock, Neonatal Arrhythmia, Simulation, Interdisciplinary Care, Physician, Neonatal-Perinatal Medicine, Pediatric Cardiology

## Educational Objectives

By the end of this activity, learners will be able to:

1. Differentiate cardiac causes of neonatal cyanosis and shock from noncardiac causes.
2. Identify and manage unstable tachyarrhythmias.
3. Demonstrate appropriate use of a defibrillator.
4. Utilize procedural sedation appropriately (neonatology fellows).
5. Interpret a neonatal echocardiogram (pediatric cardiology fellows).

6. Use cross-disciplinary communication and teamwork skills.
7. Initiate and provide remote cardiac consultation.

## Introduction

Neonates with critical cardiac disease require collaborative, multidisciplinary care from neonatologists and pediatric cardiologists. Neonatologists are often the first to identify the signs of undiagnosed cardiac disease in a neonate. They stabilize the infant and call for cardiac consultation. In some locations, pediatric cardiologists are not available onsite and must provide initial guidance remotely, followed by a bedside evaluation. Together with the neonatologists, they establish a plan of care for the infant.

In our experience, specific training in the multidisciplinary management of neonatal cardiac emergencies is rare within neonatology and pediatric cardiology fellowship programs. We

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found very few multidisciplinary training opportunities within our institution's neonatology and pediatric cardiology fellowship and we had no formal instruction for fellows in telephone consultation, teamwork, or cross-disciplinary communication. We therefore created a multidisciplinary curriculum to address these skills. We used simulation as our pedagogical method because of its evidence base in improving teamwork skills, neonatal resuscitation, echo interpretation, and remote consultation.<sup>1-6</sup>

We developed three simulations in which fellows from both disciplines comanaged a neonate with one of three common neonatal cardiac emergencies: (1) cyanotic heart disease, (2) cardiogenic shock due to obstruction to systemic blood flow, and (3) an unstable arrhythmia. These scenarios met critical care and cardiac physiology educational objectives for both neonatology and pediatric cardiology as recommended by the American Board of Pediatrics and the American College of Cardiology.<sup>7-9</sup>

Although *MedEdPORTAL* contains several simulations designed to teach the management of neonatal cardiac emergencies, they were primarily single discipline scenarios.<sup>10-12</sup> A search of *MedEdPORTAL* did not reveal any simulations that addressed remote cardiac consultation, multidisciplinary neonatal cardiac management, or rapid bedside echo diagnosis. We defined remote consultation as formal (e.g., through a telehealth consultation system) or informal (e.g., a telephone call between colleagues) provision of care by a practitioner who is not physically present at the patient's bedside. We defined a multidisciplinary team as a team composed of physicians in training from more than one discipline.<sup>13</sup> This simulation curriculum is unique within *MedEdPORTAL* in regards to its multidisciplinary nature, inclusion of real-time echo interpretation, and incorporation of remote consultation. This last component, remote consultation, is timely given that remote consultation is increasingly being utilized in modern-day care.

## Methods

### Development

We designed each simulation as a 1-hour session consisting of: (1) a 5-minute introduction to the simulation (Appendices A, D, and G), (2) a 20-minute simulation activity (Appendices B, E, and H), and (3) a 35-minute structured debrief (Appendices C, F, and I). A pre- and postparticipation survey was also included (Appendices J and K). The simulations involved one to two fellows from neonatology and one to two fellows from pediatric cardiology. We ran three simulations each academic year. The

simulation curriculum was deemed exempt from Institutional Review Board oversight (HIC 2000021696).

We developed the curriculum for fellows with a prerequisite knowledge of: (1) neonatal resuscitation, (2) causes of neonatal cyanosis and shock and, for pediatric cardiology fellows, (3) a basic knowledge of congenital echocardiography (including recognition of structures imaged in different echo windows and different forms of cyanotic and noncyanotic congenital heart disease), and (4) familiarity with EKG interpretation (including the identification of common arrhythmias). We expected simulation facilitators to be trained in simulation and debriefing. They were expected to know the scenario's learning objectives, scenario details, critical action checklist, diagnostic testing results, and to be able to adjust the simulation in response to participant decisions.

### Equipment/Environment

The simulation environment replicated the neonatal intensive care unit and equipment used for neonatal resuscitation in our institution. This included:

- A high-fidelity infant mannequin.
- Infant warmer.
- Neonatal code cart with supplies for initial resuscitation.
- Vascular access supplies (umbilical line tray, peripheral IV supplies).
- Airway management supplies (self-inflating bag and mask, appropriately sized laryngoscope with blade, endotracheal tubes in various sizes, a stylet, end-tidal CO<sub>2</sub> detector).
- Defibrillator (arrhythmia simulation only).
- Medications (including epinephrine, adenosine, saline, sedation medications, and prostaglandin).
- Routine ICU monitoring devices (telemetry, pulse oximetry).
- Laptop computer with the diagnostic testing for the simulation loaded on it (Appendices C, F, and I).
- Telephone for remote consultation.

Optional supplies included an oxyhood for hyperoxia test (cyanotic newborn simulation only) and an echo probe with or without an echo machine.

We prepared PowerPoint presentations with the diagnostic testing results for each simulation, including: (1) Cyanotic newborn - underlying diagnosis: pulmonary atresia with an intact ventricular septum (Appendix C), (2) Cardiogenic shock - underlying diagnosis: critical aortic stenosis (Appendix F), and (3) Neonatal arrhythmia - underlying diagnosis: atrial flutter (Appendix I).

## Personnel

We utilized the following personnel for each simulation:

- Facilitator: introduced the simulation, ran the simulation, and moderated the debrief.
- Simulation technologist: ran the simulation equipment during the simulation.
- Content experts in neonatology and pediatric cardiology: provided educational content during the debrief.

We also recommend including nurses, respiratory therapists, and personnel to play the infant's parents.

## Implementation

We found that the simulation was best executed by initially separating the neonatology and pediatric cardiology participants. This concealed the cardiac focus of the simulation. Prior to the simulation we gathered the cardiology and neonatology fellows in separate locations and introduced the simulation and the ground rules as follows:

1. "Maintain an environment of respect. We assume that everyone is knowledgeable, well trained, and doing his/her best. We also ask that you assume this of each other."
  - This rule was meant to establish a safe learning environment. We reassured participants that there was no evaluation associated with the simulation.
2. "Maintain confidentiality and do not discuss the case or what happened during the simulation outside of the session."
  - This rule was intended to: (1) prevent participants from sharing details of the scenario with subsequent participants, and (2) prevent discussion of individual participant's choices during the simulation outside of the safe learning environment.
3. "Suspend disbelief in the simulated quality of the scenario."
  - This rule addressed the tendency of participants to behave differently due to the simulated feel of the scenario. Despite using advanced simulation technology, there were components of the scenario that we could not realistically replicate. We hoped that by addressing this, participants would be able to suspend their disbelief and focus on the learning objectives of the scenario.

These three rules and a guide for introducing participants to the simulation are contained in the facilitator's guide for

each scenario (Appendices A, D, and G) included with this curriculum.

## Scenario Flow

After the introduction, the simulation technologist set up the mannequin and monitoring devices to display the initial vital signs and exam findings for the scenario (Appendices B, E, and H). The facilitator brought the neonatology fellows into the simulation room and read the clinical scenario stem. The fellows were given 2 minutes to discuss their approach to the situation and to assign roles. The neonatology fellows then began their evaluation and stabilization of the neonate. The facilitator provided diagnostic testing results (labs, x-ray, EKG, etc.) upon request from the diagnostic testing PowerPoint (Appendices C, F, and I).

When requested, the facilitator provided a phone number for the on-call pediatric cardiology fellows who waited in a separate location. Participants were asked to conduct the call over speakerphone. The cardiology fellows asked questions and provided guidance for care over the phone.

Following the telephone consultation, the facilitator admitted the pediatric cardiology fellows to the simulation environment and provided them with the diagnostic testing PowerPoint presentation which contained a menu of echo clips the fellows could choose from to evaluate the infant (Appendices C, F, and I). The scenario continued until participants made a diagnosis and implemented a definitive management plan. The facilitator then ended the scenario, and participants transitioned into the debrief room.

Throughout the simulation the facilitator and simulation technologist adjusted the clinical status of the mannequin to match the participants decisions. Suggested adjustments based on participants' decisions were detailed in the simulation case summaries (Appendices B, E, and H).

## Debriefing

After the simulation, the facilitator and content experts reviewed their observations of participants' actions during the simulation using the critical action checklist as a guide. They identified knowledge or practice gaps to discuss during the debrief. Following this, the entire group moved to the location for the structured debrief.

We utilized the 3D model for debriefing that included three phases: (1) defusing, (2) discovering, and (3) deepening.<sup>14</sup> After a few minutes for self-reflection, the facilitator began the defusing phase by asking, "How do you feel the simulation went?" The point of this question was to allow the fellows to express

their emotional response to the simulation, and defuse any significant emotions that may impact the discovery phase of the debrief.

Next, the facilitator began the discovery phase by asking a neonatology fellow to summarize the simulation beginning with the presentation of the infant through the decision to call for pediatric cardiology consultation. The facilitator then asked a pediatric cardiology fellow to summarize the simulation from the phone consultation through the definitive management of the infant's condition.

The facilitator then sequentially went through the simulation, highlighting critical decision moments based on the critical action checklist. The facilitator asked fellows to explain their thought process behind each critical decision. If the facilitator or content experts identified gaps in knowledge or practice, they would explore the mental model the participants used to make the decision. This allowed the facilitator and content experts to correct any misconceptions and reinforce correct thinking models that would guide the participants' subsequent decisions.

During the deepening phase of the debriefing session, participants shared one learning point that they would incorporate into their daily practice. At the end of the debrief, the facilitator reviewed the learning objectives of the session and the session was adjourned.

#### Assessment

We used a critical action checklist to assess the participants' decisions during the scenarios. These checklists were developed in an iterative fashion by the content experts (neonatology and cardiology faculty members) based on experience and resuscitation guidelines from Neonatal Resuscitation Program and Pediatric Advanced Life Support.<sup>15,16</sup> During the simulation, facilitators and content experts noted whether participants completed the actions on the checklist. The checklists can be found in facilitator guides and simulation case summaries (Appendices A, B, D, E, G, and H).

To evaluate each simulation's impact on participants' confidence in the management of neonatal cardiac emergencies, we conducted anonymous, pre- and postparticipation surveys (Appendices J and K). In these surveys, participants rated their confidence in the following skills:

1. Recognition of the signs and symptoms of congenital heart disease.
2. Differentiation of cyanosis due to cardiac disease from noncardiac causes.
3. Differentiation of cardiogenic shock from noncardiogenic shock.
4. Recognition and management of neonatal arrhythmias.
5. Interpretation of pre- and postductal oxygen saturations.
6. Knowledge of when prostaglandin is indicated to treat ductal dependent congenital heart disease.
7. For neonatology fellows:
  - Resuscitation of neonates with congenital heart disease.
  - Discussion of concern for cardiac disease with a pediatric cardiology consultant.
8. For pediatric cardiology fellows:
  - Interpretation of an echocardiogram.
  - Determination of a cardiac plan of care and communication of this plan to a neonatologist.

We adapted the pre- and postparticipation surveys based on the presenting cardiac problem in the simulation. For example, the pre- and postparticipation surveys for the cyanotic newborn simulations only asked participants about their confidence in areas 1, 2, 5, 6, 7, and 8.

In addition to the above confidence areas, the postparticipation survey also asked participants to rate the overall quality of the simulation and its impact on the participant's daily practice. For the surveys, participants used a 5-point Likert scale with 1 (*strongly disagree*) representing low confidence levels/negative experience and 5 (*strongly agree*) representing a high degree of confidence/positive experience. We also collected qualitative feedback about the simulation. In order to make the surveys anonymous, yet still be able to pair pre- and postparticipation responses, participants created self-selected identifiers that they reported on each survey. We only considered paired pre- and postparticipation surveys. If we could not identify a paired survey, we did not include the survey responses in the final analysis.

In order to safeguard the psychological safety of the simulation environment, we did not conduct faculty or facilitator evaluations of participants during the simulations.

#### Results

Over 30 months, we conducted eight simulations: four cyanotic newborn simulations, three cardiogenic shock simulations, and one arrhythmia simulation. We reviewed 33 paired pre- and postparticipation surveys (25 cyanotic newborn, five cardiogenic shock, three arrhythmia) from 20 unique participants (using the participants' self-selected identifiers). Based on the attendance logs of the simulation center, this reflected a 59% response rate (56 total participants over the 30 months). Eleven participants

identified themselves as neonatology fellows and 9 identified themselves as pediatric cardiology fellows. Eight of the paired responses indicated participation in more than one simulation (two simulations,  $n = 4$ ; three simulations  $n = 3$ ; four simulations  $n = 1$ ).

The mean overall rating of the simulation was 4.6 ( $SD = 0.7$ ) on a 5-point Likert scale. Participants reported high levels of agreement that the simulations met the stated objectives, were realistic, and that they would apply the lessons learned to their daily practice (Table 1). Overall, 67% ( $n = 22$ ) of paired survey responses showed improvement in at least one of the targeted confidence areas (mean number of improved confidence areas = 2.1, range 1-6 per paired survey). Other than the cardiology fellows' confidence in discussing cardiac care with neonatology fellows, the self-reported confidence in each of the targeted confidence areas improved across all confidence areas (Table 2). The areas in which the improvement was statistically significant were: (1) the recognition of the signs of congenital heart disease (pre = 4.1, post = 4.5,  $p = .01$ ), (2) differentiation of cardiac cyanosis from noncardiac cyanosis (pre = 3.9, post = 4.2,  $p = .05$ ), and (3) neonatology fellows' confidence in discussing cardiac concerns with cardiology fellows (pre = 3.3, post = 4.1,  $p = .02$ ).

Qualitative analysis of the responses to the question, "List the two most helpful aspects of the simulation," revealed several themes:

1. Interdisciplinary care between cardiology and neonatology.
  - "I loved the combination with cardiology."
  - "Working with the subspecialists."

**Table 1.** Postsimulation Evaluation Results<sup>a</sup>

Evaluation Statement	M (SD)	Range
Overall quality.	4.6 (0.7)	4-5
The simulation met the stated objectives.	4.8 (0.4)	4-5
The scenario was realistic.	4.7 (0.4)	4-5
I was able to practice skills relevant to my daily practice.	4.8 (0.4)	4-5
The debrief was a useful learning experience.	4.9 (0.4)	4-5
I will apply what I learned during the scenario to my daily practice.	4.9 (0.3)	4-5

<sup>a</sup>Rated on a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree).

- "Interaction with neonatal intensive care unit fellows."
- "Introduction to multiple disciplines."
2. Helpful discussion during the debrief.
  - "Discussion with cardiology fellows."
  - "Walking through the case in a 'low pressure' environment."
  - "Talking through the physiology."
3. High relevance to daily practice.
  - "Realistic case that is applicable."
  - "Relevant to our practice."
4. Ability to use equipment that was not routinely used in day-to-day neonatal care.
  - "Practice with the defibrillator."
  - "Simulation equipment."

Suggestions from the participants for improving the simulation curriculum included requests for more time for debriefing, adding additional cases, and expanding the curriculum to other subspecialties.

Direct observation of participants revealed several common knowledge and practice gaps. These included: (1) misconceptions about the safety of supplemental oxygen in the

**Table 2.** Pre- and Postparticipation Survey Responses

Item	n	M <sup>a</sup> (SD)		p <sup>b</sup>
		Preparticipation	Postparticipation	
Rate Your Ability to:				
Recognize the signs and symptoms of CHD.	25	4.1 (0.8)	4.5 (0.5)	.01
Differentiate cyanosis due to cardiac disease from non-cardiac causes.	25	3.9 (0.7)	4.2 (0.6)	.05
Differentiate cardiogenic shock from noncardiogenic shock.	5	3.6 (0.9)	4.2 (1.1)	.21
Recognize and manage neonatal tachyarrhythmias.	3	3.7 (0.6)	4.7 (0.6)	.20
Interpret pre- and postductal oxygen saturations.	24	4.2 (0.7)	4.4 (0.6)	.17
Recognize when prostaglandin is indicated to treat ductal dependent CHD.	22	4.2 (0.5)	4.5 (0.6)	.08
Interpret an echocardiogram .	9 <sup>c</sup>	3.1 (1.6)	3.8 (1.1)	.17
Discuss cardiac plan of care with neonatal intensive care unit.	9 <sup>c</sup>	4.2 (0.7)	4.2 (0.4)	.30
Resuscitate a newborn with CHD.	11 <sup>d</sup>	3.9 (0.8)	4.1 (0.5)	.34
Discuss cardiac concerns with cardiology team	11 <sup>d</sup>	3.3 (0.8)	4.1 (0.5)	.02

Abbreviation: CHD, congenital heart disease.

<sup>a</sup>Rated on a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree).

<sup>b</sup>Significant when  $p \leq .05$ .

<sup>c</sup>Pediatric cardiology fellows only.

<sup>d</sup>Neonatology fellows only.

resuscitation of neonates with ductal dependent cardiac disease, (2) the dosing and side effects of medications (i.e., prostaglandin, adenosine), (3) incorrect performance and interpretation of hyperoxia tests, and (4) the appropriateness of peri-procedural sedation for noxious procedures.

## Discussion

To our knowledge, this is the first simulation curriculum in *MedEdPORTAL* that addressed the skills of multidisciplinary management of neonatal cardiac disease and remote cardiac consultation. The curriculum was well received by our fellows and was easily accomplished in 1-hour sessions. The pre- and postparticipation surveys revealed improved confidence in the management of neonatal cardiac emergencies and confidence in consulting with other subspecialists. These findings were in accord with educational research that has shown that medical simulation improves clinical competence in high acuity situations and teamwork behaviors.<sup>2,4,17</sup>

### Lessons Learned

In reflecting on our experience, we noted several positive outcomes that were not directly evaluated in the pre- and postparticipation surveys. First, the critical action checklists used to guide the discovery phase of the debrief, were easily remembered and valued by participants. During the deepening phase of the debrief, many fellows repeated components of the critical action checklist as their main learning point from the session.

Second, we noted the development of a common language for the discussion of cardiac disease between the neonatology and cardiology fellows. Early in the curriculum, both groups of fellows often used specialty-specific language that was not familiar to the participants from the other discipline. During the discovery phase of the debrief we discussed any terms unfamiliar to the participants. In successive simulations, we noted that fellows from both disciplines began to use common terms when they described the clinical condition of the neonate. For example, the cardiology fellows often used the abbreviations “Qp” (an abbreviation for pulmonary blood flow) or “Qs” (an abbreviation for systemic blood flow) when discussing the management of congenital heart disease. During the debrief, the facilitator asked the cardiology fellows to define these terms and the concepts they represent. In subsequent simulations, we noted that both pediatric cardiology fellows and neonatology fellows adopted the terminology “limited pulmonary blood flow” or “limited systemic blood flow” when discussing the physiology of congenital heart disease, rather than using the less familiar abbreviations. It

was our impression that this change in terminology improved communication between the fellows and helped them more efficiently develop a comanagement plan.

Third, the inclusion of echo interpretation in the scenario benefited both groups of fellows. We noted that frequently the senior pediatric cardiology fellows mentored the junior pediatric cardiology fellows in the selecting echo clips and interpreting the images. The neonatology fellows also viewed the echo clips and asked questions about what the clip demonstrated. In the debrief, the junior pediatric cardiology fellows commented on the usefulness of discussing an echo strategy with the senior cardiology fellows, and the neonatology fellows commented that reviewing the echo images with the cardiologists improved their understanding of the neonate’s cardiac disease.

Another important lesson learned was how the creation of a safe psychological space was essential to this curriculum, despite the limitations it imposed on our evaluation strategy. Although we did not formally assess the psychological safety of the simulation, qualitative feedback from the fellows noted that the importance of the security of the environment. For example, one fellow reported that the best part of the simulation was the “low-pressure environment.” Another fellow reported that he/she found the debrief useful in evaluating myths he/she had learned in the management of cardiac disease. Our impression of these and similar comments was that the environment was a safe space where fellows could make mistakes and fill knowledge gaps regarding the management of neonatal cardiac disease.

In order to create psychological safety, we instituted the following measures: (1) assurance that participants’ performance in the simulation would not be used to evaluate competency, (2) use of anonymous surveys, (3) maintenance of mutual respect and confidentiality during and after the simulation, and (4) use of the defusing component of the debrief to identify and defuse emotional distress among participants. Each of these components has previously been shown to foster the safety needed for successful simulation and debrief.<sup>14,18</sup>

The multidisciplinary nature of the simulation had an inherent potential to affect interfellow trust and respect based on an individual’s performance during the simulation (e.g., a knowledgeable fellow may be more trusted by peers vs. a participant who struggled who may be perceived as unreliable). The 3D debriefing strategy was well suited to prevent negative ramification on interfellow relationships. The strategy’s emphasis on exploring a participant’s thought process behind a particular

decision allowed facilitators to identify and correct inaccuracies in a participant's mental model of the clinical situation. This empowered the participant to alter his/her decision based on a more accurate mental model and demonstrate competence in front of his/her peers. Modern simulation research has suggested that if done with the aim of fostering mutual respect, simulation improves cooperation between disciplines rather than detracting from multidisciplinary relationships.<sup>19</sup>

#### Challenges

We encountered several challenges in instituting the curriculum. First, we struggled to find a common time when all of the fellows could participate. Both fellowship programs in our institution are small and removing fellows from all clinical duties was impossible, hence one fellow was frequently called to attend to a clinical emergency during the simulations. We also were not able to include fellows who had nighttime call responsibilities.

A second challenge we encountered was difficulty concealing the cardiac focus of the simulation. We found that the distribution of preparticipation surveys biased participants toward a cardiac diagnosis. Once we had completed our data collection, we stopped sending preparticipation surveys and noted that the neonatology fellows performed a more comprehensive evaluation of the neonate before calling for cardiac consultation. Fellows commented in the debrief that this was a more realistic experience.

A third challenge we encountered was the limited ability to simulate the physical exam of patients with congenital heart disease. Despite the use of a high-fidelity mannequin, we could not replicate murmur quality, precordial findings, pulse quality, or capillary refill. The facilitator was prepared to communicate these findings to the participants, however, the participants often did not ask for these physical exam findings. To address this, we incorporated a discussion of the expected physical examination findings in neonates with cardiac disease into the discovery phase of the debrief.

A fourth challenge we identified was our use of content experts who were not trained in the 3D model of debriefing. We found that these experts sometimes shifted the focus of the debrief to that of an academic lecture or used the debrief as an opportunity to critique fellow performance. This had the potential to disrupt the psychological safety of the debrief environment. To address this, facilitators reviewed the 3D model of debriefing with content experts prior to the simulation. During the debrief, the facilitator specifically asked content experts to address participant questions.

#### Limitations

There were several major limitations to the evaluation strategy we used to assess the simulations. First, in an effort to maintain the psychological safety of participants, we only assessed fellows' self-reported confidence in managing neonatal cardiac emergencies. We did not conduct pre- or postassessments of the fellows' actual competence in these skills. Self-reported confidence in clinical skills has previously been shown to correlate poorly with actual clinical competence.<sup>20,21</sup> Studies in simulation, however, have shown that both clinical competence and self-reported confidence improve following a simulation-based educational activity. It would be reasonable to assume that competence also improved through participation in this curriculum.<sup>3,22</sup> Those who use this curriculum could also incorporate assessments of clinical competence to the simulations, but would need to include this modification in the introduction to the participants.

We also struggled to pair pre- and postparticipation surveys. When only paired responses were considered, the rate was only 59%, with many fellows completing one of the surveys, but not both. This limited the conclusions we could draw from our curriculum. There were several possible reasons for this. First, at the beginning of the project we distributed the surveys 1 week before and after the simulation. This delay likely led to the low pre- and postcompletion rate. To address this, we began distributing the surveys at the time of the simulation and this improved the response rate. Second, we noticed that some fellows either did not select a unique identifier or changed identifiers between surveys, both of which limited our ability to pair surveys. We did not investigate whether fellows' decisions to not select identifiers or change identifiers reflected a breach in the psychological safety of the simulation. Third, we did not correlate fellows' self-reported confidence with their year in training. For example, it would be reasonable to expect that senior fellows would report higher preparticipation confidence scores and smaller changes in postparticipation scores. Similarly, we did not track how the scores of fellows who participated in multiple simulations changed over time.

#### Future Directions

The simulations could easily be adapted for other combinations of learners including pediatric residents or advanced practice practitioner students. The simulations could also be done even if only one fellowship training program is present in an institution. In these situations, the content experts or facilitators would need to act as standardized participants and perform the role of the

missing subspecialty (i.e., acting as the neonatologist/cardiologist if there are no neonatology/cardiology participants present).

As noted in the methods section the following improvements could be made to the simulations: (1) inclusion of other medical professional team members such as respiratory therapists and neonatal ICU nurses, and (2) incorporation of standardized participants to play the infant's parents in the simulation. The incorporation of other medical professionals would allow for a more realistic adjustment of respiratory support and administration of medications. The inclusion of simulation personnel as the infant's parents would allow for the opportunity to provide a family-centered explanation of the infant's clinical condition. These providers and parents would be able to offer alternate perspectives and additional feedback to participants during the debriefing session.

In summary, this simulation curriculum improved neonatology and pediatric cardiology fellows' confidence in the multidisciplinary management of neonates with congenital heart disease. This curriculum could serve as a model for other simulation-based curricula that address clinical scenarios requiring the cooperation of multiple medical disciplines.

## Appendices

- A. Facilitator Guide Cyanotic Newborn.docx
- B. Simulation Case Summary Cyanotic Newborn.docx
- C. Diagnostic Testing Cyanotic Newborn.pptx
- D. Facilitator Guide Cardiogenic Shock.docx
- E. Simulation Case Summary Cardiogenic Shock.docx
- F. Diagnostic Testing Cardiogenic Shock pptx
- G. Facilitator Guide Neonatal Arrhythmia.docx
- H. Simulation Case Summary Neonatal Arrhythmia.docx
- I. Diagnostic Testing Neonatal Arrhythmia.pptx
- J. Preparticipation Survey.docx
- K. Postparticipation Survey.docx

All appendices are peer reviewed as integral parts of the Original Publication.

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## Ethical Approval

The Yale University School of Medicine Institutional Review Board approved this study.

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