dobutamine, nitroprusside, or milrinone, also may be needed. Measuring mixed venous oxygen saturation, central venous pressure, and regional oxygen saturations helps guide therapy.

CARDIOPULMONARY ARREST

The outcome of cardiopulmonary arrest in children is poor; survival to hospital discharge is about 6% for out-of-hospital arrest and about 27% for in-hospital arrest, with most survivors having permanent neurologic disability. The ability to anticipate or recognize pre–cardiopulmonary arrest conditions and initiate prompt and appropriate therapy not only is lifesaving, but also preserves the quality of life (see Table 38-2).

Children who need cardiopulmonary resuscitation (CPR) usually have a primary respiratory arrest. Hypoxia usually initiates the cascade leading to arrest and also produces organ dysfunction or damage (Table 38-3). The approach to cardiopulmonary arrest extends beyond CPR and includes efforts to preserve vital organ function. The goal in resuscitating a pediatric patient following a cardiopulmonary arrest should be to optimize **cardiac output** and tissue oxygen delivery, which may be accomplished by using artificial ventilation and chest compression and by the judicious administration of pharmacologic agents.

Pediatric Advanced Life Support and CPR

In 2010 the American Heart Association revised the recommendations for resuscitation for adults, children, and infants. The biggest change is the recommendation to start chest compressions immediately, rather than beginning with airway and breathing.

Circulation

Chest compressions should be initiated if a pulse cannot be palpated or if the heart rate is less than 60 beats/min with signs of poor systemic perfusion. Chest compressions should be performed immediately by one person while a second person prepares to begin ventilation. **Ventilation** is extremely important in pediatric arrests because of the high likelihood of a primary respiratory cause; however, ventilation requires equipment and is, therefore, sometimes delayed. For this reason the recommendation is to start chest compressions first while preparing for ventilation.

For optimal chest compressions, the child should be supine on a flat, hard surface. Effective CPR requires a compression depth of one third to one half of the anterior-posterior diameter of the chest with complete recoil after each compression. The compression rate should be at least 100/min with breaths delivered 8 to 10 times per minute. If an advanced airway is in place, compressions should not pause for ventilation; both should continue simultaneously.

Table 38-3 Target Organs for Hypoxic-Ischemic Damage

ORGAN	EFFECT
Brain	Seizures, cerebral edema, infarction, herniation, anoxic damage, SIADH, diabetes insipidus
Cardiovascular	Heart failure, myocardial infarct
Lung and pulmonary vasculature	Acute respiratory distress syndrome, pulmonary hypertension
Liver	Infarction, necrosis, cholestasis
Kidney	Acute tubular necrosis, acute cortical necrosis
Gastrointestinal tract	Gastric ulceration, mucosal damage
Hematologic	Disseminated intravascular coagulation

SIADH, Syndrome of inappropriate secretion of antidiuretic hormone.

Airway

Ventilation requires a **patent airway**. In children, airway patency often is compromised by a loss of muscle tone, allowing the mandibular block of tissue, including the tongue, bony mandible, and the soft surrounding tissues, to rest against the posterior pharyngeal wall. The head tilt–chin lift maneuver should be used to open the airway in children with no sign of head or neck trauma. In children with signs of head or neck trauma, the jaw thrust maneuver should be used.

Bag-mask ventilation can be as effective as, and possibly safer than, endotracheal intubation for short periods of time in an out-of-hospital setting. If skilled personnel and proper equipment are available, pediatric patients requiring resuscitation should be endotracheally intubated. Before intubation, the patient should be ventilated with 100% oxygen using a bag and mask. Cricoid pressure should be used to minimize inflation of the stomach. Many conscious patients may benefit from the use of induction medications (sedatives, analgesics, and paralytics) to assist intubation, but caution is necessary to prevent further cardiovascular compromise from vasodilating effects of many sedatives. The correct size of the tube may be estimated according to the size of the child's mid-fifth phalanx or the following formula: 4 + (patient age in years/4).

When the endotracheal tube is in place, the adequacy of ventilation and the position of the tube must be assessed. Use of both clinical assessment and confirmatory devices is recommended. Clinical assessment may include looking for adequate chest wall movement and auscultation of the chest to detect bilateral and symmetric breath sounds. Confirmatory devices such as end-tidal carbon dioxide (CO_2) monitoring devices are useful for validation of endotracheal placement, but low levels of detected CO_2 may be seen secondary to lack of pulmonary circulation. If the patient's condition fails to improve or deteriorates, consider the possibilities of tube **D**isplacement or **O**bstruction, **P**neumothorax, or **E**quipment failure (mnemonic DOPE).

Breathing

The major role of endotracheal intubation is to protect or maintain the airway and ensure the delivery of adequate oxygen to the patient. Because hypoxemia is the final common pathway in pediatric cardiopulmonary arrests, providing oxygen is more important than correcting the respiratory acidosis. The clinician should deliver 100% oxygen at a rate of 8 to 10 breaths/min during CPR, or 12 to 20 breaths/min for a patient who has a perfusing rhythm. Use only the tidal volume necessary to produce visible chest rise. Care should be taken not to hyperventilate the patient.