“Fast Tracking” Paediatric Cardiac Surgical Patients

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Technological advances in diagnostic cardiology, anaesthetic/surgical/extracorporeal techniques, and improvements in the perioperative management strategies have all contributed to successful outcome of surgical procedures performed on neonates, infants and children with congenital heart disease (CHD). There has been a substantial decrease in the morbidity and mortality in these groups of patients despite the complexity of disease pattern. However, improvements in morbidity and mortality are associated with a significant increase in the cost of treatment. The focus in now directed towards provision/delivery of cost–effective patient care and issues in intensive care unit (ICU) settings like duration of mechanical ventilation and length of ICU stay are gaining attention of both the clinicians and the hospital managers.

Problems in children with CHD in ICU settings include the following: (i) Infants and children are not miniature adults. They have important anatomical/physiological differences when compared to the adults and these concerns need to be addressed when dealing with children with CHD just as with any child with any other organ disorder. (ii) Neonates, infants and young children are not able to communicate their level of distress and discomfort. We rely on indirect clinical evidence from autonomic responses to stress, such as hypertension and tachycardia, and make assumptions regarding the level of pain relief or sedation. (iii) Paediatric patients are more likely to receive neuromuscular blocking agents to facilitate synchronization with mechanical ventilation and to prevent inadvertent dislodgement of invasive monitoring catheters and chest tubes. (iv) Patients with CHD depend on a delicate balance between circulatory pathophysiology and compensatory mechanisms. The compensatory mechanisms often decrease cardiopulmonary reserve and increase their susceptibility to physiological insult. This diminished margin of safety characterizes the paediatric patient with CHD and dictates the guidelines of care. The generally used criteria for weaning paediatric patients are listed in table 1.

Table 1. Criteria for withdrawal of ventilatory support and extubation following Paediatric cardiac surgery

1. Cardiovascular
   (i) Stable haemodynamics with no/minimal/moderate inotropic support
   (ii) No disturbing arrhythmias
   (iii) Evidence of adequate peripheral perfusion e.g., warm peripheries
   (iv) No risk of pulmonary hypertensive crises
   (v) Normal/acceptable filling pressures (e.g. left/right atrial pressures).
   (vi) No hypertension/risk of rupture of suture lines

2. Respiratory
   (i) Clear chest (both clinically/radiologically)
   (ii) Good blood gas exchange
   (iii) Good muscle strength/cough-reflex (full recovery from neuromuscular blockade)

3. Neurological
   (i) Adequate neurological status to protect airway from aspiration
   (ii) Good/adequate pain control

4. Renal
   (i) Adequate/satisfactory urinary output (>0.5 ml/kg/hr)

5. Metabolic
   (i) No/minimal acidosis; acidosis not increasing

6. Haematological
   (i) No excessive bleeding from chest tubes
   (ii) Acceptable haematocrit

Definition of ‘Fast-track’

The term ‘fast track’ is used to describe a method for reducing costs and length of stay for surgical patients. A “fast track” approach to cardiac surgery
can be defined as a perioperative process involving rapid progress from preoperative preparation through surgery and discharge from the hospital. Early extubation may be a component of this, however, early extubation and ‘fast track’ are not synonymous. The early tracheal extubation of children following congenital heart surgery is not a new concept, but has received renewed attention with the evolution of ‘fast track’ management for cardiac surgical patients. The debate regarding early extubation following cardiac surgery is sometimes confounded also by differing definitions of early extubation. In most studies, early extubation refers to tracheal extubation within a few hours (4–8 hours) after surgery, although functionally it means the avoidance of routine, overnight mechanical ventilation.

Although highly individualized among the various heart surgery centres, the fast-track process is a team activity. It requires a team of health care providers to interact with the patient at various phases, from admission to discharge. The necessary elements of the fast-track program are choice and the titration of short-acting anaesthetic drugs, standardized surgical procedures, early extubation, rewarming and sustained postoperative normothermia, postoperative pain control, early ambulation, alimentation and discharge, and follow-up after discharge. The factors influencing the decision to early extubation are summarized in table 2.

Factors which delay tracheal extubation and ICU discharge:

1. Over the past two decades, there has been a change in the philosophy of management of cardiac operations on neonates and infants. This relates to performing reparative operation first when the patient presents for surgery rather than initial palliation and later repair. The primary aim of early repair is to promote normal growth and development and to limit the pathophysiological consequences of congenital cardiac defects such as volume overload, pressure overload, and chronic hypoxaemia. However, because of a limited physiological reserve and the complications associated with cardiopulmonary bypass (CPB) and surgery, the risk of cardiorespiratory dysfunction in neonates and young infants in the immediate postoperative period may be increased.

2. The effects of prolonged CPB relate in part, to the interactions of blood components with the extracorporeal circuit and result in a systemic inflammatory response syndrome (SIRS). This is magnified in neonates and infants due to the large bypass circuit surface area and priming volume relative to patient blood volume. Humoral responses include activation of proinflammatory cytokines, and complement, kallikrein, eicosanoid and fibrinolytic cascades. (Eicosanoids are derived from arachidonic acid by three separate groups of enzymes, namely cyclo-oxygenases, lipo-xygenases and CYP (cytochrome P450) mono-oxygenases and CYP (cytochrome P450) mono-oxygenases; these substances are prostaglandins, prostacyclins, thromboxanes, leucotrienes, dihydrotetraenoic and epoxy eicosatrinenoic acids). Cellular

<table>
<thead>
<tr>
<th>Table 2. Considerations, which influence the decision to early extubation¹</th>
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</thead>
<tbody>
<tr>
<td><strong>Patient factors</strong></td>
</tr>
<tr>
<td>Pathophysiology of specific congenital heart defects</td>
</tr>
<tr>
<td>Premedication</td>
</tr>
<tr>
<td>Anaesthetic factors</td>
</tr>
<tr>
<td>Postoperative analgesia</td>
</tr>
<tr>
<td>Surgical factors</td>
</tr>
<tr>
<td>Conduct of CPB</td>
</tr>
<tr>
<td>Myocardial protection</td>
</tr>
<tr>
<td>Modulation of the inflammatory response and reperfusion injury</td>
</tr>
<tr>
<td>Postoperative management</td>
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responses include endothelial activation, platelet activation, endotoxin release and an inflammatory adhesion molecule cascade stimulating neutrophil activation and release of proteolytic and vasoactive substances. The clinical consequences of this reaction to CPB include increased interstitial fluid and generalized capillary leak, plus the potential for multi-organ dysfunction. For example (i) total lung water may be increased with an associated decrease in lung compliance and increase in alveolar to arterial (A–a) oxygen gradient, (ii) myocardial oedema results in impaired ventricular systolic and diastolic function, (iii) fall in cardiac output by 20–30% is common in neonates in the first 6–15 hours following surgery, (iv) decreased renal function and oliguria, (v) sternal closure may require delay due to mediastinal oedema, ascites, and hepatic congestion, (vi) bowel oedema causes a prolonged ileus or delayed feeding.

3. Ischaemia-reperfusion injury.

4. Metabolic derangements such as altered glucose homeostasis, metabolic acidosis, salt and water retention, and a catabolic state contributing to protein breakdown and lipolysis are commonly seen following major stress in sick neonates and infants. This complex of maladaptive processes may be associated with prolonged mechanical ventilation and ICU stay, as well as increased morbidity and eventual mortality.

5. These patients also provide additional challenge in the ICU because of co-morbidities related to long-standing physiological derangements such as cyanosis/hypoxaemia, pulmonary hypertension, or heart failure.

(i) With severe hypoxaemia/cyanosis, numerous adaptations occur to allow reasonable levels of oxygen consumption. These compensatory mechanisms include polycythaemia, increased blood volume, vasodilatation, neovascularization and alveolar hyperventilation with chronic respiratory alkalosis. These adaptive mechanisms increase vascular resistance, impair global ventricular function and redistribute blood flow to the heart and brain. In addition, peripheral sludging of blood in polycythemic children induces a state of hyperfibrinolysis secondary to intravascular stasis and thrombosis. These children have decreased clotting factors, increased fibrinolysis and reduced number of functional platelets predisposing them to increased postoperative blood loss and morbidity.

(ii) Cardiac failure is most commonly associated with shunt lesions in which the pulmonary-to-systemic blood flow exceeds 2:1, in vascular lesions with obstructed forward flow, coarctation of aorta or lesion like anomalous left coronary artery from pulmonary artery. The child with failing heart will increase endogenous catecholamine production and redistribute cardiac output to essential organs, resulting in increased heart rate, decreased skin temperature and metabolic acidosis. The increased work of breathing inhibits nutritional intake in infants and promotes malnutrition and failure to thrive.

(iii) Pulmonary hypertension often complicates the perioperative care of many children with congenital heart disease such as endocardial cushion defects, patent ductus arteriosus (PDA), ventricular septal defect and aortic outflow anomalies. Chronically excessive pulmonary blood flow contributes to progressive dysfunction of the mechanisms of pulmonary vasorelaxation. Changes in the pulmonary vascular endothelial surface and increased production, release, or activation of serine elastase in the vessel wall may contribute to development of pulmonary vascular obstructive changes. In addition, endothelin, a potent vasoconstrictor peptide released from endothelial cells is elevated in children with pulmonary hypertension secondary to congestive heart disease.

6. Complications such as neurological injury, renal
failure and respiratory failure (including that due to diaphragmatic paralysis) and gastric stress ulceration.

7. Sepsis and its attendant sequel.

8. High dose opioid anaesthesia: Prolongs duration of mechanical ventilation, delays establishing enteral nutrition, induces tolerance and acute withdrawal phenomena and prolongs discharge from ICU.

All of the above clinical considerations will ultimately delay recovery in the ICU following surgery and prolong stay, thereby increasing the cost of postoperative care.

Along with the advances in preoperative diagnosis and management, numerous strategies have been evolved to limit the effect of the cellular injury that results from the systemic inflammatory response. Few of the strategies which have been introduced in the last two decades to prevent/ameliorate the effects of CPB are the use of (i) modified ultrafiltration (ii) leucocyte filters (iii) heparin bound circuits (iv) methyl prednisolone (v) aprotinin (vi) all procedures directed towards organ preservation.

Relationship of the underlying disease and feasibility of early extubation:

Each patient and his/her circumstances must be viewed individually and managed according to preoperative condition and stability, surgeon preference, any surgical or CPB-related complications and postoperative cardio–respiratory status.

1. Closed cardiac procedures: In general, patients undergoing selected uncomplicated closed heart procedures, i.e. those that don't involve the use of CPB, are suitable for “fast track” management plan. Examples include infants and children undergoing ligation of PDA, repair of coarctation of aorta, Blalock-Taussig shunt, etc. However, the following patients need to be evaluated and assessed on an individual basis prior to committing them to early extubation. (i) patients in heart failure (ii) patients in respiratory failure prior to surgery (iii) patients who sustained cardiac arrest/complication during operation (iv) patients who exhibit rebound hypertension and need protection of aortic suture lines from excessive tension.

2. Open cardiac procedures:

a) Uncomplicated left to right shunts like atrial septal defect (ASD) ventricular septal defect (VSD), right ventricle to pulmonary artery conduits, with relatively short bypass times using mild to moderate hypothermia are suitable for tracheal extubation early after admission to ICU.

b) Left to right shunts, e.g. ASD, VSD, PDA, aorto-pulmonary window, complicated with pulmonary hypertension/heart failure need reassessment of their disease status prior to extubation. These patients benefit from extended mechanical ventilatory support.

c) Atroventricular canal defect, tetralogy of Fallot and large VSD: Infants who are in stable clinical condition prior to surgery and who are undergoing a complete repair using moderate-to-deep hypothermia on CPB, such as those undergoing closure of a large VSD, complete atrioventricular canal defect, or tetralogy of Fallot, are often suitable for extubation in the first 24–48 hours after surgery.

d) Cavo-pulmonary connection: Following creation of a cavo-pulmonary connection, whether it be a bi-directional Glenn shunt or a modified Fontan procedure, patients usually benefit from early tracheal extubation. Effective pulmonary blood flow is enhanced during spontaneous ventilation because of the lower mean intrathoracic pressure.

e) Two-ventricle repairs: Early tracheal extubation and ‘fast track’ management is not suitable for many neonates and infants undergoing complex two-ventricle or reparative procedures, although such an approach has been reported for selected
patients. A review of 56 patients with mean age of 32±31 days and mean weight of 3.7 ±0.9 kg, which evaluated early extubation after congenital heart surgery, reports 11% incidence of re-intubation and re-institution of mechanical ventilation. Neonates less than 7 days of age and those with complex lesions are less likely to be extubated early. Selected patients with a broad spectrum of congenital heart disease may enjoy same-day admission, limited sternotomy, immediate extubation, and very early discharge with excellent outcomes and acceptable morbidity. At Narayana Hrudayalaya, neonates undergoing two-ventricle repairs are usually managed with sedation and/or paralysis in the immediate postoperative period until haemodynamic and respiratory stability has been attained. Examples of two-ventricle repairs include arterial switch operations, Sennings/Mustards repair for transposition of great arteries, repair of interrupted aortic arch with VSD closure, etc. Neonates, children who have undergone a right ventriculotomy, such as following neonatal repair of tetralogy of Fallot or truncus arteriosus, commonly demonstrate restrictive right ventricle physiology in the immediate postoperative period. A low cardiac output state with increased right sided filling pressure may be evident, and continuing sedation and paralysis is often necessary for the first 24–48 hours until diastolic function improves.

g) Left ventricular outflow reconstruction: Infants and older children undergoing some types of left ventricular outflow tract repair, including sub-aortic stenosis repair or sub-aortic membrane resection, and aortic valvuloplasty or replacement, usually have well preserved and often hyperdynamic ventricular systolic function. Hypertension and tachycardia are frequently a management concern in these patients in the immediate postoperative period. Not only will this increase the risk for disruption of suture lines, but the increased myocardial work may contribute to ischaemia and increase the likelihood for ventricular tachyarrhythmias. This is especially a concern during emergence from anaesthesia and sedation. Provided ventricular function is stable, haemostasis has been secured, and there are no concerns for ventricular tachyarrhythmias, it is often preferable for these patients to be extubated early after surgery (6–12 hours), rather than undergoing a more prolonged weaning process.

Psychological considerations:

Patient education, family orientation, and postoperative support systems are also essential when planning early discharge. Most children prefer to be extubated early and be discharged home as soon as possible. Parents often view intubation and mechanical ventilation as an index of the severity of their child’s condition following surgery and prefer to have their child extubated early.
Conclusion

The procedure of “fast tracking” neonates and small children with CHD after cardiac surgery is highly challenging and involves interplay of several complex factors – it can be likened to a ‘tight-rope walking’. This process requires continuous evaluation, critical reappraisal and emphasis on multidisciplinary approach with particular attention to availability and expertise of nursing staff and medical/paramedical personnel involved in patient care. From the above discussion, it is clear that the decision to fast track paediatric cardiac surgical patients is dependent upon several factors. In general, patients who undergo uncomplicated (i) closed – heart procedures (ii) open-heart procedures with relatively short CPB times are suitable for fast tracking. In all others, the judgment to ‘fast track’ is taken after due consideration of several preoperative, intraoperative and postoperative issues.

References

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