Chapter 3

PBLS,PALS; Pediatric Basic Life Support, Pediatric Advanced life Support

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■1 Introduction

1. Definition of Infant and Child

Since it is reasonable for puberty to be considered the boundary between children and adults from physiological perspectives internationally, “Infant” refers to a person younger than one year of age, and “child” is defined as a person older than one year of age but prior to puberty (including junior high-schoolers). A term “child”, in a broad sense, may sometimes refer to any person prior to puberty and may include an infant.

Neonate refers to a baby in the first 28 days after birth, for whom neonatal resuscitation is applied. In pre-hospital emergency care or the pediatric intensive care unit, however, the neonate within the first 28 days after birth may receive treatment in the same way as an infant.

2. The Chain of Survival and Bow-Tie Concept

The Chain of Survival, which is now a common concept for children and adults, consists of the linking of four actions: 1) prevention of cardiac arrest; 2) immediate recognition of cardiac arrest

and activation of the EMS; 3) basic life support (including AED); and 4) advanced life support (including post-cardiac arrest care).

This is the result of the fact that the bow-tie concept that was emphasized in pediatric resuscitation in the 2005 guidelines, has become increasingly valued including among cases with adults.

1) Prevention of Cardiac Arrest

This is the concept that include prevention of injuries resulting from unexpected accidents, prevention of disease, and prevention of cardiac arrest by recognizing warning signs of disease. For infants and children, importance of prevention of injuries resulting from unexpected accidents has especially been emphasized. Prevention here also includes improvement of the emergency medical system.

2) Immediate recognition and Activation of EMS

This is the concept that covers immediate recognition of cardiac arrest, activation of the EMS or Medical Emergency Team (MET)/ Critical Care Response Team (CCRT).

As for the cause of cardiac arrest in infants and children, cardiac etiology is rare. The common etiology is respiratory failure with subsequent cardiac arrest (respiratory etiology). Infants and children who have experienced cardiac arrest will have poor outcomes. If found with only respiratory arrest and given treatment before reaching cardiac arrest, however, their survival rates are reportedly 70% or more. Hence it is crucial for the improvement in survival rates to recognize respiratory disorders and shock which directly lead to cardiac arrest in infants and children at an early stage and to deal with the situation promptly.

■2　Causes of Death in Children and Prevention of Cardiac Arrest

The primary cause of death in children over 1 year of age in Japan is injuries.

Many of the injuries are preventable, and forestalling these injuries, which might cause cardiac arrest, is important. They should be regarded as preventable injuries rather than inevitable accidents. Education for the general public on the prevention of injuries is necessary.

1. Motor Vehicle Accidents

Deaths of children under the age of 6 years in motor vehicles have been increasing at three times the rate of those of all ages even after the use of child safety seats was mandated in 2000.The low usage rate of 50% and the poor installation technique have been pointed out as the cause of the increasing death toll.

2. Bicycle Accidents

Deaths of children under the age of 15 years from bicycle accidents are now approximately

30,000 per year (Tokyo Metropolitan Police Department, 2009). This figure is decreasing but accounts for an increasing portion of total traffic fatalities. Although bicycle helmets are known to significantly reduce the severity of head injury that is closely related to deaths from bicycle accidents, public awareness of helmet safety is still low in Japan. There are also many cases where children under the age of 2 years fall off child bicycle seat, which is particularly seen in Japan.

3. Foreign Body Ingestion and Aspiration

Approximately 60% of deaths from foreign body ingestions and aspirations in children occurred in infants under the age of one year, and 90% occurred in children under the age of 5 years. Using an empty toilet paper roll to approximate the size, anything that comes through the roll can be an object that might be ingested or aspirated by children and infants. It is necessary to provide guidance for the prevention according to children's stage of development at the infant medical check-up.

4. Submersion injuries

In Japan, there are many submersion injuries in bathtubs. In households with preschool age children, precautions for various possible cases are necessary, such as draining water from the bathtub after bathing, or installing a lock on the upper part of the bathroom door.

5. Fire-related injuries

Eighty percent of deaths from fire in children and infants occurred at one's own home.

Installing smoke detectors and fire sprinklers in one's home helps reduce deaths from fire, yet they cannot prevent fire breakout from playing with fire by children who stay at home unattended.

While specifying flame-retardant materials and developing child-resistant lighters is being discussed, the major premise is to recognize parental guidance as an indispensable basis for preventing deaths from fire-related injuries.

■3 Early Recognition of Respiratory Disturbances and Shock

There is a tendency among many cases physicians to begin with seeking for diagnosis, incorrectly believing that treatments should not precede diagnosis. Even in the absence of a diagnosis in the initial treatment for emergency patients, however, physiological understanding of circulatory and respiratory function and prompt assessment based on the child's vital signs will contribute to the immediate start of initial treatment. Trying to identify the disease while stabilizing the patient's condition will eventually lead to further advanced treatment.

1. Respiratory Disturbances

Respiratory disturbances are classified according to severity into the two levels; respiratory distress and respiratory failure.

1) Respiratory Distress

Respiratory distress refers to a condition where normal or near-normal level of oxygenation and/or ventilation is maintained despite the presence of respiratory efforts such as grunting, tachypnea, retraction, or nasal flaring.

2) Respiratory Failure

Respiratory failure refers to a deteriorating condition of respiratory distress with the presence of abnormal level of oxygenation and/or ventilation.

3) Initial Treatment for Respiratory Disturbances

When respiratory distress is recognized, start oxygen administration. If accompanied with hypoxemia, supply highly concentrated oxygen. If accompanied with hypoventilation, assist breathing using a bag valve mask, while trying to determine whether a brief assistance is all that is needed or if tracheal intubation is required.

2. Shock

Shock is an acute life-threatening systemic pathological condition. Poor tissue perfusion makes oxygen and nutrient supply balance inadequate to meet metabolic demands. It results in oxygen deficiency in each cell level and leads to fatal progression of metabolic acidosis.

Typical signs of shock are deteriorated mental status, tachycardia, bradycardia, diminished pulse, drop in blood pressure, prolonged capillary refill time (>2 seconds), cold extremities and decreased urine output.

1) Compensated Shock

Compensated shock is defined as a state where systolic blood pressure is maintained within each age group's normal range despite the reduction of stroke volume. This compensatory mechanism owes it to increased heart rate and systemic vascular resistance, which together operate to keep blood pressure within normal range.

2) Decompensated Shock (Hypotensive Shock)

When compensated shock becomes exacerbated with the compensatory mechanisms failing to maintain adequate vital organ perfusion, and blood pressure fall down below the normal limit for each age group, decompensated shock (hypotensive shock) with hypotension will develop.

3) Initial Treatment for Shock

Shock results from a number of causes. As for initial treatment, 10-20ml/kg of isotonic fluids (normal saline or Ringer's solution) should be promptly administered regardless of the cause.

Hypotonic fluid should not be used. Re-evaluation of the patient should be conducted following the prompt initial evaluation. Repeated administrations of isotonic fluids will be performed if necessary, while searching for the cause of shock.

As oxygen demand in the tissues of the body exceeds supply in the state of shock, supplemental oxygen should be supplied.

■4 Systems: MET/CCRT and PICU

1. Medical Emergency or Rapid Response Team

It was shown that METs or RRTs are effective to prevent in-hospital respiratory arrests or cardiac arrests. The introduction of a MET or RRT was associated with a decrease in pediatric hospital mortality in 1 LOE 3 meta-analysis[1] and 3 pediatric LOE 3 studies with historical controls[2-4]. The introduction of a MET or RRT was associated with

- a decrease in respiratory but not cardiac arrest in 1 LOE 3[5] study with historical controls
- a decrease in total number of preventable cardiac arrests in 1 LOE 3 retrospective chart review[6]
- a decrease in preventable cardiac arrests in 1 LOE 3[4] study
- a decrease in total number of cardiac arrest and a decrease of out-of–pediatric intensive care unit (PICU) mortality in 1 LOE 3[3] pediatric cohort study using historical controls

For the prevention of respiratory and cardiac arrest in general wards (out-of-PICU), introduction of METs or RRTs can be considered on the premise that PICU can be established.

2. Pediatric Intensive Care Unit (PICU)

PICUs have already well developed in other countries, while not yet fully established in Japan. Evidence suggests that centralization of critically ill or traumatized children to PICUs improves outcomes (LOE 4[7]). One study in Japan shows that centralization of pediatric critically ill or traumatized children to PICUs improved patients' outcomes (J-LOE 4[8]).

Ideally patients after cardiac arrest should be managed by a trained PICU team, and when post-cardiac resuscitation care is necessary, interfacility transfer should be coordinated as soon as possible. Preferably the interfacility transport team should consist of personnel with broad experience in the management of critically ill patients such as pediatric intensivists or pediatric emergency physicians. Japan has been lagging behind in development and expansion of PICUs. Centralization of critically ill and traumatized children to PICU and establishment of systems are strongly called for in Japan.

■5 Pediatric Basic Life Support: PBLS

1. Introduction

When a lay rescuer gives CPR to a child, they should follow the same Basic Life Support (BLS) guidelines as for the adult. However, those who contact children on a routine basis, such as

parents or family members of children, nursery staff, school teachers, lifeguards and sports coaches are encouraged to learn Pediatric Basic Life Support (PBLS). When healthcare providers respond to a child with cardiac arrest, they should follow PBLS.

Although in the guidelines, a series of skills are sequentially presented so as for the procedures to go step by step, if more than one rescuer is present, it is recommended to perform certain steps at the same time, e.g., initiation of CPR and EMS activation. These procedures are shown in the algorithm. Each heading number corresponds to the number in each box. (This section does not deal with the neonate, which is described in the section of Neonatal Resuscitation.)

2. Changes in Guidelines

Changes in PBLS 2010 guidelines from 2005 are as follows:

- For the purpose of increasing the likelihood of bystander CPR during pediatric out-of-hospital cardiac arrest, CPR should be started with chest compression as in the case with adults. Since the effectiveness of rescue breathing is evident in the case of cardiac arrest in children, it is emphasized to give rescue breath as soon as possible.
- The pulse check to determine cardiac arrest has been proved to be unreliable. Cardiac arrest is determined by no responses and the abnormal breathing.
- AEDs with energy dose attenuator can be used for preschool age children (approximately until age 6).
- AEDs can be used for infants.

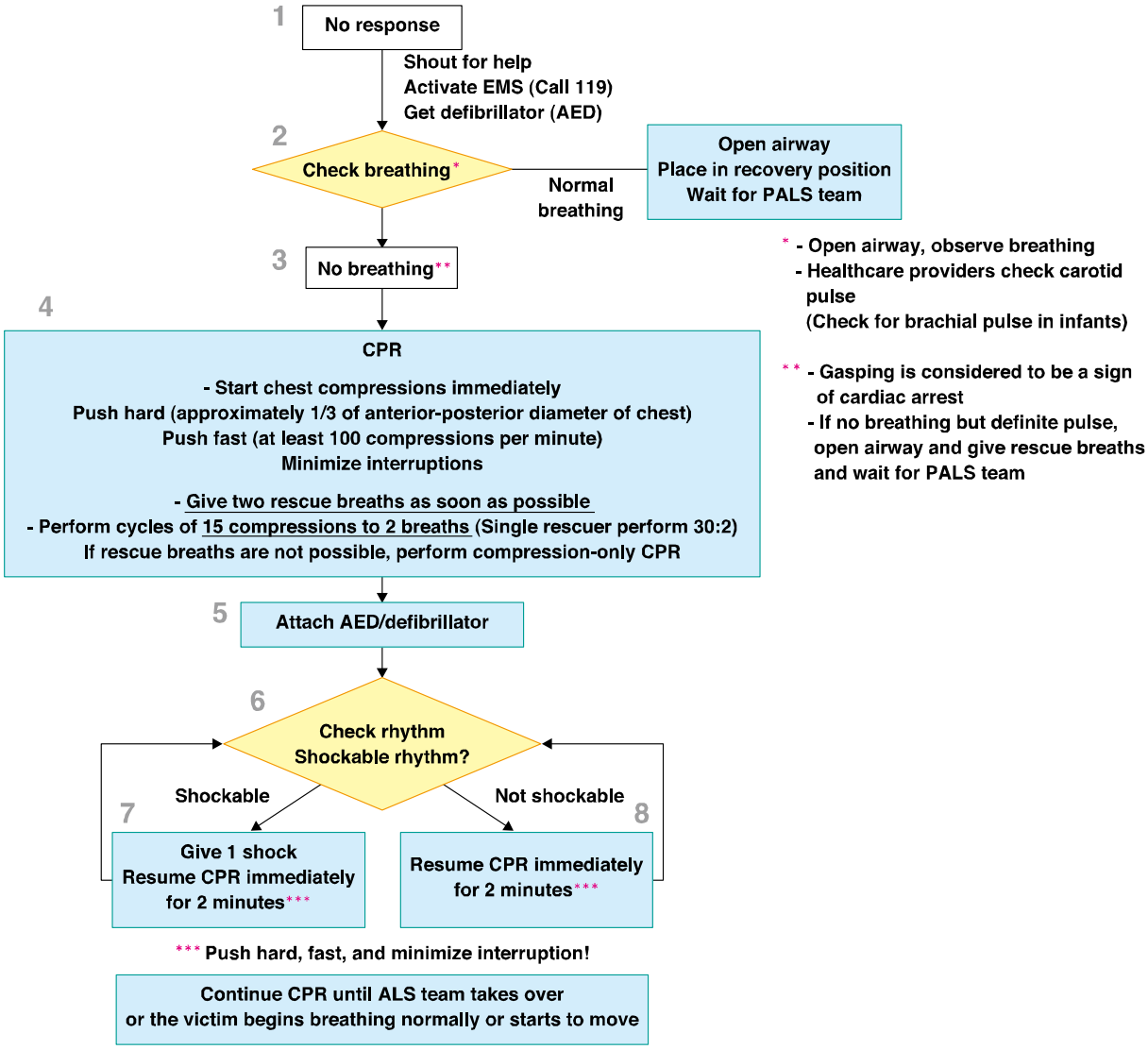

Figure 1 PBLS algorithm for healthcare providers, EMS personnel and some lay rescuers (parents, preschool teachers, etc)

3. PBLS Algorithm

1) Check for Victim's Response and EMS Activation [Box 1]

Ensure the safety of the victim and rescuer.

Speak loudly to the victim, patting them lightly on the shoulder. If there is no response or no purposeful movement, the person should be determined "unresponsive". For infants, stimulate the sole of the infant's foot to try to elicit a response.

If the victim is unresponsive, shout for help and ask people around to activate the EMS (call 119). And ask to bring a defibrillator (AED, if available nearby). The EMS dispatcher is supposed to dispatch an ambulance immediately upon suspicion of cardiac arrest based on the report from the caller. The rescuers follow telephone instructions to assess the victim and to perform CPR.

Rescuers stay at the scene and start chest compressions. If in-hospital emergency call is available, activate it and ask for help and for get crash cart.

2) Recognition of Cardiac Arrest [Box 2, 3]

If the victim is unresponsive and not breathing or breathing abnormally (gasping), rescuers assume cardiac arrest and begin CPR immediately. The rescuer should take no more than 10 seconds to check for breathing. Gasping is considered to be absence of normal breathing, and is a sign of cardiac arrest.

Healthcare providers and EMS personnel should first open the airway and check respiration. However, opening the airway should not preclude a proper respiration check or delay the start of CPR. Trained healthcare providers can check for a pulse while observing respiration. Delays of starting CPR due to pulse check should be avoided. Untrained rescuers do not have to check for a pulse.

If the victim is breathing normally, keep the airway open and wait for help and the EMS personnel. In the meantime, continue observing the victim's breathing. If the victim stops breathing, begin CPR immediately. If the rescuer needs to leave the victim to ask for help, the victim should be placed in the recovery position.

There may be rare occasions where the victim has no breathing but has a pulse. The rescuer should open the airway and provide rescue breathing. When the victim's pulse rate is below 60 beats per minute, the rescuer should follow the bradycardia algorithm. If there is a palpable pulse of more than or equal to 60 beats per minute but there is no spontaneous breathing or there is inadequate breathing, the rescuer should provide rescue breaths at a rate of about 12 to 20 breaths per minute (1 breath every 3 to 5 seconds). Subsequently while waiting for the arrival of the PALS team, the rescuer should check for the pulse frequently so as not to delay beginning chest compressions in case of cardiac arrest.

3) CPR [Box 4]

(1) Chest compressions

All rescuers should provide chest compressions to victims of cardiac arrest. Location of compressions is the lower half of the sternum. It is reasonable to refer to it as "the center of the chest."

A strong emphasis on delivering high quality chest compressions remains essential:

- Push hard approximately one-third of the anterior-posterior diameter of the chest for infants and children
- Compress at a rate of at least 100 compressions per minute
- Minimize interruptions of chest compressions

(2) Opening the Airway and Ventilation

As soon as the rescue breather is ready, the rescuer should open the victim's airway and give 2 breaths. Duration of each breath is about one second to make chest rise. If prompt rescue breath is impossible or not affordable, the rescuer should immediately begin chest compressions.

Open the airway using the head tilt-chin lift maneuver. The trained rescuer can use the jaw thrust maneuver if necessary. For the victims with suspected spinal injury, the jaw thrust maneuver should be the first choice. Use the head tilt-chin lift maneuver if the jaw thrust does not open the airway.

As pediatric cardiac arrest is likely to be respiratory origin, it is important to open the airway and start rescue breath as quickly as possible. Therefore, in the case of in-hospital patients considered at risk for cardiac arrest, preparedness of rescue breath is recommended.

(3) Compression-Ventilation Ratio

For 2-rescuer CPR, a compression-ventilation ratio of 15:2 is reasonable. For single-rescuer CPR, a ratio of 30:2 as for adult is reasonable.

When an advanced airway such as a tracheal tube is in place, compressions should not be interrupted for ventilations. Rescue breath should be performed around 10 times per minute.

When rescue breath is difficult to give, the rescuer should perform compression-only CPR.

4) ECG analysis [Box 5, 6]

Rescuers, including healthcare providers, should continue CPR without checking for a pulse until a defibrillator/AED arrives.

Whether or not using an AED or manual defibrillator, chest compressions should be continued until just before ECG analysis. Defibrillator which can be converted to AED mode, where the heart rhythm is automatically analyzed, are helpful to healthcare providers who usually have few chances to perform CPR.

For preschool-age children and infants, the rescuer should use a defibrillator with energy dose attenuator. If dose attenuator is not available, adult systems can be substituted. In such cases, the user should make sure that the pads do not overlap or even touch each other.

Pads should be placed on the exposed chest in an anterior-lateral position. The anterior-posterior position is alternatively acceptable.

5) Shockable [Box 6 to 7]

When using an AED, the rescuer should follow the audio instructions from the AED and deliver the electric shock.

When using a manual defibrillator, the shock should be delivered if ventricular fibrillation or pulseless ventricular tachycardia is recognized. Immediately after delivering a shock, two-minute CPR should be resumed starting with chest compressions. Subsequently every two minutes, the rescuer is required to check the heart rhythm on the monitor, deliver the shock if necessary, and continue CPR.

6) Not shockable [Box 6 to 8]

When using an AED, the rescuer should follow the audio instructions from the AED and resume CPR.

When using a manual defibrillator, if the QRS complex that shows the possibility of ROSC is recognized, the rescuer should check for a pulse. If a pulse is detected, the post-ROSC monitoring and management should be started.

In the case of pulseless electrical activity or asystole, two-minute CPR should be immediately resumed starting with chest compressions. Subsequently every two minutes, the rescuer is required to check the heart rhythm on the monitor and continue CPR.

7) Continuation of BLS

Rescuers should continue CPR until sufficient circulation is restored in the victim, or EMS providers or other responders take over the care of victim to provide advanced life support. CPR should not be discontinued until the victim regains obvious ROSC (such as regular respiration or purposeful movement).

4. Foreign Body Airway Obstruction; FBAO

In children 1 year of age or older with FBAO, rescuers should activate EMS. Back blows, abdominal thrusts, and chest thrusts for obstruction relief should be tried. These techniques must be repeated rapidly until the relief of the obstruction.

If the choking infants are still responsive but cannot make an effectively strong cough, rescuers are recommended to move the victim's head downward and try back blows and chest thrusts.

If the victim with FBAO becomes unresponsive, the rescuer should immediately begin CPR. Lay rescuers can begin CPR starting with chest compressions as in usual cases of cardiac arrest. It is reasonable for healthcare providers to start CPR with rescue breath. For unresponsive victims of FBAO, direct removal may be considered only when solid material is visible in the airway.

5. CPR

1) Recognition of Cardiac Arrest

Rescuers should observe movements of the victim's chest and abdomen. When no breathing is recognized, CPR should be started (Class I). Lay rescuers do not need to open the airway when assessing breathings. They should focus on the movement of the chest and abdomen instead. No more than 10 seconds should be taken to check for breathing.

Gasping is considered to be absence of normal breathing, and is a sign of cardiac arrest. Gasping, also known as agonal breathing, is an abnormal breathing-like movement occasionally seen immediately after cardiac arrest. Gasping is sometimes seen in adults, but rarely seen in children and infants.

Healthcare providers and EMS personnel should first open the airway and check the respiration of the unresponsive victim. The process of opening airway should not cause negligence of checking breathings or delay in starting CPR.

Lay rescuers should not check for a pulse to determine cardiac arrest (Class III). Healthcare providers will check for a pulse while observing respiration. However, healthcare providers not

well trained or unfamiliar with CPR could skip checking a pulse as same as lay rescuers. Delays in starting CPR due to pulse check should be avoided (Class III). If the rescuer is uncertain of the presence or absence of a pulse, they should focus on checking for respiration. Once recognizing a lack of breathing, CPR should be immediately started.

2) Pulse Check Versus Check for Signs of Life

Palpation of a pulse (or its absence) is not reliable as the sole determinant of cardiac arrest and need for chest compressions. If the victim is unresponsive, not breathing normally, and there are no signs of life, lay rescuers should begin CPR. In infants and children with no signs of life, healthcare providers should begin CPR unless they can definitely palpate a pulse within 10 seconds (Class I).

Thirteen LOE 5 studies[9-21] observed that neither laypersons nor healthcare providers are able to perform an accurate pulse check in healthy adults or infants within 10 seconds. In 2 LOE 5 studies in adults[22, 23] and 2 LOE 3 studies in children with nonpulsatile circulation[24, 25], blinded healthcare providers commonly assessed pulse status inaccurately and their assessment often took >10 seconds. In the pediatric studies, healthcare professionals were able to accurately detect a pulse by palpation only 80% of the time. They mistakenly perceived a pulse when it was nonexistent 14% to 24% of the time and failed to detect a pulse when present in 21% to 36% of the assessments. The average time to detect an actual pulse was approximately 15 seconds, whereas the average time to confirm the absence of a pulse was 30 seconds. Because the pulseless patients in these studies were receiving extracorporeal membrane oxygenation (ECMO) support, one must be cautious in extrapolating these data to the arrest situation; all pulseless patients did have perfusion and therefore had signs of circulation as evidenced by warm skin temperature with brisk capillary refill. All patients evaluated were in an intensive care unit (ICU) setting without ongoing CPR.

3) Chest Compressions

The rescuer should place the victim in a supine position[26] with the rescuer kneeling beside the victim[27].

To maximize the effectiveness of chest compressions, it is reasonable to place the victim on a firm surface if possible (Class IIa)(LOE 5[28-30]). Air-filled mattresses should be deflated when performing CPR (Class I)(LOE 5[31]). There is insufficient evidence for or against the use of backboards during CPR. When backboard is used, attention should be paid to avoid delays in initiation of CPR, to minimize interruptions in CPR, and to prevent line/tube displacement. Chest compressions for victims lying on a bed reportedly turn out to be shallow since some of the force intended to compress the chest results in mattress displacement rather than chest compression (LOE 4[32], LOE 5[28, 33-35]). No studies have examined the risks or benefits of moving the patient from a bed to the floor to perform CPR.

4) Chest Compressions for Children: Hand Position

No randomized controlled human trials support the alternatives of recommended hand position

in 2005 CoSTR ("the rescuer should compress the lower half of the victim's sternum") when performing external chest compressions for children or adults in cardiac arrest. Therefore it is reasonable to adopt the use of "the lower half of the sternum" as the hand position for chest compressions (Class IIa).

5) One- Versus 2-Hand Chest Compression in Children

There are no outcome studies comparing 1- versus 2-hand chest compressions for children in cardiac arrest. Evidence from 1 LOE 5 randomized crossover child manikin study[36] showed that higher chest-compression pressures are generated by healthcare professionals using the 2-hand technique. Two LOE 5 studies[37, 38] report no increase in rescuer fatigue comparing 1-hand with 2-hand chest compressions delivered by healthcare providers to a child-sized manikin.

Either a 1- or 2-hand technique can be used for performing chest compressions in children (Class IIb).

6) Chest Compressions for Infants: Two-Finger Technique /Two Thumb–Encircling Hands Technique

In infant victims, lay rescuer or single healthcare provider should compress the sternum with two fingers placed in the center of the chest (Class I). The two thumb–encircling hands technique is recommended for healthcare providers when two or more rescuers are present (Class I). The rescuer is required to encircle the infant's chest with both hands, spread their fingers around the thorax, and place their thumbs together over the center of the chest. If the rescuer is alone or they cannot physically encircle the victim's chest, they should compress the chest with two fingers.

The two thumb–encircling hands technique is preferred because it produces higher coronary artery perfusion pressure, more consistently results in appropriate depth or force of compression[39-42], and may generate higher systolic and diastolic pressures[43-46]. However, there are insufficient data for or against the need for a circumferential squeeze of the chest when performing the 2-thumb technique of external chest compression for infants.

7) Chest Compression Depth

Evidence from anthropometric measurements in 3 good-quality LOE 5 case series[47-49] showed that in children the chest can be compressed to one third of the anterior-posterior chest diameter without causing damage to intrathoracic organs. One LOE 5 mathematical model based on neonatal chest computed tomography scans[50] suggests that one third anterior-posterior chest compression depth is more effective than one fourth compression depth and safer than one half anterior-posterior compression depth.

A good-quality LOE 5[51] adult study found that chest compressions are often inadequate, and a good-quality LOE 4 pediatric study[48] showed that during resuscitation of patients >8 years of age, compressions are often too shallow, especially following rescuer changeover. Evidence from 1 pediatric LOE 4 systematic review of the literature[52] showed that rib fractures are rarely associated with chest compressions.

Given these facts, 2010 CoSTR states "In infants, rescuers should be taught to compress the chest by *at least* one third the anterior-posterior dimension or approximately 1 inches (4 cm). In children, rescuers should be taught to compress the chest by *at least* one third the anterior-posterior dimension or approximately 2 inches (5 cm)." A study from Japan (J-LOE 4[53]), however, showed that the average chest diameter of Japanese children aged between 1 and 7 is from 109.2 to 141.4mm. One-third of this makes 36.4 to 47.1mm, and compression at a depth of 5cm is too deep. Therefore, Japanese guidelines recommend compressing the chest by one-third the anterior-posterior diameter (Class I).

8) Chest Decompressions

While allowing complete recoil of the chest after each compression may improve circulation (Class IIa), care should be taken not to let compressions become too shallow.

9) Chest Compression Rate

It is reasonable for lay rescuers and healthcare providers to perform chest compressions at a rate of at least 100 compressions per minute. There is insufficient evidence to indicate a recommended upper limit in chest compression rate. Duration of interruptions in compressions should be minimized so as to maximize the number of compressions delivered per minute (Class I).

10) Feedback for Chest Compression Quality

When more than one rescuer is present, it is reasonable for rescuers and EMS personnel to monitor and try to improve the CPR quality, ensuring adherence to recommended compression and ventilation rates and depths (Class IIa). Real-time chest compression-sensing and feedback/prompt technology may be useful adjuncts during resuscitation efforts.

11) Pulse Check during CPR

Interrupting chest compressions for a pulse check is not recommended unless there is an obvious reaction (normal breathing or purposeful movement) that clearly shows ROSC (Class III). Healthcare providers should also continue CPR without checking for a pulse if there is no monitor available (Class I). It is reasonable to check for a pulse if an organized rhythm is visible on the monitor (Class IIa).

12) Switching Rescuers

It may be reasonable for another rescuer to take over after a period of no longer than 1 to 2 minutes, to prevent deterioration in the quality of compressions (Class IIb). Switching should be done with the minimum of interruptions in the compressions (Class I).

13) Opening the Airway

Opening and maintaining the airway is essential to ensure effective ventilation (Class I). For unresponsive children, open the airway using the head tilt-chin lift maneuver (Class IIa). The trained rescuer can use the jaw thrust maneuver if necessary as for victims with suspected spinal injury (Class IIb). Use the head tilt– chin lift maneuver if the jaw thrust does not open the airway. As the jaw lift maneuver can be harmful, it requires careful attention to adaptive decision making and practice.

14) Tidal Volume and Ventilation Rate

It is reasonable to achieve chest rise with each breath given (Class IIa). The rescuer should avoid hyperventilation during CPR, regardless of etiologies of cardiac arrest (ie. cardiac or respiratory) (Class III). In infants and children, a reduction in minute ventilation to less than baseline for age is reasonable to avoid the harmful effects of hyperventilation (Class IIa).

15) Barrier Devices

The risk of disease transmission in out-of-hospital is very low and initiating rescue breath without a barrier device is reasonable. If available, rescuers may consider using a barrier device (Class IIb). However, safety precautions should be taken both in the in-hospital and out-of-hospital situations if the victim is known to have a serious infection (e.g., human immunodeficiency virus (HIV), tuberculosis, hepatitis B virus, or severe acute respiratory syndrome (SARS)) (Class I). Healthcare providers on duty must always follow standard precautions when performing CPR (Class I).

16) Barrier Devices (Healthcare Providers)

When two or more experienced rescuers are present, ventilation using a bag-valve-mask is reasonable (Class IIa). It may be effective that one rescuer use both hands to open the airway and maintain a tight mask-to-face seal while another compresses the ventilation bag (Class IIa). Holding the mask to the victim's face with both hands can ensure a better mask seal (LOE 5[54, 55]).

In the case of in-hospital pediatric patients considered at risk for respiratory or cardiac arrest, oxygen and BVM should be readily available (Class I).

17) CPR Initiation Procedures

As most cardiac arrests in children are of respiratory origin, it is important to open the airway and start rescue breathing as promptly as possible. It is desirable that devices for rescue breathing and oxygen is readily available in the setting where PBLS may be performed. In PBLS, once rescue breath is ready, the rescuer should open the victim’s airway and perform 2 rescue breaths. If immediate rescue breath is unavailable, the rescuer should immediately begin chest compressions. As soon as it is ready, open the airway and perform 2 rescue breaths. Subsequently, chest compressions and rescue breath should be performed at a ratio of 30:2 for single-rescuer

CPR, or 15:2 for 2-rescuer CPR.

There is no direct evidence in human or animal studies that starting adult and pediatric CPR with 30 chest compressions produce a better outcome than starting with 2 rescue breaths.

18) Optimal Compression-Ventilation Ratio for Infants and Children

There are insufficient data to identify an optimal compression-ventilation ratio for CPR in infants and children. In 4 LOE 5 manikin studies[56-59] examining the feasibility of compression-ventilation ratios of 15:2 and 5:1, lone rescuers could not deliver the desired number of chest compressions per minute at a ratio of 5:1. In 5 LOE 5 studies[60-64] using a variety of manikin sizes comparing compression-ventilation ratios of 15:2 with 30:2, a ratio of 30:2 yielded more chest compressions with no, or minimal, increase in rescuer fatigue. One LOE 5 study[65] of volunteers recruited in an airport to perform 1-rescuer layperson CPR on an adult-sized manikin observed less "no flow time" with the use of a 30:2 ratio compared with a 15:2 ratio.

One LOE 5 observational human study[66] comparing resuscitations by firefighters before and after the change from a recommended 15:2 to 30:2 compression-ventilation ratio reported more chest compressions per minute with the 30:2 ratio, but the rate of ROSC was unchanged. Three LOE 5 animal studies[67-69] showed that coronary perfusion pressure, a major determinant of success in resuscitation, rapidly declines when chest compressions are interrupted; once compressions are resumed, several chest compressions are needed to restore coronary perfusion pressure to preinterruption levels. Thus, frequent interruptions of chest compressions prolong the duration of low coronary perfusion pressure and flow and reduce the mean coronary perfusion pressure.

Three LOE 5 manikin studies[65, 70, 71] and 3 LOE 5[51, 72, 73]61,72,73 in- and out-of-hospital adult human studies documented long interruptions in chest compressions during simulated or actual resuscitations. Three LOE 5 adult studies[74-76] demonstrated that these interruptions reduced ROSC.

In 5 LOE 5 animal studies[67-69, 77, 78] chest compressions without ventilations were sufficient to resuscitate animals with VF-induced cardiac arrest. Conversely in 2 LOE 5 animal studies[79, 80] decreasing the frequency of ventilation was detrimental in the first 5 to 10 minutes of resuscitation of VF-induced cardiac arrest.

One LOE 5 mathematical model[81] suggested that the compression-ventilation ratio in children should be lower (more ventilations to compressions) than in adults and should decrease with decreasing weight. Two LOE 5 studies of asphyxial arrest in pigs[82, 83] showed that ventilations added to chest compressions improved outcome compared with compressions alone. Thus, ventilations are more important during resuscitation from asphyxia-induced arrest than during resuscitation from VF. But even in asphyxial arrest, fewer ventilations are needed to maintain an adequate ventilation-perfusion ratio in the presence of the low cardiac output (and consequently low pulmonary blood flow) produced by chest compressions.

In order to simplify instruction for teaching and improve skill retention, it is reasonable for the single-rescuer to perform CPR in infants and children at a 30:2 compression to ventilation ratio

(Class IIa). After 30 chest compressions, 2 effective ventilations should be promptly given so as to minimize the interruption of chest compressions. When healthcare providers are performing 2-rescuer CPR, a compression-to-ventilation ratio of 15:2 where one is performing chest compression and the other is keeping the airway open is reasonable (Class IIa). When an advanced airway management device is in place, compressions should not be interrupted for ventilations. The rescuer in charge of ventilation should perform rescue breath at a rate of approximately 10 times per minute and avoid hyperventilation (Class I).

(1) Newborns (Out of the Delivery Area) Without an Endotracheal Airway

There are insufficient data to identify an optimal compression-ventilation ratio for all infants in the first month of life.

One LOE 5 animal study[67] showed that coronary perfusion pressure declined with interruptions in chest compressions; after each interruption, several chest compressions were required to restore coronary perfusion pressure to preinterruption levels. One LOE 5 adult human study[75] and 2 LOE 5 animal studies[68, 76] showed that interruptions in chest compression reduced the likelihood of ROSC in VF cardiac arrest.

One LOE 5 1-rescuer manikin study[59] showed that more effective ventilation was achieved with a 3:1 ratio than with a 5:1, 10:2, or 15:2 ratio. One LOE 5 mathematical study of cardiovascular physiology[84] suggested that blood flow rates in neonates are best at compression rates of >120/min.

Although based on limited data, in the case of 2-rescuer CPR in cardiac arrest with cardiac etiology, a 15:2 ratio might be more effective than 3:1 (Class IIb). To simplify instruction for teaching, for term infants in the first month of life and neonates, ratios and CPR methods should be adjusted to those most commonly used in their respective environments.

(2) Newborns (Out of Delivery Area) With a Tracheal Tube

There is insufficient evidence to determine if an intubated neonate has a better outcome from cardiac arrest using a 3:1 compression-ventilation ratio and interposed ventilations compared with continuous chest compressions without pause for ventilations (asynchronous compressions and ventilations).

Two LOE 5 adult[74, 76] and 2 LOE 5 animal[67, 77] studies demonstrated that interruptions in chest compressions reduced coronary perfusion pressure, a key determinant of successful resuscitation in adults, and decreased ROSC. There are no equivalent studies evaluating the impact of interrupted chest compressions in asphyxiated neonates or neonatal animal models.

In 1 LOE 5 piglet study[85] of VF arrest, myocardial blood flow increased using simultaneous chest compressions and high–airway pressure ventilations in a 1:1 ratio as compared with conventional CPR at a 5:1 ratio. Another LOE 5 VF piglet study[86] demonstrated equivalent cardiac output but worsened gas exchange using a 1:1 compression-ventilation ratio (ie, simultaneous compressions and ventilations) with high airway pressures compared with conventional CPR at a 5:1 ratio.

One LOE 5[82] study in nonintubated asphyxiated piglets resuscitated with a 5:1 compression-ventilation ratio showed that ventilations are important for successful resuscitation. One LOE 5 study in intubated asphyxiated piglets[87] showed that the addition of ventilations

resulted in lower arterial CO_2 tension ($PaCO_2$) without compromising hemodynamics when compared with compressions alone. One LOE 5 manikin study[88] found that healthcare providers were unable to achieve the recommended rate of ventilations during infant CPR at a 3:1 compression-ventilation ratio, with 20% delivering a net rate of 40 breaths per minute after 5 minutes of resuscitation. There are no studies that evaluate the impact of continuous compressions on minute ventilation, gas exchange, or the outcome of resuscitation during CPR for intubated neonates.

Given these study results and the necessity of simplifying education, for intubated term infants in the first month of life and neonates, ratios and CPR methods should be adjusted to those most commonly used in their respective environments (Class I). For intubated neonates in need of CPR in the settings outside of the delivery room, newborn nursery, or NICU (e.g., pre-hospital setting, emergency department or PICU), or for those in cardiac arrest with cardiac etiology regardless of place, infant CPR should be performed in accordance with the guidelines (i.e., chest compressions should not be interrupted for ventilation)(Class I).

19) Compression-Only CPR

Evidence from 1 LOE 2 large out-of-hospital pediatric prospective observational investigation[89] showed that children with cardiac arrest of noncardiac etiology (asphyxial arrest) had a higher 30-day survival with more favorable neurologic outcome if they received standard bystander CPR (chest compressions with rescue breathing) compared with chest compression-only CPR. Standard CPR and chest compression-only CPR were similarly effective and better than no bystander CPR for pediatric cardiac arrest from cardiac causes. Of note, the same study showed that more than 50% of children with out-of-hospital cardiac arrest did not receive any bystander CPR. Compression-only CPR was as ineffective as no CPR in the small number of infants and children with asphyxial arrest who did not receive ventilations.

Two LOE 5 animal studies[82, 83] demonstrated improved survival rates and favorable neurologic outcome with standard CPR compared with no CPR. One LOE 5 animal study[87] showed that blood gases deteriorated with compression-only CPR compared with standard CPR in asphyxial arrests.

Data from 1 LOE 5 animal study[83] indicated that compression-only CPR is better than no CPR for asphyxial arrest but not as effective as standard CPR, and 6 LOE 5 clinical observational studies in adults[90-95] showed that compression-only CPR can result in successful resuscitation from an asphyxial arrest. Moreover, in 10 LOE 5 animal studies[67, 77, 78, 96-102] and 7 LOE 5 adult clinical observational studies[90-95, 103] compression-only bystander CPR was generally as effective as standard 1-rescuer bystander CPR for arrests from presumed cardiac causes.

For adults in cardiac arrest, if minimizing of interruption to chest compressions is impossible, rescuers, even healthcare providers, are recommended to focus on chest compressions rather than rescue breath in CPR. However, as most cardiac arrest in children and infants is of respiratory origin, the best resuscitation for such victims in cardiac arrest due to hypoxia should be prompt

initiation of ventilation and chest compressions. Thus, rescuers should provide conventional CPR (rescue breathing and chest compressions) for in-hospital and out-of-hospital pediatric cardiac arrests (Class I). However, rescuers who cannot provide rescue breath should at least perform chest compressions for infants and children in cardiac (Class I).

20) AED Use in Children

The use of AED pads with pediatric attenuation capabilities or AEDs in the pediatric mode was limited to children between 1 and 8 years of age. The recent CoSTR 2010, however, has lowered the lower border of the age range and now an AED is applicable to infants as well.

In Japan, due to the age range in the Japanese schooling systems, there was confusion at the scene in the use of pads; children aged 6-7 (usually first or second grade) need pediatric pads, while children aged 8 or older (usually second or older grade) require adult pads. Risk of miss-applying pediatric pads to children aged 8 years or older was also reported. Given this situation, the Japanese guidelines define the age range of pediatric pad use as preschool age (until about the age of 6 years) for convenience.

This means that the adult pads will be used for children aged 6-7. A use of adult pads for this age group has previously been safely practiced when pediatric pads are not available, and a large body of evidence suggests that estimated energy dose per bodyweight given via adult pad to these children is safe., the adult pads have been applied to those in that age group in the case of the absence of pediatric pads. In addition, many studies have ensured the safety of the number of joules delivered, estimated from the average weight of Japanese children in that age group.

21) Pad Position

Pad position in children does not change the ROSC rate[104], and there is no clear evidence that it alters transthoracic impedance either[105-108]. Transthoracic impedance was increased in 1 adult LOE 5[109] study by placing the pads too close together and in 1 LOE 5[110] study when the pads were placed over the female breast. Additionally, 1 adult LOE 5[111] study showed that placing the apical pad in a horizontal position lowers transthoracic impedance.

For preschool-age children, pediatric pads with attenuation capabilities or an AED in the pediatric mode should be used (Class I). If pediatric pads are unavailable and no other choice is left, adult pads can be substituted (Class I).

There is insufficient evidence to alter the current recommendations to use the largest size paddles/pads that fit on the infant or child's chest without touching each other or to recommend one paddle/pad position or type over another.

22) AED Use in Infants

Three[112-114] studies showed that infants in cardiac arrest (in- and out-of-hospital) may have shockable rhythms. Evidence from 3 LOE 5[115-117] studies showed that many AED devices can safely and accurately distinguish between a shockable and nonshockable rhythm in infants and children.

The optimal energy dose for defibrillation in infants has not been established, but indirect data from 5 LOE 5 animal studies[118-122] showed that the young myocardium may be able to tolerate high-energy doses. In 3 LOE 5 animal studies a pediatric attenuator used with an adult-dose biphasic AED shock was as effective and less harmful than monophasic weight-based doses[123] or biphasic adult doses[124, 125].

Two LOE 4 case reports[126, 127] described survival of infants with out-of-hospital cardiac arrest when AED use was coupled with bystander CPR and defibrillation using an AED. Two pediatric LOE 5 case reports[128, 129] noted successful defibrillation with minimal myocardial damage and good neurologic outcome using an AED with adult energy doses.

The AED can be used on infants under 1 year of age in out-of-hospital VF/ pulseless VT (Class I). If AED with dose attenuator are not available, adult systems can be substituted.

For treatment of out-of-hospital VF/pulseless VT in infants, the recommended method of shock delivery by device is listed in order of preference below. If there is any delay in the availability of the preferred device, the device that is available should be used. The AED algorithm should have demonstrated high specificity and sensitivity for detecting shockable rhythms in infants. The order of preference is as follows:

1. Manual defibrillator
2. AED with dose attenuator
3. AED without dose attenuator

23) Defibrillator Pads and Paddles for Infants

In Japan, so-called “pediatric pads” and “pediatric paddles” for manual defibrillators are actually intended for use in infants aged up to 1 year who weigh less than approximately 10 kg. However, the term “pediatric” has generated confusion among practitioners. In the current guidelines, such pads and paddles are referred to as “infant” pads and “infant” paddles.

One LOE 5 study in adults[130] demonstrated that shock success increased from 31% to 82% when pad size was increased from 8x8 cm to 12x12 cm. Three pediatric LOE 4[105, 131, 132], 3 adult LOE 5[110, 130, 133], and 3 LOE 5 animal[108, 134, 135] studies demonstrated that transthoracic impedance decreases with increasing pad size. Decreased transthoracic impedance increases transthoracic current and, thus, presumably, transmyocardial current.

24) Removal of Foreign Body from Infant’s Airway

In responsive children 1 year of age or older with foreign-body airway obstruction (FBAO), rescuers should activate emergency medical systems (Class IIa) and try back blows, abdominal thrusts, and chest thrusts (Class IIa). More than one technique may be required to relieve the obstruction. These techniques must be repeated rapidly until the relief of the obstruction.

If the choking infants are still responsive but cannot make a strong cough effectively, rescuers are recommended to try back blows and chest thrusts (Class IIa). In these rescue maneuvers, it is

reasonable to move the victim's head downward as the most common cause of FBAO is liquid (Class IIa). If the choking infants are still coughing strongly, rescuers move them onto their sides encouraging their coughing so that they can spit out the obstructing liquids.

If the victim with FBAO becomes unresponsive, the rescuer should immediately begin CPR (Class I). Lay rescuers can begin CPR starting with chest compressions as in usual cases of cardiac arrest. It is reasonable for healthcare providers to start CPR with rescue breath (Class IIa). For unresponsive victims of FBAO, direct removal may be considered only when solid material is visible in the airway (Class IIb).

As with CPR, relief of FBAO is an urgent procedure that should be taught to lay-persons. Evidence for the safest, most effective, and simplest methods was sought. More than one technique may be needed for relief of FBAO; there is insufficient evidence to determine which should be used first. Case series studies and case reports have documented successful relief of FBAO in conscious victims using back blows (LOE 4[136, 137]), abdominal thrusts (LOE 4[138-140]), and chest thrusts (LOE 4[136]、LOE 5[141]).

Thirty-two case reports[142, 143] have documented life-threatening complications associated with the use of abdominal thrusts. A randomized trial of maneuvers to clear the airway in cadavers (LOE 5[144]) and 2 prospective studies in anesthetized volunteers (LOE 5[141, 145]) showed that higher airway pressures could be generated by using the chest thrust rather than the abdominal thrust. In a few case reports a finger sweeping was effective in relieving FBAO in unconscious adults and children aged 1 year or older (LOE 4[136, 137, 146136, 137, 146]). Some case reports documented harm to the victims or biting of the rescuer's finger with finger sweeping (LOE 4[147] and LOE 5[148-150]). According to a retrospective study of fifty FBAO, only the time spent between the emergency call and the hospital arrival was a significant factor of survival for discharge[151].

It is distinctive that liquids are the most common cause of FBAO in children under 1 year of age[137]. At this time, there is insufficient evidence for a treatment recommendation specific for obese or pregnant patients with FBAO.

■6 Pediatric Advanced Life Support: PALS

1. Cardiac Arrest Algorithm

The PALS Cardiac Arrest Algorithm is a set of actions for those who perform CPR on a routine basis to treat infants and children in cardiac arrest.

1) PBLS

[Box 1]

Observe the chest and abdominal movements in unresponsive infants and children. Once recognizing that there is no breathing, follow the PALS Algorithm.

[Box 2]

Begin CPR immediately. Administrate oxygen, attach an ECG monitor and a pulse oximeter, and get a defibrillator ready.

[Box 3 to 4 to 5]

Determine the victim's cardiac rhythm on the ECG. VF and pulseless VT are shockable rhythms. The initial energy dose should be 4J/kg. After giving a shock, resume CPR beginning with chest compressions immediately.

After 2 minutes of CPR, check the rhythms. If there is still VF or pulseless VT, give another shock. The energy dose should be 4J/kg also in the second and subsequent shocks. Drug dosing should be promptly done after rhythm checking.

[Box 6]

Asystole and PEA are nonshockable rhythms.

The most common ECG patterns in infants and children with cardiac arrest are asystole and PEA.

For infants and children in asystole or PEA, resume CPR and give chest compression as continuously as possible. While one rescuer is performing CPR, another rescuer should prepare adrenaline administration. Standard doses (IV dose of 0.01mg/kg, endotracheal dose of 0.1mg/kg) should be given for the initial and subsequent administrations.

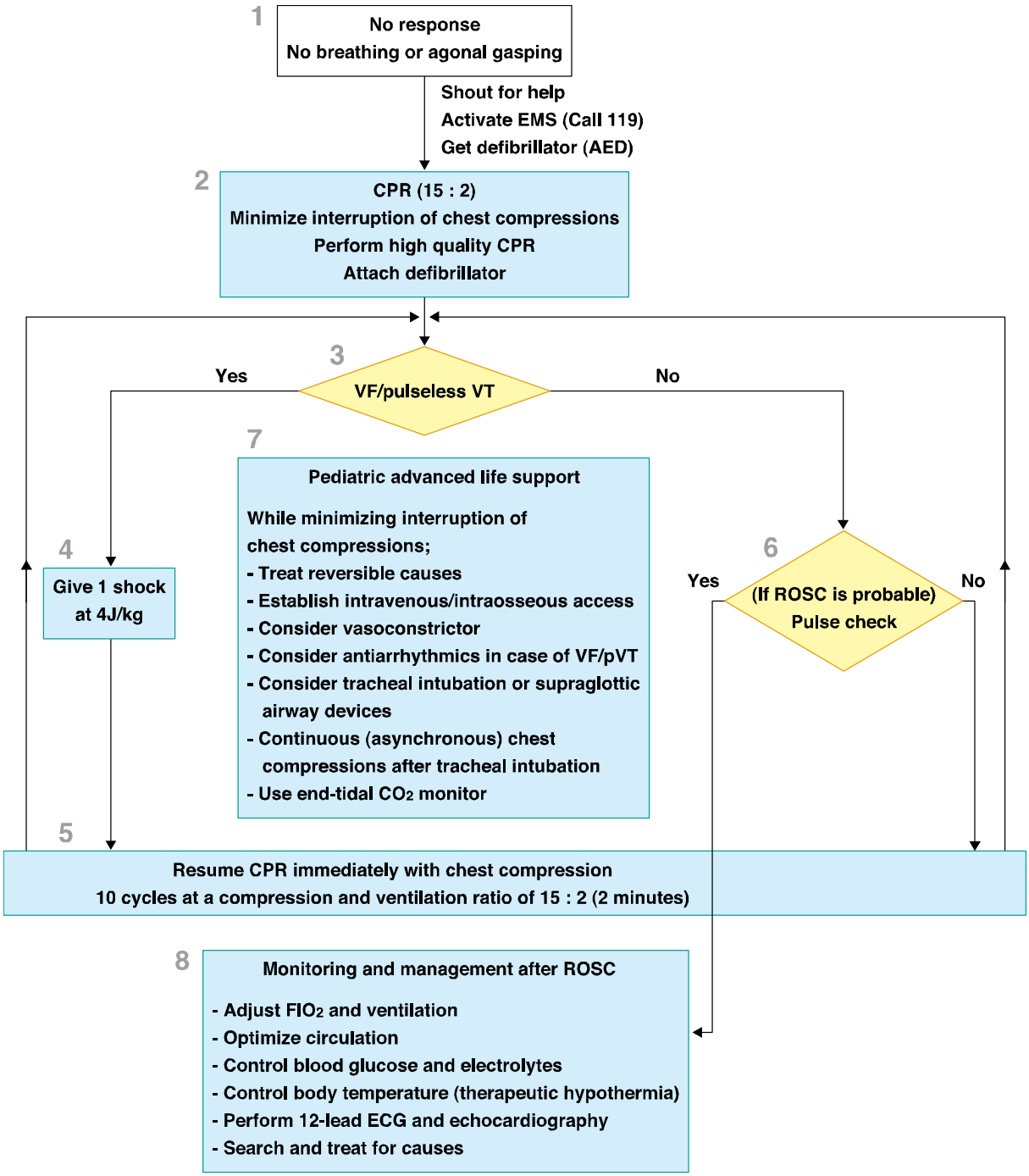

Figure 2 Pediatric cardiac arrest algorithm

2) PALS

[Box 7]

When ROSC is not achieved in PBLS, PALS is necessary. Continuous, effective chest compressions are the key to success not only in PBLS but also in PALS. Interruption of chest

compressions must be avoided in PALS as well as at any other time excepting for rescue breathing, ECG analysis, pulse check, or shock delivery.

(1) Identification and Treatment of Reversible Causes

Identifying and treating reversible causes for the cardiac arrest is required at every step in resuscitation while performing high quality CPR. Although searching for the causes is usually conducted by investigating the circumstances at the time of cardiac arrest, review of the victim's medical history, physical examination and arterial blood gas or electrolytes tests that yield results rapidly can occasionally be useful. Echocardiography can be useful for diagnosing pericardial effusion and pulmonary thromboembolism. However, there is insufficient evidence to support or refute the routine use of echocardiography.

(2) Establishment of Intravenous or Intraosseous Access

While continuing to perform CPR, peripheral intravenous access or intraosseous access should be established in order for fluids and medications to be successfully delivered. When peripheral intravenous access is not readily attainable, intraosseous access is recommended.

(3) Vasopressors

There is insufficent evidence to suggest that adrenaline improves survival to hospital discharge or neurological outcome. However, the use of adrenaline may be considered in cardiac arrest since there is evidence that adrenaline may improve the rate of ROSC and short-term survival. Adrenaline should be given at 0.01mg/kg per dose (maximum dose of 1mg) with additional dosage every 3-5 minutes. There is insufficient evidence to support or refute the routine use of vasopressin.

(4) Antiarrhythmics

Administration of antiarrhythmics may be considered in refractory VF or pulseless VT(pVT). There is, however, insufficient evidence that antiarrhythmics administration improves the rate of ROSC or survival. In Japan, amiodarone, nifekalant and lidocaine are commonly used as antiarrhythmics for VF/ pVT. Amiodarone may be used for the treatment of shock-refractory or recurrent VF/pVT (Class IIb). Nifekalant may be considered in victims in cardiac arrest and with shock refractory VF/pVT (Class IIb). If amiodarone or nifekalant is not available, lidocaine may be considered although it is less effective (Class IIb).

(5) Tracheal Intubation and Supraglottic Airway Devices

The tracheal tube is considered the optimal method of managing the airway in CPR. Since tracheal intubation is a high risk procedure, it requires adequate training and ongoing skills maintenance for secure and prompt intubation. Prolonged attempts at tracheal intubation are harmful if they lead to interruption of chest compressions. Interruption of chest compressions should be minimized when performing tracheal intubation (Class I).

Application of supraglottic airway devices (such as the laryngeal mask airway) by healthcare

professionals trained in their use may be considered as a method of airway management during CPR. These devices can be used as a backup in a difficult or failed tracheal intubation. There is inadequate evidence to define the optimal timing of advanced airway placement during cardiac arrest. In the case of shortage of rescuers, early placement of these devices might help the rescuers focus on other effective treatment without having to deal with manual airway management.

(6) Continuous Chest Compressions

When a tracheal tube is in place, continious chest compressions should be performed without pause for ventilations (asynchronous compressions and ventilations). Chest compressions should be given at least 100 times per minute, and about 10 rescue breaths per minute should be given. When a supraglottic airway device is in place, continuous, uninterrupted chest compressions can be performed if adequate ventilation can be provided.

(7) Capnometry

Waveform capnography is recommended to confirm and continuously monitor the position of a tracheal tube in victims of cardiac arrest, and it should be used in addition to clinical assessment of auscultation and direct visualization. If waveform capnography is not available, a nonwaveform CO_2 detector, a colorimetric exhaled CO_2 detector or oesophageal detector device (for children who weigh 20kg or more) in addition to physical examination is an alternative.

3) Postresuscitation Care

[Box 8]

Comprehensive treatment protocols for patients with ROSC include management of ventilation and circulation, controlling blood glucose and electrolytes, and therapeutic hypothermia.

(1) Adjustment of Concentration of Inspired Oxygen and Ventilation

Although it is necessary to avoid hypoxemia after ROSC, administration of highly concentrated oxygen may adversely affect brain damage. There is insufficient evidence that the routine ventilation with 100% oxygen is harmful. However, it is reasonable to adjust the fraction of inspiratory oxygen using PaO_2 and SpO_2 as indicators in the early treatment for patients with ROSC (Class IIa). Hyperventilation after ROSC may reduce cerebral blood flow. After restoration of circulation, routine hyperventilation leading to hypocapnia should be avoided in order to prevent additional cerebral ischemia.

(2) Circulation Management

There is insufficient evidence that early hemodynamic optimization following ROSC improves outcomes. Although there is insufficient evidence regarding administration of IV fluids after ROSC, it is reasonable to use IV fluids as a part of comprehensive treatment based on the pathophysiology after ROSC (Class IIa). There is also insufficient evidence to support the efficacy of the use of vasopressors and/or inotropes, the continuous administration of amiodarone,

nifekalant or lidocaine, or the use of mechanical circulatory support such as intra-aortic balloon pumping. Although there is limited clinical data concerning the efficacy of circulation management, hemodynamic optimization for improved organ perfusion was performed based on the pathophysiology after ROSC.

(3) Blood Glucose and Electrolytes Control

It is appropriate to monitor blood glucose levels and avoid hypoglycemia as well as hyperglycemia following cardiac arrest (Class I). It is necessary to stay alert for hypoglycemia especially during control of blood glucose using insulin . There is insufficient evidence at present to identify the specific target glucose concentration range for the control of hyperglycemia in infants and children after ROSC. It is better not to use glucose containing fluids during CPR.

Hyponatremia causes plasma osmolality to fall, which may result in cerebral edema. The use of hypotonic fluids may cause iatrogenic cerebral edema. Whereas the negative effects of hyponatremia have already been pointed out in other countries, little attention is paid to that in medical setting in Japan. In the management after ROSC, hyponatremia should be avoided especially when abnormalities are seen in the central nervous system (Class III).

(4) Temperature Control (Therapeutic Hypothermia)

Victims with high body temperature after ROSC have poor outcomes. Hyperthermia after ROSC needs aggressive treatment (Class I). Therapeutic hypothermia (to 32–34 degrees Celsius for 12-24 hours) may be beneficial for adolescents who remain comatose (not responding in a meaningful way to verbal commands) following resuscitation from out-of-hospital VF cardiac arrest (Class IIa). The use of therapeutic hypothermia in infants and children is not refuted. Therapeutic hypothermia may also be beneficial for victims who remain comatose following resuscitation from in-/out-of-hospital PEA or asystole.

(5) 12-Lead ECG and Echocardiography

Lethal arrhythmia and myocardial disorder are important reversible causes of sudden cardiac arrest. After ROSC, 12-lead ECGs should be recorded and differential diagnoses on lethal arrhythmia should be carried out.

Echocardiography is useful not only for searching for causes, but also for assessing cardiac function. In addition, it can be used non-invasively and without having to move the patient. Given this, it is reasonable to use echocardiography after ROSC (Class IIa).

(6) Search for Causes and Treatment

It is necessary to search for causes of cardiac arrest and subsequently treat the patient after ROSC. Treating the cause is essential for preventing a recurrence of cardiac arrest and hemodynamic optimization.

2. Assessment

1) Focused Echocardiogram to Detect Reversible Causes of Cardiac Arrest

In 1 small LOE 4 pediatric case series[152] cardiac activity was rapidly visualized by echocardiography without prolonged interruption of chest compressions, and this cardiac activity correlated with the presence or absence of a central pulse. In 1 pediatric LOE 4 case report[153], echocardiography was useful for diagnosing pericardial tamponade as the cause of cardiac arrest and was useful in guiding treatment.

In 8 LOE 5 adult case series[154-161], echocardiographic findings correlated well with the presence or absence of cardiac activity in cardiac arrest. These reports also suggested that echocardiography may be useful in identifying patients with potentially reversible causes for the arrest.

There is insufficient evidence to recommend for or against the routine use of echocardiography during pediatric cardiac arrest. Echocardiography may be considered to identify potentially treatable causes of an arrest when appropriately skilled personnel are available, but the benefits must be carefully weighed against the known deleterious consequences of interrupting chest compressions.

2) End-tidal CO_2 ($PETCO_2$) and Quality of CPR

Three LOE 5 animal studies[162-164], 4 LOE 5 adult[165-168], and 1 LOE 5 pediatric series[169] showed a strong correlation between $PETCO_2$ and interventions that increase cardiac output during resuscitation from shock or cardiac arrest. Similarly 3 LOE 5 animal models[170-172] showed that measures that markedly reduce cardiac output result in a fall in $PETCO_2$.

Two LOE 5 adult out-of-hospital studies[173, 174] supported continuous $PETCO_2$ monitoring during CPR as a way of determining return of spontaneous circulation (ROSC), particularly if the readings during CPR are >15 mm Hg (2.0kPa). In 1 LOE 4[175] and 2 LOE 5 adult case series[176, 177], an abrupt and sustained rise in $PETCO_2$ often preceded identification of ROSC.Two LOE 4 pediatric cases series[169, 178], 8 LOE 5 adult[174, 179-185], and 1 LOE 5 animal study[163] showed that a low $PETCO_2$ (<10 mm Hg [1.33 kPa] to <15 mm Hg [2.0 kPa]) despite 15 to 20 minutes of advanced life support (ALS) is strongly associated with failure to achieve ROSC. On the basis of 2 LOE 5 animal studies[175, 186] and 2 adult LOE 5 case series[174, 182], $PETCO_2$ after at least 1 minute of CPR may be more predictive of outcome than the initial value because the initial $PETCO_2$ is often increased in patients with asphyxial cardiac arrest.

The wide variation for initial $PETCO_2$ during resuscitation limits its reliability in predicting outcome of resuscitation and its value as a guide to limiting resuscitation efforts. Two LOE 5 animal studies[175, 186] and 2 large LOE 5 adult trials[174, 182] suggested that the initial $PETCO_2$ is higher if the etiology of the cardiac arrest is asphyxial rather than if it is a primary cardiac arrest.Interpretation of the end-tidal CO_2 during resuscitation is affected by the quality of the measurement, the minute ventilation delivered during resuscitation, the presence of lung disease that increases anatomic dead space, and the presence of right-to-left shunting.

In 1 LOE 5 adult study[187], sodium bicarbonate transiently increased end-tidal CO_2, and in 3

LOE 5 adult[188-190] and 2 LOE 5 animal[191, 192] studies, adrenaline (and other systemic vasoconstrictive agents) transiently decreased $PETCO_2$.

Continuous capnography or capnometry monitoring, if available, may be beneficial by providing feedback on the effectiveness of chest compressions. Whereas a specific target number cannot be identified, if the $PETCO_2$ is consistently <15 mm Hg, it is reasonable to focus efforts on improving the quality of chest compressions and avoiding excessive ventilation (Class IIa). Although a threshold $PETCO_2$ may predict a poor outcome from resuscitation and might be useful as a guide to termination of CPR, there are insufficient data to establish the threshold and the appropriate duration of ALS needed before such evaluation in children. The $PETCO_2$ must be interpreted with caution for 1 to 2 minutes after administration of adrenaline or other vasoconstrictive medications because these medications may decrease the $PETCO_2$.

3. Airway and Ventilation

Opening and maintaining a patent airway and providing ventilations are fundamental elements of pediatric CPR, especially because cardiac arrest often results from, or is complicated by, asphyxia. There are no new data to change the ILCOR 2005 recommendation to use manual airway maneuvers (with or without an oropharyngeal airway) and bag-mask ventilation (BMV) for children requiringairway control or positive-pressure ventilation for short periods in the out-of-hospital setting. When airway control or BMV is not effective, supraglottic airways may be helpful when used by properly trained personnel.

When performing tracheal intubation, data suggest that the routine use of cricoid pressure may not protect against aspiration and may make intubation more difficult.

Routine confirmation of tracheal tube position with capnography/capnometry is recommended with the caveat that the $PETCO_2$ in infants and children in cardiac arrest may be below detection limits for colorimetric devices.

Following ROSC, toxic oxygen byproducts (reactive oxygen species, free radicals) are produced that may damage cell membranes, proteins, and DNA (reperfusion injury). Although there are no clinical studies in children (outside the newborn period) comparing different concentrations of inspired oxygen during and immediately after resuscitation, animal data and data from newborn resuscitation studies suggest that it is prudent to titrate inspired oxygen after return of a perfusing rhythm to prevent hyperoxemia.

1) Concentration of Supplementary Oxygen

There are no studies comparing ventilation of infants and children in cardiac arrest with different inspired oxygen concentrations. Two LOE 5 meta-analyses of several randomized controlled trials comparing neonatal resuscitation initiated with room air versus 100% oxygen[193, 194] showed increased survival when resuscitation was initiated with room air. Seven LOE 5 animal studies[195-201] suggested that ventilation with room air or an FIO_2 of <1.0 during cardiac arrest may be associated with less neurologic deficit than ventilation with an FIO_2 of 1.0, whereas 1 LOE 5

animal study[202] showed no difference in outcome. In 5 LOE 5 animal studies [196, 198-200, 203] ventilation with 100% oxygen during and following resuscitation contributed to free radical–mediated reperfusion injury to the brain.

There is insufficient evidence to recommend any specific inspired oxygen concentration for ventilation *during* resuscitation from cardiac arrest in infants and children. Once circulation is restored, it is reasonable to titrate inspired oxygen to limit hyperoxemia (Class IIa)..

2) Cuffed Versus Uncuffed Tracheal Tube

There are no studies that compare the safety and efficacy of cuffed versus uncuffed tubes in infants and children who require emergency intubation.

Two LOE 5 randomized controlled studies[204, 205] and 1 LOE 5 cohort-controlled study[206] in a pediatric anesthesia setting showed that the use of cuffed tracheal tubes was associated with a higher likelihood of selecting the correct tracheal tube size (and hence a lower reintubation rate) with no increased risk of perioperative or airway complications. Cuff pressures in these 3 studies were maintained at <25 cm H_2O. Two perioperative LOE 5 cohort-controlled pediatric studies[206, 207] similarly showed that cuffed tubes were not associated with an increased risk of perioperative airway complications.

One LOE 5 pediatric case series[208] observed that the use of cuffed tracheal tubes was not a risk factor for developing subglottic stenosis in patients having corrective surgery for congenital cardiac defects. In the intensive care setting, 2 LOE 5 prospective cohort-controlled studies[209, 210] and 1 LOE 5 retrospective cohort-controlled study[211] documented no greater risk of complications for children >8 years of age who were intubated with cuffed compared with uncuffed tracheal tubes.

One small LOE 5 case-controlled study[212] showed that cuffed tracheal tubes decreased the incidence of aspiration in the PICU, and 1 LOE 5 case series[206] of children with burns undergoing general anesthesia showed a significantly higher rate of excessive air leak requiring immediate reintubation in patients initially intubated with an uncuffed tracheal tube. One study on the design of readily available pediatric cuffed/uncuffed tracheal tubes (J-LOE 5[213]) showed that cuff diameters and the distances between the cuff and the tip differ depending on manufacturer. Placing the tube tip midway between the larynx and the tracheal bifurcation, there is a danger that the upper part of the cuff would reach the glottis.

Both cuffed and uncuffed tracheal tubes are acceptable for infants and children undergoing emergency intubation (Class I). If cuffed tracheal tubes are used, avoid excessive cuff pressures (Class I). As cuff diameters and the distances between the cuff and the tip vary among manufacturers, it is necessary to take heed of the possibility that some cuffs might not fit between the glottis and the tracheal bifurcation depending on the combination of the patient's physical size and the tracheal tube size.

3) Tracheal Tube Size

Evidence from 1 LOE 2 prospective randomized trial of elective intubation in a pediatric operating room[204] was used to support the existing formula for estimation of appropriate cuffed

tracheal tube internal diameter (ID): ID (mm)=(age in years/4) + 3, also known as the Khine formula. Detailed analysis of this paper, however, reveals that the aggressive rounding up of age employed by the authors in their calculations commonly resulted in selection of a tube with an ID 0.5 mm larger than the size derived from the formula.

Evidence from 1 LOE 2 prospective randomized multicenter study[205], 1 LOE 2[214], and 3 LOE 4 prospective observational studies of elective intubation in the pediatric operating room[215-217] supported use of 3-mm ID cuffed tracheal tubes for newborns and infants (3.5 kg to 1 year of age) and 3.5-mm ID cuffed tracheal tubes for patients 1 to 2 years of age.

One LOE 2 prospective randomized multicenter study[205] and 3 LOE 4 prospective observational studies of elective intubation in the pediatric operating room[215-217] using Microcuff® tracheal tubes support the use of the following formula for cuffed endotracheal tubes in children:

ID (mm)=(age/4) + 3.5.

One LOE 2 prospective observational study of elective intubation in the pediatric operating room[214] found that formula acceptable but associated with a marginally greater reintubation rate than with the Khine formula (ID [mm]=[age in years/4] + 3).

After the age of 2, it is reasonable to estimate the uncuffed tracheal tube size with the following formula:

ID (mm) = (age in years/4) + 4

(If an uncuffed tracheal tube is used in infants weighing 3.5 kg or over and up to 1 year of age, it is reasonable to use a tube with an ID of 3.5 mm. If an uncuffed tracheal tube is used in children between 1 and 2 years of age, it is reasonable to use a tube with an ID of 4.0 mm.)

Tube size was considered optimal when an air leak was detected between the tube and the glottis and pressure was sufficient to raise the patient's chest adequately. The presence of adequate leakage indicates that the tube is not too large, which prevents laryngeal edema and difficulties in extubation. When there is no leak detected at an airway pressure of 20-30 cmH_2O, it is too large a tube and another tube with an ID 0.5 mm smaller should be used. If the airway pressure does not reach 10 cmH_2O as pressure is increased, replace it with a tube with an ID 0.5 mm larger.

4) Bag-Mask Ventilation Versus Intubation

One LOE 1 study[218] compared paramedic out-of-hospital BMV with intubation for children with cardiac arrest, respiratory arrest, or respiratory failure in an EMS system with short transport intervals and found equivalent rates of survival to hospital discharge and neurologic outcome. One LOE 1 systematic review that included this study[219] also reached the same conclusion.

One LOE 2 study of pediatric trauma patients[220] observed that out-of-hospital intubation is

associated with a higher risk of mortality and postdischarge neurologic impairment compared with in-hospital intubation. These findings persisted even after stratification for severity of trauma and head trauma.

In 1 LOE 2 (nonrandomized) prehospital pediatric study[221], if paramedics provided BMV while awaiting the arrival of a physician to intubate the patient, the risk of cardiac arrest and overall mortality was lower than if the patient was intubated by the paramedics. These findings persisted even after adjusting for Glasgow Coma Scale score.

Four LOE 4 studies[222-225] showed a significantly greater rate of failed intubations and complications in children compared with adults in the out-of-hospital and emergency department settings. Conversely 1 LOE 3 out-of-hospital study[226] and 1 LOE 4 out-of-hospital study[227] failed to demonstrate any difference in intubation failure rates between adults and children.

BMV is recommended over tracheal intubation in infants and children who require ventilatory support in the out-of-hospital setting when transport time is short (Class I).

5) Bag-Mask Ventilation Versus Supraglottic Airway

No studies have directly compared BMV to the use of supraglottic airway devices during pediatric resuscitation other than for the newly born in the delivery room. Nine LOE 5 case reports[228-236] demonstrated the effectiveness of supraglottic airway devices, primarily the LMA, for airway rescue of children with airway abnormalities.

One LOE 5 out-of-hospital adult study[237] supports the use of LMAs by first responders during CPR, but another LOE 5 out-of-hospital adult cardiac arrest study[238] of EMS personnel providing assisted ventilation by either bag-mask device or LMA failed to show any significant difference in ventilation ($PaCO_2$). Six LOE 5 studies during anesthesia[239-244] demonstrated that complication rates with LMAs increase with decreasing patient age and size. In 2 LOE 5 manikin studies[245, 246] trained nonexpert providers successfully delivered positive-pressure ventilation using the LMA. Tracheal intubations resulted in a significant incidence of tube misplacement (esophageal or right mainstem bronchus), a problem not present with the LMA, but time to effective ventilation was shorter and tidal volumes were greater with BMV.

In 2 LOE 5 studies of anesthetized children[247, 248] suitably trained ICU and ward nurses placed LMAs with a high success rate, although time to first breath was shorter in the BMV group. In a small number of cases ventilation was achieved with an LMA when it proved impossible with BMV.

BMV remains the preferred technique for emergency ventilation during the initial steps of pediatric resuscitation (Class I). In infants and children for whom BMV is unsuccessful, use of the LMA by appropriately trained providers may be considered for either airway rescue or support of ventilation.

6) MinuteVentilation duringCPR

There are no data to identify the optimal minute ventilation (tidal volume or respiratory rate)

for infants or children with an advanced airway during CPR, regardless of arrest etiology.

Three LOE 5 animal studies[82, 249, 250] showed that ventilation during CPR after VF or asphyxial arrest resulted in improved ROSC, survival, and/or neurologic outcome compared with no positive-pressure breaths.

Evidence from 4 LOE 5 adult studies[51, 72, 251, 252]showed that excessive ventilation is common during resuscitation from cardiac arrest. In 1 LOE 5 animal study[251] excessive ventilation during resuscitation from cardiac arrest decreased cerebral perfusion pressure, ROSC, and survival compared with lower ventilation rates. One good LOE 5 animal study[250] found that increasing respiratory rate during conditions of reduced cardiac output improved alveolar ventilation but not oxygenation, and it reduced coronary perfusion pressure.

In 1 LOE 5 prospective, randomized adult study[253] constant-flow insufflation with oxygen compared with conventional mechanical ventilation during CPR did not change outcome (ROSC, survival to admission, and survival to ICU discharge). In another LOE 5 adult study[254], adults with witnessed VF arrest had improved neurologically intact survival with passive oxygen insufflation compared with BMV, whereas there was no difference in survival if the VF arrest was unwitnessed.

Two LOE 5 animal studies showed that ventilation or continuous positive airway pressure (CPAP) with oxygen compared with no ventilation improved arterial blood gases[255] but did not change neurologically intact survival[256]. One good-quality LOE 5 animal study[257] showed that reducing tidal volume by 50% during CPR resulted in less excessive ventilation without affecting ROSC.

Following placement of a secure airway, avoid excess ventilation of infants and children during resuscitation from cardiac arrest, whether asphyxial or due to VF (Class III). A reduction in minute ventilation to less than baseline for age is reasonable to provide sufficient ventilation to maintain adequate ventilation-to-perfusion ratio during CPR while avoiding the harmful effects of excessive ventilation (Class IIa). There are insufficient data to identify the optimal tidal volume or respiratory rate.

7) Tracheal Tube Placement

No single assessment method accurately and consistently confirms tracheal tube position. Three LOE 4 studies[175, 258, 259] showed that when a perfusing cardiac rhythm is present in infants (>2 kg) and children, detection of exhaled CO_2 using a colorimetric detector or capnometer has a high sensitivity and specificity for confirming endotracheal tube placement. One of these studies included infants and children in cardiac arrest. In the cardiac arrest population the sensitivity of exhaled CO_2 detection was only 85% (ie, false-negatives occurred), whereas the specificity remained at 100%.

One neonatal LOE 5 study[260] of delivery room intubation demonstrated that detection of exhaled CO_2 by capnography was 100% sensitive and specific for detecting esophageal intubation and took less time than clinical assessment to identify esophageal intubation. Two additional neonatal LOE 5 studies[261, 262] showed that confirmation of tracheal tube position is faster with capnography than

with clinical assessment.

Two pediatric LOE 4 studies[263, 264] showed that in the presence of a perfusing rhythm, exhaled CO_2 detection or measurement can confirm tracheal tube position accurately during transport, while 2 LOE 5 animal studies[265, 266] showed that tracheal tube displacement can be detected more rapidly by CO_2 detection than by pulse oximetry.

One LOE 2 operating room study[267] showed that the esophageal detector device (EDD) is highly sensitive and specific for correct tracheal tube placement in children >20 kg with a perfusing cardiac rhythm; there have been no studies of EDD use in children during cardiac arrest. An LOE 4 operating room (ie, non-arrest) study[268] showed that the EDD performed well but was less accurate in children <20 kg.

Confirmation of tracheal tube position using exhaled CO_2 detection (colorimetric detector or capnography) should be used for intubated infants and children with a perfusing cardiac rhythm in all settings (eg, out-of-hospital, emergency department, ICU, inpatient, operating room) (Class I). CO_2 output should be confirmed after a few breaths. Even when the tube is properly in place inside the airway, exhaled CO_2 may not be detected due to low pulmonary blood flow during CPR. If there is suspected tube misplacement during CPR, confirmation should be undertaken under direct observation through the laryngoscope. In infants and children with a perfusing rhythm, it may be beneficial to monitor continuous capnography or frequent intermittent detection of exhaled CO_2 during out-of-hospital and intra-/interhospital transport. The EDD may be considered for confirmation of tracheal tube placement in children weighing 20 kg or more when a perfusing rhythm is present (Class IIa).

8) Cricoid Pressure

There are no data to show that cricoid pressure prevents aspiration during rapid sequence or emergency tracheal intubation in infants or children. Two LOE 5 studies[269, 270] showed that cricoid pressure may reduce gastric inflation in children. One LOE 5 study in children[271] and 1 LOE 5 study in adult cadavers[272] demonstrated that esophageal reflux is reduced with cricoid pressure.

In 1 LOE 5 adult systematic review[273] laryngeal manipulation enhanced BMV or intubation in some patients while impeding it in others. One LOE 5 study in anesthetized children[274] showed that cricoid pressure can distort the airway with a force of as low as 5 newtons.

If cricoid pressure is used during emergency intubations in infants and children it should be discontinued if it impedes ventilation or interferes with the speed or ease of intubation (Class I).

4. Defibrillation

There were a few studies with LOE 3-5 on issues related to defibrillation, including safe and effective energy dosing, stacked versus single shocks, use of AEDs in infants less than 1 year of age and paddle/pad size and position. No new data, however, are available to support a change in treatment of recurrent or refractory VT or VF. There were several publications on defibrillation-energy dosing for VF, but the data were contradictory, and the optimal safe and

effective energy dose remains unknown.

The new recommendation of an initial dose of 2–4 J/kg is based on cohort studies showing low success in termination of VF in pediatric patients with 2 J kg/1. These studies, however, do not provide data on the success or safety of higher energy doses. The recommendation for a single initial shock, which was made in 2005, is based on the adult data using biphasic defibrillation.

1) Pads and Paddles

There are limited studies comparing self-adhesive defibrillation pads (SADPs) with paddles in pediatric cardiac arrest. One pediatric LOE 4[104] study demonstrated equivalent ROSC rates when paddles or SADPs were used. One LOE 5[275]104 adult out-of-hospital cardiac arrest study suggested improved survival to hospital admission when SADPs rather than paddles were used.

One adult LOE 5[276] study showed a lower rate of rhythm conversion, and 1 small adult LOE 5[277] study showed at least equivalent success with the use of SADPs in comparison with paddles in patients undergoing cardioversion for atrial fibrillation. Two adult LOE 5[278, 279] studies showed equivalent transthoracic impedance with SADPs or paddles. One adult LOE 5[107] and 2 LOE 5 animal[280, 281] studies showed that SADPs had a higher transthoracic impedance than paddles.

One LOE 4[282] study described difficulty with fitting self-adhesive pads onto the thorax of a premature infant without the pads touching. One LOE 5[283] study demonstrated the improved accuracy of cardiac rhythm monitoring following defibrillation using SADPs compared with the combination of paddles and gel pads.

Using standard resuscitation protocols in simulated clinical environments, 1 LOE 5[284] study found no significant difference in the time required to deliver shocks using either SADPs or paddles, and 1 LOE 5[285] study found no significant difference in time without compressions when SADPs or paddles were used.

Either self-adhesive defibrillation pads or paddles may be used in infants and children in cardiac arrest (Class I).

2) Number of Shocks

There are no randomized controlled studies examining a single versus sequential (stacked) shock strategy in children with VF/pulseless VT. Evidence from 7 LOE 5 studies in adults with VF[75, 286-291] supported a single-shock strategy over stacked or sequential shocks because the relative efficacy of a single biphasic shock is high and the delivery of a single shock reduces duration of interruptions in chest compressions.

A single-shock strategy followed by immediate CPR (beginning with chest compressions) is recommended for children with out-of-hospital or in-hospital VF/pulseless VT (Class I).

3) Energy Dose

Two LOE 4[104, 292] studies reported no relationship between defibrillation dose and survival to hospital discharge or neurologic outcome from VF/pulseless VT. Evidence from 3 LOE 4 studies in

children in out-of-hospital and in-hospital settings[104, 113, 118] observed that an initial dose of 2 J/kg was effective in terminating VF 18% to 50% of the time. Two LOE 4 studies[292, 293] reported that children often received more than 2 J/kg during out-of hospital cardiac arrest, with many (69%) requiring 3 shocks of escalating energy doses. One in-hospital cardiac arrest LOE 4 study[104] reported that the need for multiple shocks with biphasic energy doses of 2.5 to 3.2 J/kg was associated with lack of ROSC.

Evidence from 2 LOE 5 animal studies[123, 294] observed that 0% to 8% of episodes of long-duration VF were terminated by a 2 J/kg monophasic shock and up to 32% were terminated by biphasic shocks. Animals in these studies received both fixed and escalated doses, and most required 2 or more shocks to terminate VF. In 1 LOE 5 animal study[108] the defibrillation threshold for short-duration VF was 2.4 J/kg, whereas in another[294] it was 3.3 J/kg.

In 4 LOE 5 animal studies[119, 123-125] of AED shocks delivered using a pediatric attenuator, 50 J and 50→76→86 J (2.5 to 4 J/ kg) escalating doses were effective at terminating long-duration VF but required multiple shocks. In 1 LOE 5 animal study[295] 10 J/kg shocks were more effective at terminating long-duration VF (6 minutes) with 1 shock than 4 J/kg shocks.

In 2 LOE 4 pediatric studies[104, 292] and 4 LOE 5 animal studies[119, 123-125], energy doses of 2 to 10 J/kg for short- or long-duration VF resulted in equivalent rates of survival. Myocardial damage, as assessed by hemodynamic or biochemical measurements, was less when a pediatric attenuator was used with an adult energy dose compared with a full adult AED dose, but the degree of myocardial damage was not associated with any difference in 4- or 72-hour survival. An LOE 5 animal study[295] found no difference in hemodynamic parameters or biochemical measurements of myocardial damage comparing biphasic 150 J (4 J/kg) with monophasic 360 J/kg (10 J/kg) shocks.

In 2 LOE 5 animal studies[123, 294] biphasic waveforms were more effective than monophasic waveforms for treatment of VF/pulseless VT. There are no human data that directly compare monophasic to biphasic waveforms for pediatric defibrillation.

High energy doses are relatively safe, and an initial dose of 4 J/kg is adequate for pediatric defibrillation. Energy doses for pediatric defibrillation are 4 J/kg (Class I).

5. Vascular Access and Drug Delivery

There is no new evidence to change the 2005 ILCOR recommendations on vascular access, including the early use of intraosseous (IO) access and deemphasis of the tracheal route of drug delivery. Epidemiological data, largely from the National Registry of CPR (NRCPR), reported an association between vasopressin, calcium, or sodium bicarbonate administration and an increased likelihood of death. These data, however, cannot be interpreted as a cause-and-effect relationship. The association may be due to more frequent use of these drugs in children who fail to respond to standard basic and advanced life support interventions. These and other data in adults question the benefit of intravenous (IV) medications during resuscitation and reemphasize the importance of high-quality CPR.

1) Intraosseous Access

There are no studies comparing IO with IV access in children with cardiac arrest. In 1 LOE 5

study of children in shock[296] IO access was frequently more successful and achieved more rapidly than IV access. Eight LOE 4 case series[297-304] showed that providers with many levels of training could rapidly establish IO access with minimal complications for children with cardiac arrest.

IO access should be considered in the care of critically ill infants or children whenever venous access is not readily attainable (Class I). Almost all fluids and drugs associated with resuscitation can be delivered through IO access.

2) Tracheal Drug Delivery

One LOE 3 study of children with in-hospital cardiac arrest[305] demonstrated similar ROSC and survival rates, whereas 2 LOE 5 studies of adults in cardiac arrest[306, 307] demonstrated reduced ROSC and survival to hospital discharge rates when tracheal instead of IV adrenaline was given. One LOE 5 case series of neonatal asphyxial bradycardia demonstrated similar rates of ROSC whether IV or tracheal adrenaline was administered, whereas another LOE 5 study[308] demonstrated a lower rate of ROSC in neonates given tracheal as opposed to IV adrenaline. Many of the human studies used tracheal adrenaline doses of <0.1 mg/kg.

In some animal studies[309-314] lower doses of tracheal adrenaline (0.01 to 0.05 mg/kg) produced transient deleterious β-adrenergic vascular effects resulting in lower coronary artery perfusion. One LOE 5 study[315] of animals in VF cardiac arrest demonstrated a higher rate of ROSC in those treated with tracheal vasopressin compared with IV placebo.

Four LOE 5 studies of animals in cardiac arrest[316-319] demonstrated similar ROSC and survival rates when either tracheal or IV routes were used to deliver adrenaline. These studies also demonstrated that to reach an equivalent biological effect, the tracheal dose must be up to 10 times the IV dose.

The preferred routes of drug delivery for infants and children in cardiac arrest are IV and IO (Class I). If adrenaline is administered via a tracheal tube to infants and children (not including the newly born) in cardiac arrest, the recommended dose is 0.1 mg/kg (Class IIb). Other drugs are as follows:

Lidocaine: 2-3mg/kg

Atropine: 0.03mg/kg

3) Calculating Drug Dose

Eight LOE 5 studies[320-327] concluded that length-based methods are more accurate than age-based or observer (parent or provider) estimate-based methods in the prediction of body weight. Four LOE 5 studies[320, 322, 328, 329] suggested that the addition of a category of body habitus to length may improve prediction of body weight.

Six LOE 5 studies[330-335] attempted to find a formula based on drug pharmacokinetics and physiology that would allow the calculation of a pediatric dose from the adult dose.

In nonobese pediatric patients, initial resuscitation drug doses should be based on actual body

weight (which closely approximates ideal body weight). If necessary, body weight can be estimated from body length.

In obese patients the initial doses of resuscitation drugs should be based on ideal body weight that can be estimated from length (Class I). Administration of drug doses based on actual body weight in obese patients may result in drug toxicity.

Subsequent doses of resuscitation drugs in both nonobese and obese patients should take into account observed clinical effects and toxicities (Class I). It is reasonable to titrate the dose to the desired therapeutic effect, but it should not exceed the adult dose.

4) Adrenaline

No studies have compared adrenaline versus placebo administration for pulseless cardiac arrest in infants and children. One LOE 5 randomized controlled adult study[336] of standard drug therapy compared with no drug therapy during out-of-hospital cardiac arrest showed improved survival to hospital admission with any drug delivery but no difference in survival to hospital discharge.

Evidence from 1 LOE 1 prospective, randomized, controlled trial[337], 2 LOE 2 prospective trials[338, 339], and 2 LOE 2 case series with concurrent controls[340, 341] showed no increase in survival to hospital discharge or improved neurologic outcome when adrenaline doses of >10 mcg/kg IV were used in out-of-hospital or in-hospital pediatric cardiac arrest. In 1 LOE 1 prospective trial[337] of pediatric in-hospital cardiac arrest comparing high-dose (100 mcg/kg) with standard-dose adrenaline administered if cardiac arrest persisted after 1 standard dose of adrenaline, 24-hour survival was reduced in the high-dose adrenaline group.

Evidence extrapolated from adult prehospital or in-hospital studies, including 9 LOE 1 randomized trials[342-350], 3 LOE 2 trials[351-353], and 3 LOE 3 studies[354-356], showed no improvement in survival to hospital discharge or neurologic outcome when doses >1 mg of adrenaline were given.

The use of adrenaline may be considered for infants and children in in-/out-of-hospital cardiac arrest (Class IIb). The appropriate dose of IV adrenaline is 10 mcg/kg per dose (0.01 mg/kg) for the first and for subsequent doses. The maximum single dose is 1 mg.

5) Vasopressin

In 1 pediatric LOE 3 study[357] vasopressin was associated with lower ROSC and a trend toward lower 24-hour and discharge survival. In 3 pediatric LOE 4[358-360] and 2 adult LOE 5[361, 362] case series/reports (9 patients) vasopressin[358] or its long-acting analogue, terlipressin[359, 360], administration was associated with ROSC in patients with refractory cardiac arrest (ie, standard therapy failed).

Extrapolated evidence from 6 LOE 5 adult studies[363-368] and 1 LOE 1 adult meta-analysis[369] showed that vasopressin used either by itself or in combination with adrenaline during cardiac arrest does not improve ROSC, hospital discharge, or neurologic outcome. Evidence from 1 LOE 5 animal study[370] of an infant asphyxial arrest model showed no difference in ROSC when terlipressin was administered alone or in combination with adrenaline as compared with adrenaline alone.

There is insufficient evidence for or against the administration of vasopressin in pediatric cardiac arrest.

Terlipressin has not been approved for use in Japan.

6) Antiarrhythmic Drug for Refractory VF/Pulseless VT

In 2 LOE 5 prospective out-of-hospital adult trials IV amiodarone improved ROSC and survival to hospital admission but not hospital discharge when compared with placebo[371] or lidocaine[372] for treatment of shock-refractory VF/pulseless VT. Evidence from 2 LOE 5 case series in children[373, 374] supported the effectiveness of amiodarone for the treatment and acute conversion of life-threatening (nonarrest) ventricular arrhythmias. There are no pediatric data investigating the efficacy of lidocaine for shock refractory VF/ pulseless VT.

Amiodarone may be used for the treatment of shock-refractory or recurrent VF/pulseless VT in infants and children (Class IIb). Dosage is 2.5-5mg/kg (maximum 300g).

Nifekalant may be considered for use in patients in in-/out-of-hospital cardiac arrest and with shock refractory VF/VT (Class IIb). Dosage is 0.15-0.3mg/kg.

If amiodarone or nifekalant is not available, lidocaine may be considered even though it is less effective (Class IIb). Dosage is 1mg/kg per dose, up to 3mg/kg.

For patients suspected to have hypomagnesemia, 1-2g/kg of magnesium should be given.

7) Calcium

Evidence from 3 LOE 2[375-377] studies in children and 5 LOE 5 adult studies[378-382] failed to document an improvement in survival to hospital admission, hospital discharge, or favorable neurologic outcome when calcium was administered during cardiac arrest in the absence of documented hypocalcemia, calcium channel blocker overdose, hypermagnesemia, or hyperkalemia. Four LOE 5 animal studies[383-386] showed no improvement in ROSC when calcium, compared with adrenaline or placebo, was administered during cardiac arrest.

Two studies investigating calcium for in-hospital pediatric cardiac arrest suggested a potential for harm. One LOE 2 study examining data from the NRCPR[376] observed an adjusted odds ratio of survival to hospital discharge of 0.6 in children who received calcium, and 1 LOE 3 multicenter study[375] showed an odds ratio for increased hospital mortality of 2.24 associated with the use of calcium. One LOE 2 study of cardiac arrest in the PICU setting[377] suggested a potential for harm with the administration of calcium during cardiac arrest; the administration of 1 or more boluses was an independent predictor of hospital mortality.

Routine use of calcium for infants and children with cardiac arrest is not recommended in the absence of hypocalcemia, calcium channel blocker overdose, hypermagnesemia, or hyperkalemia (Class III).

8) Sodium Bicarbonate

There are no randomized controlled studies in infants and children examining the use of sodium bicarbonate as part of the management of pediatric cardiac arrest. One LOE 2 multicenter retrospective in-hospital pediatric study[375] found that sodium bicarbonate administered during cardiac arrest was associated with decreased survival, even after controlling for age, gender, and first documented cardiac rhythm.

Two LOE 5 randomized controlled studies have examined the value of sodium bicarbonate in the management of arrest in other populations: 1 adult out-of-hospital cardiac arrest study[387] and 1 study in neonates with respiratory arrest in the delivery room[388]. Both failed to show an improvement in overall survival.

Routine administration of sodium bicarbonate is not recommended in the management of pediatric cardiac arrest (Class III).

■7 Arrhythmia Therapy

1. Bradycardia Algorithm

The PALS Bradycardia Algorithm is a set of actions for the treatment of poor perfusion with the heart rate less than 60 beats per minute.

[Box 1]

This algorithm applies to the care of a child with a pulse less than 60 beats per minute.

[Box 2]

Support the airway and administer oxygen as needed. Attach an ECG monitor and a pulse oximetory, and prepare a defibrillator.

[Box 3]

Reassess the patient to determine if bradycardia persists and is still causing cardiorespiratory insufficiency despite adequate oxygenation and ventilation.

[Box 4]

If the heart rate is still less than 60 beats per minute and cardiorespiratory insufficiency is seen despite adequate oxygenation and ventilation, start chest compressions immediately.

[Box 5]

Reassess the patient. If circulatory insufficiency persists despite adequate oxygenation, ventilation and chest compressions, administer adrenaline. If bradycardia is induced by vagal stimuli, administer atropine. If bradycardia is caused by complete atrioventricular block or sinus node dysfunction and persists despite adequate ventilation, oxygenation, chest compressions and medications (especially if it is associated with congenital or acquired cardiac disease), performing

emergency transcutaneous pacing can improve survival.

[Box 6]

When normal pulse, respiration and stable hemodynamics is seen, emergency treatment is not required. Careful observation is needed in preparation for the possibility of sudden change in condition. Consultation with a specialist is recommended.

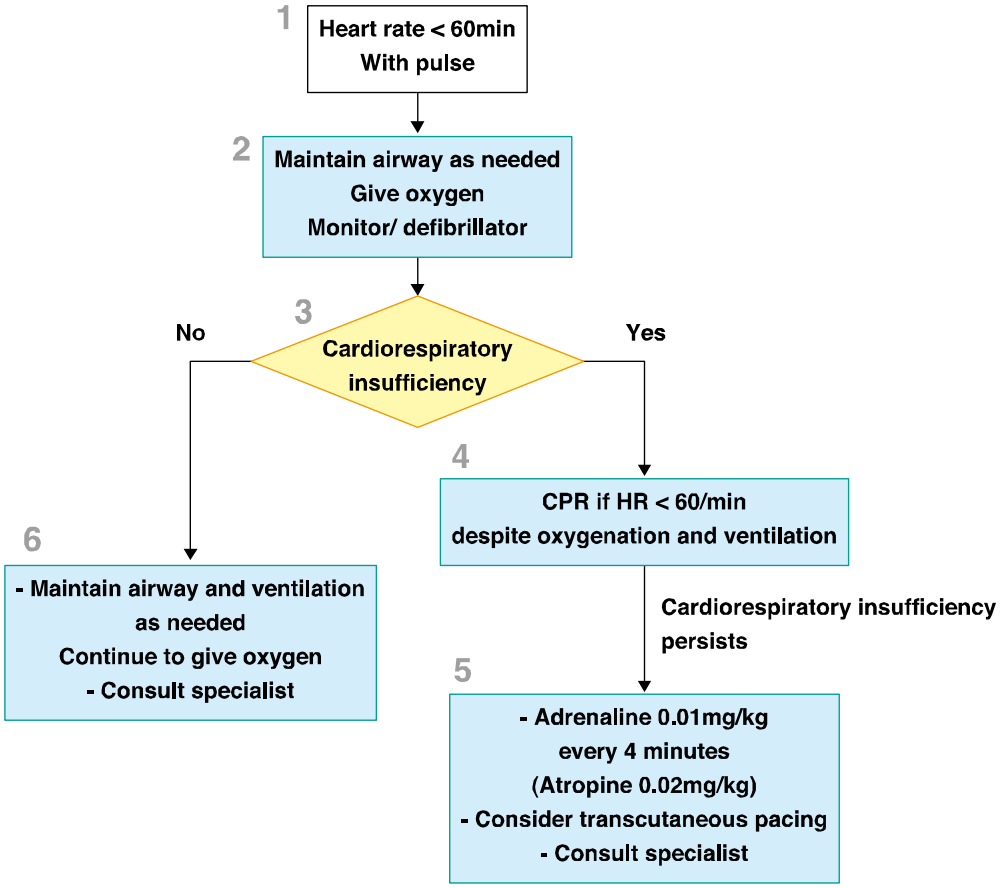

Figure 3 Pediatric bradycardia algorithm

1) Atropine Versus Adrenaline for Bradycardia

Evidence from 1 LOE 3 study of in-hospital pediatric cardiac arrest[389] observed an improved odds of survival to discharge for those patients who received atropine based on multivariate analysis, whereas the use of adrenaline was associated with decreased odds of survival. Another large LOE 3 study[390] demonstrated no association between atropine administration and survival.

In 1 LOE 5 adult case series[391], 6 of 8 patients in cardiac arrest who did not respond to adrenaline did respond to atropine with a change to a perfusing rhythm; 3 survived to hospital discharge. An LOE 5 retrospective adult review[392] observed that a small number of asystolic patients who failed to respond to adrenaline did respond to atropine, but none survived to hospital discharge.

Four LOE 5 adult studies[393-396] showed a benefit of atropine in vagally mediated bradycardia. One small LOE 4 pediatric case series[397] showed that atropine is more effective than adrenaline in increasing heart rate and blood pressure in children with post–cardiac surgical hypotension and bradycardia (Bezold-Jarisch reflex mediated bradycardia).

Four LOE 5 adult[394, 398-400] and 4 LOE 5 animal[401-404] studies showed no benefit from atropine used to treat bradycardia or cardiac arrest. One LOE 5 animal study[405] did show a benefit of atropine when used with adrenaline in cardiac arrest.

Adrenaline may be used for infants and children with bradycardia and poor perfusion that is unresponsive to ventilation and oxygenation. It is reasonable to administer atropine for bradycardia caused by increased vagal tone or cholinergic drug toxicity. There is insufficient evidence to support or refute the routine use of atropine for pediatric cardiac arrest.

- For bradycardia in infants and children, start oxygenation, airway management and adequate ventilation.
- If the heart rate is still less than 60 beats per minute and cardiorespiratory symptoms (skin pallor, cyanosis, etc) are seen despite adequate oxygenation and ventilation, start chest compressions immediately.
- The first-line drug for bradycardia in infants and children is adrenaline.
- There is insufficient evidence to support or refute the use of atropine to children in cardiac arrest.

2. Tachycardia Algorithm

The PALS Tachycardia Algorithm is a set of actions for the treatment of tachycardia.

When no pulse can be felt, follow the aforementioned pulseless cardiac arrest algorithm. It is important to distinguish whether hemodynamic status is stable or not.

[Box 1]

For infants and children in tachycardia, immediately evaluate the airway, respiration and perfusion, and administer oxygen. Support respiration if necessary. Attach an ECG monitor and a pulse oximetory, and prepare a defibrillator.

[Box 2]

Assess QRS duration to determine if the width of QRS complex is 0.08 seconds or less (narrow-complex tachycardia), or greater than 0.08 seconds (wide-complex tachycardia).

[Box 3]

Evaluate the heart rate and the presence of P waves with a standard 12-lead ECG, and check for a history of tachycardia or WPW syndrome.

[Box 4 to 6]

When sinus tachycardia is suspected, see if treatment of the primary disease is possible.

[Box 5 to 7]

When supraventricular tachycardia is suspected, the choice of treatment is determined by the patient's degree of hemodynamic instability. Attempt vagal stimulation first if the patient is hemodynamically stable.

[Box 8 to 11]

Establish IV access and give ATP rapidly with the initial dose of 0.1mg/kg. If it is ineffective, a

subsequent dose of 0.2mg/kg should be administered under heart rate monitoring.

If the patient is hemodynamically unstable and establishing IV access is difficult, perform electric synchronized cardioversion. Consider the use of sedatives if needed. Start cardioversion with a energy dose of 0.5 to 1.0 J/kg. If unsuccessful, increase the dose to 2 J/kg and retry. If a second shock is unsuccessful or the tachycardia recurs quickly, consider antiarrhythmic drug therapy (procainamide or amiodarone) before a third shock. Nifekalant can also be considered.

For hemodynamically stable patients when ATP is ineffective, other antiarrhythmic medications can be considered after expert consultation. Verapamil is contraindicated for use in infants because it may cause refractory hypotension or cardiac arrest. Verapamil should be administered to children in a cautious manner because it may cause hypotension or myocardial depression.

[Box 9]

Hemodynamically stable wide-complex tachycardia that is undifferentiated from VT should be dealt with as VT. It could be SVT with aberrant conduction.

[Box 10 to 11]

If the patient is hemodynamically unstable, perform electric synchronized cardioversion (0.5 to 1.0 J/kg). ATP can be given first if it does not delay shock delivery.

If a second shock (2 J/kg) is unsuccessful or the tachycardia recurs quickly, consider antiarrhythmic drug therapy before a third shock.

[Box 11]

If the patient is hemodynamically stable, other antiarrhythmic medications can be considered after expert consultation. The dosage for tachycardia in children is as follows:

- Procainamide: 15mg/kg, infused slowly over 1 hour or so
- Amiodarone : 2.5 - 5mg/kg (maximum 300mg), slowly administered intravenously over 30 minutes while the ECG and blood pressure are monitored. Avoid the simultaneous use of amiodarone and procainamide or other drugs that might prolong the QT interval.
- Nifekalant: 0.15-0.3mg/kg, administered intravenously over 10 minutes

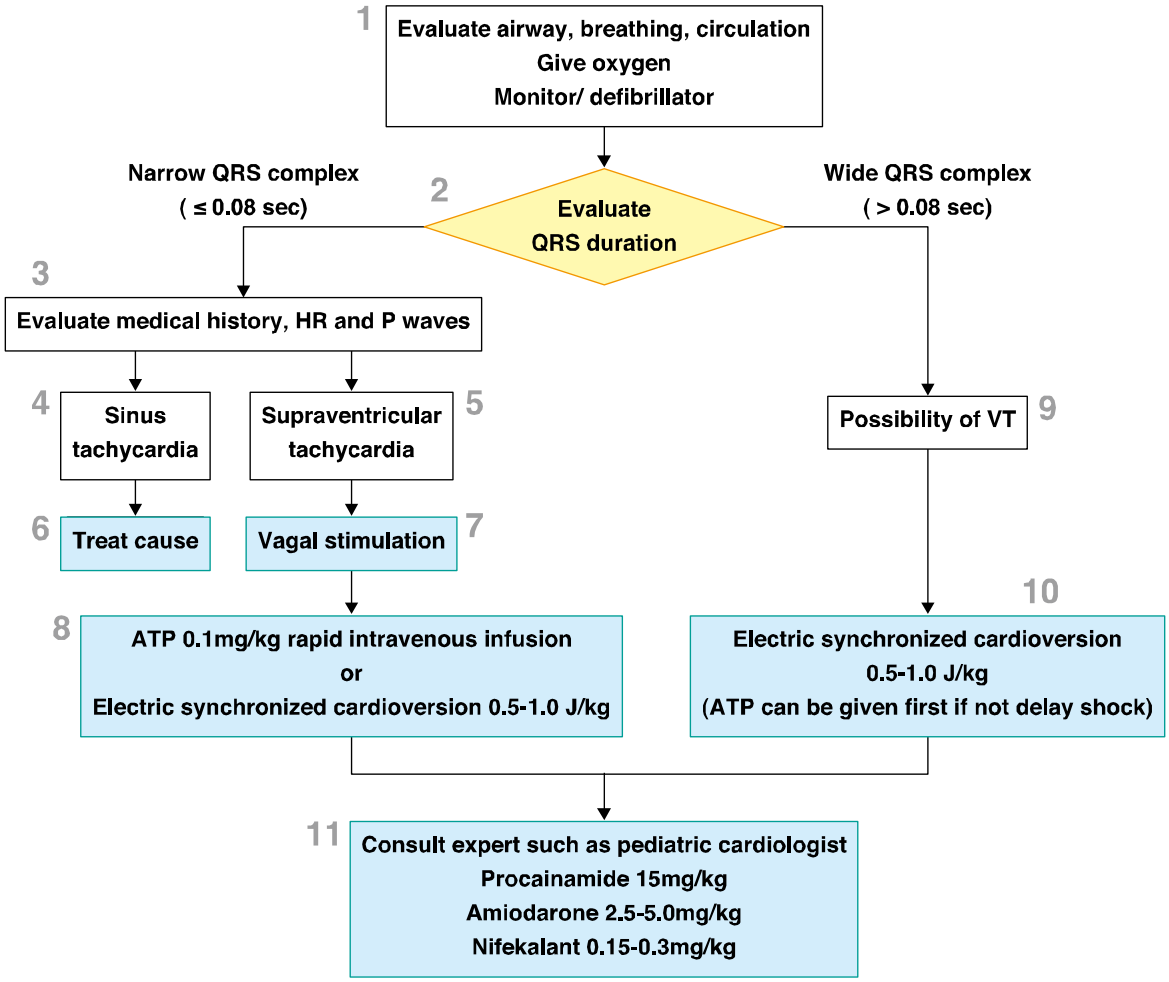

Figure 4 Pediatric tachycardia algorithm

1) Unstable VT

There is insufficient evidence to support or refute the efficacy of electric therapy over drug therapy or the superiority of any drug for the emergency treatment of unstable VT in the pediatric age group. In 2 LOE 5 adult case series[406, 407], early electric cardioversion was effective for treatment of unstable VT.

In 4 small LOE 4 pediatric case series[373, 374, 408, 409] amiodarone was effective in the management of VT. One prospective randomized multicenter safety and efficacy LOE 2 trial evaluating amiodarone for the treatment of pediatric tachyarrhythmias[410] found that 71% of children treated with amiodarone experienced cardiovascular side effects. Both efficacy and adverse events were dose-related.

For hemodynamically unstable children with VT, perform electric synchronized cardioversion promptly (Class I). If amiodarone is chosen to be administered for hemodynamically unstable VT, it should be given slowly under hemodynamic monitoring.

2) Drugs for Supraventricular Tachycardia

Twenty-two LOE 4 studies in infants and children[411-432] demonstrated the effectiveness of adenosine for the treatment of hemodynamically stable or unstable SVT. One LOE 4 study[433] and 4 larger LOE 5 studies involving teenagers and adults[434-437] also demonstrated the efficacy of adenosine, although frequent but transient side effects were reported.

One LOE 2 study[438] showed highly successful (approximately 90%) treatment of SVT in infants and children using adenosine or verapamil and superiority of these drugs to digitalis (61% to 71%). One LOE 5 randomized prospective adult study[439] and 1 LOE 5 meta-analysis, primarily involving adults but including some children[440], demonstrated the effectiveness of verapamil and adenosine in treating SVT and highlighted the cost-effectiveness of verapamil over adenosine.

One LOE 4 randomized, prospective study[410] and 15 small case series LOE 4[373, 374, 408, 409] and observational studies LOE 5[441-451] in infants and children showed that amiodarone was effective in the treatment of supraventricular tachyarrhythmias. Generalization to pediatric SVT treatment with amiodarone may be limited, however, since most of these studies in children involved postoperative junctional tachycardia.

Rare but significant side effects have been reported in association with rapid administration of amiodarone. Bradycardia and hypotension were reported in 1 prospective LOE 4 study[410], cardiovascular collapse was reported in 2 LOE 5 case reports[452, 453], and polymorphic VT was reported in 1 small LOE 4 case series[454]. Other LOE 5 case reports describe late side effects of pulmonary toxicity[453] and hypothyroidism[455].

In 1 LOE 2 pediatric comparison control study[456] procainamide had a significantly higher success rate and an equal incidence of adverse effects when compared with amiodarone for treating refractory SVT. In 5 LOE 4 observational studies[457-461] and 5 LOE 5 case reports[462-466] procainamide effectively suppressed or slowed the rate in children with SVT.

In LOE 5 studies in children[467], adults[468, 469], and animals[470], hypotension from procainamide infusion resulted from vasodilation and not decreased myocardial contractility. Initial observational LOE 4 reports[471-473] and 1 LOE 4 case series[474] described successful treatment of pediatric SVT with verapamil. However, multiple small LOE 4 case series[438, 475] and LOE 5 case reports[476, 477] documented severe hypotension, bradycardia, and heart block causing hemodynamic collapse and death following IV administration of verapamil for SVT in infants. Two small LOE 4 pediatric case series[478, 479] described esmolol and dexmedetomidine in the treatment of SVT.

For SVT with pulse in infants and children, adenosine is the drug of choice (Class I). Verapamil should be used as an alternative therapy for older children, and it should not be routinely used in infants (Class III). Procainamide or amiodarone can be considered for use for treatment of refractory SVT if it is slowly administered intravenously under hemodynamic monitoring (Class IIb).

Adenosine should be considered to be the first medication for treatment of SVT with pulse in infants and children (Class I). In Japan, ATP should be used. ATP should be administered with the initial dose of 0.1mg/kg. If it is ineffective, a subsequent dose of 0.2mg/kg should be given under ECG monitoring.

■8 Shock

The Task Force reviewed evidence related to several key questions about the management of shock in children. There is ongoing uncertainty about the indications for using colloid versus crystalloid in shock resuscitation. One large adult trial suggested that normal saline (isotonic crystalloid) is equivalent to albumin, although subgroup analysis suggested harm associated with the use of colloid in patients with traumatic brain injury. There were insufficient data to change the 2005 recommendations.

The optimal timing for intubation of children in shock remains unclear, although reports of children and adults with septic shock suggested potential beneficial effects of early intubation. When children in septic shock were treated with a protocol that included therapy directed to normalizing central venous oxygen saturation, patient outcome appeared to improve.

Performing rapid sequence induction and tracheal intubation of a child with shock can cause acute cardiovascular collapse. Etomidate typically causes less hemodynamic compromise than other induction drugs and is therefore often used in this setting. However, data suggest that the use of this drug in children and adults with septic shock is associated with increased mortality that may be secondary to etomidate's inhibitory effects on corticosteroid synthesis. Administering corticosteroids in adults failed to show a beneficial effect.

1. Shock Algorithm

The septic shock treatment algorithm is a set of actions for rapid recovery from peripheral hypoperfusion and hypotension by indentifying shock early and giving graded hemodynamic support using fluid resuscitation and vasoactive and inotropic agents from an early stage. This algorithm is based on a consensus established by an expert group of the American College of Critical Care Medicine in 2009[480].

[Box 1]

Early identification of shock is crucial for starting the treatment of shock promptly.

[Box 2]

Maintain the airway and administer high-flow oxygen. Establish IV/IO access.

[Box 3]

After shock identification, push boluses of 20ml/kg, or up to 60ml/kg if necessary, within the first 15 minutes. Correct hypoglycemia and hypocalcemia, and give antimicrobial drugs after obtaining blood culture.

[Box 4]

If shock persists despite adequate fluid resuscitaition (fluid refractory shock), establish central IV access and administer catecholamine within an hour of shock recognition. Start invasive measurement of arterial pressure, and consider beginning tracheal intubation and mechanical

ventilation.

[Box 5 to 6]

If shock persists despite catecholamine administration (catecholamine resistant shock), stroid supplementation with stress doses of hydrocortisone (approximately 50mg/m^2/24h) may be considered for patients with documented or suspected adrenal insufficiency.

[Box 7]

Select and titrate vasoactive agents and inotropics including vasodilators and phosphodiesterase III inhibitors based on central venous pressure and central venous oxygen saturation in addition to peripheral circulation and blood pressure.

[Box 8]

If the patient is intractable to the above-mentioned treatment, consider using the external cardio-pulmonary support. One study (LOE 1[481]) shows that therapy guided by $ScvO_2$ as an indicator resulted in significantly less mortality. This impact was especially significant when the original $ScvO_2$ before initiating therapy was less than 70%.

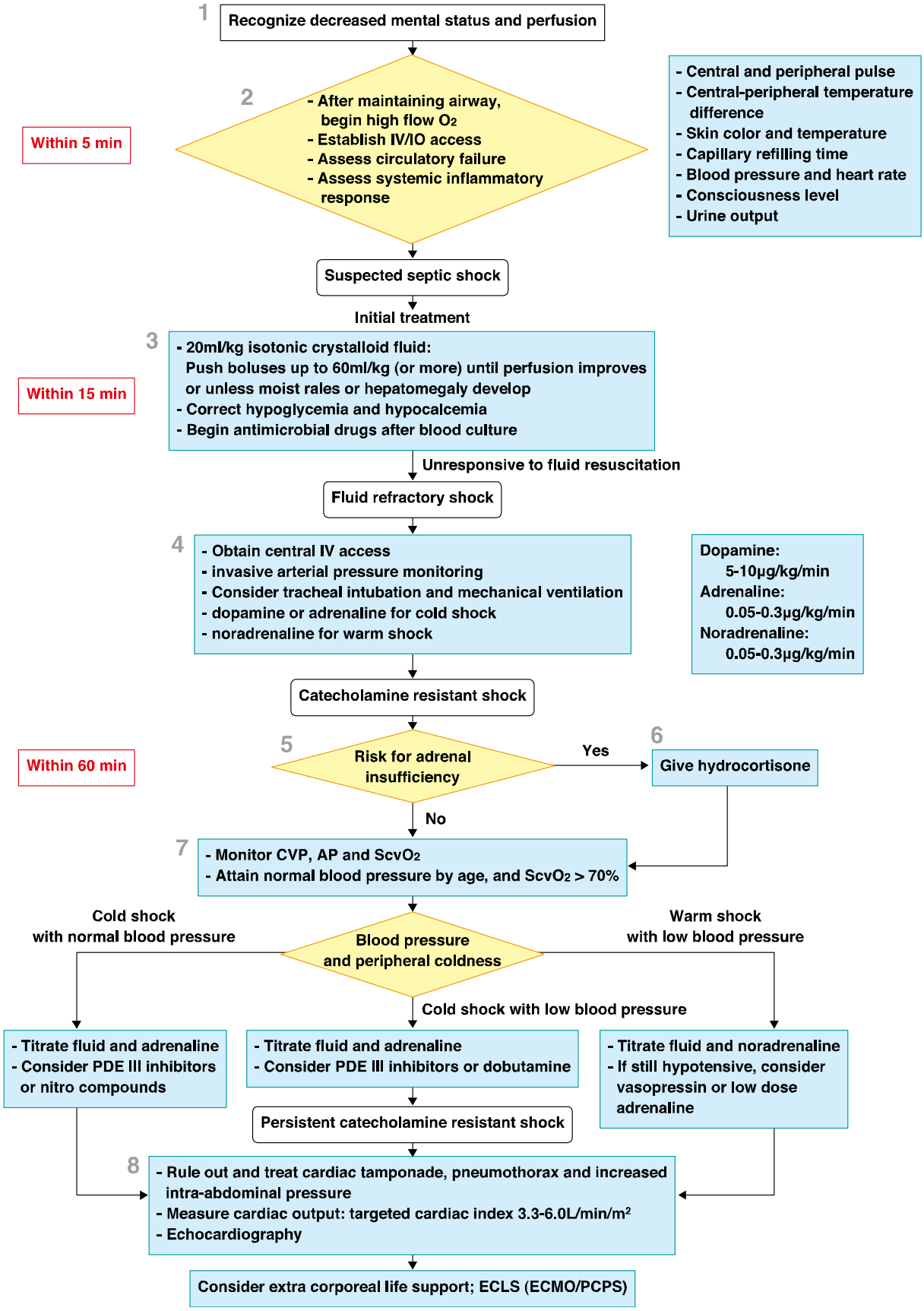

Figure 5　Initial treatment algorithm for pediatric septic shock

2. Consensus on Treatment for Different Types of Shock

1) Graded Volume Resuscitation for Hemorrhagic Shock

There are no pediatric studies evaluating the timing or extent of volume resuscitation in hemorrhagic shock with hypotension. Nine LOE 5 adult[482-490] studies reported conflicting results with regard to the effect of timing and extent of volume resuscitation on outcome of hemorrhagic shock with hypotension.

There is insufficient evidence as to the best timing or quantity for volume resuscitation in infants and children with hemorrhagic shock following trauma. For the initial resuscitation, rapid administration of 10-20ml/kg isotonic crystalloid solutions such as normal saline are recommended (Class I). Hypotonic solutions should not be used. If isotonic crystalloids do not improve perfusion, blood transfusion is considered to control bleeding by hemostasis.

2) Early Ventilation in Shock

There are no studies investigating the role of intubation and assisted ventilation before the onset of respiratory failure in infants and children with shock. Two LOE 5 animal studies in septic shock[491, 492] and 1 LOE 5 animal study in pericardial tamponade[493] showed improved hemodynamics and select organ perfusion with intubation before the onset of respiratory failure. One report of 2 adult patients (LOE 5[494]) described cardiac arrest following intubation of 1 adult patient with tamponade due to penetrating trauma and improvement in hemodynamics during spontaneous breathing in 1 mechanically ventilated adult patient with post–cardiac surgery tamponade.

One LOE 5 study of septic shock in adults[495] suggested a reduced mortality with early induction of mechanical ventilation compared with historic controls who received mechanical ventilation for respiratory failure. One LOE 5 study of animals in septic shock[496] showed that early assisted ventilation does not reduce oxygen extraction or prevent the development of lactic acidosis.

There is insufficient evidence to support or refute the use of tracheal intubation of infants and children in shock before the onset of respiratory failure. When respiratory failure or disturbance of consciousness is present, tracheal intubation can be considered (Class IIa). However, tracheal intubation in children with unstable hemodynamics requires special attention as vagal stimulus during intubation procedure could easily cause bradycardia and hypotension.

3) Colloid Versus Crystalloid Fluid Administration

Evidence from 3 randomized blinded LOE 1 controlled trials in children with dengue shock syndrome[497-499] and 1 LOE 1 open randomized trial in children with septic shock[500] suggested no clinically important differences in survival from therapy with colloid versus therapy with isotonic

crystalloid solutions for shock.

In 1 large LOE 5 randomized controlled trial of fluid therapy in adult ICU patients[501] and in 6 good-quality LOE 5 meta-analyses, predominantly of adults[502-507], no mortality differences were noted when colloid was compared with hypertonic and isotonic crystalloid solutions, and no differences were noted between types of colloid solutions.

Three LOE 5 studies comparing the use of crystalloids and colloids for adults in shock suggested that crystalloid may have an associated survival benefit over colloid in subgroups of patients with shock, including general trauma[504], traumatic brain injury[508], and burns[509]. One randomized controlled LOE 5 study of children with severe malaria suggested better survival with colloid than with crystalloid infusion[510].

Isotonic crystalloids rather than colloid solutions are recommended as the initial resuscitation fluid for shock (Class I). There is insufficient evidence to identify the superiority of any specific isotonic crystalloid over others. Normal saline or Ringer's lactate can be used, and hypotonic solutions should not be used. 10-20ml/kg rapid administration is recommended. Reevaluation should be undertaken after administration, and isotonic crystalloid solutions should be readministered if needed.

4) Vasoactive Agents in Distributive Shock

One LOE 4 observational study[511] suggested that the course of pediatric septic shock physiology is dynamic and that serial assessments are required to titrate the type and dose of inotropes or vasopresions to achieve optimal hemodynamic results. Evidence from 4 LOE 1 pediatric randomized controlled studies[512-515], 3 LOE 5 adult randomized controlled studies[516-518], and 1 LOE 5 adult systematic review[519] showed that no inotrope or vasopressor is superior in reducing mortality from pediatric or adult distributive shock. Two LOE 1 pediatric randomized controlled studies[512, 513] showed that children with "cold" (ie, low cardiac index) septic shock improved hemodynamically with brief (4-hour) administration of milrinone (bolus and infusion). One LOE 1 pediatric randomized controlled study[515] of vasodilatory shock compared the addition of vasopressin versus placebo to standard vasoactive agents and showed no change in duration of vasopressor infusion but observed a trend toward increased mortality.

Eleven small LOE 4 pediatric case series[520-530] showed improved hemodynamics but not survival when vasopressin or terlipressin was administered to children with refractory, vasodilatory, septic shock.

There is insufficient evidence to recommend a specific inotrope or vasopressor to improve mortality in pediatric distributive shock. Milrinone administration for cold shock, and vasopressin administration for warm catecholamine resistant shock may be considered with careful attention to adverse effects (Class IIa).

5) Vasoactive Agents in Cardiogenic Shock

One LOE 4 pediatric case series[531] showed that critically ill children requiring inotropic support have wide variability in hemodynamic responses to different infusion rates of dobutamine. One LOE 2 blinded crossover study[532] found dopamine and dobutamine had equal hemodynamic effects in infants and children requiring post–cardiac surgical inotropic support but that dopamine at an infusion rate of >7 μg/kg per minute increased pulmonary vascular resistance.

Six LOE 3 studies[533-538] showed that both dopamine and dobutamine infusions improve hemodynamics in children with cardiogenic shock.

Evidence from 1 LOE 1 pediatric placebo-controlled trial[539] showed that milrinone is effective in preventing low cardiac output syndrome in infants and children following biventricular cardiac repair. One LOE 4 study[540] showed that milrinone improved cardiac index in neonates with low cardiac output following cardiac surgery.

One small LOE 1 study[541] showed that children had better hemodynamic parameters and shorter ICU stays if they received milrinone compared with low-dose adrenaline plus nitroglycerin for inotropic support following repair of tetralogy of Fallot.

In 2 LOE 4 small case series[542, 543], when children with heart failure secondary to myocardial dysfunction were given levosimendan, they demonstrated improved ejection fraction, required a shorter duration of catecholamine infusions[542], and showed a trend toward improved hemodynamics and reduced arterial lactate levels[543].

In subgroup analysis from 1 LOE 5 randomized controlled trial in adults[544], patients with cardiogenic shock treated with noradrenaline versus dopamine had an improved survival at 28 days. When all causes of shock were included, patients treated with noradrenaline also had fewer arrhythmias than those treated with dopamine (12% versus 24%).

Continuous intravenous administration of vasopressors and inotropics (such as adrenaline, dopamine and dobutamine) or rapid intravenous administration of fluids are recommended as standard therapy for hemodynamic support in infants and children with cardiogenic shock or hypoperfusion from low cardiac output syndrome (Class I). Milrinone may be beneficial for the prevention and treatment of low cardiac output following cardiac surgery (Class I). There are insufficient data to support or refute the use of noradrenaline in pediatric cardiogenic shock.

6) Etomidate for Intubation in Hypotensive Septic Shock

One LOE 4 study of children with septic shock[545] showed that adrenal suppression occurred after the administration of a single dose of etomidate and persisted for at least 24 hours. Evidence from 2 LOE 4[546, 547] studies and 1 LOE 5[548] study showed that etomidate can be used to facilitate tracheal intubation in infants and children with minimal hemodynamic effect, but very few of these reports included patients with hypotensive septic shock. One LOE 4 study[545] suggested an association with mortality when etomidate is used to facilitate the intubation of children with septic shock.

One adult LOE 5 study[549] observed an increased mortality associated with the use of etomidate for intubation of patients in septic shock, even with steroid supplementation. Conversely, 1

underpowered adult LOE 5 study[550] in septic patients did not show an increase in mortality.

One multicenter adult LOE 5 comparative trial of etomidate versus ketamine for intubation[551]531 found no difference in organ failure over the first 72 hours and no mortality difference, but this study included only a small number of patients with shock. Adrenal insufficiency was more common in etomidate-treated patients.

Etomidate should not be routinely used when intubating an infant or child with septic shock. If etomidate is used in infants and children with septic shock, the increased risk of adrenal insufficiency should be recognized.

Etomidate has not been approved for use in Japan.

7) Corticosteroids in Hypotensive Shock

In 6 LOE 5 randomized controlled trials in adults with septic shock[549, 552-556] the addition of low-dose hydrocortisone decreased the time to shock reversal. Three LOE 5 randomized controlled trials in adults with vasopressor-dependent septic shock[552, 557, 558] showed that survival was improved when low-dose hydrocortisone was administered, while 1 small adult LOE 5 randomized controlled trial[559] showed a trend toward increased survival.

One fair-quality, small LOE 1 study in children with septic shock[560] found that low-dose hydrocortisone administration resulted in no survival benefit. One fair-quality LOE 1 study of administration of low-dose hydrocortisone to children with septic shock[561] demonstrated earlier shock reversal. Data from 1 LOE 4 hospital discharge database[562] noted the association between the use of steroids in children with severe sepsis and decreased survival.

In 1 LOE 5 study in adults with septic shock[552] survival improved significantly with the use of low-dose hydrocortisone and fludrocortisone compared with placebo. Conversely 4 LOE 5 adult trials in septic shock[549, 554-556] showed no survival benefit with low-dose corticosteroid therapy. In 1 large LOE 5 randomized controlled trial of adults in septic shock[549], corticosteroid administration was associated with an increased risk of secondary infection.

There is insufficient evidence to support or refute the routine use of steroids in infants and children with septic shock. Steroids may be considered in replacement therapy for septic shock unresponsive to fluids and vasopressors or inotropics (Class IIa).

8) Diagnostic Tests as Guide to Management of Shock

In 1 LOE 1 randomized controlled trial in children with severe sepsis or fluid-refractory septic shock[481], protocol-driven therapy that included targeting a superior vena caval oxygen saturation >70%, coupled with treating clinical signs of shock (prolonged capillary refill, reduced urine output, and reduced blood pressure), improved patient survival to hospital discharge in comparison to treatment guided by assessment of clinical signs alone.

Two LOE 5 studies of adults with septic shock, one a randomized controlled trial[563] and the other a cohort study[564], documented improved survival to hospital discharge following implementation of

protocol-driven early goal-directed therapy, including titration to a central venous oxygen saturation ($SvcO_2$) 70%. In 1 large multicenter LOE 5 adult study[565] evaluating the "Surviving Sepsis" bundle, early goal-directed therapy to achieve an $SvcO_2$ 70% was not associated with an improvement in survival, but venous oxygen saturations were measured in <25% of participants.

There are insufficient data on the utility of other diagnostic tests (eg, pH, lactate) to help guide the management of infants and children with shock.

An early goal-directed therapy targeting SvO_2 and $ScvO_2$ should be considered for infants and children with fluid-refractory septic shock (Class I). Under continuous or intermittent monitoring, SvO_2 or $ScvO_2$ >70% should be achieved.

■9 Special Situations

New topics introduced in this document include resuscitation of infants and children with a category of congenital cardiac abnormalities, such as single ventricle repair following stage I procedure and following the Fontan or bidirectional Glenn procedures (BDGs) and resuscitation of infants and children with pulmonary hypertension.

1. Life Support for Trauma

Cardiac arrest due to major (blunt or penetrating) trauma in out-of-/in-hospital children has a very high mortality rate[566-568]. In 1 LOE 4[568] and 1 LOE 5[219] study there was no survival advantage in intubating child victims of traumatic cardiac arrest in the out-of-hospital setting. Two LOE 4 studies[569, 570] suggested that survival in children with cardiac arrest from penetrating trauma is improved by thoracotomy if time from event to hospital is short and signs of life are restored on site.

Traumatic cardiac arrest results in poor outcomes. Standard resuscitation should be performed for infants and children suffering cardiac arrest due to major trauma (Class I). Consideration may be given to selectively performing a resuscitative thoracotomy in children with cardiac arrest from penetrating chest injuries whose vital signs are restored on site and who quickly transferred to the hospital.

2. Single-Ventricle Post Stage I Repair

In 1 LOE 4 case series[571] , cardiac arrest occurred frequently (in 20% of 112 patients) in infants following stage I repair for single-ventricle anatomy. Two LOE 5 case series of mechanically ventilated, paralyzed patients with a single ventricle in the preoperative period[572, 573] showed that excessive pulmonary blood flow may be attenuated in the short term by increasing the inspired fraction of CO_2 to achieve a $PaCO_2$ of 50 to 60 mm Hg. In the same population, decreasing the fraction of inspired oxygen below 0.21 did not appear to improve systemic oxygen delivery. Three LOE 4 studies[574-576] showed that clinical identification of the prearrest state in patients with a single ventricle is difficult and may be aided by monitoring systemic oxygen extraction using

superior vena caval oxygen saturation or near infrared spectroscopy of cerebral and splanchnic circulations.

One LOE 3 prospective, crossover design study[577] of infants following stage I repair showed that inspired carbon dioxide increased systemic oxygen delivery. Evidence from 3 LOE 4 studies of infants following stage I repair[578-580] showed that reducing systemic vascular resistance with agents such as phenoxybenzamine improved systemic oxygen delivery[579], reduced the risk for cardiovascular collapse[578], and improved survival[580].

Five LOE 4 pediatric studies[581-585] showed that survival to hospital discharge for patients with single-ventricle anatomy following ECPR (see ECPR above) is comparable to that of other neonates undergoing cardiac surgery. In 1 LOE 4 study[583] survival following ECPR initiated as a consequence of systemic-to-pulmonary artery shunt occlusion after stage I repair was consistently higher than for other etiologies of cardiac arrest.

Standard resuscitation (prearrest and arrest) procedures should be applied to infants and children with single-ventricle anatomy following stage I repair (Class I). Neonates with a single ventricle before stage I repair who demonstrate shock caused by elevated pulmonary to systemic flow ratio (Qp-to-Qs ratio) might benefit from inducing mild hypercarbia ($PaCO_2$ to 50 to 60 mm Hg). Alpha-adrenergic antagonists, such as phenoxybenzamine, are occasionally beneficial in order to improve systemic blood flow and systemic oxygen delivery in neonates following stage I repair. Assessment of systemic oxygen extraction by monitoring $SvcO_2$ or near infrared spectroscopy monitoring of cerebral and splanchnic circulation may help identify evolving hemodynamic changes in infants following stage I procedures; such hemodynamic changes may herald impending cardiac arrest.

3. Single-Ventricle Post-Fontan and Bidirectional Glenn Procedures

In 1 LOE 4 case series[586] , ECLS was useful in resuscitating patients with Fontan circulation but was not successful in hemi-Fontan/BDG patients. One LOE 4 case report[587] described manual external abdominal compressions with closed chest cardiac compressions as an alternative for standard CPR following a modified Fontan procedure.

Evidence from 4 LOE 5 studies[588-591] of patients with BDG circulation who were not in cardiac arrest or shock supports increasing CO_2 tension and hypoventilation to improve cerebral, superior vena caval, and pulmonary blood flow in order to increase systemic oxygen delivery. In 2 LOE 5 studies[592, 593] of patients with BDG circulation who were not in cardiac arrest or a prearrest state, excessive ventilation reduced cerebral oxygenation. In 2 LOE 5 studies[594, 595] of patients following a Fontan procedure who were not in cardiac arrest or a prearrest state, negative-pressure ventilation improved stroke volume and cardiac output compared with intermittent positive-pressure ventilation.

One LOE 5 case series[596] of patients following a Fontan procedure who were not in cardiac arrest or a prearrest state showed that high-frequency jet ventilation improved pulmonary vascular resistance and cardiac index. However, another LOE 5 case series[597] found that high-frequency oscillation ventilation did not increase cardiac index or decrease pulmonary vascular resistance.

Changes in pulmonary blood flow typically reflect changes in cardiac output, but in infants and

children with right-to-left shunts, an increase in right-to-left shunting that bypasses the lungs, as occurs in some infants and children with congenital heart disease or pulmonary hypertension, decreases the proportion of blood flowing through the pulmonary circulation, and as a result, the $PETCO_2$ falls[598]. Conversely, increasing pulmonary blood flow, as happens following aorto-pulmonary shunting in infants with cyanotic heart disease, increases the $PETCO_2$ and reduces the difference between the $PaCO_2$ and end-tidal CO_2[599, 600]. Likewise, if there are intrapulmonary shunts that bypass the alveoli, there will be a greater difference between the $PaCO_2$ and $PETCO_2$[601].

In patients with Fontan or BDG/hemi-Fontan physiology, CPR should be performed in the standard manner (Class I). In patients with BDG circulation who are in a prearrest state, hypercarbia achieved by hypoventilation may be beneficial in increasing oxygenation and cardiac output (Class IIb). In patients with Fontan circulation, negative-pressure ventilation, if available, may be beneficial for improving cardiac output (Class IIb). As for CPR, it is reasonable to consider extracorporeal CPR (ECPR) for patients with Fontan physiology (Class IIa). There is insufficient evidence to support or refute the use of ECPR in patients with hemi-Fontan/BDG physiology.

4. Pulmonary Hypertension

Two LOE 5 observational pediatric studies[602, 603] showed that children with pulmonary hypertension are at increased risk for cardiac arrest. There are no studies that demonstrate the superiority of any specific therapy for resuscitation from cardiac arrest in infants and children with a pulmonary hypertensive crisis.

In 1 LOE 5 retrospective study in adults[604] , standard CPR techniques were often unsuccessful in victims with pulmonary hypertension and cardiac arrest. Those who were successfully resuscitated had a reversible cause and received a bolus of IV iloprost or inhaled nitric oxide (NO) during the resuscitation.

One LOE 5 study of adults after cardiac transplant[605] and 2 LOE 5 studies in children with congenital heart disease[606, 607] observed that inhaled NO and aerosolized prostacyclin or analogues appear to be equally effective in reducing pulmonary vascular resistance. In 1 LOE 5 study in children with pulmonary hypertension after cardiac surgery[608] inhaled NO and alkalosis appeared to be equally effective in reducing pulmonary vascular resistance.

There is no evidence of benefit or harm of excessive ventilation for infants and children in cardiac arrest with pulmonary hypertension.

Four LOE 5 studies in pulmonary hypertensive adults and children with crises or cardiac arrest[609-612] showed that mechanical right ventricular support improved survival.

Patients with pulmonary hypertension are considered to have a high risk of cardiac arrest. Rescuers should provide conventional pediatric advanced life support in CPR for cardiac arrest associated with pulmonary hypertension (Class I). It may be beneficial, though its effectiveness has not been demonstrated yet, to attempt hypercarbia correction, inhaled NO administration, or IV or inhaled prostacyclin administration as supportive therapies during resuscitation. If pulmonary vasodilation therapy has been interrupted, reinstituting it may be considered (Class IIa). It may be beneficial to use ECLS early in resuscitation (Class IIb).

■10 Extracorporeal CPR; ECPR

One LOE 2[613] and 26 LOE 4 studies[581-583, 614-636] reported favorable early outcome after ECPR in children with primary cardiac disease who were located in an ICU or other highly supervised environment using ECPR protocols at the time of the arrest.

One LOE 2[613] and 2 LOE 4[581, 621] studies indicated poor outcome from ECPR in children with noncardiac diseases.

In 1 LOE 4 study[614] survival following ECPR in children was associated with shorter time interval between arrest and ECPR team activation and shorter CPR duration. Two LOE 4 studies[617, 637] found insignificant improvements in outcome after ECPR in children following protocol changes leading to shorter durations of CPR. One LOE 2[613] and 3 LOE 4[581, 616, 622] studies found no relationship between CPR duration and outcome after ECPR in children.

Three small LOE 4 studies[638-640], including a total of 21 children, showed favorable outcome with ECPR following out-of-hospital cardiac arrest associated with environmentally induced severe hypothermia (temperature <30°C).

Circumstances where ECPR may be employed are 1) in-hospital cardiogenic cardiac arrest that occurred in the ICU, in the operating room, or in the cardiac catheterization room, or 2) out-of-hospital cardiac arrest with an environmentally induced severe case of accidental hypothermia (temperature <30◦C). The impact on outcomes that the duration of standard CPR before the beginning of ECPR has not been fully evaluated.

ECPR may be beneficial for infants and children with cardiac arrest if they have heart disease amenable to recovery or transplantation and the arrest occurs in a highly supervised environment such as an ICU with existing clinical protocols and available expertise and equipment to rapidly initiate ECPR (Class IIb).

It is demonstrated that if the patient with in-hospital cardiac arrest is unresponsive to standard ALS, starting ECPR within 30-90 minutes results in favorable outcomes. However, good outcomes are mostly seen in patients with cardiac disease. Whether ECPR needs to be introduced in Japan should be decided after careful assessment of the data on the difference in full readiness for ECPR between Japan and overseas, and the presence or absence of high quality CPR.

■11 Post-Resuscitation Care

There is clear benefit for adult patients who remain comatose after VF arrest, but there is little evidence regarding effectiveness for infants (ie, beyond the neonatal period) and young children who most commonly have cardiac arrest with respiratory etiology.

Some patients with sudden death without an obvious cause have a genetic abnormality of myocardial ion channels (ie, a channelopathy), which presumably leads to a fatal arrhythmia. Because this is an inherited abnormality, family members might be affected, but special tests are required for the detection of this inherited genetic defect.

The goal of CPR is getting the blood to circulate to preserve good brain function. With careful

attention to the following points, complications of secondary central nervous system damages should be minimized.

1. Management of Ventilation and Circulation

Hyperventilation should not be routinely used. Since hyperventilation has the potential to lead to reduce venous return, or to cause cerebral ischemia. It may be harmful to patients who are comatose after cardiac arrest. The goal in the control of comatose patients is to keep $PaCO_2$ within the normal range. However, if signs of impending cerebral herniation are seen, short-term hyperventilation may be used as an emergency measure.

Several clinical studies including children documented that myocardial dysfunction is common following cardiopulmonary resuscitation. Thus using vasoactive medications for hemodynamics improvement in circulatory management after ROSC should be considered. The optimal vasoactive drug and its amount differ from one patient to another, and should be decided based on monitoring data.

1) Vasoactive Drugs

There are no studies evaluating the role of vasoactive medications after ROSC in children. Evidence from 2 LOE 3 studies in children[641, 642], 2 LOE 5 studies in adults[643, 644], and 2 LOE 5 animal studies[645, 646] documented that myocardial dysfunction and vascular instability are common following resuscitation from cardiac arrest.

Evidence from 6 LOE 5 animal studies[645-650] documented hemodynamic improvement when vasoactive medications (dobutamine, milrinone, levosimendan) were given in the post–cardiac arrest period. Evidence from 1 large LOE 5 pediatric[539] and 4 LOE 5 adult[651-654] studies of patients with low cardiac output or at risk for low cardiac output following cardiac surgery documented consistent improvement in hemodynamics when vasoactive medications were administered.

It is reasonable to administer vasopressor or inotropics to infants and children for hemodynamics improvement after ROSC (Class IIa). There is insufficient evidence to identify the superiority of any specific drug over others. Medications should be chosen based on the victim's cardiac function and peripheral perfusion.

2. Temperature Control

After ROSC, temperature needs to be monitored to avoid hyperthermia. In case of hyperthermia, temperature should be actively lowered using antipyretics and cooling devices.

Therapeutic hypothermia (central body temperature of 32–34 ◦C maintained for 12–24 h) may be considered for comatose patients after ROSC. However, the use of therapeutic hypothermia in infants and children requires deliberation since there are no clinical study data on therapeutic hypothermia in infants and children after ROSC.

Temperature elevation is commonly seen following ROSC, which is reportedly a factor for poor outcomes. Since hyperthermia affect post-ischemic cerebral damages, it must be treated aggressively (Class I). There are still insufficient clinical trial data on therapeutic hypothermia in

infants and children after ROSC even from an international perspectives. A retrospective study from overseas indicated that therapeutic hypothermia might result in rather poor outcomes. It is inappropriate to use therapeutic hypothermia arbitrarily in infants and children. Consideration should be given to whether therapeutic hypothermia is applicable or not to each pediatric patient. It is preferable to give therapeutic hypothermia under proper monitoring in a highly supervised environment such as a PICU.

The ideal method of implementation, duration and rewarming during therapeutic hypothermia are not known. Sedatives should be administered for prevention of shivering, and muscle relaxants as well if needed. Signs of infection need to be closely observed, and careful attention should be paid to diminished cardiac output, arrhythmia, pancreatitis, coagulopathy, thrombocytopenia, hypokalemia, hypophosphatemia, and hypomagnesemia. It is important to note that muscle relaxants may hide on-going seizures.

1) Hypothermia

There are no randomized pediatric studies on induced therapeutic hypothermia following cardiac arrest.

Two prospective randomized LOE 5 studies of adults with VF arrest[655, 656] and 2 prospective randomized LOE 5 studies of newborns with birth asphyxia[657, 658] showed that therapeutic hypothermia (32° to 34°C) up to 72 hours after resuscitation has an acceptable safety profile and may be associated with better long-term neurologic outcome.

One LOE 2 observational study[659] neither supports nor refutes the use of therapeutic hypothermia after resuscitation from pediatric cardiac arrest. However, patients in this study were not randomized, and the cooled patients were much sicker and younger than those not cooled.

Hyperthermia after ROSC must be treated aggressively (Class I). Therapeutic hypothermia may be considered for adolescents who remain comatose following resuscitation from cardiac arrest (Class IIb). There is insufficient data to support or refute the use of therapeutic hypothermia in infants and children.

3. Blood Glucose and Electrolyte Control

Blood glucose level and electrolyte concentration need to be measured after ROSC. Blood glucose level should be checked during cardiac arrest, and subsequently be carefully monitored to maintain a normal blood glucose level. Glucose containing fluids should not be administered during CPR unless the patient suffers hypoglycemia. Some adult studies have demonstrated that tight glucose control improves outcomes. There are insufficient data to document that the advantages of tight glucose control exceed the risks of accidental hypoglycemia.

Hyponatremia causes plasma osmolality to fall, which may result in cerebral edema. In management after ROSC, the use of hypotonic fluids especially in pediatric patients with severe lesions of the central nervous system may cause hypo-osmolality that leads to iatrogenic cerebral edema. Although the negative effects of hyponatremia have already been pointed out in other countries, little attention is paid to them in medical settings in Japan. In management after ROSC,

hyponatremia should be avoided especially when abnormalities are seen in the central nervous system (Class III).

1) Glucose

There is insufficient evidence to support or refute any specific glucose management strategy in infants and children following cardiac arrest. Although there is an association of hyperglycemia and hypoglycemia with poor outcome after ROSC, there are no studies that tight treatment for hyperglycemia or for hypoglycemia following ROSC improves outcome.

Two studies of adult survivors of cardiac arrest, including 1 LOE 5 prospective observational study[660] and 1 LOE 5 randomized controlled trial comparing tight with moderate glucose control[661] observed no survival benefit with tight glucose control. Two studies of tight glucose control in adult surgical ICU patients, including 1 LOE 1 prospective randomized controlled trial[662] and 1 LOE 1 meta-analysis[663] observed reduced mortality with tight glucose control. Two LOE 5 meta-analyses comparing tight with moderate glucose control in adult ICU patients[664, 665] and 1 LOE 5 randomized controlled trial comparing tight with moderate glucose control in adult medical ICU patients[666] observed no differences in survival. Three LOE 5 studies of tight glucose control in adult ICU patients, including 1 randomized controlled trial in cardiac surgical patients[667], 1 multicenter randomized controlled trial in medical and surgical ICU patients[668], and 1 cohort-controlled study of medical and surgical ICU patients[669] demonstrated increased mortality with tight glucose control.

One LOE 5 randomized controlled trial of critically ill children[670] observed an improvement in inflammatory biochemical markers and reduced ICU length of stay with tight glucose control. One study of tight glucose control of critically ill neonates[671] was terminated early for reasons of futility. Significant rates of hypoglycemia are widely reported with the use of tight glucose control without explicit methodology or continuous glucose monitoring in critically ill neonates[671], children[670], and adults[663, 664, 668].

Evidence from LOE 5 animal studies of neonatal cerebral ischemia[672] and critically ill adults [673, 674] suggest that hypoglycemia combined with hypoxia and ischemia is harmful and associated with higher mortality. Evidence from 3 LOE 5 animal studies[675-677] showed that prolonged hyperglycemia after resuscitation is harmful to the brain. One LOE 5 animal study[567] showed that glucose infusion with associated hyperglycemia after resuscitation worsened outcome, whereas another LOE 5 animal study showed that moderate hyperglycemia managed with insulin improved neurologic outcome.

It is appropriate to monitor blood glucose levels and avoid hypoglycemia as well as hyperglycemia following cardiac arrest (Class I). It is necessary to be vigilant for hypoglycemia especially during blood glucose-lowering therapy. There is insufficient evidence to identify the specific target glucose concentration range for infants and children after ROSC. It is better not to use glucose containing fluids during CPR.

■12 Termination of CPR

1. Prognostication

In 1 LOE 3[678] and 1 LOE 4[679] study, survival from in-hospital pediatric cardiac arrest in the 1980s was approximately 9%. One LOE 1[390] and 1 LOE 3 pediatric study[680] showed that survival from in-hospital cardiac arrest in the early 2000s was 16% to 18%. Three prognostic LOE 1 prospective observational pediatric studies from 2006[389, 681, 682] reported that survival from in-hospital cardiac arrest in 2006 was 26% to 27%.

One LOE 1 prospective study[112] showed that survival from all pediatric out-of-hospital cardiac arrest was 6% compared with 5% for adults. Survival in infants was 3%, and in children and adolescents survival was 9%. This study demonstrated that earlier poor survival rates were heavily influenced by poor infant survival (many of whom probably had sudden infant death syndrome and had probably been dead for some time).

Thirteen (LOE 1[112, 114, 389, 390, 681, 683, 684]; LOE 3[634, 678, 685]; LOE 4[679, 686, 687]) studies found associated factors and survival from cardiac arrest. These factors include duration of CPR, doses of adrenaline, age, witnessed versus unwitnessed cardiac arrest, obesity and the first and subsequent cardiac rhythm. Thirteen studies (LOE 1[112, 688]; LOE 2[689]; LOE 3[685, 690-696]; LOE 4[697, 698]) showed an association between mortality and causes of arrest such as submersion and trauma for out-of-hospital cardiac arrest. None of the associations reported in these studies allow prediction of outcome.

Many studies have dealt with the factors influencing recovery of children after cardiac arrest. These factors may include patient backgrounds, causes of cardiac arrest, conditions before and after resuscitation, and content of resuscitation therapies.

There is insufficient evidence to suggest a reliable prediction of success or failure to achieve ROSC or cessation of the resuscitative efforts. Thus, it is inappropriate to adopt simple time factors to make a decision to terminate resuscitation efforts.

In Japan, especially in the field of pediatric medicine, termination of CPR and medical futility has not been sufficiently discussed. Further discussions would be needed on terminating or withholding of practice in the field of pediatric resuscitation and critical care medicine.

2. Family Presence

Ten studies (LOE 2[699]; LOE 3[700]; LOE 4[701-708]) documented that parents wish to be given the option of being present during the resuscitation of their children. One LOE 2[699], 1 LOE 3[700], 2 LOE 4[702, 708], and 1 LOE 5[709] studies confirmed that most parents would recommend parent presence during resuscitation.

One LOE 2[699], 1 LOE 3[700], 6 LOE 4[701, 703, 708, 710-712], and 2 LOE 5[709, 713] studies of relatives present during the resuscitation of a family member reported that they believed their presence was beneficial to the patient.

One LOE 2[699], 1 LOE 3[700], 6 LOE 4[701, 702, 705-708], and 2 LOE 5[713, 714]studies reported that most relatives present during the resuscitation of a family member benefited from the experience.

One LOE 2[713] and 2 LOE 4[701, 702] studies observed that allowing family members to be present during a resuscitation in a hospital setting did them no harm, whereas 1 LOE 4[715] study suggested

that some relatives present for the resuscitation of a family member experienced short-term emotional difficulty.

One LOE 2[699], 1 LOE 3[716], 3 LOE 4[701, 712, 717], and 3 LOE 5[709, 713, 718] studies showed that family presence during resuscitation was not perceived as being stressful to staff or to have negatively affected staff performance. However, 1 survey (LOE 4[719]) found that 39% to 66% of emergency medical services (EMS) providers reported feeling threatened by family members during an out-of-hospital resuscitation and that family presence interfered with their ability to perform resuscitations.

Family presence during resuscitations has been shown to be beneficial for the grieving process and in general was not found to be disruptive. Thus, family presence is supported if it does not interfere with the resuscitative effort.

There should be opportunities for healthcare providers to ask family members whether or not they prefer to be present at the resuscitation setting (Class I). This may be accomplished by establishing systems where a member of the resuscitation team is assigned to sufficiently communicate with family members.

Further consideration is required on family presence during resuscitation considering cultural and social backgrounds in Japan, where general citizens are much less commonly present at acute medical care settings. Attention should be given to the knowledge gap between healthcare providers and family members. In addition, the potential negative impact due to family presence on resuscitation performance must be considered.

3. Search for the Cause: Channelopaty

In 4 LOE 4 studies[566, 568, 720, 721]14% to 35% of young patients with sudden, unexpected death had no abnormalities found at autopsy.

In 7 LOE 3 studies[722-728] mutations causing channelopathies occurred in 2% to 10% of infants with sudden infant death syndrome noted as the cause of death. In 1 LOE 3[729] and 2 LOE 4[730, 731] studies 14% to 20% of young adults with sudden, unexpected death had no abnormalities on autopsy but had genetic mutations causing channelopathies. In 4 LOE 4 studies[732-735], using clinical and laboratory (electrocardiographic, molecular-genetic screening) investigations, 22% to 53% of first- and second-degree relatives of patients with sudden, unexplained death had inherited, arrhythmogenic disease.

The victim of a sudden, unexpected cardiac arrest should be examined to search for the cause of death. Any available previous ECGs should be reviewed, and complete autopsy is recommended. Reports from abroad suggest the association between Sudden Infant Death Syndrome and channelopathy (ion channel abnormality), which reportedly involves variations at a genetic level.

In Japan, it is necessary to establish diagnostic methods and systems for cardiogenic cardiac arrest including ion channel abnormalities linked to medical check-up in the school. Establishment of fatal case registry, and pathological and judicial autopsy systems should be considered.

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