Development of a Neonatal Cardiac Curriculum for Neonatal-Perinatal Fellowship Training

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Abstract

Background
The topic of neonatal cardiovascular care in neonatal-perinatal fellowship training has continued to transform due to the increased complexity of patients, the development of specialized units, continued ACGME educational requirements, and clinical practice variation across centers that care for neonates with congenital heart disease.

Methods
We developed a formal neonatal cardiac curriculum, comprised of eight interactive sessions, with novel active learning concepts specific to our neonatal-perinatal fellows that were presented annually.

Results
There was an overall 10-point increase in the comfort level in managing infants with congenital heart disease among neonatal fellows. The average American Board of Pediatrics Subspecialty In-Training Exam scores improved from baseline in all years of the intervention.

Conclusion
Due to the variable clinical exposure and differing practice models of congenital heart disease a formal neonatal cardiac curriculum may be beneficial to neonatal-perinatal trainees.

Introduction
Neonatal-perinatal fellowship has continued to advance over the last sixty years since the development of neonatal training programs in the early 1960s. French et al, recently highlighted the essentials of neonatal fellowship training including the current transformations in clinical practice seen in the United States [1]. Specific to the evolution of neonatal cardiovascular care, increased patient complexity, development of specialized units, patient safety driven niche skilled teams, and trainee duty hour restrictions are a few of the recent changes that have led to a wide spectrum of training and variable experiential learning amongst neonatal fellows [2–3]. There is remarkable practice variation in the United States among primary teams who care for neonates with congenital heart disease [4]. One such contributing factor includes the different locations of neonates at different time points of perioperative patient care as patients are transferred from neonatal intensive care units to cardiac or pediatric intensive care units, resulting in gaps in knowledge and clinical experience amongst neonatal fellowship trainees. The development of a neonatal cardiac curriculum in large centers has shown a positive correlation with multidisciplinary collaboration [5], but no such formal curriculum has been established other than a requirement to meet core competencies determined by the Accreditation Council of Graduate Medical Education (ACGME) and the American Board of Pediatrics (ABP) [6–7].

Moreover, there is an emergence of neonatologists that have research and clinical interests in cardiovascular care with specific fellowship programs that offer both structured and non-structured training pathways to improve skillsets in congenital and acquired heart disease [8]. The use of non-invasive hemodynamic monitoring such as near-infrared spectroscopy, functional point of care ultrasound (POCUS), and large data-aggregate heart rate
variability models to predict mortality have pushed the boundaries of neonatal hemodynamic research. Additionally, targeted neonatal echocardiography has significantly increased the level of cardiovascular understanding and hemodynamic assessment to improve the care of neonates with hemodynamic instability. Despite the development of these specialized structured and unstructured pathways, advanced cardiac intensive care and hemodynamic skillsets are not required as core competencies described by the ABP and ACGME [6–7].

In 2018, the collective scores of the ABP Subspecialty In-Training Exam (SITE) for neonatal-perinatal medicine fellowship at Northwestern Feinberg School of Medicine in the cardiology section were eleven points (~two standard deviations) below the national average. This gap in knowledge of cardiovascular physiology along with sensing the growing concerns of the variable landscape in training and the experience trainees have in neonatal cardiovascular care led to a call for action. The authors of this manuscript developed a formal active-learning neonatal cardiac curriculum based on core competencies outlined by the ABP and ACGME and describe the results of the implementation of this curriculum and educational intervention.

Methods

Curriculum Development

We used the six-step approach described by Kern et al to initially assess and build our neonatal cardiac curriculum [9]. After (1) problem identification and a (2) targeted needs assessment within the neonatal-perinatal fellowship, a unique collaborative effort between the Departments of Neonatology and Cardiology sought to identify (3) goals and objectives, (4) educational strategy and curriculum design, (5) implementation, and (6) evaluation and feedback. The content outline for cardiology provided by the ABP Subspecialty Board of Neonatal-Perinatal Medicine for the purpose of developing in-training, certification, and maintenance of certification examinations was used as a baseline guide to ensure that the cardiology curriculum within neonatology addressed the specific elements of knowledge within each section of the outline. Knowledge content was developed by the core faculty who were comprised of two board-certified cardiologists and one double-boarded in neonatology and pediatric cardiology. The curriculum consisted of eight sessions that included basics of echocardiography, cardiac physiology, neonatal arrhythmias, cyanotic and non-cyanotic congenital heart disease commonly seen in the newborn period, single ventricle lesions, and perioperative management for various cardiac pathologies.

Participant Selection

All neonatal-perinatal fellows at Northwestern University Feinberg School of Medicine between September 2019 to 2022 participated in the neonatal cardiac curriculum. Baseline data were collected on all twelve neonatal-perinatal fellows, four fellows matriculating each year over a three-year program. A targeted needs assessment survey was developed that included their year of training, comfort level in clinical management of an infant with congenital heart disease, and personal perception of knowledge and competency in basics of echocardiography, cardiac physiology, neonatal arrhythmias, cyanotic and non-cyanotic congenital heart disease commonly seen in the newborn period, single ventricle lesions, and perioperative management for various cardiac pathologies.

Curriculum Design

The neonatal cardiac curriculum was implemented in eight sessions outlined in Table 1 that involved an array of unique learning strategies encouraging adult learning and concepts from active learning such as flipped classroom methodology [10–11]. The educational sessions were planned such that there was pre-reading material provided in the form of one to two articles and a recorded video lecture that was given one week before the actual teaching session. Prior to each session, a short pre-test was conducted consisting of five questions pertaining to the topic of
the session. Each teaching session lasted one hour except for the first session which was two hours to encompass the comprehensive session on cardiac anatomy and physiology. An integrative audience response platform software Poll Everywhere (pollev.com) (San Francisco, USA) was used to generate multiple choice questions and word clouds to describe clinical scenarios and generate qualitative audience engagement. Zoom Video Communications, Inc (San Jose, CA) and their video communication platform was used during the teaching sessions once the COVID-19 pandemic began. Features such as Zoom Annotate were utilized to allow fellows to create interactive drawings to map out cardiac pathways and heart box diagrams, an example shown in Fig. 1. The chat box function was used as an additional mode of interaction. A post-test was conducted using the same questions as the pretest at the end of each session. Answers to the post-test with explanations were emailed to the learners after the sessions.
<table>
<thead>
<tr>
<th>Session Title</th>
<th>Length</th>
<th>Topics Covered</th>
<th>Objective</th>
<th>Covered ABP Content Domain/Subdomain</th>
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</table>
| 1. Cardiac Physiology: Cardiac Equations, Myocardial Performance, and Neonatal Myocardium | 2 hours | - Cardiac equations and determinants of cardiac output  
- Myocardial performance and pressure volume loops  
- Differences in neonatal myocardium | - Review basic concepts in cardiac function.  
- Understand determinants of cardiac output and how they relate to one another.  
- Review of neonatal myocardium.  
- Correlate these concepts with clinical and laboratory findings using pressure-volume loops. | Domain 2: Cardiovascular  
A. Anatomy and development of the cardiovascular system  
B. Cardiovascular physiology |
| 2. Approach to the Cyanotic Newborn                              | 1 hour | - Cyanotic heart lesions  
- Cardiac anatomy and broad overview of congenital heart disease  
- Categorization of cyanotic heart lesions  
- Initial stabilization and approach to cyanotic newborns | - Understand cardiac anatomy that can present with central cyanosis.  
- Understand cardiovascular pathophysiology contributory to central cyanosis.  
- Draw a cardiac box diagram (anatomic connections, blood flow).  
- Identify cardiac pathology depicted by a box diagram.  
- Identify the broad categories of cyanotic heart defects. | Domain 2: Cardiovascular  
A. Anatomy and development of the cardiovascular system  
B. Cardiovascular physiology  
I. Cyanotic congenital heart disease |
| 3. Understanding Basics of Echocardiography for Neonatologists    | 1 hour | - Basics of ultrasound physics  
- Standard view and planes of pediatric echocardiogram  
- Left and right ventricular functional assessment | - Review basics of ultrasound physics and terminology.  
- Review the primary planes and angles used in a pediatric echocardiogram.  
- Understand quantitative measurements in | Domain 2: Cardiovascular  
A. Anatomy and development of the cardiovascular system  
B. Cardiovascular physiology  
F. Patent ductus arteriosus |

ABP, American Board of Pediatrics; ASD, atrial septal defect; AVSD, atroventricular septal defect; CICU, cardiac intensive care unit; ECG, electrocardiogram; ECMO, extracorporeal membrane oxygenation; LCOS, low cardiac output syndrome; NICU, neonatal intensive care unit; PDA, patent ductus arteriosus; TAPVC, total anomalous pulmonary venous connection; TGA, transposition of the great arteries; TOF, Tetralogy of Fallot; VSD, ventricular septal defect
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<tbody>
<tr>
<td>4. Neonatal Arrhythmias</td>
<td>1 hour</td>
<td>• Normal and abnormal ECG parameters in newborns</td>
<td>• Review normal and abnormal ECG parameters in healthy newborns.</td>
<td>Domain 2: Cardiovascular</td>
</tr>
<tr>
<td></td>
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<td>• bradyarrhythmias</td>
<td>• Identify the most common types of bradyarrhythmias in neonates.</td>
<td>J. Cardiac arrhythmias</td>
</tr>
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<td></td>
<td></td>
<td>• narrow complex tachycardia</td>
<td>• Understand differential diagnosis and treatment of narrow and wide</td>
<td>L. Cardiomyopathies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• wide complex tachycardia</td>
<td>complex tachycardia.</td>
<td></td>
</tr>
<tr>
<td>5. Single Ventricle: Anatomy, Physiology, and</td>
<td>1 hour</td>
<td>• Single ventricle anatomy</td>
<td>• Review the variety of anatomically single ventricles.</td>
<td>Domain 2: Cardiovascular</td>
</tr>
<tr>
<td>Staged Palliation</td>
<td></td>
<td>• Single ventricle physiology</td>
<td>• Review the physiology of functionally single ventricles.</td>
<td>A. Anatomy and development of the</td>
</tr>
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<td></td>
<td></td>
<td>• Staged approach to single ventricle palliation</td>
<td>• Review the staged palliative procedures for single ventricles.</td>
<td>cardiovascular system</td>
</tr>
<tr>
<td>6. Left to Right Shunts: ASD, VSD, AVSD, PDA</td>
<td>1 hour</td>
<td>• Atrial septal defects</td>
<td>• Understand pathophysiology and significant of left to right shunts.</td>
<td>Domain 2: Cardiovascular</td>
</tr>
<tr>
<td></td>
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<td>• Ventricular septal defects</td>
<td>• Know the different types of left to right shunts and the key differences in magnitude, direction of shunting, and which chambers of the heart are affected.</td>
<td>E. Congestive heart failure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Atrioventricular septal defects</td>
<td>• Understand specific lesions, ASD, VSD, AVSD, and PDA regarding</td>
<td>F. Patent ductus arteriosus</td>
</tr>
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<td></td>
<td></td>
<td>• Patent ductus arteriosus</td>
<td>pathophysiology, natural history, and how it impacts.</td>
<td>H. Acyanotic congenital heart disease</td>
</tr>
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</table>

ABP, American Board of Pediatrics; ASD, atrial septal defect; AVSD, atrioventricular septal defect; CICU, cardiac intensive care unit; ECG, electrocardiogram; ECMO, extracorporeal membrane oxygenation; LCOS, low cardiac output syndrome; NICU, neonatal intensive care unit; PDA, patent ductus arteriosus; TAPVC, total anomalous pulmonary venous connection; TGA, transposition of the great arteries; TOF, Tetralogy of Fallot; VSD, ventricular septal defect
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</table>
| 7. Low Cardiac Output Syndrome in the CICU: Bedside Assessment of Cardiac Output | 1 hour  | • Basics of cardiopulmonary bypass  
• Physiologic effects of cardiopulmonary bypass on neonates  
• Cardiac dysfunction and LCOS post-surgery  
• Peri-operative monitoring  
• Bedside assessment and markers of cardiac function | • Understand neonatal considerations post cardiopulmonary bypass surgery.  
• Recognize physiologic changes seen with cardiopulmonary bypass.  
• Understand low cardiac output syndrome and postoperative management strategies.  
• Review peri-operative invasive and noninvasive hemodynamic monitoring.  
• Review proper bedside assessment and markers of cardiac function. | Domain 14: Surgical and Complex NICU Patient Management  
A. Physiologic principles and pharmacology of neonatal anesthesia, analgesia, and sedation  
B. Perioperative care of newborn infants (eg, respiratory, fluid, temperature, antibiotics, pain management)  
C. Indications, management, and complications of medical technology (eg, central lines, gastronomy, tracheostomy, ostomy, ventriculoperitoneal shunt, ECMO) |
| 8. Neonatal Cardiac Lesions: TOF, TGA, Coarctation, TAPVC                   | 1 hour  | • Neonatal presentation and considerations of Tetralogy of Fallot, transposition of the great arteries, coarctation of aorta, and total anomalous pulmonary venous connections  | • Understand anatomy and pathophysiology of each lesion, and the spectrum of neonatal clinical presentation.  
• Review etiology of hypercyanotic spells in TOF and strategies to treatment.  
• Understand goals of complete repair of each lesion.  
• Understand concepts leading to clinical features of coarctation of aorta. | Domain 2: Cardiovascular  
A. Anatomy and development of the cardiovascular system  
B. Cardiovascular physiology  
I. Cyanotic congenital heart disease |
### Session Title | Length | Topics Covered | Objective |
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<td>• Preoperative management and neonatal considerations of each lesion.</td>
</tr>
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</table>

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### Evaluation and Feedback

Assessment of these educational sessions was made by comparing SITE scores following the implementation of this curriculum to prior year SITE scores. The trainees were also asked to repeat a self-assessment in comfort and competence which was compared to baseline. Assessment of the individual sessions and presenters was also collected based on evaluation forms filled by the fellows using Likert scales (1 to 5) to assess if the objectives of the presentation were met, if the learning objectives of the session were met, if the presentation had good images, if the presenter had good knowledge of the subject area and if the presenter engaged the audience. Narrative feedback obtained on these evaluations included what the fellows liked about the talk, how the talk could be improved and if there were any comments for the presenters.

### Results

There was an overall 10-point increase in the comfort level of the fellows in managing infants with congenital heart disease (Fig. 2A), after the implementation of the curriculum. The first-year fellows had an increase in their comfort score from 33 to 47, the second years showed an increase in their comfort score from 72 to 76 and the third years increased their score from 75 to 86. There was an overall increase in self-perceived knowledge and competence in the basics of echocardiography, cardiac physiology, neonatal arrhythmias, cyanotic and non-cyanotic congenital heart disease in newborns, single ventricle lesions and perioperative management considerations for these various cardiac pathologies (Fig. 2B) with an overall 9-point increase in perception of competence. The average SITE scores improved from the 2018 baseline (Fig. 3) in all years of the intervention. First-year trainees had a 10-point average increase from baseline, second-years had a 19-point average increase from baseline, and the third-years had a 10-point average increase from baseline. The two fellowship classes that completed the entire curriculum (2018–2019) increased their scores by five points (2018) and six points (2019) which is approximately one standard deviation over three years. Based on narrative feedback from faculty and fellows in the individual post-session evaluation forms and feedback provided to the program by the fellows during their semi-annual review, the cardiology curriculum was well received.

### Discussion

To the best of our knowledge, this is the first description of a formal ABP competency-based neonatal cardiac curriculum showing improvement in core knowledge of cardiology for neonatal-perinatal fellowships. Our experience in designing and implementing a cardiology curriculum for the neonatology fellowship program was a positive one with increased self-perception of knowledge and competence by all neonatology fellows, particularly in our first-year trainees with the largest improvement in overall comfort level in taking care of infants with congenital heart disease.
Although ABP SITE scores improved overall in all fellowship years compared to baseline, the largest improvement was seen in our second-year class who would have also completed at least four months of rotations in our cardiac intensive care during their first year. Additionally, feedback from fellows included improved multidisciplinary interactions with other subspecialties including cardiac anesthesia, cardiac intensive care, and pediatric cardiologists which was consistent with previous findings [5].

Of note is that several of the novel adult learning strategies forcibly emerged during the timing and designing of this curriculum as it took place during the COVID-19 pandemic prompting the use of Zoom video chat and its features to create the interactive sessions. There was positive feedback from fellows when remote learning was offered along with the use of flipped classroom methodology (recorded lectures and pre-reading material provided ahead of time to learn the core concepts) which fellows found helpful to learn at their own pace. The interactive teaching sessions reiterated the core learning objectives and were reinforced with pre- and post-test questions.

Initial challenges in curriculum development included discovering which portions of curricular needs were unmet, addressing the imbalance between clinical demands and educational time, and correlation of educational endeavors with actual clinical competence. Use of these novel educational methods have not been validated, and variability of impact was dependent on the participation and engagement of the adult learner. We also did not account for the variability of in-person versus virtual interactive teaching sessions, and the overall impact of remote virtual-based learning. Lastly, this study obtained data from a single center and fellowship program, with a limited sample size of twelve fellows, and was unable to provide formal statistical significance.

**Conclusion**

Implementation of a dedicated neonatal cardiac curriculum for neonatology fellows improved knowledge of neonatal cardiac anatomy and physiology, application and analysis of concepts in cardiac pathophysiology in neonatal clinical care based on an increase in ABP SITE scores as compared to baseline. There was an increase in comfort and competence perception by the neonatology fellows following a formalized curriculum. This interactive, collaborative effort between both the Divisions of Neonatology and Cardiology, unique to the needs of the trainees led to the additional benefit of identifying neonatology fellows who had a strong interest in cardiology, both research and clinical. The use of formal educational methodology including curriculum development, knowledge gaps were identified and presented us with an opportunity to address those gaps.

**Declarations**

**Sources of Financial Assistance:** None

**Potential Conflicts of Interest:** Authors declare no conflicts of interest.

**Author Contributions:** All authors equally contributed to the synthesis, writing, and development of this manuscript.

**References**


Figures

A. Which of the following is not a component of the Hybrid stage I palliative surgery

- Atrial stenting or balloononing
- Branch pulmonary artery banding
- PDA stent
- Arch reconstruction

B. Annotate:
   Diagnosis: Severe Ebstein with tricuspid valve regurgitation
   Draw the circulation of blood flow

   Diagnosis: New with Pulmonary Insufficiency
   Draw Circular Shunt!

Figure 1

Strategies used to improve adult learning during interactive teaching sessions that incorporated A) integrative audience response polls using Poll Everywhere and B) Zoom Annotate function on Zoom Communications video
platform allowing the audience to draw on cardiac heart box diagram.

**Figure 2**

Fellows completing one full year of the formal neonatal cardiac curriculum showed A) self-perception of knowledge and competence in different areas of cardiac topics and B) comfort level in taking care of infants with congenital heart disease.

![Difference in SITE scores (Local-National) over the last 4 years](image)

**Figure 3**

Difference in ABP SITE exam scores amongst neonatal fellows from 2019-2022 during implementation of a dedicated neonatal cardiac curriculum.