Aetiology and outcome of paediatric cardiopulmonary arrest

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Abstract

Paediatric cardiopulmonary arrest is an uncommon event in the general population but is not infrequent in the paediatric hospital setting. 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

Royal College of Anaesthetists CPD Matrix: 1B04, 2C04, 2D01, 3D00

Learning objectives

After reading this article, you should be able to:

- understand the aetiology of paediatric cardiopulmonary arrest
- understand outcomes of paediatric cardiopulmonary arrest
- discuss new techniques and changes in paediatric resuscitation guidelines that may influence outcome

Introduction

Cardiopulmonary arrest (CPA) is less common in children than in adults. However it is not uncommon in the hospital setting particularly in the operating theatre and paediatric intensive care unit (PICU). Intraoperative use of halothane used to be the most common cause of CPA but this has diminished along with its use in the developed world. Hypovolaemia, electrolyte disturbances and laryngospasm are now the most frequent causes. 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, although 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 adolescents. Survival to discharge is more likely if the initial rhythm is shockable.

Epidemiology

Paediatric CPA has an incidence of around 8–9 per 100,000 person-years in the out-of-hospital setting and approximately 1 per 1000 in hospital patients. Evidence indicates that children and adolescents have a decreased incidence of CPA (~5/100,000) compared to infants (~70/100,000) and adults (~125/100,000) and have better outcomes.[1] Data have been difficult to analyse in the past due to differences in the recording of information between different centres. The Utstein template 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 that choose to join and has published data on outcomes in children and paediatric in-hospital cardiac arrests. The Cardiac Arrest Registry for Enhanced Survival (CARES) established a database in 2004 for outcomes of all out of hospital cardiac arrests in the USA. The UK Out Of Hospital Cardiac Arrest Outcome Project is currently underway, focussing on identifying variation in outcome and long term survival. The group wants to investigate the feasibility of developing a UK OHCA registry.

Aetiology

Three physiological derangements lead to CPA – asphyxia (respiratory arrest), ischaemia and arrhythmia. Asphyxia occurred in 67%, ischaemia in 61% and arrhythmia in 10% in the NRCPR database. Some had both ischaemia and asphyxia. Sixty-five percent of arrests occurred in the PICU 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] The diagnosis of paediatric CPA is often difficult to define and cardiopulmonary resuscitation (CPR) may be 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 resuscitation 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 most common cause of out-of-hospital arrest followed by trauma, airway problems and near-drowning. A single centre Canadian study showed that 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.[3]

The CARES registry analysed data from 4198 paediatric OHCA from 2005 to 2013. There were 47% of patients who had a non-cardiac cause, of which respiratory and trauma were the main categories. Within the cardiac causes group, 90% presented with a non-shockable rhythm; 8.2% survived to hospital discharge. Survival was more common in those with a shockable rhythm (45%), witnessed arrests and teenagers. There was no improvement in survival rates over time despite an increase in

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bystander CPR to 40% and bystander automatic external defibrillator (AED) use in 8% of cases.[4]

Unwitnessed arrests and increased time to initiation of CPR correlate with mortality. SIDS and blunt trauma carry the highest mortality with the lowest mortality due to respiratory arrest.[5]

In-hospital cardiac arrest (IHCA)

In-hospital cardiac arrest (IHCA) is 100 times more frequent than OHCA. One paper showed that 66% of the arrests occur in the ICU environment with 1–6% of PICU and 4–6% of cardiac ICU admissions requiring CPR. IHCA is more commonly cardiac in origin and patients have more co-morbidities.[2] A multicentre retrospective review of nearly 330,000 critically ill children found an incidence of cardiac arrest of 2.2% and mortality of 35% in 2014.[6]

IHCA outcomes 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 one-third of survivors. Although overall outcomes are better, mortality is increased in cardiac compared to 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 because high-risk patients are identified and patients are usually monitored in an intensive care setting allowing early diagnosis and management.

Outcomes

There has been an improvement in cardiac arrest outcome over the last thirty years. In the 1980s survival after in-hospital cardiac arrest was only 9% whereas by 2006 it was over 25%. Interestingly the CARES registry has shown no improvement in outcomes since 2005 when the database was created.[4]

Phases of cardiac arrest

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. 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 for prevention and treatment.[7]

Pre-arrest

Patients at risk of arrest can often 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 can be identified by the use of early warning scores and action of the medical emergency team to prevent arrests. 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. Adult data have been able to demonstrate increased ROSC, survival to hospital discharge and 1-year survival following the introduction of life support courses.[9] Simulation training is becoming more commonplace in medical education and may enhance resuscitation outcomes.

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. Early identification of arrest and initiation of chest compressions is associated with better outcomes and for this reason, recent guidelines de-emphasize the 'pulse check for 10 seconds' and emphasize 'looking for signs of life'.[7]

Low-flow

During this phase, CPR restores a low blood flow state. The purpose of CPR is to maintain coronary and cerebral perfusion, augmented by adrenaline-induced vasoconstriction. Discontinuing chest compressions to ventilate has 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 depth and ratio for compressions to ventilations has been extensively studied, the current recommendations are 30:2 for the lone rescuer at all ages to avoid confusion and minimize position change, and 15:2 for two rescuers. Compression to a depth of one-third of the hemithorax is now recommended in children. This is more effective than one-quarter, but safer than a half. The importance of chest wall recoil is emphasized.[7]

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 haven't been extensively studied in children.

Defibrillation is essential for shockable rhythms. It has been found that a single shock strategy is more successful, and limits interruptions to CPR. A stacked three shock strategy is recommended in patients with a likely primary cardiac arrhythmia that is witnessed or a history of cardiac surgery.[7]

Management of the airway may influence outcome during this stage. Endotracheal intubation should be performed if the provider is appropriately skilled, if not the use of a supraglottic airway device is recommended. Cuffed endotracheal tubes (ETT) were previously not widely used in children due to concerns about subglottic oedema and subsequent tracheal stenosis. The correct size is smaller than an uncuffed ETT and can be calculated using the formula ETT internal diameter = age/4 + 3.5. In OHCA arrests, particularly trauma, paramedic-performed intubation is associated with a poorer outcome and management with bag-mask ventilation is recommended. Compression-only CPR has been proposed as an alternative to conventional CPR, especially when performed by untrained or inexperienced bystanders.

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