Procedures in Family Practice

Cardiopulmonary Resuscitation in Infants and Children

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Cardiopulmonary arrest is a sudden, life threatening emergency in infants and children. Techniques of cardiopulmonary resuscitation vary from those used in adults. The successful management of cardiac arrest requires not only knowledge of pediatric techniques and drug dosages, but also prior organized preparation by all those involved in management of infants and children. This paper outlines a step-by-step approach to management of cardiopulmonary resuscitation, lists appropriate pediatric drug dosages, and outlines a plan for prior preparation of personnel and equipment which will permit a successful outcome for the patient.

Cardiopulmonary arrest is, fortunately, an uncommon occurrence in infants and children. However, because of its infrequent nature, limited information is available regarding the management of this problem.[1-5] Because of the sudden occurrence of this emergency, there is little time to organize an appropriate response. Cardiac arrest may occur in outpatient settings such as the physician's office or Emergency Room, or in several areas within the hospital. Successful resuscitation will occur only if there has been prior preparation for cardiac arrest, by an organized team which can react immediately, almost reflexly, to manage the arrest and resuscitation.

Preparation should include: definition of roles to be played by team members, practice during mock arrests, knowledge of pediatric drug doses, availability of necessary drugs and equipment, and organization of a stepwise approach to management. This paper provides an organized approach to the management of cardiopulmonary resuscitation (CPR) in infants and children (Table 1), and makes suggestions regarding prior preparation. It is intended as a framework which may be modified by individuals or groups to fit the needs and capabilities of their own settings.

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Table 1. Steps in Cardiopulmonary Resuscitation

I. Confirm Arrest
II. Call for Help (Do not leave patient)
III. Initial Management
  A. Airway
  B. Breathe
    1. Mouth to mouth
    2. Intubation
    3. Ventilation
    4. Oxygen
    5. Nasogastric tube
  C. Circulate—Cardiac Massage
  D. Drugs (Table 2)
    1. ECG
    2. Intravenous cutdown
IV. Post-Resuscitation Management
  A. Monitor patient's status
  B. Determine cause(s) of arrest
  C. Assess for complications of resuscitation
  D. Document details of arrest and treatment

An Organized Approach

Steps I and II. Confirm Arrest—Call for Help

The infant who has sustained a cardiorespiratory arrest is usually encountered by a single person. Immediately that person should confirm the arrest by observing that the patient is: unresponsive, not breathing, and has an ineffective cardiac contraction (absence of carotid or femoral pulses, and/or heart sounds). Do not waste time while confirming the arrest. Do not leave the patient's side. Call for help, and if possible, note the time. Immediately give a single brisk thump over the midsternal area with a closed fist. If the patient has sustained cardiac standstill or ventricular tachycardia, this maneuver may convert the heart action to sinus rhythm.

Step III. Initial Management

Airway

If the patient is a newborn, position yourself above his head; if an older infant or child, move to the patient's side. Turn the head to one side and clear the airway with a finger, or suction if available. Grasp the infant's forehead with your left hand and place your right under the neck to extend it. If the patient is a newborn, place your mouth over both mouth and nose of the patient, forming a tight seal. If the patient is an infant or child, the left hand extends the forehead and simultaneously closes the nostrils while your mouth is placed over the infant's mouth. Four quick breaths are administered while watching the chest movement for a symmetrical rise indicating that the airway is clear.

Breathe

Begin to breathe for the patient, using a regular even rate. In the newborn infant, puff gently with air in the cheeks. Turn your mouth away to permit the patient to exhale. Gastric distention often results from this method of ventilation, eventually elevating the diaphragm and initiating a vagal response, both of which may interfere with resuscitative efforts. If distention becomes significant,

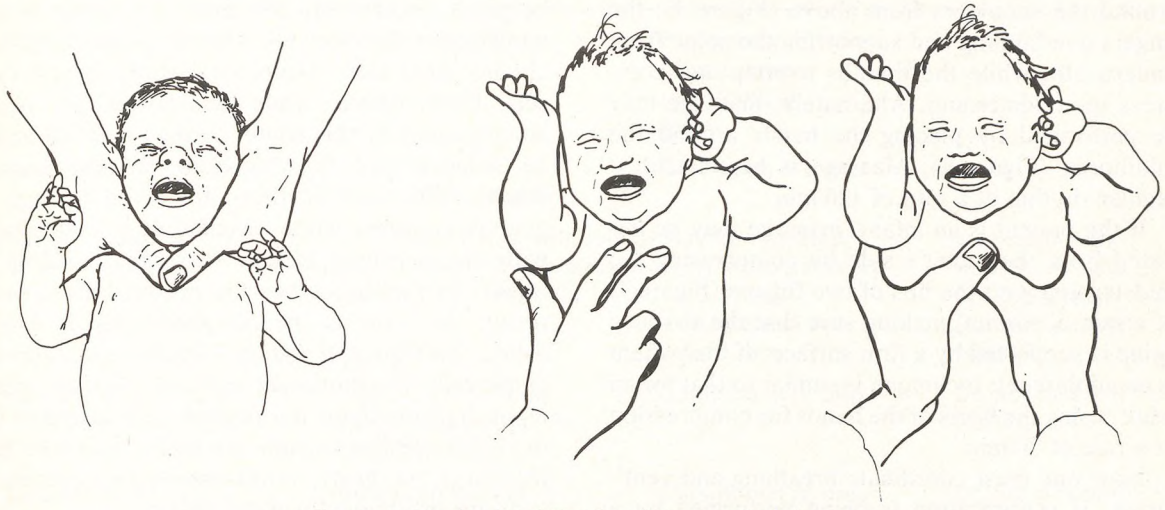

Figure 1. Methods of Cardiac Message in Infants

A. Method for small infants (left panel). The observer is above the infant's head, with his thumbs overlapping to compress the midsternum and his fingers overlapping and supporting the posterior spine. An advantage of this technique is the ability of a single person to maintain the head in proper position for ventilation and simultaneously to continue cardiac massage.

B. Alternative method for infants (middle panel). The observer is situated to the side of the infant and compresses the midsternum with two fingers.

C. Alternative method for small infant (right panel). The observer is situated below the infant and compresses the midsternum with his thumbs overlapping and his fingers supporting the posterior spine. This method is more likely to be associated with trauma to the liver.

turn the patient's head to the side and gently compress the stomach to expel air and fluid. At the earliest opportunity, when additional help is available, a nasogastric tube should be inserted to decompress the stomach.

Circulate—Cardiac Massage

Attention is next turned toward restoring blood flow to the tissues. To produce an effective forward flow, the technique of cardiac massage must be performed properly. As a general rule, the sternum must be depressed by one third of the anterior-posterior chest dimension. One of the commonest errors in CPR is inadequate compression of the heart during cardiac massage. To produce an effective stroke volume, the heart must be compressed between the sternum and the thoracic spine. One must avoid applying pressure to the ribs lateral to the sternum because of the danger of rib fracture. Furthermore, it must be remembered that the heart is situated relatively higher in the thorax of the infant than the adult (Figure 1). Pressure should never be applied over the lower por-

tion of the sternum, as compression of the heart will be ineffective and, in addition, the liver may be damaged by pressure over the lower sternum. If the infant is a newborn, the hands may be placed around the shoulders from above (Figure 1), the fingers overlapping and supporting the spine from underneath, while the thumbs overlap and compress the midsternum. Alternately, massage may be performed by placing the hands around the midthorax (Figure 1). Massage is begun with a regular rhythm at a rate of 120/min.

If the patient is an infant, massage may be initiated from the infant's side by compressing the midsternum with the tips of two fingers (Figure 1) at a rate of 90/min, making sure that the thoracic spine is supported by a firm surface. If the patient is an adolescent, technique is similar to that for an adult, using the heels of the hands for compression at a rate of 70/min.

Now one must coordinate breathing and ventilation. If resuscitation is being performed by a single person, a ratio of 15 compressions to 2 ventilations may be used. If two people are coordinating their efforts, a sequence of 5 compressions followed by a single respiration is recommended. A second person may also assess the adequacy of cardiac massage by palpating the carotid pulses. At this point, one has established circulation to the body, and is providing ventilation of the lungs. These efforts can be continued until additional assistance arrives.

When an additional person is available, the patient should be intubated with an appropriate sized endotracheal tube, to which is attached a bag for ventilating the patient. As soon as possible, connect an oxygen line to the bag to increase the inspired oxygen level. Check the tube position by auscultating both sides of the chest for breath sounds.

Drugs

Attention is now turned to correction of pump function. This is usually accomplished with medication (Table 2), but not infrequently the arrest in an infant is primarily respiratory, and adequate ventilation alone results in a return of sinus rhythm and effective cardiac output. In order to determine the underlying electrical activity of the heart, peripheral electrocardiographic (ECG) leads are placed and a rhythm strip is recorded.

In preparation for administration of medications, a cutdown should be performed on a peripheral ankle vein. Because peripheral veins are often collapsed, attempts to insert an intravenous line are usually unsuccessful. While drugs may be given directly into the heart, this route of administration is associated with significant risks, including laceration of coronary or intercostal vessels. Furthermore, while medications are being administered by this route, cardiac massage must be stopped and thus perfusion of the tissues ceases. When medications are given through a venous cutdown while circulation is maintained with uninterrupted cardiac massage, the drug is rapidly carried to the heart to produce the desired result. As soon as the peripheral line is established, 2 mEq/Kg of sodium bicarbonate are given empirically to counteract acidosis. Further treatment depends upon the rhythm demonstrated on the ECG. While attempts are made to correct the rhythm of the heart, ventilation and cardiac massage are maintained without let-up.

Ventricular Fibrillation—When the ECG shows a pattern of ventricular fibrillation, electrical defibrillation should be performed using an initial setting of approximately 2 watt sec/Kg. If there is no response, the setting is doubled and electrical conversion again attempted. If the ECG continues to show a pattern of fibrillation, the patient should be given 2mEq/Kg of sodium bicarbonate intravenously, followed by cardiac massage for 2 minutes, and defibrillation again attempted. If the patient still has not responded, a final approach is to give intravenous lidocaine, and again attempt defibrillation. Settings for defibrillation should be kept to a minimum, to prevent damage to the myocardium. Furthermore, defibrillation is usually accomplished in quite low doses in infants and children.

Asystole—When the ECG shows no electrical activity, the patient should be rapidly given intravenous epinephrine 0.2 to 0.3 cc of 1:10,000 dilution. If there is no response, 2 mEq/Kg of sodium bicarbonate are given to correct acidosis, and the same dose of 1:10,000 aqueous epinephrine is repeated. If the ECG is still flat, a continuing drip of isoproterenol may be started to increase ventricular irritability.

Bradycardia or Complete Heart Block—When the ECG shows a severe sinus bradycardia (<80 beats/min in newborn) or complete heart block (no relation between atrial and ventricular com-

Table 2. Drugs Used in Pediatric Cardiopulmonary Resuscitation

Drug	Dosage	Frequency	Contraindication
Sodium bicarbonate	2-3 mEq/Kg, IV	Push every 10 min after 2 doses, use ½ initial dose	
Aqueous epinephrine	0.2-0.3 cc of 1/10,000 dilution, IV	Give every 3-5 min	
Calcium chloride	0.5 cc/Kg of 10% solution Give *slowly*—1-2 cc/min up to 10 cc maximum	May be repeated —in newborn every 30-60 min —in infant every 5-10 min	Use cautiously in patients who are digitalized Do not mix with $NaHCO_3$
Isoproterenol	0.05-2 μgm/Kg/min to increase HR to 120-140 beats/min	Continuous IV drip	Do not mix with $NaHCO_3$
Dopamine	5-20 μgm/Kg/min	Continuous IV drip	Do not mix with $NaHCO_3$
Lidocaine	1 mg/Kg IV push; 50 μgm/Kg/min infusion	Every 20 min × 2, followed by continuous IV drip	
Atropine	0.01 mg/Kg, IV	Every 5-10 min	
Electrical defibrillation	2 watt sec/Kg	As needed—double dose if no response	

plexes), the cause is frequently an elevated vagal tone, which will respond to atropine 0.01 mgm/Kg given intravenously. If there is no response to atropine, an intravenous drip of Isoproterenol should be immediately started to increase heart rate. If the patient has a complete heart block, consideration should be given to insertion of a pacemaker.

Ventricular Tachycardia—This is uncommon in infants and children, but when present will usually revert to sinus rhythm with the intravenous administration of lidocaine (1 mgm/Kg). This dose may be repeated in 20 minutes, and then an intravenous drip of 50 μ/Kg/min of lidocaine is begun. Depending upon the circumstances of the arrest, an alternative method of conversion is the use of electrical cardioversion.

Electromechanical Dissociation—Occasionally, one finds a sinus rhythm with normal QRS complex on the electrocardiogram, and yet the normal electrical activity does not generate an effective cardiac contraction. Calcium is the "coupler" of excitation and contraction, and the administration of calcium chloride (0.5 cc/Kg by slow intravenous

push) may restore effective pump action. Consider other causes for poor pump function such as: hypovolemic shock (secondary to hemorrhage or severe dehydration), cardiac tamponade (secondary to trauma), or gastric dilatation (secondary to resuscitative efforts). Treatment is directed appropriately toward: correction of volume deficits with blood or plasma expanders; maintenance of normal arterial pressure with dopamine (5 micrograms/Kg/min by intravenous drip), and relief of gastric distension by placement of a nasogastric tube.

Cardiopulmonary resuscitation is generally continued for longer periods in infants and children than in adults. While appropriate therapy frequently results in effective resuscitation, when there is no response a decision must be made as to when to stop the team's efforts. This decision should be made by the physician directing the arrest, and depends upon such factors as: the patient's underlying medical condition, circumstances of the arrest, and duration of resuscitative efforts. In general, lack of spontaneous efforts by the patient, fixed dilated pupils, and persisting ECG evidence of asystole or an arrhythmia that cannot be corrected to sinus rhythm would suggest that cessation of resuscitation be considered.

Step IV. Post-Resuscitation Management

Monitor Patient's Status

Following a successful cardiac resuscitation, a crucial period ensues during which the patient is especially vulnerable to recurrence. Therefore, the child should be placed in an environment which permits constant monitoring of vital signs, including: continuous display of ECG for rate and rhythm, observation of ventilatory rate and effort, repeated determination of blood pressure, assessment of neurological status, measurement of urine output, and frequent determination of arterial blood gases. An intravenous line must be in place at all times to administer needed supportive medications and fluids as well as to withdraw blood for electrolytes, hemoglobin, hematocrit, calcium, and glucose determinations.

Determine Cause(s) of Arrest

When the physician feels that the patient has stabilized, he/she next turns to a determination of the cause(s) of the arrest. Respiratory problems are probably the most frequent cause of cardiac arrest in infants and children, including: accidental extubation, pneumothorax, foreign body aspiration, and pneumonia. Less frequently, cardiac arrest is due to metabolic or electrolyte abnormalities, sudden infant death syndrome, toxic drug effects, electrical shock, arrhythmias, congestive failure, poisoning, drowning, allergic reactions, trauma, shock, or cardiac tamponade. If the circumstances of the arrest can be documented precisely, the physician should be able to take appropriate measures to prevent a recurrence.

Assess for Complications of Resuscitation

Because of the emergency nature of a cardiac arrest, and the rapidity and vigor of the efforts in resuscitation, it is not uncommon for complications to result. Therefore, the next step in management should be to assess the patient for evidence of complications, which usually result from incorrect or too vigorous techniques of resuscitation. The most frequently encountered complications include: pneumothorax, hepatic rupture, rib fracture, gastric dilatation, aspiration, and cerebral edema. These complications can be prevented by prior training of personnel in proper techniques of resuscitation.

Document Details of Arrest

Finally, the details of the arrest, the patient's underlying condition prior to the arrest, techniques of resuscitation including drugs given, complications of the arrest, and present status of the patient should all be carefully documented in the chart for later review.

Prior Preparation for Cardiac Arrest

Successful resuscitation of infants and children depends to a large degree on prior organization and preparation. In the inpatient setting such as Emergency Room, pediatric ward, intensive care unit, and operating room, all personnel working in areas where infants and children are cared for

should be trained in pediatric cardiopulmonary resuscitation and have periodic assessment of their competence. Crash carts containing all needed medications, oxygen, suction, intubation equipment, and a defibrillator should be available at all times. One person, perhaps the head nurse, should be charged with the responsibility of restocking medications, and checking the cart for the presence and functional capabilities of needed equipment at weekly intervals. Drugs and equipment have a habit of "disappearing" from crash carts at inopportune moments.

Pediatric dosages of all important medications (Table 2) should be posted on crash carts and on the walls of all areas where pediatric cardiac arrest may be anticipated. For all acutely ill infants, the nursing staff should prepare a sheet of drug dosages precalculated for the particular patient. This sheet is posted at the bedside—immediately available if needed.

Mock arrests should be held at frequent intervals, permitting physicians and nurses to define roles and coordinate efforts. In the inpatient setting, the senior physician present should be in charge of the resuscitation to designate responsibilities and coordinate efforts. A second physician should perform cardiac massage while a third physician, preferably an anesthesiologist, should be in charge of ventilation. The senior nurse present should be in charge of recording all details related to the arrest. She should also delegate responsibility to other nurses, and direct the activities of the ward clerk as a runner to obtain other needed drugs and equipment. A second nurse takes vital signs, assists the physicians, draws up and administers medications, and regulates intravenous fluids. If available, a third nurse takes the parents to a nearby area and keeps them informed. These roles should be clearly defined and practiced repeatedly in anticipation of an arrest.

However, not infrequently cardiac arrest occurs in outpatient settings where aid is not as readily available. In these circumstances, prior preparation will help to achieve a successful outcome. The school nurse must be prepared to maintain life support by means of cardiac massage and mouth-to-mouth resuscitation until additional help arrives. The team physician must have intubation equipment, drugs for resuscitation, and oxygen available on the sidelines at sporting events.

The physician must also anticipate the need for resuscitation in his office. A successful outcome can be achieved with the help of a single nurse, if there has been prior review and designation of duties. Furthermore, nonmedical office personnel can be assigned specific tasks and should be encouraged to take basic CPR courses offered by the local heart association.

Finally, any cardiac arrest which does occur should be used at a *later time* as a teaching review. All persons involved should meet to review the circumstances of the arrest and to discuss the team's management and the outcome of the resuscitation.

Because the myocardium is structurally and functionally normal in most infants and children, cardiopulmonary resuscitation (performed properly) is associated with a high frequency of success. Besides the pre-existing disease, the outcome depends upon prior organization and preparation, which permits a rapid and appropriate response to the circumstances of the arrest. The loss of an infant or child because of disorganization of the team, lack of necessary equipment, or absence of a needed drug at a crucial moment, is a tragedy which must be avoided.

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