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Chapter 1

Resuscitation

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Cardiopulmonary Resuscitation Overview

Cardiopulmonary arrest in infants and children is rarely a sudden event. The usual progression of arrest begins with hypoxia, hypercarbia, and acidosis resulting in respiratory failure, which eventually leads to asystolic cardiac arrest. Etiologies include sudden infant death syndrome (SIDS), respiratory disease, sepsis, major trauma, submersion, poisoning, metabolic/electrolyte imbalance, and congenital anomalies. In contrast, primary cardiac arrest is relatively rare in the pediatric age group and is most frequently caused by congenital heart disease, myocarditis, and chest trauma with myocardial injury. Although asystole and pulseless electrical activity (PEA) are the primary rhythms in pediatric cardiac arrest, patients with sudden cardiac arrest are likely to have ventricular tachycardia (VT) or ventricular fibrillation (VF).

The outcome of unwitnessed cardiopulmonary arrest in infants and children is poor. Less than 10% of pediatric patients who have out-of-hospital cardiac arrests survive to discharge and most are neurologically impaired. In contrast, about one-third of children with in-hospital cardiac arrest survive to hospital discharge, with a better neurological outcome.

Begin resuscitation with C-A-B: Chest compression, Airway and Breathing, as the key factor in return of spontaneous circulation (ROSC) and survival is the maintenance of adequate coronary artery and cerebral artery perfusion. This is best achieved by starting resuscitation with chest compressions. However, individualize the CPR sequence based upon the location of the arrest and the presumed etiology.

Emergency Department Priorities

To optimize outcome, it is essential to recognize early signs and symptoms of impending respiratory failure and circulatory shock prior to the development of full cardiopulmonary arrest. All equipment, supplies, and drugs must be available and organized for easy access. It is imperative that the staff have training in American Heart Association Pediatric Advanced Life Support (PALS), and routinely practice mock pediatric resuscitations. Pediatric Advanced Life Support utilizes a systematic approach to the assessment and treatment of seriously ill or injured pediatric patients.

In order to optimize care in a high-stress situation, use pre-calculated drug sheets or the Broselow tape, a height-based weight system for accurate dosing of resuscitation medication which also offers immediate access to pre-sized emergency equipment. In addition, develop and maintain a comprehensive plan to organize the resuscitation team (Figure 1.1). Assign

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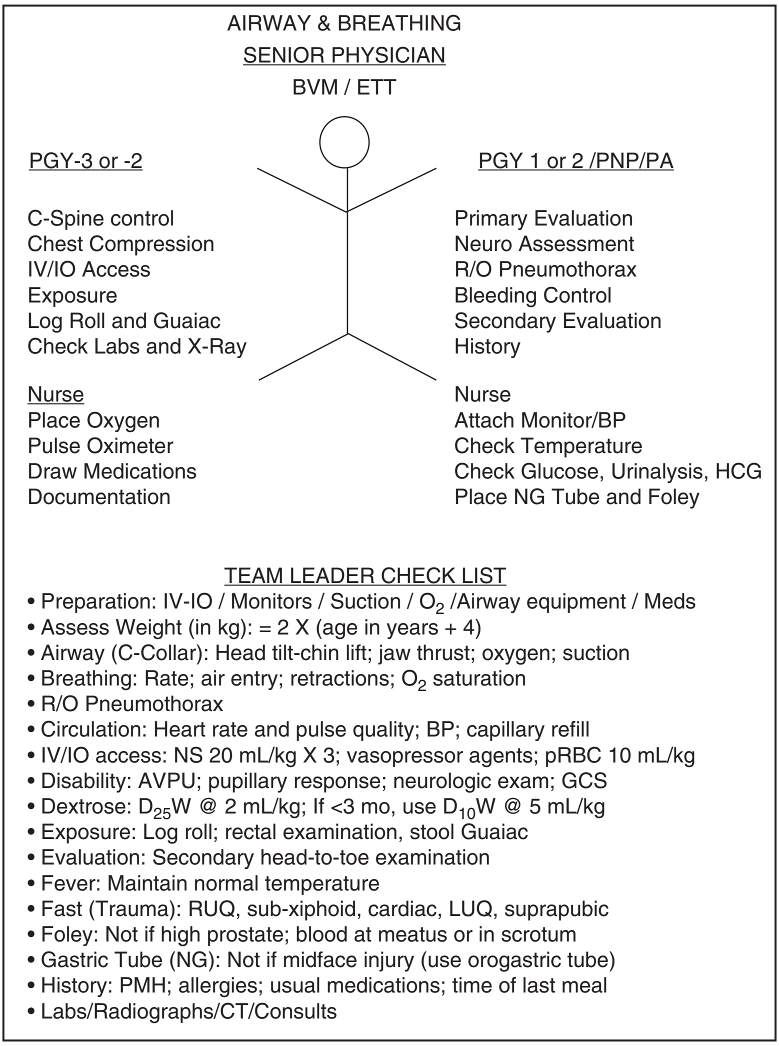

Figure 1.1 Resuscitation team roles and preparation

a role to each team member: team leader, airway management, chest compressions, achieving vascular access, obtaining a history, medication administration, recorder, and runner. Identify a team leader early whose sole responsibility is to oversee the resuscitation and coordinate the team dynamics. Ideally, along with the physicians and nurses, a respiratory therapist and pharmacist will assist the team. Prepare the essential equipment needed for resuscitation in advance, using the mnemonic IMSOAPP (Table 1.1).

Rapid Cardiopulmonary Assessment

Quickly perform a primary evaluation, which focuses on the *A*ppearance, *A*irway, *B*reathing and *C*irculatory (ABCs) status of the patient. This initial examination provides assessment

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Table 1.1 IMSOAPP mnemonic for resuscitation

I	IV fluids/IV catheter/intraosseous needle
M	Monitors: cardiorespiratory; pulse oximeter; blood pressure
S	Suction: tonsil tipped (Yankauer) and flexible catheters
O	100% Oxygen source
A	Airway equipment Bag-mask: different size masks Oral airway: nasopharyngeal and oral Laryngoscope with assorted blades: Miller, Macintosh Tracheal tube: cuffed and uncuffed, multiple sizes Stylet
P	Pharmacy: medications, either a pre-calculated drug sheet or Broselow tape
P	Personnel: call a code, have resuscitation team available

of the patient's acuity, and prioritizes the urgency and aggressiveness of intervention in response to the degree of physiologic compromise. Following stabilization of the ABCs, the secondary assessment includes a complete head-to-toe examination of the patient, while maintaining normothermia and normoglycemia.

Appearance

Assess the general appearance of the patient. Evaluate the activity level of the child, reaction to painful or unfamiliar stimuli, interaction with the caretaker, consolability, and the strength of cry, relative to the patient's age.

Airway

Airway patency is particularly prone to early compromise in pediatric patients, as the airway diameter and length are smaller than in adults. Determine whether the airway is clear (no intervention required), maintainable with noninvasive intervention (positioning, suctioning, oropharyngeal or nasopharyngeal airway placement, bag-mask ventilation) or not maintainable without intubation.

Breathing

Ventilation and oxygenation are reflected in the work of breathing and can be quickly assessed by the mnemonic RACE:

- Rate: age-dependent. Tachypnea is often the first sign of respiratory distress, but it may also be secondary to acidosis.
- Air entry:
  - listen to breath sounds in all areas: anterior and posterior chest, axillae
  - a priority is to rule-out tension pneumothorax: absent breath sounds, tracheal deviation
  - abnormal sounds: rales, rhonchi, wheezing.

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- Color
  - pink, pallid, cyanotic, or mottled
  - pulse oximetry: use the O_2 saturation as the fifth vital sign.
- Effort/mechanics:
  - "Tripod" position, nasal flaring, grunting, stridor, head bobbing;
  - Accessory muscle use: sternocleidomastoid prominence;
  - Retractions: suprasternal, subcostal, intercostal.

The presence of abnormal clinical signs of breathing such as grunting, severe retractions, mottled color, use of accessory muscles, and cyanosis are precursors to impending respiratory failure.

Circulation

The circulatory status reflects the effectiveness of cardiac output as well as end-organ perfusion. The rapid assessment includes:

- Cardiovascular function:
  - heart rate: age-dependent
  - central and peripheral pulses: compare the femoral, brachial, and radial pulses
  - blood pressure: age-dependent; use the following guidelines to estimate the lowest acceptable (fifth percentile) systolic BP:
    - Newborn to 1 month = 60 mm Hg
    - 1 month to 1 year = 70 mm Hg
    - 1–10 years = 70 mm Hg + (2 × age in years)
    - >10 years = 90 mm Hg.
- End-organ perfusion (systemic circulation):
  - skin perfusion: capillary refill (<2 seconds normal), color, extremity temperature (relative to ambient temperature)
  - renal perfusion: urinary output = 0.5–1 mL/kg/h (about 30 mL/h for an adolescent)
  - CNS perfusion: mental status, level of consciousness, irritability, consolability, AVPU response:

    A awake
    V responsive to voice
    P responsive to pain
    U unresponsive.

Tachycardia and tachypnea are early signs of cardiorespiratory compromise. Observe for central or peripheral cyanosis and feel the skin temperature and moisture. With the fingers at the level of the heart, apply pressure to the nail bed until it blanches, then release, timing the interval until the fingertip "pinks up." Delayed capillary refill (>2 seconds), and cool, clammy extremities are clinical indicators of poor perfusion. A systolic blood pressure below the fifth percentile (measured with an appropriate-size cuff), loss of central pulses, oliguria, and altered level of consciousness are ominous signs of impending hypotensive/decompensated circulatory shock.

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Initial Management

Immediate goals in the emergency department (ED) include supporting ventilation and organ perfusion. After a quick initial assessment, determine if the child is responsive and is breathing with a pulse. If the patient is unresponsive, not breathing or only gasping, without a pulse, immediately start CPR starting with chest compression, open and maintain the airway, support ventilation and perfusion, and identify and treat reversible causes (Table 1.2 and Figure 1.2).

Airway Management

Airway management is always the initial priority. To open the airway, first use simple maneuvers such as repositioning the head, suctioning secretions from the mouth, and placing an oropharyngeal or nasopharyngeal airway.

Head Tilt–Chin Lift

Open the airway using the head tilt–chin lift technique or jaw thrust maneuver. In an unresponsive child, perform the head tilt–chin lift maneuver by placing one hand on the patient's forehead and gently tilting the head back into a neutral position. Curl the fingers of the other hand gently under the jaw near the chin, and lift the mandible upward to open the airway.

Jaw Thrust

In a known or suspected trauma victim, use the jaw thrust maneuver without head extension. Protect the cervical spine by providing manual in-line traction. Place one hand on each side of the patient's head to hold it still, since immobilization devices may interfere with maintaining a patent airway. Perform the jaw thrust by keeping the head midline, placing the fingers at the angle of the jaw on both sides, and lifting the mandible upward and forward without extending the neck. If a jaw thrust does not open the airway, protect the C-spine and use a gentle head tilt–chin lift maneuver to open the airway, since maintaining airway patency is critical in providing adequate ventilation.

Suction Catheters

Suction secretions and blood from the nasal passages, oropharynx, and trachea with flexible suction catheters. These must be available in sizes small enough to pass through the smallest endotracheal tube (ETT). A 5 Fr catheter will pass through a 2.5 mm ETT (usually 2 × the ETT size). Large rigid tonsil tip catheters (Yankauer) have rounded tips which are less likely to injure the tonsils and are useful for clearing blood and particulate matter from the mouth and hypopharynx. Limit suctioning to less than ten seconds, while monitoring the pulse oximeter and heart rate, as vigorous suctioning may cause vagal stimulation resulting in bradycardia and hypoxia.

Oropharyngeal Airway

The oropharyngeal airway is an adjunct for ventilating an unresponsive patient with an absent gag reflex. It will keep the base of the tongue away from the posterior pharyngeal wall to maintain airway patency, and it will also serve as a bite block in intubated patients. Do not use in an awake patient as it can precipitate vomiting and laryngospasm.

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Table 1.2 Summary of BLS maneuvers for infants, children, and adolescents

Maneuver	1 month to 1 year	≥1 year to puberty
Scene safety	Make sure environment is safe for resc	
Recognition of cardiac arrest	Check for responsive versus unre No breathing or gasping No pulse palpated within 10 se Breathing and pulse check performed s	
Activate Emergency Response System If mobile phone – call EMS	Activate after verifying that victim is unresponsive Unwitnessed arrest: CPR 5 cycles in 2 min then call EMS Witnessed sudden arrest: activate EMS, get AED, start CPR	
CPR sequence	**C – A – B (COMPRESSION – AIRWAY –**	
C: CIRCULATION Pulse check in <10 seconds	Brachial or femoral	Femoral or carotid
Compression landmark	Just below nipple line One rescuer: 2 fingers Two rescuers: 2-thumb encircling chest	Center of chest, mid-sternum One hand: heel of one hand Two hands: heel of one hanc
Compression depth	At least ⅓ AP diameter About 1½ inches (4 cm)	At least ⅓ AP diameter About 2 inches (5 cm)
Compression rate	100–120/min Push hard and fast; allow complete recoil bet	
Compression–ventilation ratio	One rescuer = 30:2 Two rescuers = 15:2	
A: AIRWAY	Head tilt–chin lift Suspected trauma: use jaw thrust. If unable, protect C	

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B: BREATHING Initial	2 effective breaths at 1 second/breath; c	
Rescue breathing without chest compressions	12–20 breaths/min = about 1 breath every 3–5 seconds)	
Rescue breaths with advanced airway	10 breaths/min (1 breath every 6 seconds) with continuous chest c	
Foreign body obstruction	Back slaps and chest thrusts	Ab
D: DEFIBRILLATION AED *Witnessed sudden collapse*	<1 year of age or weight <10 kg Manual defibrillator preferred Give one shock and resume CPR	≥1 to 8 years Use pediatric dose-attenuato pads Give one shock and resume

Adapted from AHA PALS 2015 Guidelines.

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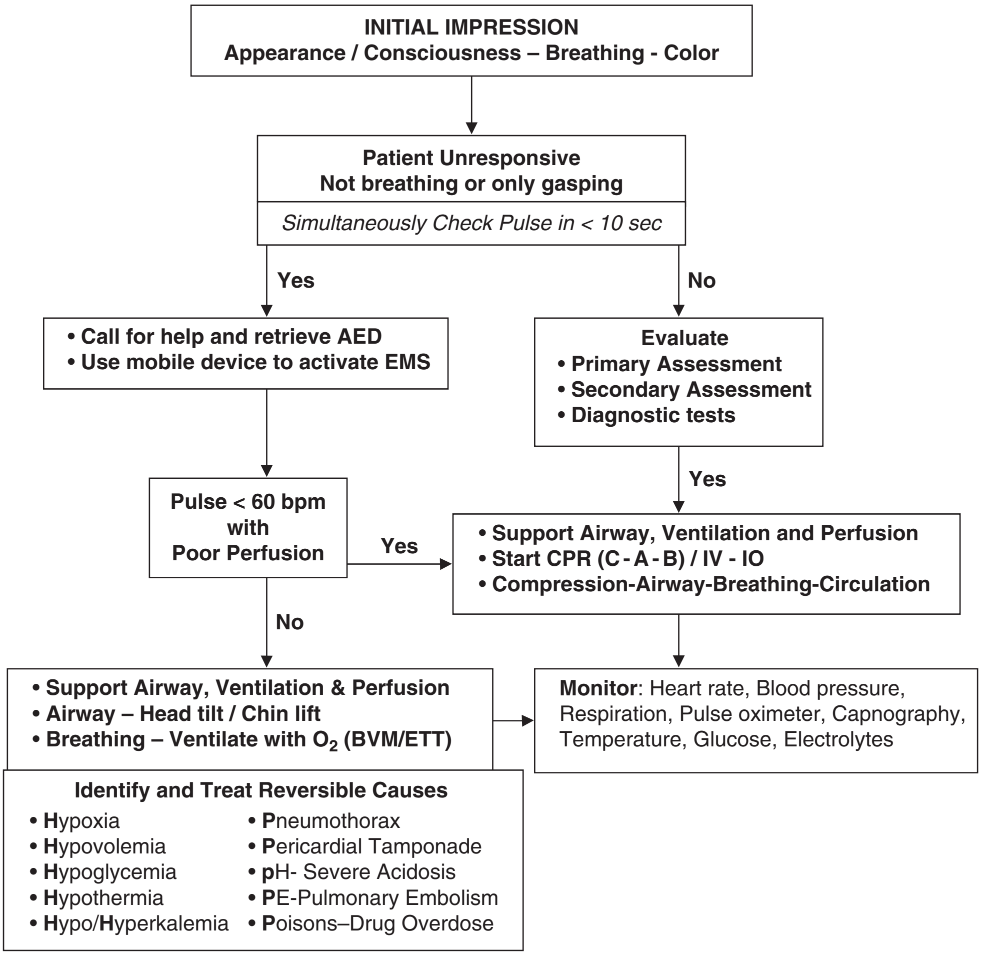

Figure 1.2 Summary of PALS 2015 Systematic Approach Algorithm.
Adapted from AHA PALS 2015 Guidelines

An appropriately sized oral airway extends from the corner of the patient's mouth to the angle of the jaw. Use a tongue depressor to push the tongue down, and insert the oropharyngeal airway with its curvature along the hard palate. In infants and children, avoid inserting an airway that is too large. Do not attempt to insert the airway in an inverted position and then rotate it 180°, as this technique may damage the palate and push the base of the tongue posteriorly, occluding the airway. The proximal part of the oral airway is firm and flat and is designed to be placed between the teeth to prevent biting (the tracheal tube or your finger). Tape the flange to the lips to prevent it from being dislodged.

Nasopharyngeal Airway

Use a nasopharyngeal airway in an obtunded patient with an intact gag reflex to prevent upper airway obstruction secondary to a floppy tongue. Estimate the size by measuring the distance from the tip of the nose to the tragus of the ear; the appropriately sized airway

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extends from the nostril to the base of the tongue without compressing the epiglottis. Lubricate the device and gently insert it along the floor of the nostril to avoid injuring the nasal mucosa or adenoids. A nasopharyngeal airway is contraindicated in a patient with a suspected basilar skull or nasal bone fracture.

Foreign Body Airway Obstruction

If choking or airway obstruction from a foreign body is suspected and the patient is awake and can speak, make no attempts to remove the object. Allow the patient to cough and clear the airway while observing for signs of complete obstruction (i.e., the victim is gagging, struggling to breathe, has high-pitched noise while breathing, is unable to make a sound, or is cyanotic). Remove the foreign body from the mouth only if it is visible. Do not perform blind finger sweeps in any age because the obstructing object may be pushed further into the pharynx and cause complete airway obstruction. If the patient deteriorates, use the following procedures, as summarized in Table 1.2.

Infants <1 Year of Age

Lay the infant prone over your thighs, with the head supported in a dependent position. Alternatively, hold the infant over your arm, in the prone position, supporting the head in your hand. Deliver five sharp back slaps, in rapid succession, between the baby's scapulae. Turn the infant over and give five chest thrusts using two fingers on the mid-sternum, as in giving chest compressions. Look into the mouth to see if the foreign body is dislodged. Repeat these maneuvers until the object is expelled or the infant becomes unconscious. Do not perform abdominal thrusts in infants as there is risk of injury to the abdominal organs.

Unconscious Infant

First open the mouth wide by grasping the tongue and jaw, and look for the foreign body in the oral cavity. If an object is seen, remove it, but do not perform a blind finger sweep. If there is no improvement, begin cardiopulmonary resuscitation (CPR) providing five cycles (30 compressions and 2 breaths per cycle) over 2 min. If breaths cannot be delivered, reposition the head and try again, or proceed with advanced airway maneuvers until respirations have been restored.

Children >1 Year of Age to Adolescent

Use the Heimlich abdominal thrust maneuver in this age group. If the patient is awake, stand or kneel behind the child and position the heel of the hand in the midline of the epigastrium with the other hand on top of the first, then give a rapid series of separate and distinct upward thrusts. With each thrust use sufficient force to dislodge the foreign body. For a small child, the heel of one hand is sufficient, as overly vigorous abdominal thrusts may cause damage to internal organs. If the patient loses consciousness, lay the child supine on the floor, reposition the head, and attempt to visualize the object. Do not attempt a blind finger sweep. If the object is not visualized, begin CPR, providing five cycles for 2 min.

A foreign body may also be removed under direct visualization with a laryngoscope and Magill forceps. Consult an otolaryngologist to remove more distal tracheal or laryngeal foreign bodies via flexible bronchoscopy.

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Oxygenation, Ventilation, and Intubation

Once the airway has been stabilized and the breathing assessed, the need for oxygenation and ventilation takes priority. Provide supplemental oxygen to all patients with respiratory distress. Reassess breathing effort by physical examination and pulse oximetry. The equipment for airway support is described below.

Nasal Cannula

Oxygen can be delivered by a low-flow or high-flow system. The actual oxygen concentration delivered by nasal cannula is unpredictable, so this method is appropriate only for a patient who requires minimal O_2 supplementation. Low-flow oxygen is delivered by nasal cannula at rates of 1–4 L/min and provides O_2 concentrations of 22–60%. However, flow rates >3 L/min are usually poorly tolerated by children, while flow rates >1–2 L/min may inadvertently administer positive pressure to newborns.

High-flow nasal cannula (HFNC) delivers an oxygen concentration of >60% at flow rates from 1–8 L/min in infants to 50–60 L/min in children and adults. Titrate the flow for additional inspiratory and expiratory pressure based on the patient's work of breathing. High-flow nasal cannula uses a special device that warms and humidifies high flows of a combination of room air and oxygen. It can be used as an alternative to standard oxygen therapy or noninvasive positive pressure ventilation in a patient with acute hypoxemic respiratory distress without hypercapnia. Maximum deliverable flow rates vary by device manufacturer.

Simple O_2 Mask

This is the most frequently used method for oxygen delivery in spontaneously breathing patients and it is more easily tolerated than nasal cannula. The actual O_2 concentration that the patient receives is dependent on the flow rate and the patient's ventilatory pattern, as room air enters through the ventilation holes on the sides of the mask. Oxygen flow rates of 6–10 L/min will deliver O_2 concentrations of 35-60% and prevent rebreathing of exhaled CO_2.

O_2 Mask With Reservoir

A nonrebreather (NRB) mask is another form of high-flow delivery system which consists of a simple mask attached to a reservoir bag that is connected to an oxygen source. The NRB contains one-way valves at the exhalation ports to prevent the entrainment of room air, and a second valve at the reservoir bag to prevent the entry of exhaled gas back into the reservoir bag. The reservoir bag must be larger than the patient's tidal volume (5–7 mL/kg) and remain inflated during inspiration. Oxygen concentrations up to 60% can be achieved in partial rebreathing systems, and >95% is possible if the oxygen flow rate is 10–15 L/min, and a good seal is maintained around the facemask.

Ventilation

For patients with respiratory failure, ventilate with a bag-mask apparatus until all the appropriate equipment and personnel for intubation are assembled. For optimum airway alignment, position the patient so that the auditory meatus is in line with the top of the anterior shoulder. Use the "sniffing" position in an older child by placing a folded towel under the head and elevating it. Due to a relatively larger head in an infant, keep the head

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