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Original Article

Training fellows and residents in paediatric cardiac critical care

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Abstract As pediatric cardiac critical care becomes more sub-specialized it is reasonable to assume that dedicated units may provide a better infrastructure for improved multidisciplinary care, cardiac-specific patient safety initiatives, and dedicated training of fellows and residents. The knowledge base required to optimally manage pediatric patients with critical cardiac disease has evolved sufficiently to consider a standardized training curriculum and board certification for pediatric cardiac critical care. This strategy would potentially provide consistency of training and healthcare and improve quality of care and patient safety.

Keywords: Cardiac critical care; pediatric cardiac critical; care; curriculum; fellow training; postgraduate medical education

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Introduction and historical perspective

The field of congenital heart surgery was launched in 1938 with the ligation of a patent ductus arteriosus by Gross (Boston). Subsequent landmark surgeries include the first Blalock–Taussig shunt in 1944 (Baltimore), the first closure of an atrial septal defect using cardiopulmonary bypass by Gibbon in 1953 (Philadelphia), the first closure of a ventricular septal defect using cross-circulation by Lillehei in 1954 (Minnesota), the first successful palliation of hypoplastic left heart syndrome by Norwood in 1983 (Boston), and the first infant heart transplant by Bailey in 1985 (Los Angeles).[1] As congenital heart surgery evolved, the impact of preoperative stabilisation and postoperative management on outcomes became readily apparent. Thus, in the late 1980s, the first dedicated paediatric cardiac ICUs were established.

In concert with developments in congenital heart surgery was an evolution in knowledge of unique complex cardiac physiologies and the introduction of novel therapies. Important physiologies included balancing systemic and pulmonary circulations in single-ventricle heart defects, differentiating systolic from diastolic dysfunction, preventing and treating pulmonary hypertension, understanding post-operative low cardiac output syndrome, optimising the Fontan circulation, and recognising the impact of complex arrhythmias. Key advances in therapies included new modes of mechanical ventilation, introduction of inhaled nitric oxide, institution of temporary and permanent pacing systems, new vasoactive and anti-arrhythmic pharmaceuticals, and the development of mechanical circulatory support devices. As the sophistication of diagnostic techniques and intensive care therapies grew, it became apparent that sub-specialty training is required to optimally manage children with critical cardiac disease.

Initial sub-specialty training in paediatric cardiac intensive care followed the model of the earliest dedicated cardiac ICUs, which were managed by paediatric cardiology – for example, Children's Hospital Boston,

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University of Michigan, Ann Arbor. This transition occurred at a time when cardiac critical care management was most commonly delivered within paediatric ICUs directed by critical care specialists – a practice that continues in some units in the current era. In 2005, the American College of Cardiology, the American Heart Association, and the American Academy of Pediatrics published guidelines for training in paediatric cardiac critical care.[2] They recommended a categorical Accreditation Council for Graduate Medical Education (ACGME) paediatric cardiology fellowship followed by an additional 9 months of training at a programme performing over 250 annual cardiopulmonary bypass cases. The 9 months should include at least 1 month of cardiac anaesthesia, 4 months of paediatric critical care, and 4 months of paediatric cardiac intensive care. In addition, specific knowledge and competence goals were outlined. The authors were all paediatric cardiologists, and some were additionally board certified in paediatric critical care. Not surprisingly, a rebuttal was written primarily by paediatric intensivists stating that patients in the cardiac ICU should be cared for by board-certified critical care physicians, and that the 4 months of exposure to critical care recommended by Kulik et al was insufficient.[3]

Sub-specialty ICU

In 2012, the American Heart Association published a comprehensive review of critical care cardiology focussing on adults.[4] They describe the evolution of critical care cardiology from reactive – prompt and effective cardiopulmonary resuscitation – to anticipatory – prevention of cardiac arrest. Cardiac critical care in the current era emphasises a focus to improve patient safety, given that ICU-related complications have been reported to be a determinant of poorer outcome; a shift towards staffing models that place an emphasis on the involvement of dedicated intensivists with specialised advanced training in cardiac critical care; a recognition of the importance of integrated multidisciplinary care in which the activities of physicians, nurses, respiratory therapists, pharmacists, and others are coordinated; and an increase in patient complexity.

Penny and Shekerdemian[5] provide a thoughtful review and extension of this statement paper to address cardiac critical care in children with congenital or acquired heart disease and adults with congenital heart disease. They make several important points regarding the evolution of paediatric cardiac intensive care. There is an increasing complexity in the patient population; complex congenital heart lesions formerly felt to be inoperable are now approached with palliative surgery, and the majority of patients who survive to adulthood have associated morbidities. Mechanical circulatory support is rapidly evolving to address the growing number of children with heart failure, the most severe of which may also require mechanical ventilation and/or renal replacement therapy. Heart transplantation is becoming more common, and the immunology underpinning its application is complex. For those who are not candidates for transplantation, well-executed end-of-life care is essential. Penny and Shekerdemian also make several important recommendations regarding paediatric cardiac intensive care. Reduction in hospital-acquired infections is an important patient safety measure. A dedicated, multidisciplinary cardiac critical care team, led by a cardiac intensivist, should manage patients. A structured multidisciplinary handover should occur when patients are admitted from the operating room. Family presence on rounds and during cardiopulmonary resuscitation should be supported. Postoperative low cardiac output syndrome and high-acuity admissions often occur at night, justifying an attending presence 24/7. Finally, it is important to perform continuous quality evaluations by data collection and benchmarking through national databases and public reporting.

A 2009 survey analysis of 122 congenital heart centres in the United States of America demonstrated significant variations in unit structure, staffing, and training of cardiac intensivists.[6] Approximately half of the 94 responding centres had a dedicated cardiac ICU. Clinical care was provided by fellows (60%), residents alone (23%), and physician extenders alone (11%). When the results of this survey were linked to the Society of Thoracic Surgeons Congenital Heart Surgery Database, 25 of the 57 congenital heart surgery centres in the United States of America had a dedicated paediatric cardiac ICU.[7] Patients in centres with a dedicated cardiac ICU tended to be younger and have a higher Society of Thoracic Surgeons – European Association for Cardiothoracic Surgery mortality risk stratification. The only significant difference in surgical risk-adjusted mortality between centres with and without a dedicated cardiac ICU was in Society of Thoracic Surgeons – European Association for Cardiothoracic Surgery risk category 3 – primarily atrioventricular canal repairs and the arterial switch operation – where a lower mortality rate was observed in centres with a dedicated cardiac ICU. Although not yet confirmed by data, it is reasonable to assume that dedicated paediatric cardiac ICUs provide a better infrastructure for improved multidisciplinary care, cardiac-specific patient safety initiatives, and dedicated fellow and resident training.

Training fellows in paediatric cardiac critical care

Pathway

The American Board of Internal Medicine recognises a pathway for dual sub-specialty training and certification in cardiovascular disease and critical care medicine for adult critical care cardiology. This pathway for dual certification requires 4 years of fellowship with a minimum of 30 months of clinical training, of which 6 months of clinical training must be in critical care medicine within an ACGME-accredited critical care training programme. The requirements for dual certification by the American Board of Pediatrics are more rigorous; the candidate must have completed a 3-year categorical ACGME-accredited fellowship in cardiology or critical care followed by another 2 years in an ACGME-approved fellowship programme in the other discipline (5 years total).

In 2015, the American College of Cardiology, the American Academy of Pediatrics, and the American Heart Association in collaboration with the Society of Pediatric Cardiology Training Program Directors published a thorough and thoughtful statement paper outlining the extensive training and knowledge goals specifically for those who have successfully completed a ACGME-approved paediatric cardiology fellowship and wish to pursue a career in paediatric cardiac intensive care.[8] These guidelines were consistent with the 2005 consensus statement recommending a minimum of 9 additional clinical months and 3 research months at a programme with over 250 annual cardiopulmonary bypass cases for adequate training.

In 2015, a panel of cardiac intensivists with formal training in paediatric cardiac anaesthesiology, neonatal intensive care, paediatric critical care, and paediatric cardiology discussed optimal training pathways for paediatric cardiac intensivists.[9] There was consensus that specialised training was necessary but no consensus on the best training pathway. Non-traditional training pathways included paediatric cardiac anaesthesia and neonatology. The cardiac anaesthesiologist is well trained for acute management – including vascular access, airway, and low cardiac output syndrome – but perhaps less prepared for managing chronic heart failure, mechanical circulatory support, continuous renal replacement therapy, and chronic respiratory failure. The neonatologist is likely to be less familiar with treatment of older children and adults with CHD.

At present, there are three principal pathways by which physicians currently train for and provide paediatric cardiac intensive care: categorical paediatric cardiology followed by specialty training in paediatric cardiac intensive care, paediatric critical care fellowship followed by specialty training in paediatric cardiac intensive care, or board certification in both paediatric cardiology and paediatric critical care. A total of 23 North American cardiac centres, listed in Table 1, are currently offering subspecialty training in paediatric cardiac critical care. With rare exceptions, they accept applicants who

Table 1. Programmes with 4th year training programmes in paediatric cardiac intensive care.

Programme	Location
Arkansas Children's Hospital	Little Rock, Arkansas
Ann & Robert Lurie Children's Hospital	Chicago, Illinois
Children's Hospital of Alabama	Birmingham, Alabama
Children's Healthcare of Atlanta	Atlanta, Georgia
Children's Hospital Boston	Boston, Massachusetts
Children's Hospital of Colorado	Aurora, Colorado
Children's Hospital of Philadelphia	Philadelphia, Pennsylvania
Children's Hospital of Pittsburgh	Pittsburgh, Pennsylvania
Children's Hospital of Los Angeles	Los Angeles, California
Children's Hospital of Wisconsin	Milwaukee, Wisconsin
Children's National Health System	Washington, District of Columbia
CS Mott Children's Hospital	Ann Arbor, Michigan
Heart Institute at Cincinnati Children's Hospital	Cincinnati, Ohio
Hospital for Sick Children	Toronto, Ontario
Lucile Packard Children's Hospital	Palo Alto, California
Medical University of South Carolina	Charleston, South Carolina
Monroe Carell Children's Hospital	Nashville, Tennessee
Nicklaus Children's Hospital	Miami, Florida
Seattle Children's Hospital	Seattle, Washington
St Louis Children's Hospital	St Louis, Missouri
Stollery Children's Hospital	Edmonton, Alberta
Texas Children's Hospital	Houston, Texas

are either board eligible or certified in paediatric cardiology or paediatric critical care.

Recently, a 48-month integrated training programme for paediatric cardiac critical care has also been proposed: 20 months of cardiology, including non-invasive, inpatient, catheterisation, electrophysiology, heart failure, and pulmonary hypertension, 12 months of research, 8 months of critical care, including paediatric, neonatal, and anaesthesia, and 8 months of cardiac intensive care.[5]

Sub-specialty curriculum

The 2015 position paper by Feltes et al provides a detailed outline of the knowledge goals for those who have successfully completed an ACGME-approved paediatric cardiology fellowship and wish to pursue a career in paediatric cardiac intensive care.[8] The rigorous expectations described are specifically for the cardiologist who plans to undertake primary responsibility for the comprehensive management of critically ill patients with congenital or acquired heart disease. In addition to medical knowledge, the authors emphasise patient care, systems-based practice, professionalism, and excellent communication and procedural skills. Developing advanced procedural skills – airway management, percutaneous line and tube placements, and mechanical circulatory support management – are perhaps the most challenging competencies to achieve with this particular curriculum.

In 2015, the Pediatric Cardiac Intensive Care Society created an Education and Training committee whose responsibilities include creating an educational curriculum for paediatric cardiac intensivists. The recommended areas of knowledge-based competency are summarised in Table 2.[10] For 4th year training programmes, the curriculum must be customised to the primary fellowship, either paediatric critical care or paediatric cardiology.

Research

Trainees should be encouraged to undertake a research project associated with the science or clinical practice of paediatric cardiac critical care. Potential areas of research include but are not limited to effects of cardiopulmonary bypass, factors impacting neurodevelopmental outcomes, genetic factors contributing to cardiovascular disease, mechanisms and therapies for pulmonary hypertension, technological advances in neuroimaging, mechanical circulatory support, and haemodynamic monitoring, database integration and benchmarking, practice pattern variation and improved care through critical care consortia, and haemodynamic big data analyses.

Table 2. Summarised curriculum for fellowship training in paediatric cardiac intensive care.

Cardiovascular
Aortic valve disease
Cardiac transplantation
Cardiogenic shock
Cardiopulmonary interaction
Cardiomyopathy and myocarditis
Coronary vascular disease
Diastolic dysfunction
Systolic dysfunction
Arrhythmia and pacing
Echocardiography
Mechanical circulatory support
Mitral valve disease
Monitoring
Pericardial disease
Pulmonary hypertension
Vasoactive medications
Pressure volume loading
Ventricular interdependence
CHD
Ebstein's
Aortic valve disease
Anomalous pulmonary venous connections
Bidirectional Glenn
Fontan
Arch abnormalities
Cardiopulmonary bypass
Transposition of the great arteries
Left-to-right shunt (PDA, ASD, VSD, AVC)
Pulmonary atresia with intact ventricular septum
Neonatal single ventricle physiology
Tetralogy of Fallot and variants
Truncus arteriosus
Other systems
Hormonal replacement
Nutrition, necrotising enterocolitis
Coagulation
Nosocomial infections
Sepsis
Cerebral vascular physiology and neurological events
Sedation, analgesia, muscle relaxation
Acute kidney injury and continuous renal replacement therapies
Airway disease
Airway management
Gas exchange
Mechanical ventilation
Neonatal lung disease
Pulmonary oedema
Pulmonary physiology and mechanics

ASD = atrial septal defect; AVC = atrioventricular canal; PDA = patent ductus arteriosus; VSD = ventricular septal defect

Competency

Consistency in paediatric cardiac critical care training curricula and assessment of competency are important and active topics in the sub-specialty. A potential mechanism to achieve these goals is the creation of ACGME-approved training and board certification in paediatric cardiac intensive care.

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Table 3. American board of paediatrics certification costs.

Exam	Cost
Paediatrics	US $2265
Critical care	US $2900
Cardiology	US $2900
Cardiac critical care	US $2900
Maintenance of certification (5 years)	US $1230

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Pros and cons of a more formalised paediatric cardiac critical care training requirement have been debated.[9] Proponents of board certification argue that it provides objective evidence of additional sub-specialty training, and that creation of core competencies and skill sets will reduce variation in practice and improve quality of care. In the current era, patients, families, insurers, and regulators are particularly interested in high-quality and consistent care. Those who oppose board certification raise concerns that a required ACGME-approved training pathway through paediatric cardiology and/or critical care will exclude excellent cardiac intensivist trained in cardiac surgery, anaesthesia, and/or neonatology. The expense of multiple board certifications must also be considered and cost reductions offered to those with additional training, Table 3. Smaller programmes with mixed units or shared staffing between units may be challenged to support board-certified paediatric cardiac intensivists. Most importantly, although additional sub-specialty training and certification should advance patient care, improved outcomes directly related to this training have not yet been demonstrated.

Establishment of an American Board of Pediatrics sub-board in cardiac critical care

The general consensus in the field is that an ACGME-training platform and demonstrated competency via an American Board of Pediatrics sub-board in cardiac critical care will provide consistent training between programmes and result in improved patient care. There are five guiding principles from the American Board of Pediatrics: children will be better served, the sub-specialist will not supplant the role of the general paediatrician, the sub-specialists will teach trainees, provide consultation, provide tertiary care, and create new knowledge through research, there must be a sufficient number of current and potential sub-specialists to justify the certification process, and proficiency in procedural skills does not justify additional certification.[11]

In 2015, a working group of six paediatric cardiac intensivists with varied pathways of formal cardiac intensive care training was assembled to consider a formal petition for creation and recognition by the American Board of Pediatrics for sub-specialty training and certification in paediatric cardiac critical care. The working group developed a white paper proposing that paediatric cardiac critical care sub-specialists function as an invaluable resource in the teaching of residents, fellows, and other health professionals and that they serve as primary caretakers in the evaluation and management of critical congenital and acquired heart disease in newborns, infants, children, and adults with CHD in the ICU. In addition, they serve as an important resource throughout the hospital, including, but not limited to, the emergency department, cardiac step-down units, and neonatal and paediatric ICUs. The white paper proposes that formalised training and examination be established by the American Board of Pediatrics to provide standards for physician certification and re-certification, ensuring the maintenance of core competencies, and to establish programme standards and requirements through the ACGME-accreditation process.

The white paper proposes that current practicing paediatric cardiac intensivists will have a 3-year grace period to take the cardiac critical care sub-board examination following its inception, independent of their formal training. This recommendation addresses the concern that current practitioners who have a different training pathway would be excluded from obtaining the new board certification. Those completing training after initiation of the sub-board examination will be eligible only if they have completed an ACGME-accredited program in pediatric cardiac critical care or have dual board eligibility/certification in both cardiology and critical care. Only those who have completed a categorical ACGME-approved fellowship in paediatric cardiology or paediatric critical care would be qualified for the additional training in paediatric cardiac critical care. Development of an integrated fellowship in paediatric cardiac critical care was not included in the petition, but should be considered. The concept was presented to the American Board of Pediatrics Cardiology and Critical Care sub-boards who both encouraged further discussion and fact-finding. There is a planned survey to American Board of Pediatric diplomats and centres providing 4th year training in paediatric cardiac critical care, the findings of which will inform a formal application to the American Board of Pediatrics Board of Directors for consideration of recognition.

Training residents in paediatric cardiac critical care

The role of the resident in the paediatric cardiac ICU can be challenging owing to several factors including

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the high level of acuity, the dynamic changes in patients' clinical status, and the sophisticated knowledge base required for effective patient management.[12] Residents in hospitals at some of the largest congenital heart programmes have opted out of routine rotations through the cardiac ICU – for example, Children's Hospital Boston, University of Michigan, Children's Hospital of Philadelphia, and Lucile Packard Children's Hospital Stanford – whereas other programmes – for example, Children's Hospital of Wisconsin and the Benioff Children's Hospital University of California San Francisco – encourage resident participation because the cardiac ICU is an ideal location to educate paediatricians in several aspects of paediatric cardiology and early recognition and management of cardiorespiratory insufficiency. Furthermore, timely paediatric resident exposure to cardiac intensive care may influence sub-specialty training in cardiac critical care. The ACGME's residency review committee for paediatric cardiology states that "there must be an ICU in each centre in which patients with heart disease are cared for under the supervision of the training program staff and are available to the residents". Clearly at some training programmes this exposure is occurring in the paediatric or neonatal ICUs.

Programmes that do not routinely include resident coverage within the cardiac ICU commonly offer an elective in cardiac ICU. Ideally, the rotations should be at least 1 month and offered to the more experienced – that is, 2nd or 3rd year – residents. It is probably best proposed as an elective rotation. Specific learning goals should be outlined. For the motivated and interested paediatric resident, the cardiac ICU is the best environment to learn the anatomy and physiology of various types of CHD. Programmes focussing on optimising the paediatric resident's experience in the cardiac ICU are likely to find that it becomes a popular rotation particularly with those residents who have an interest in intensive care or paediatric cardiology.

Conclusion

Paediatric cardiac intensive care is a rapidly evolving field. As the knowledge base of the field expands, there is an increasing need for standardised sub-specialty training and the assessment of competency. It is likely that the best platform to achieve these goals is through an ACGME-standardised training programme and sub-board overseen by the American Board of Pediatrics. Whether formalised training will be dual fellowship training in paediatric cardiology and paediatric critical care, a focussed 4th year of training following a categorical fellowship in paediatric cardiology or paediatric critical care, or a specialised integrated training programme remains to be determined.

Acknowledgement

None.

Conflicts of Interest

James Fortenberry and Sarah Tabbutt are currently members of the American Board of Pediatrics, Critical Care Sub-board.

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