ARTICLE

Development of a neonatal cardiac curriculum for neonatal-perinatal medicine fellowship training

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BACKGROUND: The topic of neonatal cardiovascular care in neonatal-perinatal medicine (NPM) fellowship training has continued to transform due to increased complexity of patients, development of specialized units, continued Accreditation Council for Graduate Medical Education requirements, and clinical practice variation across centers that care for neonates with congenital heart disease (CHD).

METHODS: We developed a neonatal cardiac curriculum comprised of eight interactive sessions with novel active learning concepts specific to our NPM fellows. A self-assessment survey in comfort in managing infants with CHD and perceived competency in neonatal cardiology topics was performed by all neonatology fellows at baseline and after completion of the curriculum. The American Board of Pediatrics Subspecialty In-training Exam (SITE) scores for fellows were compared to that of the national average.

RESULTS: The average comfort score (0–100) of the first-year fellows increased from 33 to 76, and that of the second and third-year fellows increased from 72 to 86, and 75 to 86, respectively. The first-year fellows improved their competency score by 44 points (3 standard deviations), the second-year fellows improved their score by about 26 points (one standard deviation), and there was an overall 9-point increase in the competency score of all fellows (one standard deviation). The average local SITE score was lower than the national average before the initiation of this curriculum, became nearly equal to the national average score at the end of the first year the curriculum was implemented, and has progressively become higher since then.

CONCLUSION: Due to the variable clinical exposure and differing practice models of managing CHD a neonatal cardiac curriculum may be beneficial to NPM trainees.

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INTRODUCTION

Neonatal-perinatal medicine (NPM) fellowship has continued to develop over the last sixty years since the emergence of neonatal training programs in the early 1960s. Recently, French et al highlighted the essentials of NPM training including the current transformations in clinical practice seen in the United States [1]. Several factors have influenced the change in neonatal cardiovascular care including increased patient complexity, development of neonatal specialized units, creation of patient safety-driven teams, and trainee duty hour restrictions. These recent changes have led to variations in training and experiential learning amongst neonatal fellows [2, 3]. Additionally, there is remarkable clinical practice variation in the United States among primary teams who care for neonates with congenital heart disease (CHD) [4]. Location and type of care team vary for infants with cardiac anomalies based on institutional guidelines. This results in potential gaps in knowledge and clinical experience amongst NPM trainees. The development of neonatal cardiac conferences in large centers has shown a positive correlation with multidisciplinary collaboration [5], but no such educational curriculum in neonatal cardiology has been established other than the 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 who have research and clinical interests in cardiovascular care with the introduction of fellowship programs that offer both structured and non-structured training pathways to improve skillsets in congenital and acquired heart disease [8]. 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 NPM 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 the growing concerns about the variable landscape in neonatal cardiovascular

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training and experience led to a call for action. The authors of this manuscript developed an 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 (2) targeted needs assessment within the neonatal-perinatal fellowship, a unique collaborative effort between the Departments of Neonatology and Cardiology sought to (3) identify goals and objectives, (4) develop the educational strategy and design the curriculum, (5) implement the curriculum and (6) obtain evaluation and feedback. The content outline for cardiology provided by the ABP Subspecialty Board of NPM to develop 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. We used the content outline that was used by the ABP prior to March 1, 2022, since it is a significantly more robust and detailed content outline for NPM [10]. Additionally, it is the content outline that was current at the start of curriculum development.

Knowledge content was developed and presented by the core faculty who were comprised of two board-certified cardiologists and one double-boarded in neonatology and pediatric cardiology. This was a concerted effort by both departments to collaborate in improving the training provided to the neonatology fellows. The curriculum consisted of eight sessions that included basics of echocardiography, cardiovascular physiology, neonatal arrhythmias, cyanotic and non-cyanotic CHD commonly seen in the newborn period, single ventricle lesions, and perioperative management for these cardiac pathologies. While each session was led by one of the core faculty members, the other two faculty members served as an interactive expert panel for individual questions brought up by the audience. The core faculty estimate that a total of 60 h (20 h/faculty) was spent in the creation of the curriculum including live interactive sessions, preparation of the recorded sessions, creating pre and post-tests, assessment surveys, and additional logistics of running a session that provided continuous medical education (CME) to the neonatology department. No additional education time was provided to the faculty for this endeavor.

Participant selection

All NPM 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 NPM fellows (four fellows per year for a 3-year NPM fellowship program) prior to the initiation of the curriculum. This baseline data was from a targeted needs assessment survey (see Supplement 1) that included their year of training, comfort level in the clinical management of an infant with CHD (on a scale of 0 to 100 with 0 being not ready to manage an infant with CHD and 100 being fully prepared to manage an infant with CHD), and personal perception of knowledge and competency (on a scale of 0 to 100 with 0 being not competent and 100 being highly competent) in basics of echocardiography, cardiac physiology, neonatal arrhythmias, cyanotic and non-cyanotic CHD in newborns. The average comfort score for four fellows from each academic year, and an average comfort score for all twelve fellows were calculated every year from 2019 to 2022.

Curriculum design

The neonatal cardiac curriculum was implemented in eight sessions outlined in Table 1 that involved an array of unique learning strategies incorporating flipped classroom methodology and encouraging concepts from adult and active learning [11, 12]. These eight sessions were conducted over the academic year starting in August of each year to July of the subsequent year. 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. Before each session, a short pre-test was conducted consisting of five questions about 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 is 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.

Evaluation and feedback

The impact of these educational sessions was made by comparing the SITE scores for the Northwestern fellows to that of the national average for each year that the curriculum was implemented. The differences in the SITE scores between the Northwestern fellows and the national average for each academic level were compared over the years from 2018 to 2021. The 12 trainees were also asked to repeat a self-assessment at the end of the academic year after completion of all eight sessions in the curriculum during the academic year. This self-assessment in comfort and competence was compared to the baseline that had been performed at the beginning of the academic year.

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 (1) if the learning objectives of the overall session were met, which included the pre-recorded learning material sent ahead of time, (2) if the learning objectives of the interactive presentation were met, (3) if the presentation had good images, (4) if the presenter had good knowledge of the subject area, and (5) if the presenter engaged the audience. These evaluation forms also contained narrative feedback by the fellows on what they liked about the talk, how the talk could be improved, and if there were any comments for the presenters. All these evaluations and scores were anonymous in nature and were program aggregates.

The ABP SITE exam is 150 questions of which cardiology consists of only 9% (13–14 questions) per year. As a result, there is significant year-to-year variation of scores across all tested domains which does not allow direct year-to-year comparisons. We evaluated the difference in average class scores compared to the national class average to be able to compare the impact of the curriculum compared to learners without the curriculum.

RESULTS

Table 2 shows the average comfort and competency scores from the self-assessment survey for fellows from each academic year and an average score for all fellows from 2019 through 2020. At the end of the academic year, the average comfort score of the first-year fellow increased from thirty-three at baseline to seventy-six at the completion of the curriculum. Similarly, the average comfort score of the second-year fellow increased from seventy-two at baseline to eighty-six at the completion of the curriculum. The third-year fellows graduated, and therefore we didn't have any data in 2020 for them. There was a significant overall increase in self-perceived knowledge and competence in the basics of echocardiography, cardiac physiology, neonatal arrhythmias, cyanotic and non-cyanotic CHD in newborns, single ventricle lesions, and perioperative management considerations for these cardiac pathologies. The first-year fellows improved their competency score by forty-four points (about three standard deviations), and the second-year fellows improved their score by about twenty-six points (more than one standard deviation), with an overall 9-point increase in the competency score of all fellows (approximately one standard deviation).

Figure 2 and Table 3 describe the difference in average SITE scores between NPM fellows at Northwestern University and the national average SITE score for each academic level from 2018 to 2021. The average Northwestern University (local) SITE score was lower than the national average in 2018, improved at the end of the academic year, and was nearly equal to the national average in

Table 1. Neonatal cardiac curriculum content topics and objectives.

Session title	Length	Topics covered	Objective	Covered ABP content domain/subdomain
1. Cardiac Physiology: Cardiac Equations, Myocardial Performance, and Neonatal Myocardium	2 h	• 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 h	• 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 h	• 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 assessment of ventricular function. • Review of common phrases used in echocardiographic reports.	Domain 2: Cardiovascular A. Anatomy and development of the cardiovascular system B. Cardiovascular physiology F. Patent ductus arteriosus H. Acyanotic congenital heart disease I. Cyanotic congenital heart disease
4. Neonatal Arrhythmias	1 h	• Normal and abnormal ECG parameters in newborns • bradyarrythmias • narrow complex tachycardia • wide complex tachycardia	• Review normal and abnormal ECG parameters in healthy newborns. • Identify the most common types of bradyarrhythmias in neonates. • Understand differential diagnosis and treatment of narrow and wide complex tachycardia.	Domain 2: Cardiovascular J. Cardiac arrythmias L. Cardiomyopathies
5. Single Ventricle: Anatomy, Physiology, and Staged Palliation	1 h	• Single ventricle anatomy • Single ventricle physiology • Staged approach to single ventricle palliation	• Review the variety of anatomically single ventricles. • Review the physiology of functionally single ventricles. • Review the staged palliative procedures for single ventricles.	Domain 2: Cardiovascular A. Anatomy and development of the cardiovascular system B. Cardiovascular physiology I. Cyanotic congenital heart disease
6. Left to Right Shunts: ASD, VSD, AVSD, PDA	1 h	• Atrial septal defects • Ventricular septal defects • Atrioventricular septal defects • Patent ductus arteriosus	• Understand pathophysiology and significant of left to right shunts. • 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. • Understand specific lesions, ASD, VSD, AVSD, and PDA regarding pathophysiology, natural history, and how it impacts management in the neonate. • Characterizing PDA by echocardiography,	Domain 2: Cardiovascular E. Congestive heart failure F. Patent ductus arteriosus H. Acyanotic congenital heart disease

Table 1. continued

Session title	Length	Topics covered	Objective	Covered ABP content domain/subdomain
			reviewing hemodynamic significance and pathogenesis.	
7. Low Cardiac Output Syndrome in the CICU: Bedside Assessment of Cardiac Output	1 h	• 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 output.	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 h	• 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. • Preoperative management and neonatal considerations of each lesion.	Domain 2: Cardiovascular A. Anatomy and development of the cardiovascular system B. Cardiovascular physiology I. Cyanotic congenital heart disease

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.

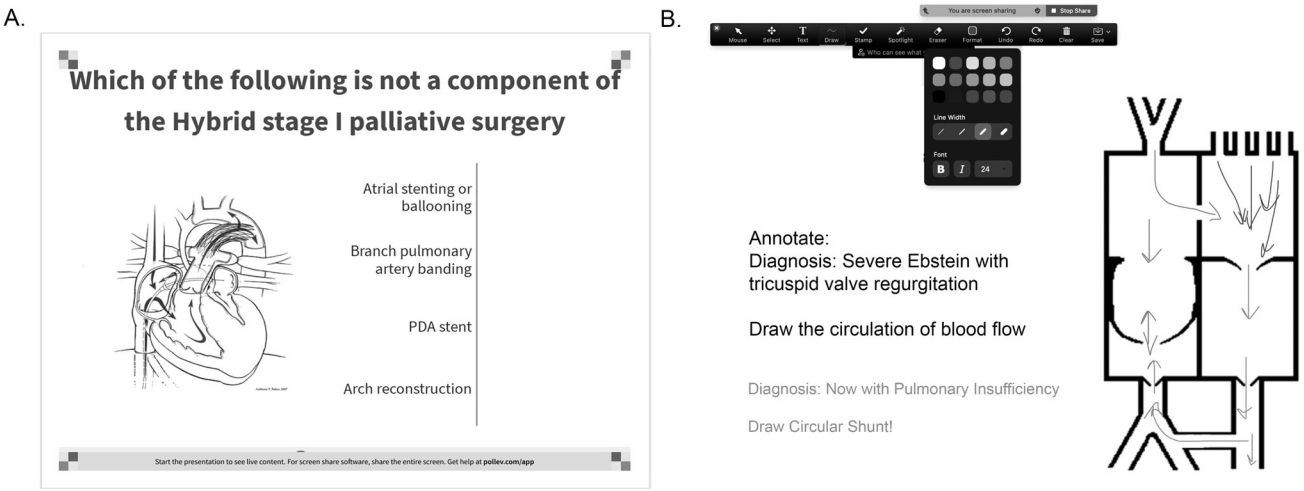

Fig. 1 Example of tools used during interactive teaching sessions. Strategies to improve adult learning during interactive sessions incorporated **A** integrative audience response polls using Poll Everywhere and **B** Zoom Annotate function on Zoom Communications video platform allowing the audience to draw on cardiac heart box diagram.

Table 2. Average comfort and competency scores from the self-assessment survey for fellows from 2019 through 2020.

Fellow Year		2019: Start of academic year				2020: Start of academic year				score improvement at end of academic year		
		1st	2nd	3rd	All	1st	2nd	3rd	All	1st	2nd	All
Comfort Score (0–100)		33	72	75	57	47	76	86	61	43	15	4
Competence Score (0–100)	**avg**	35	58	58	50	49	79	84	59	44[a]	26[a]	9[a]
	stdev	19	14	14	9	16	8	9	10	15	20	8

[a]Improvement in competence score at the end of one year for both the 1st and 2nd-year NPM fellows as they entered the next academic year, with an increase in overall competence score for all fellows. Comparisons were made between the scores of the same set of fellows as they moved onto the next academic year (i.e., first-year fellows in 2019 who became second-year fellows in 2020, and second-year fellows in 2019 who became third-year fellows in 2020).

2019, and continued to improve by becoming higher than the national average in 2020, and 2021. The average SITE scores improved from the 2018 baseline (see Fig. 2) 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 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 overall well received with key themes being, “do more of these sessions”, “loved the interactive visual components”, “use of poll during lecture was useful”, and we also received valuable feedback from the trainees which we implemented in subsequent years. This included including more clinical vignettes, making talks more complex and giving fellows more time to review pre-reading material. Additionally, the close collaboration between the two divisions led to increased fellow research that bridged both sections.

DISCUSSION

To the best of our knowledge, this is the first description of an 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 CHD. Although ABP SITE scores improved overall in all fellowship years compared to baseline, the largest improvement was seen in our second-year class. As noted in the results section the changes in comfort and competence score, and the actual improvement in SITE scores varied between the different classes. The self-perception of comfort and competence in neonatal cardiology for the first-year fellows is likely to depend significantly on their individual exposure to pediatric cardiology during pediatric residency. This exposure is also likely to impact the SITE score of the incoming first-year neonatology fellow. As seen by our comfort and competency survey assessment the highest increase amongst all the classes was seen in the first-year fellows who started to feel comfortable as soon as their clinical exposure to neonatal cardiology increased in their first year of fellowship. As there is continued exposure to cardiology, especially during rotations in the CICU and the NICU, with a better understanding and application of the complex neonatal cardiac physiology and pathophysiology in clinical management, repeat versions of the same educational sessions in subsequent years allow the trainee to absorb and grasp and further delve into the complexities of each topic covered in the educational sessions. 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].

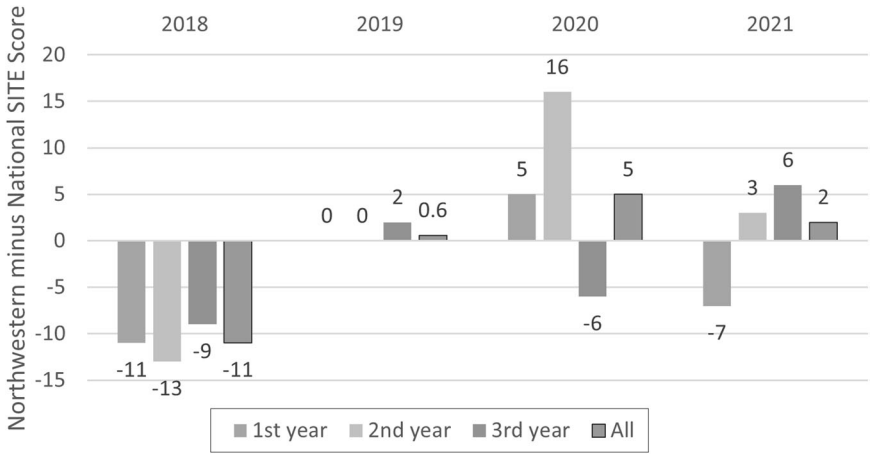

Fig. 2 Improvement in SITE exam scores for the Northwestern University neonatology fellows as compared to the national average scores from 2018 to 2021. For each of the four years, the difference in Northwestern and National ABP SITE exam scores are depicted for 1st, 2nd, 3rd year and all fellows. The general trend is an improvement in SITE scores from baseline (2018) with implementation of a dedicated neonatal cardiac curriculum.

Table 3. Difference in SITE scores between the Northwestern University Neonatal-Perinatal Medicine fellows and the national average.

	2018	2019	2020	2021
1st year	−11	0	5	−7
2nd year	−13	0	16	3
3rd year	−9	2	−6	6

Of note, several of the novel adult learning strategies in the curriculum's design were motivated by the social distancing required during the concurrent COVID-19 pandemic. 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, which were reinforced with pre- and post-test questions. Prior to the pandemic, the sessions were in-person and interactive using tools such as heart models, crayons, use of the chalkboard, and intermittent Socratic style of questioning. With the transition to online learning, there was an increased chance of losing or being unable to decipher the level of engagement by the trainee given that the tools of in-person eye contact, body language, facial expressions, and easy verbal discourse were lost. Some of this was attempted to be overcome by asking that the trainees had their videos on, using an integrative audience response platform software which allowed for participation by all trainees in answering multiple choice questions that led to clinical understanding, and also the use of word clouds to describe clinical scenarios and generate a qualitative audience engagement. The Zoom Annotate tool proved to be useful and engaging and allowed participants to see each other's drawings. Post-COVID we have continued to keep a hybrid model for this curriculum series due to a higher number of trainees being able to participate and the flexibility offered to the core faculty. The use of pre-recorded learning material to establish a baseline and online post-tests to consolidate the learning has also been a useful strategy to further strengthen the education provided.

The need for a robust neonatology-focused cardiology curriculum is significant with several neonatal fellowships nationally inquiring about our curriculum. Continuing a hybrid learning approach enabled us to invite other neonatology programs to these sessions. In 2022, we had one additional neonatology fellowship program join these sessions. For the 2023–2024 curriculum year, we have invited seven other NPM fellowship programs to participate in the curriculum nationally. Although our core educational topics have not changed over the last three years, we continue to modify sessions yearly based on the feedback received and continually tailor learning methods to our fellow audience.

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. The use of these novel educational methods has not been validated, and the 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

Implementing a dedicated neonatal cardiac curriculum for neonatology fellows improved knowledge of neonatal cardiac anatomy and pathophysiology based on an increase in average ABP SITE scores compared to national averages. There was also a perceived improvement in the application and analysis of concepts in cardiac pathophysiology in clinical care with an increase in comfort and competency perceived by the fellows who were exposed to this curriculum. Collaborative efforts between the Divisions of Neonatology and Cardiology led to the additional benefit of identifying neonatology fellows who had a strong interest in cardiovascular hemodynamics research and patient care. With the current landscape of differing clinical exposure to managing CHD, we hope a neonatal cardiac curriculum on a national level could be established to benefit all neonatal-perinatal trainees.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

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AUTHOR CONTRIBUTIONS

Authors SP, PK, PM, and SS equally contributed to the design, collection of data and analysis, and writing of this manuscript.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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