

Pediatric Advanced Life Support Study Overview

This text is an outline of the Pediatric Advanced Life Support Guidelines published in the “Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care, International Consensus on Science” by the American Heart Association. It is not meant as a replacement for the PALS textbook but as a supplement and study guide.

Introduction

Pediatric BLS refers to the provision of CPR, with no devices or with bag-mask ventilation or barrier devices, until advanced life support (ALS) can be provided. The age addressed in this course include infants from birth to 1 year of age and children from 1 to 8 years of age.

Sudden cardiopulmonary arrest in infants and children is much less common than sudden cardiac arrest in adults. Arrest in infants and children is rarely a sudden event, and non-cardiac causes predominate.

Cardiac arrest in the under-21 year old age group occurs most commonly at either end of the age spectrum: under 1 year of age and during the teenage years. In the newly born infant, respiratory failure is the most common. During infancy the most common causes of arrest include sudden infant death syndrome, respiratory diseases, airway obstruction, submersion, sepsis and neurological disease. Beyond 1 year of age, injuries are the leading cause of death.

Cardiac arrest in children typically represents the terminal event of progressive shock or respiratory failure. Rescuers must detect and promptly treat early signs of respiratory and circulatory failure to prevent cardiac arrest.

CPR has been associated with successful return of spontaneous circulation and neurologically intact survival. BLS courses should be offered to target populations such as expectant parents, child care providers, teachers, sports supervisors and others who regularly care for children.

Intervention Classifications

Throughout the overview, the following definitions of classes of recommendations are used:

- **Class I** recommendations are always acceptable. They are proven safe and definitely useful, and they are supported by excellent evidence from at least 1 prospective, randomized controlled clinical trial.
- **Class IIa** recommendations are considered acceptable and useful with good to very good evidence providing support. The weight of evidence and expert opinions strongly favor these interventions.

- **Class IIb** recommendations are considered acceptable and useful with weak or only fair evidence providing support. The weight of evidence and expert opinion are not strongly in favor of the intervention.
- **Class II** refers to interventions that are unacceptable. These interventions lack any evidence of benefit, and often the evidence suggest or confirms harm.
- **Class Indeterminate** refers to an intervention that is promising, but the evidence is insufficient in quantity and/or quality to support a definitive class of recommendation. The Indeterminate Class was added to indicate interventions that are considered safe and perhaps effective and are recommended by expert consensus. However, the available evidence supporting the recommendation is either too weak or too limited at present to make a definite recommendation based on the published data.

A high degree of uniformity exists in current guidelines for resuscitation of the newly born, neonates, infants, and young children endorsed by the resuscitation councils in developed countries around the world.

Definition of Newly Born, Neonate, Infant, Child and Adult

- Neonate – infants in the first 28 days of life.
- Newly Born refers specifically to the neonate in the first minutes to hours after birth. The term is used to focus attention on the needs of the infant at and immediately after birth
- Infant – includes the neonatal period and extends to the age of 1 year
- Child – ages 1 to 8 years.
- Adult – victims > 8 years of age

The child's developing anatomy and physiology and the most common causes of cardiopulmonary arrest should be considered in the development and use of resuscitation guidelines for children of different ages. For purposes of BLS the term "infant" is defined by the approximate size of the young child who can receive effective chest compression given with 2 fingers or 2 thumbs with encircling hands. However, variability in the size of the victim or the size and strength of the rescuer can require use of the 2 finger or 2 thumb encircling hands technique for chest compression in a small toddler or 2 handed adult compression technique for chest compression in a large child who is 6 to 7 years old.

Anatomic and Physiological Differences Affecting Cardiac Arrest and Resuscitation

Respiratory failure or arrest is a common cause of cardiac arrest during infancy and childhood. These guidelines emphasize immediate provision of bystander CPR – including opening of the airway and delivery of rescue breathing – before activation of the local EMS system. Optimal application of early oxygenation and ventilation requires an understanding of airway anatomy and physiology.

The upper and lower airways of the infant and child are much smaller than the airways of the adult. As a result, modest airway obstruction from edema,

mucous plugs, or a foreign body can significantly reduce pediatric airway diameter and increase resistance to air flow and work of breathing.

1. The infant tongue is proportionately large in relation to the size of the oropharynx. As a result, posterior displacement of the tongue occurs readily and may cause severe airway obstruction in the infant.
2. In the infant and child the subglottic airway is smaller and more compliant and the supporting cartilage less developed than in the adult. As a result, this portion of the airway can easily become obstructed by mucus, blood, pus, edema, active constriction, external compression, or pressure differences created during spontaneous respiratory effort in the presence of airway obstruction. The pediatric airway is very compliant and may collapse during spontaneous respiratory effort in the face of airway obstruction.
3. The ribs and sternum normally contribute to maintenance of lung volume. In infants these ribs are very compliant and may fail to maintain lung volume particularly when the elastic recoil of the lungs is increased and/or lung compliance is decreased. As a result, functional residual capacity is reduced when respiratory effort is diminished or absent. The limited support of the lung volume expansion by the ribs makes the infant more dependent on diaphragm movement to generate a tidal volume. Anything that interferes with diaphragm movement may produce respiratory insufficiency.
4. Infants and children have limited oxygen reserve. Physiological collapse of the small airways at or below lung functional residual capacity and an interval of hypoxemia and hypercarbia preceding arrest often influence oxygen reserve and arrest metabolic conditions.

Cardiac Output, Oxygen Delivery and Oxygen Demand

Cardiac output is the product of heart rate and stroke volume. Although the pediatric heart is capable of increasing stroke volume, cardiac output during infancy and childhood is largely dependent on maintenance of an adequate heart rate. Bradycardia may be associated with a rapid fall in cardiac output, leading to rapid deterioration in systemic perfusion. Bradycardia is one of the most common terminal rhythms observed in children. For the reason lay rescuers are taught to provide chest compressions when there are no observed signs of circulation. Healthcare providers are taught to provide chest compressions when there are no observed signs of circulation (including absence of a pulse) or when severe Bradycardia (heart rate <60) develops in the presence of poor systemic perfusion.

Phone Fast (Infant, Child), Phone First (Adult)

The causes of pediatric cardiopulmonary arrest include SIDS, asphyxia, near drowning, trauma and sepsis. Therefore there is no single gold standard pediatric cardiac arrest response. In the pediatric age group, resuscitation is most frequently required at the time of birth.

In general, pediatric out of hospital arrest is characterized by a progression from hypoxia and hypercarbia to respiratory arrest and Bradycardia and then asystolic cardiac arrest. Ventricular tachycardia or fibrillation has been reported in <15% of pediatric victims, even when the rhythm is assessed by first responders. Survival after out of hospital arrest ranges from 3-17% in most studies and survivors are often neurologically devastated. Neurologically intact survival rates of 50% have been reported for resuscitation of children with respiratory arrest alone. Prompt effective chest compressions and rescue breathing have been shown to improve return of spontaneous circulation and increase neurologically intact survival in children with arrest, however, no other intervention has been definitively shown to improve survival or neurological outcome.

Immediate CPR (phone first) is recommended for pediatric victims of arrest in the out of hospital setting rather than the adult approach, immediately EMS activation (phone first).

There are some circumstances in which primary arrhythmic cardiac arrest is more likely. Examples include the sudden collapse of children with underlying cardiac disease or a history of arrhythmias. Families of children with identified risk should be taught to phone first if the child collapses suddenly, a lone bystander should first activate the local EMS system and then return to the victim to begin CPR.

A sudden witnessed collapse in a previously healthy child or adolescent suggests that the arrest is cardiac in origin and immediate activation of the EMS system may be beneficial even if the child is less than 8. Potential causes of sudden collapse in children with no known history include prolonged QT syndrome, hypertrophic cardiomyopathy and drug induced cardiac arrest.

In the hospital setting the most common causes of cardiac arrest include sepsis, respiratory failure, drug toxicity, metabolic disorders and arrhythmia. These in hospital causes of arrest are often complicated by underlying conditions.

Prevention of Sudden Infant Death Syndrome

SIDS is the sudden death of an infant, typically between the ages of 1 month and 1 year that is unexpected from history and unexplained by other causes when a postmortem examination is performed. Probably represents a variety of causes all of which result in death while sleeping.

The peak incidence of SIDS occurs in infants 2 to 4 months of age, 70-90% of SIDS deaths are reported in the first 6 months of life. Many characteristics are associated with increased risk of SIDS including:

- Prone sleeping position
- The winter months
- Infants of lower-lower income families
- Males

- Siblings of SIDS victims
- Infants of mothers who smoke cigarettes
- Infants who have survived severe apparent life-threatening events
- Children of mothers who are drug addicts
- Low birthweight infants

The prone position, particularly on a soft surface, is thought to contribute to rebreathing asphyxia. All parents and those responsible for the care of children should be aware of the need to place healthy infants supine for sleeping. The supine position has not been associated with an increase in any significant adverse events, such as vomiting or aspiration. A side position may be used as an alternative, but infants in this position should be propped and positioned to prevent them from rolling to the prone position. The infant should not sleep on soft surfaces such as lambswool, fluffy comforters or other objects that might trap exhaled air near the infant's face.

INJURY

The Magnitude of the Problem

Injury is the leading cause of death in children and adults aged 1 to 44 years and is responsible for more childhood deaths than all other causes combined.

Injury Control

Injury control attempts to prevent injury or minimize the effects on the child and family in 3 phases:

1. Prevention
2. Minimization of injury damage
3. Postinjury Care

Passive injury prevention strategies are generally preferred because they are more likely to be used than active strategies, which require repeated conscious effort. Specific instructions are more likely to be followed than general advice. Individual education reinforced by community wide educational programs is more effective than isolated educational sessions.

Prevention of Common Childhood and Adolescent Injuries

The six most common types of fatal childhood injuries amenable to injury prevention strategies are motor vehicle passenger injuries, pedestrian injuries, bicycle injuries, submersion, burns and firearm injuries.

Motor Vehicle Injuries

Motor vehicle related trauma accounts for nearly half of all pediatric injuries and deaths in the United States and 40% of injury mortality in children 1 to 14 years of age internationally. Contributing factors include:

- Failure to use proper passenger restraints
- Inexperienced Drivers
- Alcohol

Proper use of child seat restraints and lab shoulder harnesses will prevent an estimated 65-75% of serious injuries and fatalities to passengers <4 years of age.

CHILD SEAT GUIDELINES

1. Children should ride in rear facing infant seats until they are at least 20 lbs and at least 1 year of age with good head control.
2. A child who is >1 year old and weights 20-40 lbs should be placed in a convertible care safety seat used in the upright position and forward facing positions as long as he or she fits will in the seat. The seat **SHOULD ALWAYS BE PLACED IN THE BACK SEAT.**
3. Belt positioning booster seats should be used for children weighing 40-80 pounds until they are at least 58 to 60 inches in height.
4. Children may be restrained in automobile lap and shoulder belts when they weight 40-80 pounds and are at least 58 inches tall.
5. Children approximately 12 years old and younger should not sit in the front seat of cars equipped with passenger side air bags.

AIR BAGS

The benefits of air bags continue to far outweigh the risks, saving approximately 2663 lives in the US alone from 1987 to 1997. The vast majority of the 74 US children with fatal airbag related injuries reported through April 1999 were improperly restrained for their age or not restrained at all. To prevent airbag and most other occupant injuries, children <12 years of age should be properly restrained for age and size in the back seat of cars.

Adolescent drivers are responsible for disproportionate number of motor vehicle related injuries. Approximately 50% of motor vehicle fatalities involving adolescents also involve alcohol.

Pedestrian Injuries

Pedestrian injuries are the leading cause of death among children 5-9 years of age in the United States.

Bicycle Injuries

Bicycle crashes are responsible for approximately 200,000 injuries and >600 deaths to children and adolescents in the United States every year. Head injuries are the cause of most bicycle injury related morbidity and mortality. Bicycle helmets can prevent an estimated 85% of head injuries and 88% of brain injuries.

Submersion/Drowning

15% of injury deaths to children 1-14 years of age. A significant cause of death and disability in children <4 years old and is a leading cause of death in this age group in the United States.

For every death due to submersion, 6 children are hospitalized, and approximately 20% of hospitalized survivors are severely brain damaged. Young children and children with seizure disorders should never be left unattended in bathtubs or near swimming pools, ponds or beaches. Children >5 years of age should learn how to swim. Alcohol appears to be a significant risk factor in adolescent drowning.

BURNS

Fires, burns and suffocation are a leading cause of injury death worldwide and are higher in the US and Scotland than in the other countries surveyed. Most fire related deaths occur in private residences, usually in homes without working smoke detectors.

Socioeconomic factors such as overcrowding, single parent families, scarce financial resources, inadequate child care/supervision and distance from fire department all contribute to increased risk for burn injury. When used correctly, they can reduce fire-related death and severe injury by 86% to 88%.

Firearm Injuries

The United States has the highest firearm related injury rate of any industrialized nation more than twice that of any other country. Firearm homicide remains the leading cause of death among African American adolescents and young adults and the second highest cause of death among all adolescents and young adults in the United States.

Thirty four percent of high school students surveyed reported easy access to guns, and an increasing number of children carry guns to school. The mere presence of a gun in the home is associated with an increased likelihood of adolescent suicide as well as an increased incidence of adult suicide or homicide.

Guns should be stored locked and unloaded, with ammunition stored separately from the gun. The consistent use of trigger locks may not only reduce the incidence of unintentional injury and suicide among children and young adolescents but will most likely reduce the number of homicides. "Smart guns" which can only be fired by the gun owner, are expected to reduce the frequency of unintentional injuries and suicides among children and young adolescents and limit the usefulness of guns obtained during burglaries.

Sequence of Pediatric BLS: The ABCs of CPR

When a child develops respiratory or cardiac arrest, immediate bystander CPR is crucial to survival. Unfortunately, bystander CPR is provided for only approximately 30% of out of hospital pediatric arrests.

- I. Ensure the Safety of the Rescuer and Victim
 - A. In the case of trauma, the victim should not be moved unless it is necessary to ensure the victim's or other rescuer's safety
 - B. The risk of infectious disease transmission is extremely low

- II. Assess responsiveness
 - A. Gently stimulate the child and ask loudly, "Are you alright?" Quickly assess the presence or extent of injury and determine whether the child is responsive.
 - B. Responsive children with respiratory distress will often assume a position that maintains airway patency and optimizes ventilation; they should be allowed to remain in the position that is most comfortable to them
 - C. If the child is unresponsive be prepared to provide CPR for approximately 1 minute before leaving the child to activate the EMS system.
 - D. If trauma has not occurred and the child is small, you may consider moving the child near a telephone so that you can contact the EMS system more quickly.

- III. Activate EMS
 - A. Current American Heart Association guidelines instruct the rescuer to provide approximately 1 minute of CPR before activating the EMS system in out of hospital arrest for infants and children up to 8 years of age.
 - B. Sophisticated healthcare providers, family members and potential rescuers of infants and children at high risk for cardiopulmonary emergencies should be taught a sequence of rescue actions tailored to the potential victim's specific condition. For example, parents and child care providers of children with congenital heart disease should be instructed to "phone first" if they are alone and the child suddenly collapses.
 - C. The rescuer calling the EMS system should be prepared to provide the following information:
 1. Location of the emergency, including address and names of streets or landmarks.
 2. Telephone number from which the call is being made
 3. What happened, auto accident, submersion

4. Number of victims
5. Condition of the victims
6. Nature of aid being given
7. Any other information requested
8. The caller should hang up only when instructed to do so by the dispatcher, then the caller should report back to the rescuer doing CPR

IV. Airway, Positioning the Victim

- A. Move the child as a unit to the supine position, and place the child on a flat hard surface, such as a sturdy table, the floor or the ground.
- B. If the victim is an infant and no trauma is suspected, carry the child supported by your forearm to a prone position while beginning the steps of CPR.
- C. Open the airway using Head Tilt-Chin Lift Maneuver, Jaw Thrust Maneuver. The most common cause of airway obstruction in the unresponsive pediatric victim is the tongue.

V. Breathing

- A. Look for the rise and fall of the chest and abdomen. Listen at the child's nose and mouth for exhaled breath sounds, and feel for air movement from the child's mouth on your cheek for no more than 10 seconds.
- B. If you are not confident that respirations are adequate, proceed with rescue breathing.
- C. If the child is breathing spontaneously and effectively and there is no evidence of trauma, turn the child to the side in a recovery position.
- D. With each rescue breath provide a volume sufficient for you to see the chest rise. Provide 2 slow breaths (1- 1 ½ seconds per breath pausing after the first breath to take a breath to maximize oxygen content and minimize carbon dioxide in the delivered breath.
- E. There is no data to support the choice of any single number of initial breaths to be delivered to the unresponsive nonbreathing infant. Therefore, lay rescuers and healthcare providers should administer 2 initial **effective breaths**. The rescuer should ensure that at least 2 breaths delivered are effective and produce visible chest rise.

VI. Ventilation with Barrier Devices

- A. Despite decades of experience indicating its safety for victims and rescuers alike, some potential rescuers may hesitate to perform mouth to mouth rescue breathing because of concerns about transmission.
- B. Bag-Mask Ventilation

1. Healthcare providers who provide BLS for infants and children should be trained to deliver effective oxygenation and ventilation with a manual resuscitator bag and mask.
2. Neonatal size ventilation bags may be inadequate to support effective tidal volume and the longer inspiratory times required by full term neonates and infants. Resuscitation bag used for ventilation of full term newly born infants, infants and children should have a minimum volume of 450-500ml
3. Regardless of the size of the manual resuscitator used, the rescuer should use only the force and tidal volume necessary to cause the chest to rise visibly.
4. Bag Valve systems should either have no pressure relief valve or have a valve with an override feature to permit use of high pressures, if necessary to achieve visible chest expansion. High pressures may be required during ventilation of patients with upper or lower airway obstruction or poor lung compliance. In these patients a pressure-relief valve may prevent delivery of sufficient tidal volume.
5. Place your thumb and forefinger in a C shape of the mask and exert downward pressure on the mask. This hand position uses the thumb and forefinger to squeeze the mask onto the face while the remaining fingers of the same hand lift the jaw pulling the face toward the mask. This is called the “E-C Clamp”

VII. Oxygen

- A. Healthcare providers should administer oxygen to all seriously ill or injured patients with respiratory insufficiency, shock or trauma as soon as it is available.
- B. The combination of low blood flow and oxygenation contributes to metabolic acidosis and organ failure. For these reasons, oxygen should be administered to children with demonstrated cardiopulmonary arrest or compromise, even if measured arterial oxygen tension is high.
- C. Whenever possible, oxygen should be humidified to prevent drying and thickening of the pulmonary secretions; dried secretions may contribute to obstruction of natural and artificial airways.

VIII. Circulation

- A. Cardiac arrest results in the absence of signs of circulation, including the absence of a pulse. The pulse check has been the “gold standard” usually relied on by professional rescuers to evaluate circulation. The carotid artery pulse is palpated in adults and children; brachial artery palpation is recommended in infants.
- B. The pulse check is not recommended for lay rescuers.

1. Rescuers take far too much time to check to pulse.
2. When used as a diagnostic test, the pulse check is extremely inaccurate. Overall accuracy in testing was 65% leaving an error rate of 35%.
3. It was concluded that the pulse check could not be recommended as a tool for lay rescuers to use in the CPR sequence to identify victims of cardiac arrest.
4. The lay rescuer will be taught to look for signs of circulation (normal breathing, coughing, or movement) in response to rescue breaths. This recommendation applies to victims of any age. Healthcare providers should continue to use the pulse check as one of the several signs of circulation.
5. If signs of circulation are absent (or for the healthcare provider, the heart rate is <60 with signs of poor perfusion) begin chest compressions.
6. If there are no signs of circulation, the victim is >8 years of age, and an AED is available in the out of hospital setting, use the AED.

IX. Provide Chest Compressions

1. Chest compressions provide circulation as a result of changes in intrathoracic pressure and/or direct compression of the heart. Chest compressions for infants and children should be provided with ventilations.
2. Compress the lower half of the sternum to a relative depth of one third to one half the anterior posterior diameter of the chest at a rate of at least 100 compressions per minute.
3. The neonatal guidelines call for depth of one third the depth of the chest.
4. Chest compressions must be adequate to produce a palpable pulse during resuscitation. Lay rescuers will not attempt to feel a pulse, so they should be taught a compression technique that will most likely result in delivery of effective compressions.
5. Supine on a hard, flat surface. Spine boards, preferably with head wells can be used in ambulances and mobile life support unites. They provide a firm surface for CPR and are also useful for extricating and immobilizing the victim.
6. Infants with no signs of head or neck trauma may be successfully carried during resuscitation on the rescuer's forearm.
7. Place the 2 fingers of one hand over the lower half of the sternum approximately 1 finger's width below the intermammary line, ensuring that you are not on or near the xiphoid process.

8. After 5 compressions, open the airway with a head tilt-chin lift and give 1 effective breath.
9. Continue compressions and breaths in a ratio of 5:1. Note that this differs from the recommended ratio of 3:1 for the newly born or premature infant in the neonatal ICU.
10. Chest compressions for 1 to 8 years with the heel of one hand over the lower half of the sternum and compress to a depth of 1 to 1 ½ inches. 5:1 ratio whether one or two rescuers are present.

Coordination of Compression and Rescue Breathing

External chest compressions for infants and child should always be accompanied by rescue breathing. When 2 rescuers are providing CPR for an infant or child with an unsecured airway, the rescuer providing the compressions should pause after every fifth compression to allow the second rescuer to provide one effective ventilation. This pause is necessary until the airway is secure (intubated).

Coordination of compressions and ventilation may facilitate adequate ventilation even after tracheal intubation and is emphasized in the newly born. Reassess the victim after 20 cycles of compressions and ventilations (slightly longer than 1 minute) and every few minutes thereafter for any sign of resumption of spontaneous breathing or signs of circulation.

The use of mechanical devices to provide chest compressions during CPR are not recommended for children.

Relief of Foreign-Body Airway Obstruction

BLS providers should be to recognize and relieve complete FBAO. There is consensus that the lack of protection of the upper abdominal organs by the rib cage renders infants and young children at risk for trauma from abdominal thrusts. Therefore the use of abdominal thrusts is not recommended for the relief of FBAO in infants.

Signs of FBAO in infants and children include the SUDDEN onset of respiratory distress associated with coughing, gagging or stridor. These signs and symptoms of airway obstruction may also be caused by infections such as epiglottitis and croup, which result in airway edema. However signs of FBAO typically develop very abruptly, with no other signs of illness or infection. Infectious airway obstruction is often accompanied by fever, with other signs of congestion, hoarseness, drooling, lethargy or limpness.

FBAO IN THE RESPONSIVE INFANT

- 1) hold the infant prone with the head slightly lower than the chest resting on your forearm.

- 2) Delivery up to 5 back blows, forcefully in the middle of the back between the infant's shoulder blades, using the heel of the hand.
- 3) After delivering up to 5 back blows, place your free hand on the infant's back, supporting the occiput of the infant's head with the palm of your hand. The infant will be effectively cradled between your 2 forearms, with the palm of one hand supporting the face and jaw while the palm of the other hand supports the occiput.
- 4) Turn the infant as a unit while carefully supporting the head and neck.
- 5) Provide up to 5 quick downward chest thrusts in the same location as chest compressions at approximately 1 per second.
- 6) If the airway remains obstructed, repeat the sequence of up to 5 back blows and up to 5 chest thrusts until the object is removed or the victim becomes unresponsive.

FBAO IN THE RESPONSIVE CHILD

- 1) Stand or kneel behind the victim, arms directly under the victim's axillae, encircling the victim's torso.
- 2) Place the flat, thumb side of 1 fist against the victim's abdomen in the midline slightly above the navel and well below the tip of the xiphoid process.
- 3) Grasp the first with the other hand and exert a series of up to 5 quick inward and upward thrusts, careful not to touch the xiphoid process or the lower margins of the rib cage because force applied to these structures may damage internal organs.
- 4) Each thrust should be a separate, distinct movement, delivered with the intent to relieve the obstruction.

Relief of FBAO in the Unresponsive Infant or Child

Lay Rescuer Actions

If the infant or child becomes unresponsive, attempt CPR with a single addition – each time the airway is opened, look for the obstructing object in the back of the throat. If you see an object, remove it.

Healthcare Provider Actions

Blind finger sweeps should not be performed in infants and children because the foreign body may be pushed back into the airway, causing further obstruction or injury to the supraglottic area. When abdominal thrusts or chest thrusts are provided to the unresponsive/unconscious non breathing victim, open the mouth by grasping both the tongue and lower jaw between the thumb and finger and lifting.

If the infant victim becomes unresponsive, perform the following:

- 1) Open the victims airway using a tongue-jay lift and look for an object in the pharynx. If an object is visible, remove it with a finger sweep. Do not perform a blind finger sweep.

- 2) Open the airway with a head tilt-chin lift and attempt to provide rescue breaths. If the breaths are not effective, reposition the head and reattempt ventilation.
- 3) If the breaths are still not effective, perform the sequence of up to 5 back blows and up to 5 chest thrusts.
- 4) Repeat steps 1 through 3 until the object is dislodged and the airway is patent or for approximately 1 minute. If the infant remains unresponsive after approximately 1 minute, activate the EMS system.
- 5) If breaths are effective, check for signs of circulation and continue CPR as needed, or place the infant in a recovery position if the infant demonstrates adequate breathing and signs of circulation.

If the child victim becomes unresponsive:

- 1) Open the airway using a tongue-jaw lift and look for an object in the pharynx. If an object is visible, remove it with a finger sweep. Do not perform a blind finger sweep.
- 2) Open the airway with a head tilt-chin lift and attempt to provide rescue breaths. If breaths are not effective, reposition the head and reattempt ventilation.
- 3) If the breaths are still not effective, kneel beside the victim or straddle the victim's hips and prepare to perform the Heimlich maneuver abdominal thrusts.
 - a. Place the heel of one hand on the child's abdomen in the midline slightly above the navel and well below the rib cage and xiphoid process. Place the other hand on top of the first.
 - b. Press both hands onto the abdomen with a quick inward and upward thrust. Direct each thrust upward in the midline and not to either side of the abdomen. Perform a series of up to 5 thrusts. Each thrust should be a separate and distinct movement of sufficient force to attempt to dislodge the obstruction.
- 4) Repeat steps 1 through 3 until the object is retrieved or rescuer breaths are effective.
- 5) Once effective breaths are delivered, assess for signs of circulation and provide additional CPR as needed or place the child in the recovery position if the child demonstrates adequate breathing and signs of circulation.

BLS for the Trauma Victim

The principles of resuscitation of the seriously injured child are the same as those for any pediatric patient. However some aspects of pediatric trauma care require emphasis because improper resuscitation is a major cause of preventable pediatric trauma death.

Common errors in pediatric trauma resuscitation include failure to open and maintain the airway with cervical spine protection, inadequate or overzealous fluid resuscitation and failure to recognize and treat internal bleeding.

Children with multisystem trauma should be transported rapidly to trauma centers with pediatric expertise.

BLS support requires meticulous attention to airway, breathing and circulation from the moment of injury. The airway may become obstructed by soft tissues, blood or dental fragments. These causes of airway obstruction should be anticipated and treated. Airway control includes spinal immobilization, which is continued during transport and stabilization in an ALS facility.

It may be difficult to immobilize the cervical spine of an infant or young child in a neutral position. When a young child is placed supine on a firm surface, the large head tends to encourage neck flexion. Spinal immobilization of young children with a backboard with a recess for the head is recommended. If such a board is unavailable, the effect of a head recess can be simulated by placing a layer of towels or sheets $\frac{1}{2}$ to 1 inch high on the board so that it elevates the torso and maintains the neck in neutral alignment.

BLS for the Submersion Victim

Submersion is a leading cause of death in children worldwide. The duration and severity of hypoxia sustained as a result of submersion is the single most important determinant of outcome. CPR, particularly rescue breathing, should be attempted as soon as the unresponsive submersion victim is pulled from the water. If possible, rescue breathing should be provided even while the victim is still in the water if the rescuer's safety is ensured.

There is no evidence that water acts as an obstructive foreign body, and time should not be wasted in attempting to remove water from the victim.

Comparison Across Age Groups of Resuscitation Interventions

CPR/Rescue Breathing	Adult and Older Child	Child (1-8)	Infant (Less than 1 Year)	Neonate and Newly Born
Establish unresponsiveness, Activate EMS				
Open airway	Head tilt-chin lift (if trauma, jaw thrust)	Head tilt-chin-lift (if trauma, jaw thrust)	Head tilt-chin lift (if trauma, jaw thrust)	Head tilt-chin lift (if trauma, jaw thrust)
Check for Breathing, If not, Give 2 effective breaths (Initial)	2 effective breaths at 2 seconds per breath	2 effective breaths at 1 to 1 ½ seconds per breath	2 effective breaths at 1 to 1 ½ seconds per breath	1 effective breaths at 1 second per breath
Subsequent	12 breaths/min	20 breaths/min	20 breaths/min	30-60 breaths/min
FBAO	Abdominal thrusts or back blows or chest thrusts	Abdominal thrusts or back blows or chest thrusts	Back blows or chest thrusts (no abdominal thrusts)	Back blows or chest thrusts (no abdominal thrusts)
Check for Signs of Circulation	Pulse check (healthcare providers only; Carotid)	Health Care Providers: carotid	Healthcare Providers (Brachial)	Healthcare Providers (Umbilical)
Compression Landmarks	Lower half of the sternum	Lower half of the sternum	Lower half of the sternum (1 finger width below the intermammary line.)	Lower half of the sternum (1 finger width below the intermammary line)
Compression Depth	1 ½ - 2 inches	1/3 to ½ depth of the chest	1/3 to ½ the depth of the chest	1/3 to ½ the depth of the chest
Compression Method	Heel of 1 hand, other hand on top	Heel of 1 hand	Two thumbs encircling hands for 2 rescuer healthcare provider or 2 fingers	Two thumbs encircling hands for 2 rescuer healthcare provider or 2 fingers
Compression Rate	100/min	100/min	At least 100/min	120/min
Compression/Ventilation Ratio	15:2 5:1 (2 rescuers, protected airway)	5:1	5:1	3:1

PEDIATRIC ADVANCED LIFE SUPPORT

Changes:

- The need for better data regarding the Epidemiology and treatment of pediatric cardiopulmonary arrest is recognized. There is a critical need for identification, tracking and reporting of key resuscitation interventions and their relationship to various outcome measures.

Support of Airway:

- The method of advanced airway support provided to the patient should be selected on the basis of the training and skill level of providers in a given advanced life support system and on the arrest characteristics and circumstances.
- Proficiency in the skill of bag-mask ventilation is mandatory for anyone providing ALS in the prehospital and hospital setting.
- Secondary confirmation of proper tracheal tube placement is required for patients with a perfusing rhythm by capnography or exhaled co2 detector immediately after intubation and during transport. Adequate oxygenation should also be confirmed in a victim with a perfusing rhythm using pulse oximetry.

Fluid Therapy:

- Increase attention to early vascular access, including immediate intraosseous access for victims of cardiac arrest, and extend the use of intraosseous techniques for victims >6 years old.

Medications:

- There is renewed emphasis on the need to identify and treat reversible causes of cardiac arrest and symptomatic arrhythmias, such as toxic drug overdose or electrolyte abnormalities.
- Specific drug selection and dose recommendations are provided for cardiac arrest victims, but acknowledge the lack of adequate data to make such recommendations on the basis of firm evidence.

Treatment of Arrhythmias

- Introduce vagal maneuvers into the treatment algorithm for SVT
- Introduce the drug Amiodarone into the treatment algorithms for VT and shock refractory VF
- Automated external defibrillators may be used in the treatment of children > 8 years of age.

Postarrest Stabilization:

- Increased emphasis on posresuscitation interventions that may influence neurological survival, which include maintenance of normal ventilation rather than hyperventilation.

Education and Training:

- Simplification of education and reinforcement of skill acquisition and core competencies

PALS for Children with Special Needs

Children with special healthcare needs have chronic physical, developmental, behavioral, or emotional conditions and also require health and related services of type or amount not usually required by other children.

Approximately half of the EMS responses for children with special healthcare needs are unrelated to those special needs. It can be complicated by lack of specific medical information about the child's baseline condition, plan of medical care, currently medications and any "Do Not Resuscitate" orders. The best source of information about a chronically ill child is a concerned and compassionate person who cares for the child on a daily basis. Parents and child care providers should be encouraged to keep copies of essential medical information at home, with the child, and at the child's school or child-care facility.

Whenever a child with a chronic or life threatening condition is discharged from the hospital, parents, school nurses, and any home healthcare providers should be informed about possible causes of deterioration or complications that the child may experience and anticipated signs of deterioration.

Epidemiology

Ideally the sequence of resuscitation should be tailored to the most likely cause of the arrest, but this increases the complexity of BLS and ALS education. In the newly born infant, respiratory failure is the most common cause of cardiopulmonary deterioration and arrest.

In general pediatric out of hospital arrest is characterized by a progression from hypoxia and hypercarbia to respiratory arrest and Bradycardia and then to asystolic cardiac arrest. Therefore a focus on immediate ventilation and compressions rather than the "adult" approach of immediately EMS activation or defibrillation appears to be warranted.

If a previously well child experiences a sudden witnessed collapse, this suggests a previously undetected cardiac disorder, and immediate activation of the EMS system may be beneficial. Children with sudden collapse may have a prolonged QT syndrome, hypertrophic cardiomyopathy or drug induced cardiac arrest.

Recognition of Respiratory Failure and Shock

Survival after cardiac arrest in children averages 7-11% with most survivors neurologically impaired. Early recognition and treatment respiratory failure and shock is imperative to prevent cardiac arrest.

Deterioration in respiratory function or imminent respiratory arrest should be anticipated in infants or children who demonstrate any of the following signs:

- Increase Respiratory Rate, particularly if accompanied by signs of distress
- Increased Respiratory Effort
- Inadequate Respiratory Rate, effort or chest excursion
- Diminished Peripheral Breath sounds
- Gasping or Grunting Respirations
- Decreased Level of Consciousness or response to pain
- Poor skeletal Muscle Tone
- Cyanosis

RESPIRATORY FAILURE – state characterized by inadequate oxygenation, ventilation or both.

SHOCK – is a clinical state in which blood flow and delivery of tissue nutrients do not meet tissue metabolic demand. Shock may occur with increased, normal or decreased cardiac output or blood pressure.

DECOMPENSATED SHOCK – is a clinical state of tissue perfusion that is inadequate to meet metabolic demand and hypotension (systolic BP less than the 5th percentile for age)

Hypotension Guidelines:

- For term neonates (0-28 days) SBP <60mmHg
- For Infants (1 – 12 months) SBP <70mmHg
- For Children (>1 year to 1-yrs) 70 + (2x age in years)
- Beyond 10 years, hypotension is defined as a SBP <90mmHg

COMPENSATED shock is detected by;

- Evaluation of heart rate
- Presence and volume of peripheral pulses
- Adequacy of end organ perfusion
- Assessment of Mental status
- Capillary refill
- Skin Temperature
- Urine Output
- Presence and Magnitude of metabolic acidosis

Sustained sinus tachycardia in the absence of known causes such as fever or pain may be an early sign of cardiovascular compromise. Bradycardia on the

other hand may be a preterminal cardiac rhythm indicative of advanced shock and is often associated with hypotension.

Adjuncts for Airway and Ventilation

Out of Hospital Considerations

Ventilation via a properly placed tracheal tube is the most effective and reliable method of assisted ventilation. However this “gold standard” method requires mastery of the technical skill to successfully and safely place tube in the trachea, and it may not always be appropriate in the out of hospital setting, depending on factors such as the experience and training of the healthcare provider and the transport time.

In retrospective studies, increased accuracy and reduced complication rate are associated with increased training, the use of minimal requirements ensuring adequate ongoing experience and the use of paralytic agents.

In some EMS systems the success rate for pediatric intubation is relatively low and the complication rate is high. This probably reflects the infrequent use of intubation skills in the pediatric population. Dedicated critical care or interhospital transport personnel have a high success rate with endotracheal intubation.

Randomized, controlled trials comparing bag mask ventilation with endotracheal intubation in the prehospital setting, bag mask ventilation was generally as effective as intubation; for the subgroup with respiratory failure, bag mask ventilation was associated with improved survival. Overall the studies suggest that endotracheal intubation may not improve survival over bag mask ventilation in all EMS systems and endotracheal intubation appears to result in increased airway complications.

A device to confirm tracheal tube placement in the field, in the transport vehicle and on arrival to the hospital is required. Displacement of the tube is most likely to occur when the patient is moved into and out of the transport vehicle. Detection of a displaced or obstructed tube using pulse oximetry or changes in heart rate or blood pressure may be delayed more than 3 minutes.

Oxygen Administration

Administer oxygen to all seriously ill or injured patients with respiratory insufficiency, shock or trauma. In these patients inadequate pulmonary gas exchange and inadequate cardiac output resulting from conditions such as a low circulatory blood volume or disturbed cardiac function limit tissue oxygen delivery.

Oxygen should be administered to children demonstrating cardiopulmonary arrest or compromise to maximize arterial oxygen content even if measured arterial oxygen tension is high, because oxygen delivery to tissues may still be compromised by a low cardiac output.

If the patient demonstrates effective spontaneous ventilation, use a simple face mask to provide oxygen at a concentration of 30-50%. If a higher concentration is desired, it may be administered through a nonrebreathing mask, typically at a flow rate of 15L/min.

Nasal cannulas are often better tolerated than a face mask and are suitable to use in children who require modest oxygen supplementation.

Oropharyngeal and Nasopharyngeal Airways

Oropharyngeal airways are available for pediatric patients of all ages. Appropriate selection of airway size requires training and experience. An improperly sized airway may fail to keep the tongue separated from the back of the pharynx or may actually cause airway obstruction.

Nasopharyngeal airways are soft rubber or plastic tubes that may be used in conscious patients requiring relief of upper airway obstruction. They may be useful in children with a diminished level of consciousness or in neurologically impaired children who have poor pharyngeal tone leading to upper airway obstruction.

In very young patients, airway secretions and debris readily obstruct small nasopharynx airways, making them unreliable. Children may have large adenoids, which can lead to difficulty in placing the airway, trauma, and bleeding may occur during placement. Large adenoids also may compress the airway after placement leading to increased airway resistance and an ineffective airway.

Laryngeal Mask Airway

The LMA is introduced into the pharynx and advanced until resistance is felt as the tube locates in the hypopharynx. The balloon cuff is then inflated, which seals the hypopharynx, leaving the distal opening of the tube just above the glottic opening and providing a clear, secure airway.

- Widely used in operating room and provide an effective means of ventilation
- Contraindicated in an infant or child with an intact gag reflex
- Useful in patients with difficult airways
- Used successfully in emergency airway control of adults in hospital and out of hospital settings
- Data shows that mastering LMA insertion may be easier than mastering endotracheal intubation skills
- Paramedics have been trained to insert an LMA with a higher success rate than endotracheal intubation.

Although LMA's do not protect the airway from aspiration of refluxed gastric contents, a meta-analysis showed that aspiration is uncommon with LMA use in the operating room and was less common than with BVM.

NEGATIVES

- May be more difficult to maintain during patient movement than a tracheal tube, making it problematic to use during transport
- Relatively expensive and a number of sizes are needed to provide airway support to any child at risk.

Bag – Mask Ventilation

- Training should focus on selecting an appropriately sized mask and bag.
- Two types of manual resuscitations: self-inflating and flow-inflating. Ventilation bags used for resuscitation should be self-inflating and should be available in child and adult sizes
- Superior bag mask ventilation can be achieved with 2 persons, and this technique may be necessary when there is significant airway obstruction or poor lung compliance

Gastric Inflation and Cricoid Pressure

Gastric inflation in unconscious or obtunded patients can be minimized by increasing inspiratory time to deliver the necessary tidal volume at low peak inspiratory pressures.

To reduce gastric inflation a second rescuer can apply cricoid pressure, but use this procedure only with an unconscious patient. Cricoid pressure may also prevent regurgitation and aspiration.

Avoid excessive cricoid pressure because it may produce tracheal compression and obstruction or distortion of the upper airway.

Endotracheal Intubation

The tracheal tube is the most effective and reliable method of assisted ventilation. Advantages include:

- The airway is isolated to ensure adequate ventilation and delivery of oxygen without inflating the stomach
- The risk of pulmonary aspiration of gastric contents is minimized
- Inspiratory time and peak inspiratory pressures can be controlled
- Secretions and other debris can be suctioned from the airways
- Positive end-expiratory pressure can be delivered, if needed.

Indications for Intubation include:

- Inadequate central nervous system control of ventilation resulting in apnea or inadequate respiratory effort
- Functional or anatomic airway obstruction
- Excessive work of breathing leading to fatigue

- Need for high peak inspiratory pressures or positive end-expiratory pressures to maintain effective alveolar gas exchange
- Lac of airway protective reflexes
- Permitting paralysis or sedation for diagnostic studies while ensuring protection of the airway and control of ventilation

The airway of the child differs from that of the adult. The child's airway is;

- More compliant
- The tongue is relatively larger
- The glottic opening is higher and more anterior
- Airway is proportionally smaller
- Narrowest diameter of the child's airway is located below the vocal cords at the level of the cricoid cartilage.

Uncuffed tubes are typically used for children <8 years old. However, cuffed tracheal tubes sized for younger children are available and may be appropriate under circumstances in which high inspiratory pressure is expected, such as status asthmaticus or acute respiratory distress syndrome.

$$\text{Tracheal tube size (mm)} = (\text{age in years}/4 + 4)$$

If a cuffed tube is needed a slight modification of this formula works.

$$\text{Tracheal tube size (mm)} = (\text{age in years}/4 + 3)$$

Before attempting intubation assemble the following equipment:

- Tonsil-tipped suction device or large bore catheter
- A suction catheter of appropriate size to fit into the tracheal tube
- Manual resuscitator, oxygen source, and a face mask of appropriate size
- Stylet to provide rigidity to the tracheal tube.
- Three tracheal tubes, 1 tube of the estimated required size and tubes 0.5mm smaller and 0.5mm larger
- A laryngoscope blade and handle
- An exhaled CO₂ detector or in older children and adolescents, an esophageal tube detector
- Tape to secure the tube and gauze to dry the face.

VERIFICATION OF TUBE PLACEMENT

1. Observe chest wall movement and listen for breath sounds over the peripheral lung fields
2. Breath sounds should be absent over the upper abdomen
3. The presence of water vapor in the tube is NOT a reliable indicator of proper tube position.
4. Monitor exhaled CO₂, especially in children with a perfusing rhythm.
5. Continuous pulse oximetry.

6. Confirm by chest x-ray as soon as possible.

- No single confirmation technique is 100% reliable under all circumstances
- Devices to confirm placement should always be used in the perfusing patient and are highly recommended in the cardiac arrest patient
- If the infant or child has a perfusing rhythm exhaled CO₂ detection is the best method for verification
- Once placement is confirmed, the tube should be secured and the tube position at the level of the lip or teeth recorded
- Repeated confirmation or continuous monitoring of tube placement is highly recommended during stabilization and transport

Of the condition of the intubated patient deteriorates, consider several possibilities that can be recalled by the mnemonic

DOPE: Displacement of the tube, Obstruction of the tube, Pneumothorax and Equipment failure.

Rapid Sequence Intubation

RSI uses pharmacological agents to facilitate emergent intubation while reducing adverse effects in responsive patients, including pain, arrhythmias, rise in systemic and intracranial pressures, airway trauma, gastric regurgitation and aspiration, hypoxemia, psychological trauma and death. The term rapid sequence intubation is preferred over rapid sequence induction because the latter denotes the technique used by anesthesiologists for rapid airway control coincident with the initiation of anesthesia.

RSI is not indicated for patients in cardiac arrest or for those who are deeply comatose and require immediate intubation without delay. Relative contraindications to RSI include, provider concern that intubation or mask ventilation may be unsuccessful; significant facial or laryngeal edema or trauma or distortion or a spontaneously breathing, adequately ventilated patient whose airway maintenance depends on his own upper airway muscle tone and positioning. (such as upper airway obstruction or epiglottitis)

Non-Invasive Respiratory Monitoring

A. Pulse Oximetry

Pulse oximetry is an important noninvasive monitor of the child with respiratory insufficiency because it enables continuous evaluation of the arterial oxygen saturation. It may provide early indication of respiratory deterioration causing hypoxemia. It ideally should be used during stabilization and transport because clinical recognition of hypoxemia is not reliable.

If peripheral perfusion is inadequate, (shock is present or the child is in cardiac arrest) pulse oximetry is unreliable and often unobtainable because accurate readings require the presence of pulsatile blood flow. In addition, if a patient is hyperoxygenated before intubation, incorrect tube position may not be recognized by pulse oximetry for a variable period depending on the rate of oxygen consumption.

Exhaled or End-tidal Co2 Monitoring

Exhaled CO₂ detection using a colorimetric device or continuous capnography is recommended to confirm tube placement in infants. A positive color change or the presence of a capnography waveform showing exhaled CO₂ confirms tube position in the tracheal when assessed after six ventilations. Six ventilations are recommended to wash out CO₂ that may be present in the stomach and esophagus after bag mask ventilation. After 6 ventilations detected CO₂ can be presumed to be from the trachea rather than from a misplaced tube in the esophagus.

CO₂ may be detected with right main bronchus intubation, so exhaled CO₂ detection does not replace the need to document proper tube position in the tracheal by chest x-ray and clinical examination.

CO₂ detection in patients in cardiac arrest is not as useful. The presence of a color change or waveform reliably confirms tracheal tube placement, but the absence of detectable CO₂ does not confirm esophageal tube placement in the cardiac arrest patient. Infants, children and adolescents in cardiac arrest Establish and maintain airway. Administer high flow oxygen. Have limited pulmonary blood flow and therefore undetectable exhaled CO₂ despite proper placement of the tube in the tracheal. If placement is uncertain, tube position must be confirmed by clinical examination and direct laryngeal examination.

In addition to cardiac arrest, other conditions leading to very low exhaled CO₂ may also produce misleading results. Severe airway obstruction, status asthmaticus and pulmonary edema may impair CO₂ elimination sufficiently to cause a false negative test results.

If the detector has been contaminated with acidic gastric contents or acidic drugs such as tracheally administered epinephrine, the colorimetric detector may not be reliable.

Esophageal Detector Devices

Esophageal detector devices are based on the ability to readily aspirate air from the cartilage supported trachea by drawing from gas in the lower airways. If the tracheal tube is placed in the esophagus, the walls of the esophagus collapse when aspiration is attempted by an esophageal detector device, preventing filling of a syringe or self inflating rubber bulb.

Although an esophageal detector device has been successfully used in children, it appears to be unreliable in children <1 year of age, in morbidly obese patients and in patient late in pregnancy.

Circulatory Adjuncts

Bedboard

CPR should be performed where the victim is found. If cardiac arrest occurs in a hospital bed, place firm support beneath the patient's back. A bedboard that extends from the shoulders to the waist and across the full width of the bed provides optimal support.

Mechanical Devices for Chest Compression

Are not recommended for pediatric patients because they were designed and tested for use in adults and data on pediatric safety and effectiveness is absent.

Interposed Abdominal Compression CPR

The technique of interposed abdominal compressions does not use an adjunct piece of equipment but does require a third rescuer. This form of chest compression has been shown to increase blood flow in laboratory and computer models of adult CPR and in some in hospital clinical settings. It has been recommended as an alternative technique (Class IIb) for in hospital CPR in adult victims but it cannot be recommended for use in children at this time.

Medical Antishock Trousers (MAST)

The effects of MAST during resuscitation of pediatric cardiac arrest are unknown and the use of MAST cannot be recommended. Randomized trials show either no benefit of MAST or an increased mortality with their use. Potential complications of MAST include lower extremity compartment syndrome and ischemia, and compromised ventilation.

Open Chest Compression

Internal cardiac compressions generates better cardiac output and cerebral and myocardial blood flow in animals and in adults. However comparable improvement in cardiac output may not be observed in infants and children because the chest wall is extremely compliant in this age group.

ESTABLISHING AND MAINTAINING VASCULAR ACCESS

Vascular access is vital for drug and fluid administration but may be difficult to achieve in the pediatric patient. During CPR the preferred access site is the largest, most accessible vein that does not require interruption of resuscitation.

Although central venous drug administration results in more rapid onset of action and higher peak drug levels than peripheral venous administration in

adults, these differences were not shown in a pediatric resuscitation model and may not be important during pediatric CPR. Central venous lines provide more secure access to the circulation and permit administration of agents that might cause tissue injury if they infiltrate peripheral sites. For this reason, if a central venous catheter is in place at the time of arrest, it should be used. The femoral vein is probably the safest and easiest to cannulate.

Peripheral venous access provides a satisfactory route for administration of drugs and fluids if it can be achieved rapidly. Venipuncture can be performed in the veins of the arm, hand, leg or foot. Drugs administered via peripheral vein during CPR should be followed by a rapid isotonic crystalloid fluid (5-10cc) to move the drugs into the central circulation.

In infants and children requiring emergent access for severe shock or for prearrest conditions, establish intraosseous vascular access if reliable venous access cannot be achieved rapidly. Because establishment of vascular access in pediatric cardiac arrest victims is difficult it may be preferable to attempt intraosseous access immediately.

If vascular access is not established rapidly in cardiac arrest and the airway is secured, lipid-soluble resuscitation drugs such as epinephrine may be administered through the trachea route. Whenever a vascular route is available, however, it is preferable to tracheal drug administration.

INTRAOSSIOUS ACCESS

Provides access to a noncollapsible marrow venous plexus, which serves as a rapid, safe and reliable route for administration of drugs, crystalloids, colloids and blood during resuscitation. It can often be achieved in 30-60 seconds.

The intraosseous needle typically is inserted into the anterior tibial bone marrow; alternative sites include the distal femur, medial malleolus, or anterior superior iliac spine. In older children and adults, IO cannulas were successfully inserted into the distal radius and ulna.

Resuscitation drugs including epinephrine and adenosine, fluids and blood products can be safely given IO. Potent catecholamine solutions can be infused by IO.

Onset of action and drug levels IO are comparable to those achieved following vascular administration and drug concentrations similar to those from central venous administration. To overcome resistance rapid volume expansion and viscous drugs and solutions may require administration under pressure via an infusion pump or forceful manual pressure.

The IO route also may be used to obtain blood specimens for chemical and blood gas analysis, type and crossmatch even during CPR. Complications were reported in less than 1%.

Tracheal Drug Administration

Until vascular access is obtained, the tracheal route may be used for administration of lipid-soluble drugs, including Lidocaine, epinephrine, atropine and Narcan. (Mnemonic LEAD)

Drugs that are not lipid soluble should not be administered by this route because they will injury the airways. Optimal drug dosages for administration by the tracheal route and unknown because drug absorption across the alveolar and bronchiolar epithelium during cardiac arrest may vary widely.

The standard dose of Epinephrine administered via the tracheal route produces serum concentrations that are only 10% or less than those of a dose administered IV. For this reason the recommended tracheal dose of epinephrine during pediatric resuscitation is 10 times the dose given IV. (Utilizing 1:1000 Epinephrine instead of 1:10000)

When drugs are given by the trachea route dilution of the drug in up to 5cc of NSS followed by 5 manual ventilations results in equivalent absorption and pharmacological effect compared with through a catheter or feeding tube inserted into the tracheal tube.

Fluid and Drug Therapy

Pharmacotherapy in children is complicated by the need to adjust dosages to a wide variety of body weights. Skilled personnel may not accurately estimate weight on the basis of appearance. Length is easily measured and enables reliable calculation of emergency medication doses. Tapes to determine weight from length are available with precalculated doses printed at various lengths.

For hospitalized children weight should be recorded and emergency drug doses precalculated, and this information should be easy to locate in case of an emergency.

Expansion of circulating blood volume is a critical component of PALS in children who have sustained trauma with acute blood loss. It may also be lifesaving in the treatment of nontraumatic shock, such as severe dehydration or septic shock. Volume expansion is best achieved with isotonic crystalloid solutions, such as Ringer's lactate or normal saline.

Consistent with adult trauma life support guidelines, blood replacement is indicated in children with severe acute hemorrhage if the child remains in shock after infusion of 40-60cc/kg of crystalloid.

Dextrose solutions should not be used for initial fluid resuscitation of children because large volumes of glucose containing intravenous solutions do not effectively expand the Intravascular compartment and may result in hyperglycemia and secondary osmotic diuresis. If hypoglycemia is suspected or confirmed, it is readily treated with IV glucose.

Drugs Used for Cardiac Arrest and Resuscitation

EPINEPHRINE

Is an endogenous catecholamine with potent alpha and beta adrenergic stimulating properties. In cardiac arrest, alpha mediated vasoconstriction is the most important pharmacological action: vasoconstriction increases aortic diastolic pressure and coronary perfusion pressure which is a critical determinant of success or failure of resuscitation. Epinephrine induced elevation of coronary perfusion pressure during chest compressions enhances delivery of oxygen to the heart. Epinephrine also enhances the contractile state of the heart, stimulates spontaneous contractions, and increases the vigor and intensity of VF increasing the success of defibrillation.

In a child with symptomatic Bradycardia that is unresponsive to effective assisted ventilation and supplemental O₂, epinephrine may be given in a dose of 0.01mg/kg IV or IO. Continuous epinephrine infusion may be considered for refractory Bradycardia.

There is no benefit shown from high dose epinephrine. Adverse effects including increased myocardial oxygen consumption during CPR, a postarrest hyperadrenergic state with tachycardia, hypertension and ventricular ectopy, myocardial necrosis and worse post arrest myocardial function were found. Since great interpatient variability in catecholamine response is well established in the nonarrest state, it is possible that a dangerous dose in one patient may be lifesaving in another.

VASOPRESSIN

Is an endogenous hormone that acts at specific receptors to mediate systemic vasoconstriction and reabsorption of water in the renal tubule. This hemodynamic action produces favorable increases in blood flow to the heart and brain in experimental models of cardiac arrest and improved long term survival compared with epinephrine. The patients receiving vasopressin plus epinephrine were significantly more likely to survive to hospital admission and for 24 hours. Even low dose vasopressin infusions demonstrated significant pressor effect in critically ill adults and critically ill infants and children during evaluation for brain death and organ recovery.

Calcium

Is essential in myocardial excitation contraction coupling. However, routine calcium administration does not improve outcome of cardiac arrest. Route administration of calcium in resuscitation of asystolic patients cannot be recommended. Calcium is indicated for treatment of documented hypocalcemia and Hyperkalemia particularly in hemodynamically compromised patients.

MAGNESIUM

Is a major intracellular cation and serves as a cofactor in >300 enzymatic reactions. Data, however supports only the routine use of magnesium sulfate in patients with documented hypomagnesemia or with torsades de Pointes, VT.

GLUCOSE

Infants have a high glucose requirements and low glycogen stores. As a result, during periods of increased energy requirements such as shock, the infant may become hypoglycemic. For this reason, monitor blood glucose concentrations closely using rapid bedside tests during coma, shock or respiratory failure.

SODIUM BICARBONATE

Although it has been previously recommended for the treatment of severe metabolic acidosis in cardiac arrest in most but not all studies routine sodium bicarbonate administration failed to improve outcome of cardiac arrest. It is recommended in the treatment of symptomatic patients with Hyperkalemia, hypermagnesemia, tricyclic antidepressant overdose or overdose from other sodium channel blocking agents.

Excessive administration may have several adverse effects. Resulting metabolic alkalosis produces leftward displacement of the oxyhemoglobin dissociation curve with impaired delivery of oxygen to tissues, acute intracellular shift of potassium, decreased plasma ionized calcium concentration, decreased VF threshold and impaired cardiac function.

**PALS MEDICATIONS FOR CARDIAC ARREST AND SYMPTOMATIC
ARRHYTHMIAS**

Drug	Dosage/Pediatric	Remarks
Adenosine	0.1mg/kg Repeat Dose: 0.2mg/kg Maximum Single Dose: 12mg	Rapid IV/OI Bolus Rapid Flush to Central Circulation Monitor ECG during dose
Amiodarone for Pulseless VF/VT	5mg/kg IV IO	Rapid IV Bolus
Amdiodarone for Perfusing Tachycardias	Loading: 5mg/kg IV/IO Maximum Dose: 15mg/kg per day	IV over 20-60 minutes Routine use in combination with drugs prolonging QT interval is not recommended. Hypotension is most common side effect
Atropine Sulfate	0.02mg/kg Minimum Dose: 0.1mg Maximum Single Dose: 0.5mg in child, 1.0 mg in adolescent. May repeat once	May give IV, IO or ET Tachycardia and pupil dilation may occur but not fixed dilated pupils
Calcium Chloride 10% = 100mg/ml	20mg/kg (0.2ml/kg) IV/IO	Give slow IV push for hypocalcemia, hypermagnesemia, calcium channel blocker toxicity, preferably via central vein. Monitor heart rate; Bradycardia may occur
Epinephrine for Symptomatic Bradycardia	IV/IO: 0.01mg/kg (1:10,000, 0.2ml/kg)	Tachyarrhythmias, hypertension may occur.
Epinephrine for Pulseless Arrest	First Dose: IV/IO: 0.01mg/kg (1:10000, 0.1ml/kg) ET: 0.1mg/kg (1:1000 0.1cc/kg) Subsequent doses, repeat initial dose or may increase up to 10 times.	
Glucose (10% or 25% or 50%)	IV/IO 0.5-1.0 g/kg <ul style="list-style-type: none"> ▪ 1-2 cc/kg 50% ▪ 2-4 cc/kg 25% ▪ 5-10cc/kg 10% 	For suspected hypoglycemia; avoid hyperglycemia
Lidocaine	IV/IO/ET: 1mg/kg	Rapid bolus
Lidocaine Infusion	IV/IO 20-50 ug/kg/min	
Magnesium	IV/IO 25-50 mg/kg Maximum dose: 2 g per dose	Rapid IV infusion for torsades or suspected hypomagnesemia: 10-20 minute infusion for asthma that responds poorly to Beta agonists
Naloxone	<5yrs or <20kg: 0.1mg/kg >5 yrs or >20kg: 2.0mg	For total reversal of narcotic effect Use small repeated doses titrated to desired effect

RHYTHM DISTURBANCES

Although primary cardiac events are uncommon in the pediatric age group, the ECG's of all critically ill or injured children should be monitored. Most pediatric arrhythmias are the consequence of hypoxemia, acidosis, and hypotension rather than the cause of these clinical states, but children with myocarditis or cardiomyopathy are at increased risk of primary arrhythmias as are children after heart surgery.

The likelihood of VF increases with age, based on an analysis of out of hospital data. The likelihood of detecting a ventricular arrhythmia may depend on the response time or other characteristics of the EMS system, since only 4% of 300 children experiencing an out of hospital arrest in the Houston metropolitan area has a ventricular arrhythmia identified by EMS.

Bradycardias

Hypoxemia, hypothermia, acidosis, hypotension, and hypoglycemia may depress normal sinus node function and slow conduction through the myocardium.

In the small infant (<6 months) cardiac output is more dependent on heart rate than in older infant and children. It is therefore more likely to cause symptoms. Clinically significant Bradycardia is defined as a heart rate less than 60 or a rapidly dropping heart rate despite adequate oxygenation and ventilation associated with poor systemic perfusion.

Epinephrine is the most useful drug in the treatment of symptomatic Bradycardia caused by heart block or increased vagal tone. For vagally mediated Bradycardia, atropine is the initial drug of choice. If the Bradycardia persists after adequate oxygenation and ventilation and responds only transiently or not at all to bolus epinephrine or atropine consider a continuous infusion of epinephrine or dopamine.

In selected cases of Bradycardia caused by complete heart block or abnormal function of the sinus node, emergency Transthoracic pacing may be lifesaving. Pacing is not helpful in children with Bradycardia secondary to post arrest hypoxic/ischemic myocardial insult or in respiratory failure. Pacing also was not shown to be effective in the treatment of asystole in children.

Pulseless Electrical Activity

Clinical state characterized by organized electrical activity observed in the absence of detectable cardiac output. This clinical state often represents a preterminal condition that immediately precedes asystole. It frequent represents the final organized electrical state of a severely hypoxic, acidotic myocardium and is usually characterized on the monitor by a slow wide complex rhythm in a child who has experienced a prolonged period of hypoxia, ischemia or hypercarbia. In this setting treat PEA in the same way as asystole.

Occasionally PEA is due to a reversible cause that often occurs rapidly and represents a sudden impairment of cardiac output. 4H's and 4T's:

- Hypovolemia
- Hypoxemia
- Hypothermia
- Hyperkalemia
- Tension Pneumothorax
- Pericardial Tamponade
- Toxins
- Pulmonary Thromboembolus

If EMD is observed, search for evidence of these reversible causes. If the patient remains pulseless after you have established an airway, ventilated the lungs, provided supplemental oxygen and delivered chest compressions, Epinephrine should be given.

Supraventricular Tachycardia

SVT is the most common nonarrest arrhythmia during childhood and is the most common arrhythmia that produces cardiovascular instability during infancy. Usually caused by a reentrant mechanism SVG in infants generally produces a heart rate >220 and sometimes as high as 300. Lower heart rates may be observed in children during SVT. The QRS is narrow in >90% of involved children making the differentiation between marked sinus tachycardia due to shock and SVT somewhat difficult. The following characteristics may aid differentiation between ST and SVT:

- A history consistent with shock (dehydration or hemorrhage) is usually present with ST, whereas the history is often vague and nondescript with SVT.
- The heart rate is usually <220 in infants and <180 in children with ST, whereas with SVT typically have a heart rate of >220 and children >180.
- P waves may be difficult to identify in both ST and SVT once the ventricular rate exceeds 200, but they are usually present in infants and children with ST. If P waves are identifiable in ST, they are usually upright in leads I and aVF, whereas in SVT they are negative in leads II, III and aVF.
- In ST the heart rate varies from beat to beat and is often responsive to stimulation, but there is no beat to beat variability in SVT. Termination of SVT is abrupt, whereas the heart rate slows gradually in ST.

TREATMENT:

Vagal Maneuvers

In children with milder symptoms who are hemodynamically stable or during preparation for cardioversion or drug therapy vagal maneuvers may be tried.

Cardioversion

SVT that causes circulatory instability is most expeditiously treated with cardioversion. Synchronized electrical cardioversion is recommended at a starting dose of 0.5 to 1 J/kg. If vascular access is already available, adenosine may be administered before electrical cardioversion.

Adenosine

Adenosine is the drug of choice for SVT in children. It is an endogenous nucleoside that acts at specific receptors to cause a temporary block of conduction through the AV node; it interrupts the reentry circuits that involve the AV node. Adenosine is very effective; side effects are minimal because its half life is only 10 seconds. Administer 0.1mg/kg as rapid IV bolus. The bolus must be followed by a rapid flush of NSS.

Verapamil

Should not be used to treated SVT in infants because refractory hypotension and cardiac arrest have been reported following its administration.

Treatment of Wide QRS Tachycardia

The decision to initiate treatment is based on whether the patient is hemodynamically stable. Urgent treatment of a wide complex tachycardia includes synchronized cardioversion if pulses are present and defibrillation if pulses are lost.

VT and VF are uncommon in children. When seen, consider either congenital heart disease, cardiomyopathy or acute inflammatory injury to the heart. In addition, identify and treat reversible causes, including drug toxicity.

Hemodynamically Stable VT

Careful evaluation and early consultation with a cardiologist are indicated before any therapy is given. Focus initial efforts on determining the origin of the arrhythmia based on analysis of the 12 lead ECG and a careful history. Amiodarone and procainamide can be used but a cautious approach is necessary in children who are hemodynamically stable because all of these drugs have intrinsic risks. Amiodarone and procainamide can cause hypotension and procainamide is a potent negative inotrope.

Cardioversion for VT with pulses

In the infant or child with VT and palpable pulses associated with signs of shock immediate cardioversion is indicated. Depending on the severity of hemodynamic compromise and the patient's level of consciousness, cardioversion may be provided before vascular access is obtained. The rhythm should be examined for a torsades de pointes appearance. If torsades de points

is suspected, administer 25mg/kg of magnesium by a slow IV bolus over 10-20 minutes.

Pulseless VT/VF

Delivering shocks to produce defibrillation is the definitive therapy. Ventilation, oxygenation and chest compressions should be delivered and vascular access may be attempted until the defibrillator arrives and is charged, but these interventions should not delay shocks. If the patient fails to defibrillate after 3 shocks, Epinephrine is indicated. If VT continues or recurs Amiodarone (5mg/kg) is indicated. The recommendation that no more than 30-60 seconds of artificial circulation before the next shock. The use of amiodarone is based on adult data of shock resistant VF/VT and experience with the use of amiodarone in children in the intensive care unit.

Amiodarone

Is a highly lipid-soluble antiarrhythmic with complex pharmacology, making it difficult to classify. Amiodarone has been used most commonly in children to treat ectopic atrial tachycardia or junctional ectopic tachycardia after cardiac surgery and VT in postoperative patients or children with underlying cardiac disease.

Potential long term complications include interference with thyroid hormone metabolism leading to hypothyroidism or hyperthyroidism interstitial pneumonitis, corneal microdeposits, blue gray skin discoloration and elevated liver enzyme levels. ARDS is an unusual but potentially life threatening complication seen in patients receive chronic amiodarone therapy who undergo a surgical procedure, especially a pulmonary or cardiac procedure.

Lidocaine

Is a sodium channel blocker that reduces the slope of phase 4 diastolic repolarization which decreases automaticity and therefore suppresses ventricular arrhythmias. It may be considered in children with shock resistant VT/VF (Class Indeterminate). The recommended dose is 1mg/kg

DEFIBRILLATION, CARIOVERSION AND EXTERNAL PACING

Defibrillation is the untimed depolarization of the myocardium that successfully terminates VF or pulseless ventricular tachycardia. Electric shocks are used to achieve defibrillation; shocks produce a simultaneous depolarization of a critical mass of myocardial cells, which may then allow resumption of spontaneous depolarization especially if the myocardium is oxygenated and normothermic and acidosis is not excessive. When VF occurs suddenly, an immediate shock is usually effective. If the arrest is prolonged or the child does not respond to the initial attempts at defibrillation, then ventilation, oxygenation, chest compressions, and pharmacological therapy may be needed to improve the metabolic environment of the myocardium.

Paddle size is one determinant of Transthoracic impedance, which determines the current flow through the chest.

- The larger adult paddles are recommended for children weighing over 10kg (approximately 1 year of age)
- Selection of paddle size is based on providing the largest surface area of paddle contact with the chest wall without contact between the paddles or electrodes.

The optimum electrical dose is not conclusively established but available data suggests an initial dose of 2J/kg and if this is unsuccessful, 4J/kg.

The first three shocks should occur in rapid succession, with pauses long enough to confirm whether VF persists.

Newer defibrillators use biphasic waveforms, this waveform appears to be effective at lower energy doses. Although there is no published data in young children, biphasic AED's may be used in children > 8 years of age.

Based on available data, AED's may be considered for rhythm identification in children < 8 years old but are not recommended for younger children or infants. The energy dose delivered by currently available monophasic and biphasic AED's exceeds the recommended dose of 2-4 J/kg for most children < 8 years of age.

Synchronized Cardioversion

Is the timed depolarization of myocardial cells that successfully restores a stable rhythm. The synchronizer circuit on the defibrillator must be activated before each cardioversion attempt. The initial energy dose is 0.5 to 1J/kg. The dose is increased up to 2J/kg with subsequent attempts. If a second shock is unsuccessful or the tachycardia recurs quickly, consider antiarrhythmic therapy before a third shock. Hypoxemia, acidosis, hypoglycemia or hypothermia should be corrected if the patient fails to respond to attempts at cardioversion.

Noninvasive Transcutaneous Pacing

Experience with children is limited and does not support a beneficial effect of pacing on outcome of children with cardiac arrest. Since this form of pacing is very uncomfortable, its use is reserved for children with profound symptomatic Bradycardia refractory to BLS and ALS.

PALS FOR THE PEDIATRIC TRAUMA PATIENT

Some aspects of pediatric trauma care require emphasis because improper resuscitation may be a major cause of preventable pediatric trauma death. Common errors in pediatric trauma include; failure to open and maintain the airway, failure to provide appropriate fluid resuscitation for children (including those with head injury) and failure to recognize and treat internal bleeding.

If possible children with multisystem trauma should be transported rapidly to trauma centers with pediatric expertise.

PRIMARY AND SECONDARY SURVEYS

- A= Airway
- B= Breathing
- C= Circulation
- D=Disability to evaluate neurological condition
- E = exposure to keep the child warm and expose the skin to look for hidden injuries

Airway control includes cervical spine immobilization. Immobilization can best be achieved by using a backboard with a recess for the head or using a roll under the back from the shoulders to the buttocks.

In the out of hospital setting, bag mask ventilation may enable adequate support of oxygenation and ventilation particularly when the transport time is short. Endotracheal intubation is indicated if the trauma victim's respiratory effort is inadequate, airway patency is compromised or coma is present. Cricoid pressure may facilitate intubate when movement of the neck can be avoided.

Although initial hyperventilation for patients with head trauma was previously recommended, routine hyperventilation is not associated with an improved outcome in these patients and may increase intrathoracic pressures, adversely affecting venous return and cardiac output. In addition, hyperventilation may adversely affect cerebral perfusion in areas of the brain still responsive to changes in PCO₂ leading to local or global brain ischemia. Hyperventilation is no longer routinely recommended.

Major thoracic injuries may be present in the absence of external evidence of chest trauma because the child's chest is extremely compliant. Even severe blunt chest trauma may fail to produce rib fractures. Thoracic injuries must be suspected, identified and treated if there is a history of thoracoabdominal trauma or difficulty in providing effective ventilation. After the airway is secured, a nasogastric or an orogastric tube should be inserted to prevent or relieve gastric inflation.

Support of circulation in the trauma victim often requires treatment of hemorrhagic shock. Circulatory support requires simultaneous control of external hemorrhage, assessment and support of systemic perfusion and restoration and maintenance of blood volume.

If systemic perfusion is inadequate provide rapid volume replacement with a bolus of 20cc/kg of an isotonic crystalloid. Administer a second bolus rapidly if heart rate, level of consciousness, capillary refill and other signs of systemic perfusion fail to improve.

The presence of hypotension was assumed to indicate a blood volume loss of >20% and the need for urgent volume replacement and blood transfusion, however, minimal data supports this assumption. It is important to note that hypotension also may occur secondary to reversible causes such as a tension pneumothorax or pericardial Tamponade and hypotension may result from a neurological insult.

If the poorly perfused victim fails to respond to administration of 40-60cc/kg of crystalloid, transfusion of 10-15cc/kg of blood is indicated. The blood should be warmed otherwise rapid administration may result in significant hypothermia and can result in transient ionized hypocalcemia.

SPECIAL RESUSCITATION SITUATIONS

Toxicological Emergencies

Drug-induced cause of death are uncommon in younger children but become an important cause of death in the 15-24 year old age group. The most important agents associated with cardiac arrest are cocaine, narcotics, tricyclic antidepressants, calcium channel blockers and beta adrenergic blockers.

The initial approach in toxicological emergencies uses basic PALS principles: assess and rapidly ensure adequate oxygenation, ventilation and circulation. Subsequent priorities include reversing the adverse effects of the toxin and preventing further absorption.

Cocaine

Cocaine has complex pharmacological effects, which are made more complex clinically by the varying onset, duration and magnitude of these effects related to the route of administration and form of cocaine used. Accumulation of norepinephrine and epinephrine leads to tachycardia, tremor, diaphoresis and mydriasis. The tachycardia increases myocardial oxygen demand while reducing the time for diastolic coronary perfusion. Vasoconstriction and resultant hypertension develop from the accumulation of neurotransmitters at peripheral alpha adrenergic receptors.

The most frequent complication of cocaine use leading to hospitalization is acute coronary syndrome producing chest pain and various types of cardiac rhythm disturbances. Stimulation of beta adrenergic myocardial receptors increases myocardial oxygen demand and its alpha adrenergic and 5HT agonist actions cause coronary artery constriction leading to ischemia. In addition, cocaine stimulates platelet aggregation. Through the combination of adrenergic and sodium channel effects cocaine use may cause various tachyarrhythmias, including VT and VF.

Initial treatment consists of oxygen administration, ECG monitoring and administration of benzodiazepine, aspirin and heparin.

Although epinephrine may exacerbate cocaine-induced arrhythmias and is contraindicated in ventricular arrhythmias if VF or pulseless VT occur (Class III) it may be considered to increase coronary perfusion during CPR.

Tricyclic Antidepressants and Other Sodium Channel Blocking Agents

Tricyclic antidepressants continue to be a leading cause of morbidity and mortality despite the increasing availability of safer selective serotonin reuptake inhibitors for the treatment of depression. The toxic effects of Tricyclic agents result from their inhibition of fast sodium channels in the brain and myocardium.

With serious intoxication, rhythm disturbances are due to prolongation of the action potential produced by inhibition of phase 0 of the action potential resulting in delayed conduction.

- An R wave in lead aVR >3mm or an R wave to S wave ratio in lead aVR >.0 was reported to be a superior predictor of serious toxicity
- Tricyclics also inhibit potassium channels leading to prolongation of the QT interval.
- May result in preterminal sinus Bradycardia and heart block with junctional or ventricular wide complex escape beats.

Treatment includes protecting the airway, ensuring adequate oxygenation and ventilation, continuous monitoring and administration of Sodium Bicarbonate. Bicarb narrows the QRS complex, shortens the QT interval and increases myocardial contractility. These actions often suppress ventricular arrhythmias and reverse hypotension. In severe cases consensus recommendations are to increase the pH to a level between 7.50 and 7.55.

Class III antiarrhythmics (amiodarone and sotalol) prolong the QT and are not indicated.

Calcium Channel Blocker Toxicity

All of the calcium channel blockers bind to calcium channels, thereby inhibiting the influx of calcium into cells. The clinical manifestations of toxicity include bradyarrhythmias and hypotension due to vasodilatation and impaired cardiac contractility. Altered mental status, including syncope, seizures and coma may occur because of cerebral hypoperfusion.

Initial therapy is to provide oxygenation, and ventilation, continuously monitor ECG and perform frequent clinical assessments including close monitoring of blood pressure and hemodynamic status. If hypotension occurs, it may respond to normal saline bolus in milder cases, but with more severe intoxication it is often unresponsive to fluid. To avoid pulmonary edema. Limit fluid boluses to 5-10cc/kg with frequent reassessments because of the high frequency of myocardial dysfunction in such patients. Calcium is often infused in calcium channel blocker overdose in an attempt to overcome the channel blockage but case reports suggest only variable effectiveness. The optimal dose

of calcium is unclear. High dose vasopressors therapy (norepinephrine or epinephrine) may be considered on the basis of successful treatment Bradycardia and hypotension. Animal data and recent small case studies suggest that insulin plus glucose may be beneficial. Because insulin and glucose stimulate movement of potassium from the extracellular to the intracellular space, potassium concentrations should be monitored closely.

Beta Adrenergic Blocker Toxicity

Beta blockers compete with norepinephrine and epinephrine at the receptor sites resulting in Bradycardia and decreased cardiac contractility. In severe intoxication some beta blockers have sodium channel blocking effects as well leading to a prolongation of the QRS and the QT intervals. Hypotension usually with Bradycardia and varying degrees of heart block are common clinical manifestations of beta blocker toxicity. Altered mental status including seizures and coma may occur particularly with propranolol.

Initial approach to treatment includes adequate oxygenation and ventilation, assessing perfusion and establishing vascular access and treating shock if present. To overcome the beta adrenergic blockade epinephrine infusions may be effective although very high doses may be needed. As with calcium channel blocker overdose, insulin with glucose may be useful.

Opioid Toxicity

Narcotics produce central nervous system depression and may cause hypoventilation, apnea and respiratory failure requiring resuscitation. Naloxone is an effective opioid receptor antagonist that has been used in >20 years of clinical experience and it remains the treatment of choice to reverse narcotic toxicity. The recommended dose of Naloxone is 0.1mg/kg administered IV with up to 2mg in a single dose. Alternatively to avoid sudden hemodynamic effects from opioid reversal repeated doses of 0.01 to 0.03mg/kg may be used.

Drowning/Submersion

Resuscitation, particularly rescue breathing should begin when the child is in the water. The Heimlich maneuver is not indicated before rescue breathing is begun and it should not be performed unless foreign body airway obstruction is suspected. Poor prognostic indicators after submersion include a prolonged submersion interval in non-icy water, VF on initial rhythm and absence of perfusing rhythm on arrival to the hospital. Signs of increased intracranial pressure that develop subsequent to a submersion injury are consistent with devastating neurological insult, but there is no evidence that invasive monitoring or aggressive treatment of the increased intracranial pressure alters outcome.

POST RESUSCITATION STABILIZATION

The postresuscitation phase begins after initial stabilization of the patient with shock or respiratory failure or after return of spontaneous circulation in a patient who was in cardiac arrest. This phase may include transport to a pediatric tertiary care facility or intrahospital transport from the Emergency Department to a pediatric intensive care unit. The goals of care are to preserve brain function, avoid secondary organ injury, seek and correct the cause of illness and enable the patient to arrive at a tertiary care setting in the best possible physiological state.

Respiratory System

All children should receive supplemental oxygen until adequate oxygenation is confirmed by direct PaO₂ measurement or use of pulse oximetry and until adequate oxygen carrying capacity is confirmed. To achieve airway control so that diagnostic studies such as a CT scan can be safely performed, elective intubation using appropriate sedation and paralysis is sometimes used.

Ongoing confirmation of tube placement especially if the patient undergoes interhospital or intrahospital transport is essential. Oxygen saturation and the cardiac rhythm and rate should be continuously monitored and blood pressure, breath sounds, perfusion and color should be assessed frequently in intubated patients with a perfusing rhythm. Reevaluate tracheal tube position and patency in patients who remain agitated despite effective mechanical ventilatory support and each time the patient is moved, such as into or out of a transport vehicle. If the condition of an intubated patient deteriorates assume several possibilities:

- Displacement of the tube
- Obstruction of the Tube
- Pneumothorax
- Equipment Failure

Gastric distention may cause discomfort and interfere with ventilation if distention develops, an orogastric or nasogastric tube should be inserted. Initial mechanical ventilation of an intubated patient should provide 100% oxygen at a typical rate of 20-30 breaths per minute for infants and 12-20 for older children. Delivered tidal volume should be just sufficient to cause the chest to rise.

Cardiovascular System

Persistent circulatory dysfunction is observed frequently after resuscitation from cardiac arrest. Clinical signs of decreased systemic perfusion include, decreased capillary refill, absent or decreased intensity of distal pulses, altered mental status and hypotension. Decreased cardiac output or shock may be secondary to insufficient volume resuscitation, loss of peripheral vascular tone, and/or myocardial dysfunction. Treatment includes, fluid resuscitation,

vasoactive agents to increase or decrease vascular resistance, inotropic agents and/or correction of hypoxia and metabolic disorders.

Cuff pressures may be inaccurate in the child who remains hemodynamically unstable, consider arterial monitoring as soon as possible. Urine output is an important indicator of organ perfusion.

Drugs Used to Maintain Cardiac Output

The classes of agents used to maintain circulatory function can be divided into inotropes, vasopressors, and vasodilators. Inotropes increase cardiac pumping function and often increase heart rate as well. Vasopressors increase systemic and pulmonary vascular resistance; they are most commonly used in children with inappropriately low systemic vascular resistance. Vasodilators are designed to reduce systemic and pulmonary vascular resistance. Optimal use of these agents requires knowledge of the patient's cardiovascular physiology, which is not always clearly discerned from the clinical examination. Invasive hemodynamic monitoring, including measurement of central venous pressure, pulmonary capillary wedge pressure and cardiac output may be needed.

Epinephrine

Is indicated in the treatment of shock with diminished systemic perfusion from any cause that is unresponsive to fluid administration. It is a potent inotrope and typically is infused at a rate sufficient to increase systemic vascular resistance and therefore blood pressure. It may be useful in patients with hemodynamically significant bradycardia that is unresponsive to oxygenation and ventilation. Epinephrine may be preferable to dopamine in patients with marked circulatory instability particularly in infants.

Dopamine

Is an endogenous catecholamine with complex cardiovascular effects. At low rates dopamine typically increases renal and splanchnic blood flow with little effect on systemic hemodynamics although increases in blood pressure and cardiac output were observed in neonates after infusions at low doses. At infusion rates $>5\mu\text{g}/\text{kg}/\text{min}$ dopamine can result in both direct stimulation of cardiac beta receptors and indirect stimulation through release of norepinephrine stored in cardiac sympathetic nerves. Dopamine infusions may produce tachycardia, vasoconstriction and ventricular ectopy. Infiltration of dopamine into tissues can produce local tissue necrosis.

Dobutamine Hydrochloride

Is a synthetic catecholamine with a relatively selective effect on beta 1 adrenergic receptors and a lesser effect on beta 2 receptors. Thus Dobutamine is a relatively selective inotrope increasing myocardial contractility and usually decreasing peripheral vascular tone. May be particularly useful in the treatment of low cardiac output secondary to poor myocardial function such as following cardiac arrest.

Norepinephrine

Is the neurotransmitter released from sympathetic nerves; it is therefore a potent inotropic agent that also activates peripheral alpha and beta adrenergic receptors.

At the infusion rates used clinically, alpha effects predominate and result in both the beneficial and adverse effects of norepinephrine. Since it is a potent vasoconstricting agent it is reserved for children with low systemic vascular resistance that is unresponsive to fluid resuscitation. This is most commonly seen in septic shock but may also be seen in spinal shock and anaphylaxis.

Sodium Nitroprusside

Vasodilator that reduces tone in all vascular beds by stimulating local nitric oxide production. It has no direct effect on the myocardium when infused at therapeutic doses, but cardiac output often increases because systemic and pulmonary vascular resistance (afterload) is reduced. Indicated in the treatment shock or low cardiac output states characterized by high vascular resistance. Since it is rapidly metabolized, it must be infused continuously.

Inodilators

The class of agents combines inotropic stimulation of the heart with vasodilation of the systemic and pulmonary vascular beds. Amrinone and milrinone do not depend on activation of the receptors. Inodilators are used to treat children with myocardial dysfunction and increased systemic or pulmonary vascular resistance. They are used for conditions such as congestive heart failure in postoperative cardiac surgical patients or patients with dilated cardiomyopathy and even in selected children with septic shock and myocardial dysfunction with a high systemic vascular resistance. Unlike vasodilators, inodilators have the ability to augment cardiac output with little effect on myocardial oxygen demand and often with little change in heart rate. Blood pressure is usually well maintained, provided that the patient has adequate volume. The disadvantage is an extremely long half life and so if toxicity occurs, stopping the infusion will not eliminate the adverse effect. Instead you will have to wait until the drug is metabolized over several hours.

Neurological Preservation

The key to preserving neurological function is the rapid restoration and maintenance of adequate oxygen delivery to the brain and avoidance of secondary injury to the neurons. Since increasing metabolic demand may worsen neurological injury, it is not surprising that the presence of fever following brain injury is associated with worsened neurological outcome in adults with cerebral ischemia.

General Post Resuscitation Care

- Change Intraosseous lines to intravenous ones and secure all IV lines
- Splint any apparent fractures
- The underlying cause of the arrest should be treated if known
- Monitor serum glucose level and core body temperature frequently and take corrective measures

NEONATAL RESUSCITATION

Resuscitation of the newly born infant presents a different set of challenges than resuscitation of the adult or even the older infant or child. The transition from placental gas exchange in a liquid filled intrauterine environment to spontaneous breathing of air requires dramatic physiological changes in the infant within the first minutes to hours after birth. Approximately 5-10% of the newly born population require some degree of active resuscitation at birth and approximately 1% to 10% born in the hospital are reported to require assisted ventilation.

Definition of Newly Born, Neonate and Infant

- Newly Born refers specifically to the infant in the first minutes to hours after birth
- Neonate is generally defined as an infant during the first 28 days of life
- Infancy includes the neonatal period and extends through 12 months of age

The transition from fetal to extrauterine life is characterized by a series of unique physiological events: the lungs change from fluid filled to air filled, pulmonary blood flow increases dramatically and the intracardiac and extracardiac shunts (foramen ovale and ductus arteriosus) initially reverse direction and subsequently close. For initial lung expansion, fluid filled alveoli may require higher ventilation pressures than are commonly used in rescue breathing in the infant.

Anticipation of Resuscitation Need

Appropriate preparation for an anticipated high risk delivery requires communication between the person caring for the mother and those responsible for resuscitation of the newly born. Personnel capable of initiating resuscitation should attend every delivery. At least 1 such person should be responsible solely for the care of the infant. A clean and warm environment with a complete inventory of resuscitation equipment and drugs should be maintained at hand in fully operational condition wherever deliveries occur.

Standard precautions should be followed carefully in delivery areas, where exposure to blood and body fluids is likely.

Evaluation

Determination of the need for resuscitative efforts should begin immediately after birth and proceed throughout the resuscitation process. Evaluation and intervention for the newly born are often simultaneous processes, especially when more than 1 trained provider is present. To enhance educational retention, this process is often taught as a sequence of distinct steps.

Response to Extrauterine Environment

Most newly born infants will respond to the stimulation of the Extrauterine environment with strong inspiratory efforts, a vigorous cry, and movement of all extremities. The infant who responds vigorously to the Extrauterine environment and who is term can remain with the mother to receive routine care (warmth, drying, clearing the airway). Indications for further assessment under a radiant warmer and possible intervention include:

- Meconium in the amniotic fluid or on the skin
- Absent or weak responses
- Persistent cyanosis
- Preterm birth

Respiration

After initial respiratory efforts, the newly born infant should be able to establish regular respirations sufficient to improve color and maintain a heart rate of >100. Gasping and apnea are signs that indicate the need for assisted ventilation.

Heart Rate

Heart rate is determined by listening to the precordium with a stethoscope or feeling pulsations at the base of the umbilical cord. Central and peripheral pulses in the neck and extremities are often difficult to feel in infants, but the umbilical pulse is readily accessible in the newly born and permits assessment of the heart rate without interruption of ventilation for auscultation. Heart rate should be consistently >100 bpm in an uncompromised newly born infant.

Color

An uncompromised newly born infant will be able to maintain a pink color of the mucous membranes without supplemental oxygen. Central cyanosis is determined by examining the face, trunk and mucous membranes. Acrocyanosis is usually a normal finding at birth and is not a reliable indicator of hypoxemia, but it may indicate other conditions, such as cold stress. Pallor may be a sign of decreased cardiac output, severe anemia, hypovolemia, hypothermia or acidosis.

Techniques of Resuscitation

Warmth

Preventing heat loss in the newly born is vital because cold stress can increase oxygen consumption and impede effective resuscitation. Hyperthermia should be avoided, however, because it is associated with perinatal respiratory depression.

Clearing the Airway

The infant's airway is cleared by positioning of the infant and removal of secretions if needed.

- **Positioning:** The newly born infant should be placed supine or lying on its side, with the head in a neutral or slightly extended position. If respiratory efforts are present but not producing effective tidal ventilation, often the airway is obstructed; immediate efforts must be made to correct overextension or flexion or to remove secretions. A blanket or towel placed under the shoulders may be helpful in maintaining proper head position
- **Suctioning:** If time permits, the person assisting delivery of the infant should suction the infant's nose and mouth with a bulb syringe after delivery of the shoulders but before delivery of the chest. Healthy, vigorous newly born infants generally do not require suctioning after delivery. Secretions may be wiped from the nose and mouth with gauze or a towel. If suctioning is necessary, clear secretions first from the mouth and then the nose with a bulb syringe or suction catheter.
- **Clearing the Airway of Meconium**
 - A. Approximately 12% of deliveries are complicated by the presence of Meconium in the amniotic fluid.
 - B. Suction the mouth, pharynx and nose as soon as the head is delivered regardless of whether the meconium is thick or thin.
 - C. If the fluid contains meconium and the infant has absent or depressed respirations, decreased muscle tone or heart rate <100 bpm perform direct laryngoscopy immediately after birth for suctioning of residual meconium from the hypopharynx and intubation/suction of the trachea.
 - D. Evidence shows that tracheal suctioning of the vigorous infant with meconium stained fluid does not improve outcome and may cause complications.
 - E. Warmth can be provided by a radiant heater; however, drying and stimulation generally should be delayed in depressed meconium infants.
 - F. If the infant's heart rate or respiration is severely depressed, it may be necessary to institute positive pressure ventilation despite the presence of some meconium in the airway.
 - G. Delay gastric suctioning to prevent aspiration of swallowed meconium until initial resuscitation is complete. Meconium

stained infants who develop apnea or respiratory distress should receive tracheal suctioning before positive pressure ventilation, even if they are initially vigorous.

Tactile Stimulation

Drying and suctioning produce enough stimulation to initiate effective respirations in most newly born infants.

Oxygen Administration

Hypoxia is nearly always present in a newly born infant who requires resuscitation. Therefore, if cyanosis, bradycardia or other signs of distress are noted in a breathing newborn during stabilization, administration of 100% is indicated while determine the need for additional intervention.

Free-flow oxygen can be delivered through a face mask and flow inflating bag, an oxygen mask or hand cupped around oxygen tubing. The oxygen source should delivery at least 5L/min and the oxygen should be held close to the face to maximize the inhaled concentration.

The goal of supplemental oxygen use should be normoxia: sufficient oxygen should be administered to achieve pink color in the mucous membranes. If cyanosis returns when oxygen is removed, care should include monitoring of administered oxygen concentration and arterial oxygen saturation.

Ventilation

Most newly born infants who require positive pressure ventilation can be adequately ventilated with a bag and mask. Indications for positive pressure ventilation include apnea or gasping respirations, heart rate <100 and persistent central cyanosis despite 100% oxygen.

Although the pressure required for establishment of air breathing is variable and unpredictable, however higher inflation pressures and longer inflation times may be required for the first several breaths than for subsequent breaths. Visible chest expansion is a more reliable sign of appropriate inflation pressures than any specific manometer reading. The assisted ventilation rate should be 40-60 breaths per minute (30 breaths per minute when chest compressions are also being delivered).

After 30 seconds of adequate ventilation with 100% oxygen, spontaneous breathing and heart rate should be checked. If spontaneous respirations are present and the heart rate is >100 bpm, positive pressure ventilation may be gradually reduced and discontinued. Gentle tactile stimulation may help maintain and improve spontaneous respirations while free flow oxygen is administered.

The key to successful neonatal resuscitation is establishment of adequate ventilation. Reversal of hypoxia, acidosis, and bradycardia depends on adequate inflation of fluid filled lungs with air or oxygen.

Face Masks

Masks should be of appropriate size to seal around the mouth and nose but not cover the eyes or overlap the chin.

Laryngeal Mask Airway Ventilation

Masks that fit over the laryngeal inlet have been shown to be effective for ventilating newly born full term infants. The laryngeal mask airway, when used by appropriately trained providers, may be an effective alternative for establishing an airway in resuscitation of the newly born infant, especially in the case of ineffective bag mask ventilation or failed endotracheal intubation.

Endotracheal Intubation

Is indicated at several points during resuscitation:

- When tracheal suctioning is needed for meconium
- If bag mask ventilation is ineffective or prolonged
- When chest compressions are performed
- When tracheal administration of medications is desired
- Special resuscitation circumstances, such as congenital diaphragmatic hernia or extremely low birth weight.

Chest Compressions

Asphyxia causes peripheral vasoconstriction, tissue hypoxia, acidosis, poor myocardial contractility, bradycardia and eventually cardiac arrest. Establishment of adequate ventilation and oxygenation will restore vital signs in the vast majority of newly born infants. In deciding when to initiate chest compressions consider the heart rate, the change of the heart rate and the time elapsed after initiation of resuscitative measures. Because chest compressions may diminish the effectiveness of ventilations do not initiate them until lung inflation and ventilation have been established.

The general indication for initiation of chest compressions is a heart rate <60 bpm despite adequate ventilation with 100% oxygen for 30 seconds. Although it has been common practice to give compressions if the heart rate is 60-80 bpm and the heart rate is not rising, ventilation should be the priority in resuscitation of the newly born.

Technique:

- 2 thumbs on the sternum, superimposed or adjacent to each other according to the size of the infant, with fingers encircling the chest and supporting the back

- 2 fingers placed on the sternum at right angles to the chest with the other hand supporting the back.

Data suggests that the 2 thumb encircling hands technique may offer some advantages in generating peak systolic and coronary perfusion pressure and that providers prefer this technique to the 2 finger technique.

Medications

Drugs are rarely indicated in resuscitation of the newly born infant. Bradycardia in the newly born infant is usually the result of inadequate lung inflation or profound hypoxia and adequate ventilation is the most important step in correctly bradycardia. Administer medications if despite adequate ventilation with 100% oxygen and chest compressions, the heart rate remains <60 bpm.

Routes of Medication Administration

The tracheal route is generally the most rapidly accessible route for administration during resuscitation. It may be used for administration of epinephrine and Naloxone. The tracheal route results in more variable response to epinephrine than the IV route. Attempt to establish IV access in neonates who fail to respond to tracheally administered epinephrine. The umbilical vein is the most rapidly accessible venous route. Peripheral sites for venous access may be adequate but are usually more difficult to cannulate. Naloxone may be given IM or SQ but only after effective assisted ventilation has been established and only if the infant's peripheral circulation is adequate.