REVIEW

Paediatric cardiac intensive care unit: Current setting and organization in 2010

Réanimation cardiaque pédiatrique : statuts et organisation en 2010

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Summary Over recent decades, specialized paediatric cardiac intensive care has emerged as a central component in the management of critically ill, neonatal, paediatric and adult patients with congenital and acquired heart disease. The majority of high-volume centres (dealing with over 300 surgical cases per year) have dedicated paediatric cardiac intensive care units, with the smallest programmes more likely to care for paediatric cardiac patients in mixed paediatric or adult intensive care units. Specialized nursing staff are also a crucial presence at the patient’s bedside for quality of care. A paediatric cardiac intensive care programme should have patients (preoperative and postoperative) grouped together geographically, and should provide proximity to the operating theatre, catheterization laboratory and radiology department, as well as to the regular ward. Age-appropriate medical equipment must be provided. An optimal strategy for running a paediatric cardiac intensive care programme should include: multidisciplinary collaboration and involvement with paediatric cardiology, anaesthesia, cardiac surgery and many other subspecialties; a risk-stratification strategy for quantifying perioperative risk; a personalized patient approach; and anticipatory care. Finally, progressive withdrawal from heavy paediatric cardiac intensive care management should be institutionalized. Although the countries of the European Union do not share any common legislation on the structure and organization of paediatric intensive care or paediatric cardiac intensive care, any paediatric

Abbreviations: ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit; PCIC, paediatric cardiac intensive care; PCICU, paediatric cardiac intensive care unit; PICU, paediatric intensive care unit.

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Introduction

Over recent decades, specialized paediatric cardiac intensive care (PCIC) has emerged as a central component in the management of critically ill, neonatal, paediatric and adult patients with congenital and acquired heart disease. Despite the large numbers of paediatric cardiac centres worldwide, few papers have been published that describe adequately the components that make up a dedicated cardiac intensive care service [1–3]. The concept of a PCIC unit (PCICU) varies widely, ranging from units that are largely managed surgically, to those in which children with heart disease are cared for in a general intensive care environment [4]. We review here different elements that seem to us to be important in the establishment of a PCICU, based on clinical experience within a contemporary legal and administrative framework.

Organization and equipment

Human resources

Medical personnel

Paediatric intensivists lead 94% of general paediatric intensive care units (PICUs) [5]. With regard to PCICUs, a recent survey of both North American and worldwide paediatric cardiac surgical programmes showed that 73% of North American units and 59% of worldwide units involved care by paediatric intensivists. All but two of 29 high-volume centres (dealing with > 300 surgical cases/year) cared for paediatric cardiac intensive care patients in dedicated PCICUs, with the smallest programmes more likely to care for these children in mixed paediatric or adult intensive care units (ICUs) [6]. Paediatric cardiac intensivists usually train in either paediatric medicine or anaesthesia as a ‘base specialty’, with further specialist training in paediatric intensive care and paediatric cardiac intensive care or cardiology. While they clearly must have expertise in the management of congenital and acquired heart disease in children, these intensivists also require expertise in the management of non-cardiac organ failure and the interaction of whole body systems.

Experience from high-performance programmes shows that intensive care for children with heart disease is best delivered by a well-structured, multidisciplinary, medical team comprising critical care medicine, paediatric cardiology, cardiac surgery and cardiac anaesthesia, supported by specialized paediatric cardiac trained nurses and others, including paediatric pharmacists, physiotherapists and support staff for families [3]. Additional medical specialists that are involved closely include neonatologists, paediatric general surgeons, paediatric pulmonologists and paediatric cardiologists.
neurologists. Recent studies have demonstrated that multidisciplinary rounds in the critical care environment increase communication, reduce medical errors, shorten hospital stay and consequently produce economic savings [7,8].

In-house, 24-hour, attending-level coverage is recommended for any general PICU as well as for PCICUs [3,9], although this ideal is rarely achieved and may not be affordable in many health economies. While institutions with training programmes often have residents or fellows to provide night and weekend call coverage, other institutions will need coverage to be provided by physician extenders and/or attending staff. It is certainly questionable whether standards of care can remain at the highest level, when junior, inexperienced staff alone assess and treat children ‘out of hours’.

Education of all members of the team is a vital part of a PCIC programme. Orientation of trainees and nurses should be included on a systematic basis. Specific knowledge areas, such as single ventricle pathophysiology, pulmonary hypertension and low cardiac output management, mechanical support usage and the diagnosis and treatment of complex tachydysrhythmias should be reviewed on a periodic basis. Finally, both trainee and nursing staff should be encouraged to train together as a team. Recent development of medical simulation training has enabled advanced team training and safety to be taught in ways originally developed in aviation and other ‘high resilience’ industries.

Nurses and other ancillary personnel

Nurses provide a unique contribution to the delivery of care for PCICU patients. Specialized nursing staff are a crucial presence at the patient’s bedside for quality of care, and have a strong influence on the rate of preventable adverse events [3]. A study conducted recently in an ICU demonstrated that 51% of incidents are detected by direct observation versus 27% by monitors [10]. The patient-to-nurse ratio can range from 1:3 to 2:1 in PICUs [11]. In some European countries, such as the UK, 1:1 nursing is regarded as standard for a ventilated adult or child, with a higher 2:1 ratio for complex care, including extracorporeal membrane oxygenation (ECMO). Other health systems have adopted different standards, and there is little high-quality research to support the ‘rules’ applied to PICU nursing ratios. Other factors should be considered, including the level of experience, available technology and monitoring, and support staff. For instance, a highly experienced nurse may be capable of directing the care of several patients located in close proximity, provided they have support staff nearby and more experienced staff to call upon should an emergency arise.

The nursing staff in PCICUs should be encouraged to attain some degree of clinical autonomy. Many programmes have developed ‘practitioners’ who have extended their professional practice variously into areas regarded traditionally as ‘medical’. It is essential that whoever leads the care ensures open and clear communication with all members of the care team. Recently introduced communication tools adopted from other industries, such as Situation-Background-Assessment-Recommendation [12], can be adopted across whole units or hospitals and have been shown to result in better communication of critical information, especially when the information is passed from junior to senior team members or in stressful situations. It is often productive for cardiac intensive care nurses to rotate periodically through other areas of the cardiac programme, such as the catheterization laboratory or the operating theatre, to gain more extensive knowledge of these clinical areas. In addition, rotations through general PICUs and transport programmes can be beneficial. Regular meetings between physicians and nursing staff should be organized on a weekly basis to discuss both clinical and administrative aspects of unit work.

Numerous other personnel are mandatory for the optimal care of the PCICU patient. A dedicated pharmacist should be close to the PCICU, or an organization must at least be available to allow 24-hour dispensation of medication. Nutritionists, physical therapists, psychologists and social workers also play important roles in PCICUs.

Facility and equipment

Issues to consider regarding PCICU location strategy

It is preferable to have PCIC patients grouped together geographically, whether in a separate PCICU or in part of a general PICU; this permits specialized nursing and focuses the medical care from the ‘cardiac’ multidisciplinary team [1–3]. Proximity to the operating room, catheterization laboratory and radiology department has the obvious advantage of minimizing transport time and enables ready communication between key team members. Having preoperative patients in the same location as postoperative patients facilitates ongoing management, especially when surgery or interventional catheterization has to be scheduled. Finally, proximity to the regular ward is also advantageous.

Issues to consider regarding PCICU conception and construction

Medical and nursing directors, the hospital architect, the hospital administrator and operating engineer should all be involved at the conception and building phase of a PCICU. The central area should have adequate visualization of the patient rooms as well as adequate desk space. A centralized monitoring system with telemetry for any ‘mobile’ patients is mandatory. There should be individual rooms that are large enough to accommodate the patient’s bed, echocardiographic machines, mechanical support and vacuum source. The minimum recommendation for paediatric patients is 23 m² per bed space [13]. Some units are designed with patients in multibedded bays; while these give patients and families less privacy, they may prove effective and popular with nurses, particularly if nurse ratios are lower than 1:1, permitting mutual support from adjacent nurses at times of crisis. In addition, a movable glass partition door between rooms enables the space around the bed to be doubled in certain emergency situations. Adherence to regulatory standards, including isolation rooms, clean and dirty utility rooms, and nutrition preparation areas, is also important [13,14].

Issues to consider regarding PCICU equipment

Age-appropriate medical equipment must be provided, according to previously published guidelines for PICUs
In addition, PCICUs have several specialized equipment needs, such as inhaled nitric oxide, mechanical cardiopulmonary support and echocardiographic machines with transesophageal probes [1,2]. This equipment should be inside or in close proximity to the PCICU and able to be readily deployed when needed. In addition, there must be accurate and unbiased recording of data from monitoring equipment, which is retrievable for at least the previous 24 hours. Specific cardiac monitors should automatically record, interpret and immediately communicate any abnormal data (e.g. significant arrhythmias). Electronic patient charting systems allow for semi-automated data acquisition and automatic calculation of fluid and drug administration. Many of these systems include e-prescribing for drugs, which, if set up properly, can be a valuable decision-support tool for prescribers and can improve medicine safety. Data can also be collected and be readily available for discharge notes or clinical audit. All PICUs should audit practice against standards, ideally benchmarking externally using severity of illness scores such as the Paediatric Index of Mortality score or the Paediatric Risk of Mortality score, in addition to paediatric cardiac specific ‘complexity’ scores, such as the Risk Adjustment for Congenital Heart Surgery score or surgical interventions. Finally, any referral PCICU should incorporate telemedicine technology to provide interactive consultation and supportive care to other external units with or without a PICU [3].

Issues to consider regarding PCICU clinical practice

Admission and discharge criteria should be discussed with members of the paediatric cardiology and paediatric cardiac surgery teams. Although individualized variations in clinical practice are unavoidable — and possibly useful to some extent — they should be minimized. Cardiopulmonary arrest and emergency situations deserve special protocols, particularly regarding the intervention of the ECMO team. Protocols for specialized patient populations, from neonates to adults with congenital heart disease, are also useful. A regular cardiac intensive care physician and nursing staff meeting is a valuable forum for discussing and establishing new policies [3]. Also, a weekly morbidity and mortality conference for all admissions and discharges is mandatory to improve quality of care.

Other PCICU issues to consider

Patient satisfaction is an important aspect of the quality of medical care. Visitation policy for families should be fairly open and support for parents should be readily available from physicians, nurses and a dedicated psychologist. Finally, as with every PICU or adult ICU, the staff physicians should be knowledgeable about cost-to-charge ratios as well as direct and indirect expenses in the intensive care setting [15].

Strategy

Several principles are of primary importance if a PCIC programme is to be run optimally.

### Multidisciplinary collaboration and involvement

In addition to paediatric cardiology, PCIC, anaesthesia and cardiac surgery, a PCICU incorporates many other subspecialties, such as neonatology, paediatric pulmonology and adult cardiology [3,7].

### Risk stratification

In the field of PCIC medicine, it is difficult to estimate risk for individual patients. A global score, such as the Physical Status Classification score of the American Society of Anesthesiology, is not valid because age and underlying diagnoses are not taken into account [17]. For congenital heart surgery, several risk models (e.g. the Risk Adjustment in Congenital Heart Surgery score and the Aristotle score) have been established over the past few years to quantify perioperative risk more specifically. Also, some blood markers (e.g. N-terminal pro-brain natriuretic peptide) may be capable of predicting postoperative morbidity and mortality [18].

### Continuation of care

As long as the intensive care admission is predictable, PCIC should not start with postoperative or postcatheterization care. Rather, the patient’s intensive care management should begin with their initial presentation at the clinic, conventional hospitalization or even the initial multidisciplinary discussion. For example, assessment of preoperative patients includes numerous issues, such as evaluation of myocardial and valve function, pulmonary artery pressure, consideration for preoperative and intraoperative inotropic support, assessment of any extracardiac associated anomaly and potential sequelae after cardiopulmonary bypass [2,3].

### Personalized approach

The intensivist must consider the extreme variability in patients with CHD [3]. For example, after a modified fenestrated Fontan operation, any patient may use their fenestration variably, with a consecutive wide degree of postoperative cyanosis [19]. The individual approach for such patients needs to consider many clinical factors (rhythm, pulmonary pressure and resistance, systemic pressure, etc.), biological factors (lactates, pH, arteriovenous difference, etc.) and echocardiographic factors (ventricular function, valve function, etc.), as well as the patient’s postoperative treatment — particularly optimization for afterload reduction.

### Anticipatory care

Anticipation has become a concept of paramount importance as experience in PCIC medicine has grown and given the rapidity of development of many fatal complications in the critically ill paediatric cardiac patient [3]. A well-known example is the instauration of mechanical support in a patient in whom continuous inotropic support with epinephrine exceeds 0.2 μg/kg/min [20].
Progressive withdrawal from heavy PCIC management

Progressive withdrawal from heavy PCIC management should be institutionalized instead of making abrupt changes, especially with inotropic and ventilator management. For example, inhaled nitric oxide withdrawal should be very progressive, even at extremely low doses, to avoid rebound pulmonary hypertension [21].

Centralizing care

There are strong arguments in favour of centralizing the care of critically ill paediatric cardiac patients at the inter-regional level. Several key elements play a crucial role in optimizing the interactions between the referral centre and the external centre: the use of common protocols; routine consultation with the inter-regional PCICU; the use of telemedicine; and continuous medical education to enhance the skills and experience of local staff [15,22]. The existence of a dedicated inter-regional paediatric team optimizes patient care during transportation, and a mobile ECMO team delivers care in an urgent and lifesaving manner [23].

Peer review of the programme

Both internal and external periodic peer review of the programme should be institutionalized to optimize performance of the team responsible for PCIC. While an unbiased assessment might be better provided by a respected external expert, the use of a standardized scorecard is an effective tool for internal as well as for external reviewers. After quantitative assessment of the PCICU team is accomplished by giving a score to each of the issues (e.g. multidisciplinary collaboration, location strategy, etc.), recommendations and/or interventions are suggested. This is followed later by a comparative reassessment of the improvement in performance. A very good example of such scorecard has been published in a recent review on PCICUs [3].

Legal aspects

The countries of the European Union do not share any common legislation about the structure and organization of general paediatric intensive care or PCIC. In France, several decrees have been published by the Health Ministry regarding the practice of paediatric cardiac surgery. Any paediatric cardiac surgery programme must be agreed by the French Health Ministry and programmes must fit closely with the decree issued on 24 January 2006 and modified on 07 March (n° 2006-77, n° 2006-78) [24] and with the Interministerial Circular issued on 03 July 2006 (n° 2006-293) from the Direction hospitalière de l’organisation des soins, regulating cardiac surgery practice in France [25]. To be acknowledged, a paediatric cardiac surgery programme must complete at least ‘150 major procedures per year in children’. Each institution should have a ‘dedicated paediatric cardiology unit, a paediatric catheterization laboratory and a PCICU’. Postoperative care of the paediatric cardiac patient is provided ‘in a dedicated PCICU or in a general ICU with identified cardiosurgical beds’. Such a specialized unit is defined legally as a ‘specialized PICU’. Managers of such units can be board-certified intensivists or paediatricians who have the appropriate intensive care medicine board certification. Specialized PICUs also benefit from a 2:1 patient-to-nurse ratio instead of the ‘standard’ 5:2 ratio in general PICUs. Protocols on organization and medical care must be established between the paediatric cardiac surgical department and the PCICU.

Conclusion

Seriously ill and postoperative cardiac patients are best managed in the ICUs designed for them. A multidisciplinary team of intensivists, paediatric cardiologists, paediatric cardiac surgeons and others is designed to provide optimal care to the critically ill paediatric cardiac patient, using specifically dedicated facilities, equipment and strategies.

Conflict of interest statement

None.

References