Aetiology and outcome of paediatric cardiopulmonary arrest

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Learning objectives

After reading this article you should be able to:

- understand the aetiology of paediatric cardiopulmonary arrest
- understand outcomes of paediatric cardiopulmonary arrest and recent changes in guidelines that may influence outcome
- introduce recent techniques being used in paediatric resuscitation

Abstract

Paediatric cardiopulmonary arrest is an uncommon event in children, but with appropriate management of their prevention and treatment, outcomes can be reasonable. This article looks at the causes of arrests in children, the likely outcomes, and the ways in which this can be improved.

Keywords Cardiopulmonary arrest; extracorporeal life support; hypothermia therapy; ILCOR; paediatric; resuscitation

Introduction

Cardiopulmonary arrest (CPA) is less common in children than in adults; however it is not uncommon in the hospital setting, particularly in operating theatres and paediatric intensive care units (PICUs). Under anaesthesia, overdose of anaesthetic drugs, especially halothane, used to be the most common cause but this has diminished along with its use. Hypovolaemia, electrolyte disturbances and laryngospasm are now the most frequent causes. Overall outcome from paediatric CPA is better than in adults. The best outcomes are seen in witnessed arrests and when resuscitation is started early and performed by properly trained teams. Respiratory arrest alone has a good outcome, but the chance of successful resuscitation decreases quickly with time compared to cardiac causes. In cardiac arrest, the predominant rhythms are asystole or pulseless electrical activity (PEA), but the shockable rhythms — ventricular fibrillation or tachycardia (VF/VT) are more common than formerly thought especially in hospitalized children and in adolescents. Survival to discharge is more likely if the initial rhythm is shockable.

In this article the epidemiology of paediatric CPA and recent work on outcome is reviewed, and the question of predicting outcome is addressed.

Epidemiology

Paediatric CPA has an incidence of around 8–9/100,000[1] person-years in the out-of-hospital setting and approximately one per 1000 in-hospital patients.[2] Evidence indicates that children and adolescents have better outcomes from CPA and have a decreased frequency (~5/100,000) compared to infants (~70/100,000) and adults (~125/100,000).[1] Data have been difficult to analyse in the past due to differences in the recording of information between different centres. The Utstein template[3] for data collection has been widely adopted and is used by the National Registry of Cardiopulmonary Resuscitation in North America (NRCPR). This registry prospectively records cardiac arrest data from a number of institutions and has so far published on outcomes, hospital characteristics, calcium use, VF in children and paediatric in-hospital cardiac arrests.

Aetiology

Three physiological derangements lead to CPA — asphyxia (respiratory arrest), ischaemia and arrhythmia. In the NRCPR database asphyxia occurred in 67%, ischaemia in 61% and arrhythmia in 10%. Some had both ischaemia and asphyxia. 65% of arrests occurred in the ICU and 95% were witnessed or monitored. The initial rhythm was asystole in 40%, VF or VT in 14%, PEA in 24% and undocumented in the remainder.[2] It is important to remember that the diagnosis of paediatric CPA is often difficult to define and that cardiopulmonary resuscitation (CPR) is often commenced in the presence of a weak pulse or when the child is bradycardic, especially since the use of a pulse check has been de-emphasized in recent guidelines. These events are often not included in studies, but may represent two-thirds of initial rhythms.

Out-of-hospital arrest (OHCA)

Sudden infant death syndrome (SIDS) is the commonest cause of out-of-hospital arrest followed by trauma, airway problems and near-drowning. Out-of-hospital arrest carries a very high mortality with only 1–2% surviving to hospital discharge and only about 25% of the survivors having a favourable neurological outcome.[4] The majority of arrests are unwitnessed and bystander CPR is commenced in under a third. Unwitnessed arrests and increased time to initiation of CPR correlate with mortality.[5] SIDS and blunt trauma carry the highest mortality with the lowest seen after respiratory arrest. The initial rhythm documented by medical personnel at presentation was more frequently asystole or pulseless electrical activity (PEA) than a shockable rhythm. In-hospital arrest (IHCA) is 100 times more frequent than OHCA. Two-thirds of the arrests occur in the ICU environment with 1–6% of PICU and 4–6% of cardiac ICU admissions experiencing CPA.[2] IHCA is more commonly cardiac in origin and patients have increased co-morbidities. Outcomes

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are better than OHCA with return of spontaneous circulation (ROSC) seen in approximately two-thirds of patients and survival to discharge varying from 16% to 44%.[2] Neurological outcomes are reported as favourable in up to a third of survivors. Although overall outcomes are better, mortality is increased in cardiac versus respiratory arrest, unwitnessed arrest or in the presence of sepsis, inotropic support and/or mechanical ventilation.[5] Cardiac arrest following cardiac surgery has the most favourable prognosis, presumably since it is somewhat expected and the patients are usually monitored in an intensive care setting.

Outcomes

There has been a demonstrable improvement in outcome over the last 30 years or so. In the 1980s survival after in-hospital cardiac arrest was only 9%, whereas by 2006 it was over 25%. The most recent work on outcomes has focused on predicting which children will do badly after CPA, as well as concentrating on therapeutic and technological interventions that can be applied to improve prognosis. Cardiopulmonary arrest can be divided into four phases: pre-arrest; no-flow phase; low-flow phase and post-resuscitation. Outcomes may be influenced by interventions at any of these stages. There is a paucity of level 1 or 2 evidence (randomized controlled trials with large or smaller benefit) in paediatric resuscitation, but some strategies are supported by good-quality evidence, for example bag-mask ventilation is as effective as intubation; the use of appropriately sized cuffed endotracheal tubes is safe in infants and children; and high-dose adrenaline is associated with a worse outcome in most circumstances. The International Liaison Committee on Resuscitation (ILCOR) Paediatric Task Force meets every 5 years to review new evidence on cardiac arrest management and to provide up-to-date guidelines.[6] In the past, outcomes were so poor that resuscitation training, and work such as this, focused primarily on prevention. Now outcomes are improving and subtle changes in resuscitation guidelines may well be responsible for this enhanced survival. Some of the recent evidence on outcomes is reviewed below.

Pre-arrest

Patients at risk of arrest can be identified early and management initiated to prevent further deterioration. Paediatric cardiopulmonary arrest is usually heralded by a decline in physiology as opposed to an acute event. This lends itself to the use of early warning scores and medical emergency teams in preventing arrests.[6] In addition, resuscitation courses such as advanced paediatric life support (APLS) and European paediatric life support (EPLS) focus on the recognition and management of the sick child in addition to resuscitation, and this may modify the outcome of a paediatric CPA. Adult data have been able to demonstrate increased ROSC, survival to hospital discharge and 1-year survival following the introduction of life support courses.[6] Simulation is becoming more commonplace in medical education, and certain strategies such as 'just-in-time' and 'just-in-place' training may enhance resuscitation outcomes.[7]

No-flow

During this phase, cardiac arrest has already occurred, and there is no circulatory flow. Witnessed arrests and arrests where bystander CPR is initiated are associated with a better outcome, as is limiting the time before institution of cardiopulmonary resuscitation. For this reason, recent guidelines de-emphasize the 'pulse check for 10 seconds' and emphasize 'looking for signs of life'.[6]

Low-flow

During this phase CPR restores a low-flow state. The purpose of CPR is to maintain coronary and cerebral perfusion, augmented by adrenaline-induced vasoconstriction. Recent ILCOR guidance recommends 'push hard, push fast, minimize interruptions and do not excessively ventilate'.[6] Discontinuing chest compressions to ventilate have been shown to reduce diastolic blood pressure and therefore coronary perfusion pressure significantly. It is now recommended that chest compressions are not interrupted for ventilation once the airway is secured. The optimal ratio for compressions to ventilations has been extensively studied, the current recommendations are 30:2 for the lone rescuer at all ages, and 15:2 for two rescuers. Optimum compression depth has also been studied. Compression to a depth of one-third of the hemithorax is now recommended in children. This is more effective than a quarter, but safer than a half.[6] Devices have been developed to improve the efficiency of CPR, including the impedance threshold device (ITD) which limits inspiratory flow and maintains negative intrathoracic pressure, and the active compression decompression (ACD) device, which causes active chest wall suction to improve venous return and cardiac output. Both devices show promise, but have not been extensively studied in children. The ITD has been used in acute haemorrhagic hypovolaemia in paediatric animal models.[8] Defibrillation may be required for shockable rhythms. It has been found that a single shock strategy is more successful, and limits interruptions to CPR.[6] Management of the airway may influence outcome during this stage. Where possible endotracheal intubation should be performed. Cuffed endotracheal tubes (ETT) previously not widely used in children, improve correct choice of size using the formula ETT internal diameter = age/4 + 3.5.[6] In OHCA arrests, particularly trauma, paramedic performed intubation is associated with a poorer outcome and management with bag-mask ventilation is recommended.[6] Compression-only CPR has been proposed as an alternative to conventional CPR, especially when performed by bystanders with no experience of ventilation. Outcome using this technique may be no more superior in cardiac causes, but in respiratory arrest the outcome is worse.[6]

Extracorporeal membrane oxygenation (ECMO) and CPR (ECPR)

ECMO is one of the few interventions that significantly improves outcome in IHCA. Successful resuscitation after a CPA duration of over 90 minutes has been reported. In some paediatric centres it may be readily available and can be initiated during the low-flow phase in refractory cardiac arrest (extracorporeal cardiopulmonary resuscitation, ECPR). Patients are deemed suitable if there is a known reversible cause or the patient is a candidate for cardiac transplantation. A number of studies of ECPR in children, including those with a functional single ventricle, have demonstrated survival to hospital discharge of approximately 50% with favourable neurological outcomes in approximately 75%.[9] Patients with non-cardiac disease, arrests outside of ICU or catheter lab areas, higher post-ECMO lactate levels and longer ECMO runs tend to have poorer outcomes.[10] In a single-centre retrospective study of 172 patients,