

# 2025 Korean Guidelines for Cardiopulmonary Resuscitation: Part 8. Pediatric advanced life support

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The 2025 Korean pediatric advanced life support guideline update introduces clinically important revisions emphasizing airway strategy, physiologic resuscitation targets, post-cardiac arrest hemodynamics, neuroprotection, and extracorporeal support. In out-of-hospital pediatric cardiac arrest, bag-mask ventilation is now suggested over endotracheal intubation or supraglottic airway placement. In in-hospital arrest, evidence is insufficient to favor bag-mask ventilation versus advanced airways; however, endotracheal intubation or supraglottic airway insertion is reasonable when performed with minimal interruption or when bag-mask ventilation is ineffective. For patients with an advanced airway in place, age-adjusted ventilation rates are proposed to avoid hypoventilation and hyperventilation: 30/min (<1 yr), 20–30/min (1–8 yr), and 10–20/min (8–18 yr in healthcare settings). When invasive arterial monitoring is available during in-hospital cardiac arrest, target diastolic blood pressure is  $\geq 25$  mmHg in infants and  $\geq 30$  mmHg in children  $\geq 1$  year. After return of spontaneous circulation, systolic blood pressure during the first 6 hours should be maintained above the age-specific 10th percentile. Neuroprognostication should be multimodal, incorporating serial examinations, electroencephalography (up to 72 hours), early computed tomography (<24 hours), magnetic resonance imaging (72 hours to 2 weeks), lactate trends, and pupillary reflexes. Extracorporeal cardiopulmonary resuscitation (CPR) is limited to appropriately resourced hospitals and may be considered for selected in-hospital arrests (e.g., cardiac disease) unresponsive to conventional CPR; evidence remains insufficient for out-of-hospital use. These revisions shift pediatric resuscitation toward physiology-guided, resource-stratified, and neuroprotective care.

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## MAJOR CHANGES IN THE 2025 PEDIATRIC ADVANCED LIFE SUPPORT GUIDELINES

### Insertion of advanced airways in pediatric cardiac arrest

- (1) In the out-of-hospital cardiac arrest (OHCA) setting, as a method of ventilation for pediatric patients, it is suggested to use bag-mask ventilation (BMV) rather than endotracheal intubation or a supraglottic airway (SGA) device (weak recommendation, very low certainty).
- (2) In the in-hospital cardiac arrest (IHCA) setting, as a method of ventilation for pediatric patients, there is insufficient evidence to recommend for or against the use of BMV when compared with endotracheal intubation or an SGA device.
- (3) If the resuscitation team has sufficient expertise and necessary resources to perform endotracheal intubation or SGA insertion while minimizing interruptions in chest compressions, or if BMV does not provide adequate ventilation, it is recommended to consider transitioning to an advanced airway (good practice statement).

### Ventilation rate for pediatric cardiac arrest patients with an advanced airway in place

- (1) There is insufficient evidence to recommend a specific ventilation rate during cardiopulmonary resuscitation (CPR) in children with an advanced airway in place.
- (2) Efforts should be made to avoid the risks of hypoventilation or hyperventilation. It is suggested that pediatric cardiac arrest patients with an advanced airway in place receive ventilation at an age-appropriate respiratory rate (30/min for infants under 1 year and 20–30/min for children aged 1–8 years). For children aged 8–18 years, the ventilation rate may be set at 10–20/min at the discretion of healthcare providers when the rescuer is a healthcare professional or the cardiac arrest occurs in the hospital (expert consensus recommendation).

### Target diastolic arterial blood pressure during pediatric IHCA with invasive arterial blood pressure measurement

- (1) For pediatric patients in IHCA undergoing invasive arterial blood pressure measurement, it is suggested that the target diastolic arterial blood pressure should be at least 25 mmHg for infants under 1 year of age and at least 30 mmHg for children aged 1 year or older (weak recommendation, very low certainty).

### Target blood pressure after return of spontaneous circulation

- (1) For pediatric patients with return of spontaneous circulation (ROSC) after cardiac arrest, it is suggested to set the target blood pressure to achieve an age-specific systolic blood pressure (SBP) above the 10th percentile within the first 6 hours (weak recommendation, very low certainty).

### Effects of prophylactic anticonvulsant use and seizure treatment after ROSC

- (1) There is insufficient evidence to recommend for or against its use. It is suggested not to routinely use prophylactic anticonvulsants in pediatric patients with ROSC after cardiac arrest (good practice statement).
- (2) There is insufficient evidence to recommend for or against the treatment of seizures occurring in pediatric patients with ROSC. It is recommended to initiate seizure treatment in pediatric patients who develop seizures after ROSC (good practice statement).

### Extracorporeal CPR using extracorporeal membrane oxygenation

- (1) Because resuscitation using extracorporeal CPR (ECPR) requires substantial resources and multidisciplinary collaboration, the application of ECPR should be limited to hospitals with appropriate facilities (weak recommendation, low certainty).
- (2) In pediatric patients with IHCA who are unresponsive to conventional CPR, ECPR may be considered for a selected patient population (e.g., cardiac disease) if a facility capable of providing extracorporeal membrane oxygenation (ECMO)-facilitated CPR is available (e.g., an established ECPR protocol, trained personnel, and appropriate equipment) (weak recommendation, very low certainty).
- (3) For pediatric patients with OHCA, there is insufficient evidence to support the use of ECPR.

### Indicators for predicting neurologic outcomes after ROSC

- (1) To predict the neurologic outcomes of pediatric patients after ROSC, careful assessment using multiple modalities should be performed. Repeated neurologic examinations, hematologic tests, electroencephalography (EEG), and imaging studies such as computed tomography (CT) or magnetic resonance imaging (MRI) should be performed and considered in combination (strong recommendation, low certainty).
- (2) After ROSC, it is recommended to repeatedly assess the pupil-

- lary light reflex and to use the results as an indicator for predicting favorable or unfavorable neurologic outcomes (good practice statement).
- (3) The use of lactate levels measured early after ROSC is recommended as an indicator for predicting neurologic outcomes. However, there is insufficient evidence to recommend or restrict the use of serum biomarkers, such as S100B or neuron-specific enolase (NSE), as prognostic factors (expert consensus recommendation).
  - (4) After ROSC, the use of EEG for up to 72 hours is recommended to predict neurologic outcomes (expert consensus recommendation).
  - (5) The results of brain CT scans performed within 24 hours after ROSC and brain MRI scans performed between 72 hours and 2 weeks after ROSC are recommended for use as indicators to predict neurologic outcomes (expert consensus recommendation).

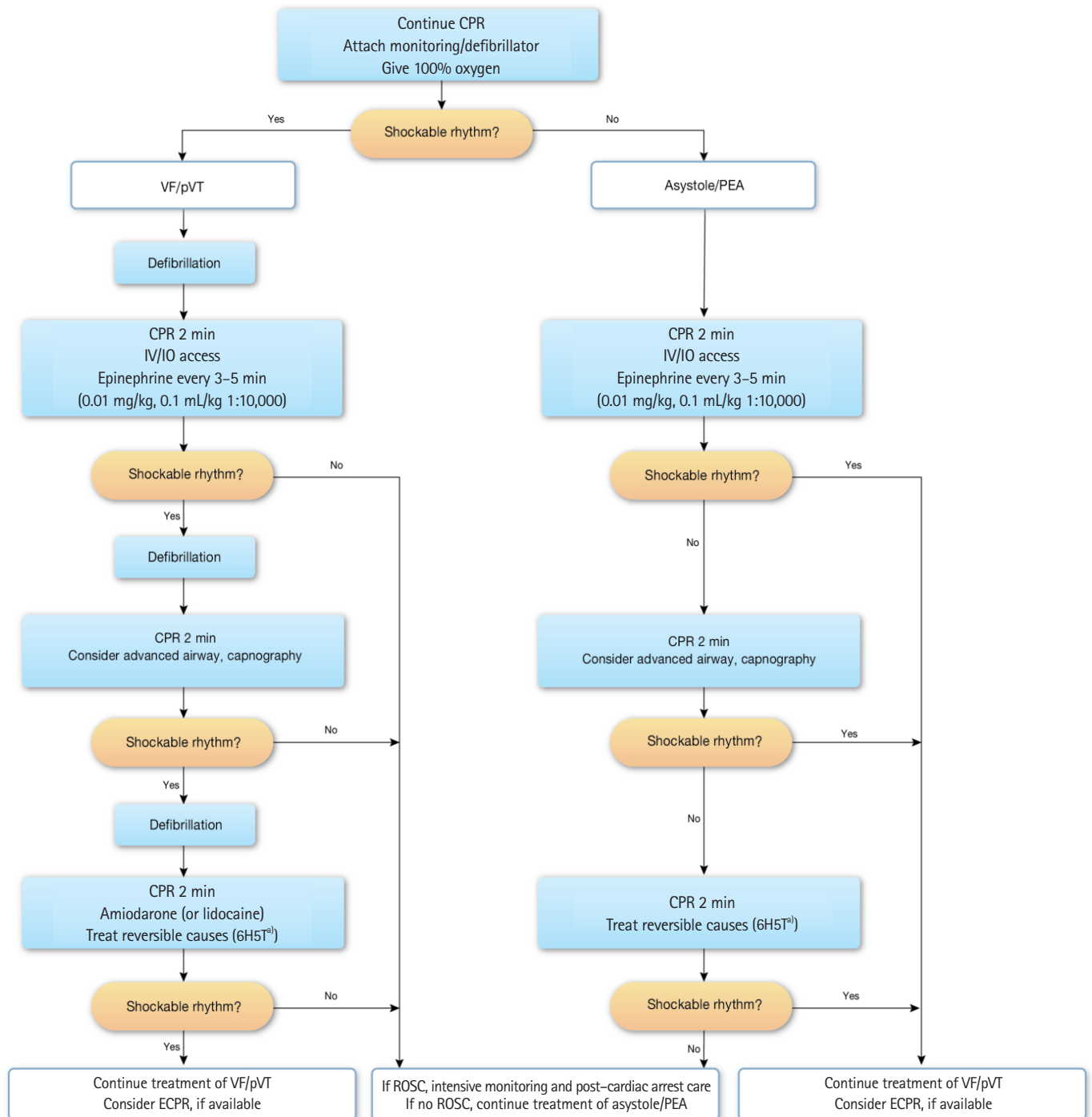
## SEQUENCE OF PEDIATRIC ADVANCED LIFE SUPPORT

The sequence of pediatric advanced life support (PALS) is shown in [Fig. 1](#) and [Table 1](#). For healthcare providers, when a pediatric victim is found to be unresponsive and not breathing (or has abnormal breathing or agonal respirations), the first rescuer should immediately call for help and ask nearby personnel to bring a defibrillator. The rescuer should check for a pulse and breathing within 10 seconds, and if there is no pulse and no breathing, CPR should be initiated. At this time, oxygen should be administered if available, and electrocardiographic (ECG) monitoring or automated external defibrillator (AED) pads should be applied as soon as possible. As in adults, high-quality CPR should be performed. That is, chest compressions should be delivered at an appropriate depth (at least one-third of the chest anteroposterior diameter, or a depth of approximately 4 cm in infants and 4–5 cm in children) and at an appropriate rate (at least 100–120 compressions per minute), allowing complete chest recoil after each compression, avoiding excessive ventilations, and minimizing interruptions in chest compressions. For ventilatory support, depending on the number of rescuers, chest compressions and ventilations are performed at a ratio of 30:2 when there is a single rescuer and 15:2 when there are two rescuers. Once an advanced airway is in place, two rescuers no longer need to continue the two-rescuer CPR cycle that pauses chest compressions for ventilations. Instead, chest compressions are delivered continuously at a rate of at least 100 to 120 per minute. The rescuer responsible for venti-

lation should provide it at an age-appropriate respiratory rate for pediatric patients with an advanced airway in place to avoid the risks of hypoventilation or hyperventilation. Considering the applicable age range of PALS, ventilations should be delivered at a rate of 30/min for infants under 1 year of age and 20–30/min for children aged 1–8 years. For children aged 8–18 years, the ventilation rate may be set at 10–20/min at the discretion of healthcare providers when the rescuer is a healthcare professional or the cardiac arrest occurs in the hospital. If it is not possible to clearly confirm the age of the pediatric cardiac arrest patient, the ventilation rate should be set at the discretion of the rescuer.

During CPR, the cardiac arrest rhythm should be assessed immediately upon the arrival of an AED or a manual defibrillator. When an AED is used, the device automatically analyzes the ECG and indicates whether the rhythm is a shockable rhythm (ventricular fibrillation [VF] or pulseless ventricular tachycardia [pVT]) or a nonshockable rhythm (asystole or pulseless electrical activity [PEA]). Chest compressions may be briefly interrupted for rhythm analysis and confirmation. In asphyxial cardiac arrest, asystole or wide QRS bradycardia is most common. Although the frequency of VF is low in infants and young children, sudden witnessed cardiac arrest in older children and adolescents is more likely to be caused by shockable rhythm.

In cases of cardiac arrest with suspected respiratory infectious diseases such as COVID-19, rescuers should wear appropriate personal protective equipment (PPE) before participating in CPR. CPR should be initiated after determining the need for resuscitation while minimizing the number of personnel involved. If a mechanical chest compression device applicable to pediatric patients is available, its use may be considered. Regarding the wearing of PPE, airborne-precaution PPE should be worn when aerosol-generating procedures (chest compressions, airway securing, and ventilation) are performed. During defibrillation, the procedure may be performed by rescuers wearing droplet-precaution PPE (a fluid-resistant surgical mask, eye protection, a short-sleeved apron, and gloves). After initiating CPR and analyzing the electrocardiographic rhythm, if the rhythm is shockable, a single defibrillation should be delivered, and early endotracheal intubation should be performed. If the rhythm is nonshockable, endotracheal intubation should be considered immediately after rhythm check. During endotracheal intubation, chest compressions should be paused, a video laryngoscope should be used whenever possible, and a ventilator with a filter attached should be connected. If endotracheal intubation is delayed, the airway should be maintained by inserting an SGA or by using BMV with a HEPA (high-efficiency particulate air) filter [1,2]. After completion of



**Fig. 1.** Pediatric cardiac arrest algorithm for advanced life support team in the hospital. CPR, cardiopulmonary resuscitation; VF, ventricular fibrillation; pVT, pulseless ventricular tachycardia; PEA, pulseless electrical activity; IV, intravenous; IO, intraosseous; ECPR, extracorporeal cardiopulmonary resuscitation; ROSC, return of spontaneous circulation. <sup>a</sup>6H (hypothermia, hypoxia, hypovolemia, hypokalemia/hyperkalemia, hypoglycemia, and hydrogen ion-acidosis) and 5T (cardiac tamponade, thrombosis-pulmonary or cardiac, toxin, tension pneumothorax, and trauma).

CPR, rescuers should, in accordance with infection control guidelines, wash their hands thoroughly with soap and water as soon as possible or disinfect their hands using an alcohol-based hand sanitizer, and a change of clothing is recommended.

## RESUSCITATION ALGORITHM SEQUENCE

### Nonshockable rhythm (asystole/PEA)

PEA refers to organized electrical activity, often with a slow rate

**Table 1.** Reference chart of the advanced life support for pediatric cardiac arrest

| Management                 | Detail                                                                                                                                                                                                                                                                   |
|----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Rhythm assessment          | Rotate compressor every 2 min and rhythm check                                                                                                                                                                                                                           |
| Defibrillation             | First shock 2 J/kg, second shock $\geq 4$ J/kg (maximum, 10 J/kg or adult dose)                                                                                                                                                                                          |
| Chest compression          | Push fast (100–120/min)<br>If no advanced airway, maintain 15:2 compression to ventilation ratio for 2 rescuers<br>Push hard (at least one-third anteroposterior diameter of chest: 4 cm in infant and 4–5 cm in children)                                               |
| Vascular access            | Establish IO or IV access, prior to advanced airway                                                                                                                                                                                                                      |
| Advanced airway            | BMV until insertion of advanced airway<br>Once advanced airway is in place, <ul style="list-style-type: none"> <li>• Infants (&lt; 1 yr): 30/min</li> <li>• Children (1–8 yr): 20–30/min</li> <li>• Children (8–18 yr): 10–20/min, based on clinical judgment</li> </ul> |
| Drug                       |                                                                                                                                                                                                                                                                          |
| All cardiac arrest victims | Epinephrine, every 3–5 min (e.g., every two rotation of compressor, 4 min) at a dose of 0.01 mg/kg (0.1 mL/kg of 1:10,000 concentration)                                                                                                                                 |
| Refractory VF/pVT          | Amiodarone: 5 mg/kg bolus, may repeat up to two times (total three doses; maximum, 15 mg/kg/D); maximum single dose, 300 mg<br>Lidocaine: 1 mg/kg IO/IV                                                                                                                  |
| Reversible causes          |                                                                                                                                                                                                                                                                          |
| 6H                         | Hypovolemia, hypoxia, hydrogen ion (acidosis), hypoglycemia, hypokalemia/hyperkalemia, and hypothermia                                                                                                                                                                   |
| 5T                         | Thrombosis (pulmonary, coronary), tension pneumothorax, cardiac tamponade, toxins, and trauma                                                                                                                                                                            |

IO, intraosseous; IV, intravenous; BMV, bag-mask ventilation; VF, ventricular fibrillation; pVT, pulseless ventricular tachycardia.

and a wide QRS interval, in which no palpable pulse is present. Resuscitation should be continued while minimizing interruptions in chest compressions. Another rescuer should establish vascular access and administer epinephrine at a dose of 0.01 mg/kg (0.1 mL/kg of a 1:10,000 solution) during ongoing resuscitation. The same dose should be repeated every 3 to 5 minutes. High-dose epinephrine does not improve survival and may be harmful in asphyxia [3–5].

Once an advanced airway is in place, the first rescuer should perform continuous chest compressions without interruption at a rate of at least 100 to 120 compressions per minute. The second rescuer should provide ventilation to pediatric patients with an advanced airway in place at an age-appropriate respiratory rate. Ventilations are delivered at a rate of 30/min for infants under 1 year of age and 20–30/min for children aged 1–8 years. If the child is 8–18 years of age, the ventilation rate may be set at 10–20/min at the discretion of the healthcare provider when the rescuer is a healthcare professional or when the cardiac arrest occurs in the hospital. Care should be taken to avoid hypoventilation or hyperventilation. Based on expert opinion that pediatric patients require a higher ventilation rate than the adult standard of 10/min, ventilation at an age-appropriate respiratory rate is recommended (expert consensus recommendation).

To prevent deterioration in the quality and rate of compressions due to fatigue of the rescuer performing chest compressions, the rescuer performing chest compressions should rotate

with another rescuer at 2-minute intervals. At the time of rotation, the cardiac rhythm should be checked while minimizing interruptions in chest compressions. If the rhythm is nonshockable, chest compressions and ventilations should be continued, and epinephrine should be administered via vascular access every 3 to 5 minutes, continuing until there is evidence of ROSC or a decision is made to terminate resuscitation. If the rhythm changes to a shockable rhythm, defibrillation should be performed at any time, and chest compressions should be resumed immediately after defibrillation. After 2 minutes of CPR, the rhythm should be checked again. The time interval between chest compressions and defibrillation should be minimized, and the time to resume chest compressions after defibrillation should also be minimized.

In nonshockable rhythms, 6H (hypothermia, hypoxia, hypovolemia, hypokalemia/hyperkalemia, hypoglycemia, and hydrogen ion-acidosis) and 5T (cardiac tamponade, thrombosis-pulmonary or cardiac, toxin, tension pneumothorax, and trauma) should be sought to identify reversible causes of pediatric cardiac arrest, and corrected when identified.

### Shockable rhythm (VF/pVT)

Defibrillation is the definitive treatment for VF, which is associated with an overall survival rate of approximately 17% to 20% [6]. Survival is higher in primary VF than in secondary VF. In adult cardiac arrest, survival is known to decrease by 7% to 10% per minute when resuscitation and defibrillation are not performed

[7]. Survival is higher when high-quality resuscitation is performed while minimizing interruptions in chest compressions from the early onset of cardiac arrest. Defibrillation outcomes are optimized when the rescuer minimizes the time interval between chest compressions and defibrillation. Chest compressions should be resumed immediately after defibrillation.

When a shockable rhythm is identified, the first defibrillation should be delivered as soon as possible at a dose of 2 J/kg, and resuscitation should be resumed immediately with chest compressions. If the first defibrillation fails, delivering successive defibrillation immediately with increased energy provides no benefit, and resumption of chest compressions is more important than immediate additional defibrillation. Continue CPR for approximately 2 minutes. If sufficient rescuers are available, establish intravenous (IV) access (or intraosseous [IO] access). After 2 minutes of resuscitation, check the rhythm, and if the shockable rhythm persists, increase the defibrillation energy dose to 4 J/kg. If the rhythm is nonshockable, follow the algorithm for asystole or PEA. Immediately resume chest compressions after the second defibrillation. Continue resuscitation for approximately 2 minutes. During resuscitation, administer epinephrine at a dose of 0.01 mg/kg (0.1 mL/kg of a 1:10,000 solution) every 3 to 5 minutes via vascular access. Immediately prior to rhythm check, the rescuer responsible for the defibrillator prepares to charge the defibrillator (using a dose of at least 4 J/kg up to a maximum of 10 J/kg, or the adult maximum dose, whichever is lower). After checking the ECG rhythm, if a shockable rhythm is identified, perform defibrillation. If defibrillation is unsuccessful, administer amiodarone or lidocaine while continuing resuscitation. If the rhythm becomes nonshockable at any time, follow the algorithm for nonshockable cardiac arrest. Two minutes after defibrillation, check the ECG again, and if an organized rhythm is observed, check for a pulse to determine whether it is a perfusing rhythm. If VF recurs after defibrillation, restart CPR according to the flowchart for shockable rhythms and repeat defibrillation using the energy dose that was successful immediately prior to recurrence. Actively find and correct other reversible causes, such as 6H and 5T.

Torsades de pointes is a polymorphic VT associated with QT interval prolongation. QT interval prolongation may be congenital or caused by drug toxicity and is associated with class IA antiarrhythmic agents (procainamide, quinidine, and disopyramide), class III antiarrhythmic agents (sotalol and amiodarone), tricyclic antidepressants, digoxin, or drug interactions [8,9]. Torsades de pointes typically progresses rapidly to VF or pVT. Therefore, if VF or pVT cardiac arrest occurs, the rescuer should initiate CPR and perform defibrillation as soon as possible. Regardless of the cause,

promptly administer magnesium IV (over several minutes, 25–50 mg/kg; maximum single dose 2 g).

## ADVANCED AIRWAY MANAGEMENT

### Oxygen

Although evidence regarding the appropriate oxygen concentration during its administration remains insufficient, 100% oxygen should be used during resuscitation. After ROSC, if appropriate equipment is available, titrate oxygen administration to maintain an oxygen saturation of 94% to 99%.

### Bag-mask ventilation

When resuscitation is performed outside the hospital, BMV may be as effective as endotracheal intubation for a short period and, in some cases, may be safer [10]. Prior to hospital arrival, particularly during short transport, it is recommended to maintain breathing using BMV for ventilation and oxygenation in infants and children. In infants and children without an advanced airway device, provide two ventilations after 30 chest compressions (15 compressions in the case of two rescuers). Chest compressions should be paused during ventilation, and each breath should be delivered over approximately 1 second.

### Supraglottic airway

If BMV is not possible or endotracheal intubation cannot be performed, a laryngeal mask airway may be used by an experienced operator [11–19]. The operator holds the airway device and begins insertion along the contour of the patient's soft palate, advancing it until resistance is felt in the hypopharynx, and then inflates the cuff. Because the position of the airway tube is much more likely to change with patient movement than with endotracheal intubation, particular care is required to secure the tube to prevent dislodgement when the patient must be moved. In infants, the frequency of complications is known to be higher than in children.

### Endotracheal intubation

#### *Size of endotracheal tubes for pediatric patients*

Considering particularly short stature, in pediatric patients weighing up to 35 kg, length-based determination of endotracheal tube size is more accurate than age-based formulas (e.g., Korean Pediatric Resuscitation Tape) [20,21]. Regardless of the presence or absence of a cuff, when preparing for intubation, an endotracheal tube that is 0.5 mm larger and an endotracheal tube that is 0.5 mm smaller than the calculated internal diameter must be prepared.

- (1) For uncuffed endotracheal tubes, use an internal diameter of 3.5 mm for infants younger than 1 year and 4.0 mm for children aged 1–2 years. For children aged 2 years or older, use the following formula:

$$\begin{aligned} \text{Internal diameter of an uncuffed endotracheal tube (mm)} \\ = 4 + \frac{\text{Age (yr)}}{4} \end{aligned}$$

- (2) For cuffed endotracheal tubes, use an internal diameter of 3.0 mm for infants younger than 1 year and 3.5 mm for children aged 1–2 years. For children aged 2 years or older, use the following formula [22–25]:

$$\begin{aligned} \text{Internal diameter of a cuffed endotracheal tube (mm)} \\ = 3.5 + \frac{\text{Age (yr)}}{4} \end{aligned}$$

### *Cuffed endotracheal tubes*

Both cuffed and uncuffed tubes may be used for endotracheal intubation in infants and children. During endotracheal intubation for general anesthesia or for mechanical ventilation in the intensive care unit (ICU), the use of cuffed endotracheal tubes has been reported to reduce the risk of aspiration [26]. When a cuffed endotracheal tube is used, cuff pressure should be continuously monitored and maintained at or below the recommended level of 20 to 25 cm H<sub>2</sub>O. If lung compliance is very low, airway resistance is high, or there is significant air leakage at the level of the glottis, a cuffed endotracheal tube may be more effective when used after considering the size, position, and cuff pressure of the endotracheal tube [27,28].

- (1) The insertion depth of the endotracheal tube can be calculated using the following formula:

$$\begin{aligned} \text{Insertion depth (cm)} = \\ \text{Internal diameter of the endotracheal tube (mm)} \times 3 \end{aligned}$$

- (2) In children aged 2 years or older, insertion depth can also be calculated using the following formula:

$$\text{Insertion depth (cm)} = \frac{\text{Pediatric age}}{2} + 12$$

### *Cricoid pressure during intubation*

There is insufficient evidence to support the routine application of cricoid pressure during intubation to prevent aspiration of gastric contents. If cricoid pressure interferes with intubation or causes breathing problems, it should not be continued.

## DRUG ADMINISTRATION

### **Establishing vascular access for resuscitative medication and weight estimation in pediatric emergencies**

#### *IO access*

IO access is a rapid, safe, and effective method for securing vascular access in children, and is particularly useful as the first-line access in cases of cardiac arrest [29–31]. The preferred insertion site is the proximal tibia, and after each medication administration, a bolus injection of 5 to 10 mL of normal saline should be given to facilitate rapid delivery of the medication to the central circulation. Most IV-administered medications used during resuscitation, such as epinephrine, as well as fluids and blood products, can be administered, and the onset of drug action is known to be similar to that with IV access [32]. Blood tests, including electrolyte testing, blood typing, and gas analysis, can also be performed immediately after IO insertion or within 15 minutes of CPR, and yield results similar to those obtained from venous blood sampling [33].

#### *IV access*

Securing peripheral IV access in pediatric patients during emergency situations can be extremely challenging [33]. In infants or children with severe shock or in the pre-cardiac arrest state in whom urgent IV access is required, if rapid establishment of IV access is not possible, IO access should be established as a priority [31,34].

#### *Endotracheal drug administration*

During resuscitation, IO or IV access is the most appropriate route for drug administration. If securing vascular access is not possible, endotracheal administration may be used only for lipid-soluble drugs (lidocaine, epinephrine, atropine, and naloxone), but the effect is inconsistent [35]. During resuscitation, chest compressions should be paused, the medication administered, followed by administration of at least 5 mL of saline, and then five positive-pressure breaths should be delivered [36]. The appropriate dose for drugs administered via the endotracheal route is not established, and approximately two to three times the IV dose is generally administered. For epinephrine, 10 times the IV dose is recommended. Non-lipid-soluble drugs, such as sodium bicarbonate or calcium, can cause airway injury and should not be administered via the endotracheal route [37].

#### *Measurement of patient body weight in emergency situations*

Even in emergency situations, drug therapy for pediatric patients

should be dosed according to body weight. Even experienced healthcare providers may not be able to accurately estimate a patient's weight based on appearance, and methods that use age-based weight estimation formulas may be impractical because the patient's age may be unknown, and the range of normal body weight for a given age is too wide. In emergency situations, height can be measured easily, and body weight can be estimated relatively accurately based on height. A resuscitation tape that estimates body weight from height and displays precalculated drug doses according to the estimated weight may be used [38,39]. However, when estimating body weight based on height, it should be considered that body weight may be underestimated in patients whose actual weight exceeds 25 kg or who are tall for their age [21,38,40].

For the calculation of drug doses used during resuscitation, if body weight is unknown, a resuscitation tape that lists drug doses calculated according to estimated body weight may be used [41]. Use of the Korean Pediatric Resuscitation Tape (Fig. 2), produced by the Korean Association of Cardiopulmonary Resuscitation in 2018, is recommended.

## Drugs used in PALS

Drugs used in PALS are summarized in Table 2.

### Epinephrine

During cardiac arrest, vasoconstriction increases aortic diastolic blood pressure (DBP), thereby elevating coronary perfusion pressure, which serves as a critical determinant of successful resuscitation [42,43]. Administration of high-dose epinephrine may decrease blood flow to the extremities, abdominal organs, and kid-

neys, and may cause excessive vasoconstriction, resulting in severe hypertension and tachyarrhythmias. During CPR for cardiac arrest in infants and children, epinephrine may be administered, whereas evidence regarding the effectiveness of other vasopressors is insufficient [3,44–46]. For pediatric patients with symptomatic bradycardia who do not respond to effective assisted ventilation or oxygen administration, epinephrine may be administered via IV or IO routes. The most commonly observed rhythms in pediatric patients with cardiac arrest are asystole and bradycardia, and epinephrine may generate a perfusing rhythm in such patients. In particular, rapid administration within 5 minutes after cardiac arrest has a positive effect on the patient's treatment prognosis [47]. The dose of epinephrine to be administered to patients with cardiac arrest is 0.01 mg/kg when given IV or IO (0.1 mL/kg of a 1:10,000 dilution). During resuscitation, epinephrine is administered repeatedly at the same dose every 3 to 5 minutes. Endotracheal administration of epinephrine results in unpredictable drug absorption and subsequent blood concentrations. However, it may be considered when vascular or IO access cannot be established. The recommended dose for endotracheal administration is 0.1 mg/kg (0.1 mL/kg of a 1:1,000 solution).

### Amiodarone

Amiodarone is administered to cardiac arrest patients presenting with pVT or VF or those with suspected supraventricular tachycardia (SVT) that is unresponsive to adenosine. During cardiac arrest, amiodarone 5 mg/kg may be administered via IV or IO routes. If a pulse is present, it is administered slowly; however, in cardiac arrest, it is administered rapidly. Hypotension may occur due to vasodilatory effects during administration. The degree of

A

B

| 7 kg                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                             | 8 kg                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                               | 9 kg                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                               | 10 kg                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Resuscitation</b><br>Epinephrine (1:10,000) 0.07 mg<br>Epinephrine ET (1:1,000) 0.7 mg<br>Atropine 1* 0.7 mg<br>Atropine 2* 1.4 mg<br>Atropine 3* 2.1 mg<br>Calcium chloride 140 mg<br>Calcium gluconate 400 mg<br>Lidocaine 7 mg<br>MgSO <sub>4</sub> 300 mg<br>NaHCO <sub>3</sub> 1 mEq | <b>Seizure</b><br>Diazepam 1.4 mg<br>Lorazepam IV, IN 0.05 mg<br>Midazolam IV, IN 0.7 mg<br>Atropine 1* 0.7 mg<br>Atropine 2* 1.4 mg<br>Atropine 3* 2.1 mg<br>Calcium chloride 140 mg<br>Calcium gluconate 400 mg<br>Lidocaine 7 mg<br>MgSO <sub>4</sub> 300 mg<br>NaHCO <sub>3</sub> 1 mEq | <b>Resuscitation</b><br>Epinephrine (1:10,000) 0.08 mg<br>Epinephrine ET (1:1,000) 0.8 mg<br>Atropine 1* 0.8 mg<br>Atropine 2* 1.6 mg<br>Atropine 3* 2.4 mg<br>Calcium chloride 160 mg<br>Calcium gluconate 480 mg<br>Lidocaine 8 mg<br>MgSO <sub>4</sub> 400 mg<br>NaHCO <sub>3</sub> 1.2 mEq | <b>Seizure</b><br>Diazepam 1.6 mg<br>Lorazepam IV, IN 0.06 mg<br>Midazolam IV, IN 0.8 mg<br>Atropine 1* 0.8 mg<br>Atropine 2* 1.6 mg<br>Atropine 3* 2.4 mg<br>Calcium chloride 160 mg<br>Calcium gluconate 480 mg<br>Lidocaine 8 mg<br>MgSO <sub>4</sub> 400 mg<br>NaHCO <sub>3</sub> 1.2 mEq | <b>Resuscitation</b><br>Epinephrine (1:10,000) 0.09 mg<br>Epinephrine ET (1:1,000) 0.9 mg<br>Atropine 1* 0.9 mg<br>Atropine 2* 1.8 mg<br>Atropine 3* 2.7 mg<br>Calcium chloride 180 mg<br>Calcium gluconate 540 mg<br>Lidocaine 9 mg<br>MgSO <sub>4</sub> 450 mg<br>NaHCO <sub>3</sub> 1.3 mEq | <b>Seizure</b><br>Diazepam 1.8 mg<br>Lorazepam IV, IN 0.07 mg<br>Midazolam IV, IN 0.9 mg<br>Atropine 1* 0.9 mg<br>Atropine 2* 1.8 mg<br>Atropine 3* 2.7 mg<br>Calcium chloride 180 mg<br>Calcium gluconate 540 mg<br>Lidocaine 9 mg<br>MgSO <sub>4</sub> 450 mg<br>NaHCO <sub>3</sub> 1.3 mEq | <b>Resuscitation</b><br>Epinephrine (1:10,000) 0.1 mg<br>Epinephrine ET (1:1,000) 1 mg<br>Atropine 1* 1 mg<br>Atropine 2* 2 mg<br>Atropine 3* 3 mg<br>Calcium chloride 200 mg<br>Calcium gluconate 600 mg<br>Lidocaine 10 mg<br>MgSO <sub>4</sub> 500 mg<br>NaHCO <sub>3</sub> 1.4 mEq | <b>Seizure</b><br>Diazepam 2 mg<br>Lorazepam IV, IN 0.1 mg<br>Midazolam IV, IN 1 mg<br>Atropine 1* 1 mg<br>Atropine 2* 2 mg<br>Atropine 3* 3 mg<br>Calcium chloride 200 mg<br>Calcium gluconate 600 mg<br>Lidocaine 10 mg<br>MgSO <sub>4</sub> 500 mg<br>NaHCO <sub>3</sub> 1.4 mEq |
| <b>Anaphylaxis</b><br>Defibrillation 1* 14 J<br>Defibrillation 2* 28 J<br>Defibrillation 3* 32 J<br>Epinephrine (1:1,000) IV 0.07 mg<br>Epinephrine (1:1,000) IV 0.7 mg<br>Methylxanthine 14 mg                                                                                              | <b>Anaphylaxis</b><br>Defibrillation 1* 16 J<br>Defibrillation 2* 32 J<br>Defibrillation 3* 36 J<br>Epinephrine (1:1,000) IV 0.08 mg<br>Epinephrine (1:1,000) IV 0.8 mg<br>Methylxanthine 16 mg                                                                                             | <b>Anaphylaxis</b><br>Defibrillation 1* 18 J<br>Defibrillation 2* 36 J<br>Defibrillation 3* 40 J<br>Epinephrine (1:1,000) IV 0.09 mg<br>Epinephrine (1:1,000) IV 0.9 mg<br>Methylxanthine 18 mg                                                                                                | <b>Anaphylaxis</b><br>Defibrillation 1* 20 J<br>Defibrillation 2* 40 J<br>Defibrillation 3* 44 J<br>Epinephrine (1:1,000) IV 0.1 mg<br>Epinephrine (1:1,000) IV 1 mg<br>Methylxanthine 20 mg                                                                                                  | <b>Anaphylaxis</b><br>Defibrillation 1* 22 J<br>Defibrillation 2* 44 J<br>Defibrillation 3* 48 J<br>Epinephrine (1:1,000) IV 0.11 mg<br>Epinephrine (1:1,000) IV 1.1 mg<br>Methylxanthine 22 mg                                                                                                | <b>Anaphylaxis</b><br>Defibrillation 1* 24 J<br>Defibrillation 2* 48 J<br>Defibrillation 3* 52 J<br>Epinephrine (1:1,000) IV 0.12 mg<br>Epinephrine (1:1,000) IV 1.2 mg<br>Methylxanthine 24 mg                                                                                               | <b>Anaphylaxis</b><br>Defibrillation 1* 26 J<br>Defibrillation 2* 52 J<br>Defibrillation 3* 56 J<br>Epinephrine (1:1,000) IV 0.13 mg<br>Epinephrine (1:1,000) IV 1.3 mg<br>Methylxanthine 26 mg                                                                                        | <b>Anaphylaxis</b><br>Defibrillation 1* 28 J<br>Defibrillation 2* 56 J<br>Defibrillation 3* 60 J<br>Epinephrine (1:1,000) IV 0.14 mg<br>Epinephrine (1:1,000) IV 1.4 mg<br>Methylxanthine 28 mg                                                                                     |

Fig. 2. Korean Pediatric Resuscitation Tape. (A) Original version. (B) English version.

**Table 2.** Medications commonly used in pediatric advanced life support

| Medication             | Dose                                                                                                                            | Detail                                                                                                                                                                                                 |
|------------------------|---------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Adenosine              | 0.1 mg/kg (maximum, 6 mg)                                                                                                       | Monitor ECG<br>Rapid IV/IO bolus with flush                                                                                                                                                            |
| Amiodarone             | 5 mg/kg IV/IO; may repeat up to two times (total three doses) up to 15 mg/kg                                                    | Monitor ECG and blood pressure; adjust administration rate according to the urgency (IV push during cardiac arrest, more slowly over 20–60 min with perfusing rhythm)                                  |
|                        | Maximum single dose, 300 mg                                                                                                     | Expert consultation strongly recommended prior to use when patient has a perfusing rhythm<br>Use caution when administering with other drugs that prolong the QT interval (obtain expert consultation) |
| Atropine               | 0.02 mg/kg IV/IO<br>0.04–0.06 mg/kg ET <sup>a)</sup><br>Maximum single dose, 0.5 mg                                             | Higher doses may be used with organophosphate poisoning                                                                                                                                                |
| Calcium chloride (10%) | 20 mg/kg IV/IO<br>Maximum dose, 2 g                                                                                             | Administer slowly                                                                                                                                                                                      |
| Epinephrine            | 0.01 mg/kg (0.1 mL/kg 1:10,000) IV/IO<br>0.1 mg/kg (0.1 mL/kg 1:1,000) ET <sup>a)</sup><br>Maximum dose, 1 mg IV/IO; 2.5 mg ET  | May repeat every 3–5 min                                                                                                                                                                               |
| Glucose                | 0.5–1 g/kg IV/IO                                                                                                                | Newborn: 5–10 mL/kg D10W<br>Infants and children: 2–4 mL/kg D25W<br>Adolescents: 1–2 mL/kg D50W                                                                                                        |
| Lidocaine              | Bolus: 1 mg/kg IV/IO<br>Infusion: 20–50 µg/kg/min                                                                               | –                                                                                                                                                                                                      |
| Magnesium sulfate      | 25–50 mg/kg IV/IO over 10–20 min<br>Faster infusion in torsades de pointes<br>Maximum dose, 2 g                                 | –                                                                                                                                                                                                      |
| Naloxone               | For full reversal:<br>• < 5 yr or < 20 kg: 0.1 mg/kg IV/IO/ET <sup>a)</sup><br>• ≥ 5 yr or ≥ 20 kg: 2 mg IV/IO/ET <sup>a)</sup> | Use lower doses to reverse respiratory depression associated with therapeutic opioid use (1–5 µg/kg titrate to effect)                                                                                 |
| Sodium bicarbonate     | 1 mEq/kg per dose IV/IO slowly                                                                                                  | After adequate ventilation                                                                                                                                                                             |

ECG, electrocardiogram; IV, intravenous; IO, intraosseous; ET, endotracheal.

<sup>a)</sup>If ET used, flush with 5 mL of normal saline and follow with five ventilations.

hypotension is related to the rate of drug administration [48].

### Lidocaine

Lidocaine reduces myocardial automaticity and suppresses ventricular arrhythmias. In infants and children who present with VF or pVT unresponsive to defibrillation, either amiodarone or lidocaine may be selected for use [49–51]. After rapid administration of 1 mg/kg, if VF or pVT refractory to defibrillation persists, repeated doses may be administered every 5 to 10 minutes.

### Adenosine

Adenosine has a short half-life of less than 10 s and therefore a wide safety margin; however, because of its short half-life, venous access close to the heart should be secured, and the drug should be administered IV rapidly within 1 to 2 seconds, followed immediately by an additional 5 to 10 mL of normal saline to facilitate rapid entry of adenosine into the central circulation. The initial IV dose is 0.1 mg/kg (maximum, 6 mg). When adenosine is administered via a peripheral vein, a higher dose than that used

for central venous administration may be required. Adenosine may also be administered via the IO route, and the dose is the same as for IV administration.

### Atropine

There is no evidence to support the administration of atropine for the treatment of cardiac arrest. During emergency endotracheal intubation in infants, atropine may be used only in cases with a high risk of bradycardia, such as when the infant is hypovolemic or when succinylcholine is used during intubation [52]. A dose of 0.02 mg/kg (maximum, 0.5 mg) is administered via IV or IO routes, and it is used with no minimum dose. However, routine administration of atropine is not recommended in all cases requiring emergency endotracheal intubation in infants and children [49,53,54]. Nerve gas poisoning or organophosphorus poisoning requires large doses of atropine [55].

### Glucose

High-concentration glucose may cause thrombosis, hyperglyce-

mia, and intracranial hemorrhage in infants, so glucose at a concentration of 10% or 25% (50% glucose diluted 1:1) should be administered. Start with a glucose bolus of 0.5 to 1.0 g/kg, and hypoglycemia should preferably be managed with a continuous infusion of glucose-containing fluids whenever possible. If a hypertonic glucose solution is administered in a single dose, it can suddenly increase plasma osmolality, leading to osmotic diuresis. Therefore, caution is required. In the absence of convincing evidence that hyperglycemia after cardiac arrest is beneficial or harmful, it is recommended to maintain blood glucose levels within the normal range during resuscitation and to prevent hypoglycemia after resuscitation.

#### *Sodium bicarbonate*

Most studies have shown that routine administration of sodium bicarbonate does not improve the prognosis after cardiac arrest [56,57]. In children, respiratory failure is a primary cause of cardiac arrest. Since the administration of sodium bicarbonate transiently increases the PCO<sub>2</sub>, its use during resuscitation may exacerbate preexisting respiratory acidosis. For this reason, assisted ventilation, oxygenation, and restoration of effective systemic perfusion (to correct tissue ischemia) should be prioritized in cardiac arrest in infants and children. Empiric administration of sodium bicarbonate in patients who have undergone prolonged CPR has been shown to decrease 24-hour survival and survival to discharge rates. Sodium bicarbonate should only be considered for patients with symptoms of hyperkalemia, hypermagnesemia, overdose of tricyclic antidepressants, and overdose of other sodium channel blockers [58]. Sodium bicarbonate should be administered via IV or IO routes only when administration is indicated, with an initial dose of 1 mEq/kg (1 mL/kg of an 8.4% solution). There is no evidence to support the use of a diluted solution in infants or children, although a diluted solution (0.5 mEq/mL of a 4.2% solution) may be used in neonates to prevent an increase in osmolality.

#### *Calcium*

Routine administration of calcium during cardiac arrest does not improve the prognosis of cardiac arrest [59–61]. Routine administration of calcium is not recommended during resuscitation in patients with asystole. The administration of calcium is indicated only in cases of documented hypocalcemia, hyperkalemia, or hypermagnesemia, or in cases of overdose with calcium channel blockers. Notably, 10% calcium chloride has three times higher bioavailability than calcium gluconate and is primarily the preferred calcium preparation in pediatric patients during cardiac

arrest [62,63]. Due to the risk of peripheral vein injury, calcium chloride should ideally be administered through a central venous catheter. However, in cardiac arrest patients where central access is unavailable, 20 mg/kg of calcium chloride may be administered via IV or IO routes over 10 to 20 seconds. During cardiac arrest, calcium may be administered repeatedly within 10 minutes if necessary. Additional doses should be administered based on the calculated deficit of ionized calcium.

#### *Magnesium*

Magnesium should only be administered to patients with documented hypomagnesemia or torsades de pointes [64–66]. Regardless of the cause, torsades de pointes should be treated with 25 to 50 mg/kg (maximum, 2 g) of magnesium sulfate, administered rapidly via IV (over several minutes). Magnesium induces vasodilation, and rapid administration may cause hypotension.

## DEFIBRILLATOR

#### **Pad size**

When performing defibrillation, the largest pads that fit the pediatric chest should be used. The pads should not be in contact with each other, and there should be at least 3 cm of space between the pads. The defibrillation effect is the same regardless of the pad type. The adhesive pads should be applied firmly to the chest to ensure full contact of the gel on the pads with the patient's chest. For infants weighing less than 10 kg or aged younger than 1 year, infant-sized electrodes should be used. For pediatric patients weighing 10 kg or more or aged 1 year or older, adult-sized pads (8–10 cm) should be used.

#### **Contact surface**

When using manual paddles, electrode gel must be used. Saline, ultrasound gel, alcohol, or other substitutes should not be used in place of electrode gel.

#### **Paddle placement**

The manual paddles are placed on the upper right side of the chest and at the apex of the heart (to the left of the nipple at the left lower rib) so that the heart is positioned between the two electrodes. Apply firm pressure to the paddles to ensure good contact. Positioning the paddles anteroposterior on the chest has no special advantages, but if the two electrodes are too close (within 3 cm), they may be placed anteroposterior. In cases of anteroposterior chest placement, the anterior pad is placed on the left side of the patient's sternum, and the posterior pad is placed

on the mid-scapular region. In particular, for infants aged 1 year or younger or children weighing less than 25 kg, anteroposterior placement of the paddles should be considered (expert consensus recommendation).

### Energy dose

The lowest effective energy dose for defibrillation and the upper limit for safe defibrillation in infants and children are not well established. In children with VF, initial monophasic defibrillation at a dose of 2 J/kg was effective in 18% to 50% of cases, while biphasic defibrillation at the same dose was effective in 48% of cases [6,67]. In pediatric patients with OHCA due to VF, it has been reported that defibrillation is often performed with a dose of more than 2 J/kg. In one study on IHCA, a defibrillation dose of 2.5 to 3.2 J/kg was used for ROSC. Effective defibrillation was achieved in children with energy doses greater than 4 J/kg (up to 9 J/kg), and in pediatric animals, there were almost no side effects at this dose [7]. Studies on adults and on pediatric animal models suggest that biphasic defibrillation is as effective and less harmful than monophasic defibrillation [68]. In infants and children with VF or pVT, the first energy dose for monophasic and biphasic defibrillators is recommended to be 2 J/kg. The second defibrillation energy dose is 4 J/kg, and if there is no response, the defibrillation energy can be further increased. The increased defibrillation energy should not exceed 10 J/kg or the adult maximum dose. If no energy dose calculated and determined based on weight is available on the defibrillator, the next higher energy on the instrument panel should be used [69–71].

### Automated external defibrillator

In institutions or organizations caring for children, an AED with a pediatric energy attenuator, suitable for use in children and capable of distinguishing shockable rhythms, should be used for children up to 25 kg in weight (approximately 8 years old). If an AED with an energy attenuator is not available, an AED with standard pads should be used. If neither an AED with an energy attenuator nor a manual defibrillator is available, an AED without an energy attenuator can be used even for infants.

## ARRHYTHMIAS OTHER THAN CARDIAC ARREST

If the patient's condition is stable, the cause should be identified and treated accordingly. After confirming the airway, if necessary, maintain the airway stably and provide oxygen if the oxygen saturation is below 94% or if the patient shows signs of respiratory distress. Attach an ECG and monitor the hemodynamic status,

and secure IV or IO access.

### Treatment of bradycardia

Despite maintaining the airway and administering oxygen, if the patient shows signs of decreased consciousness, hypotension, shock, etc., and the heart rate remains below 60/min, treatment should begin (Fig. 3, Table 3).

#### *Drug treatment for bradycardia*

If bradycardia persists or only temporarily responds to oxygen administration and ventilation support, administer epinephrine 0.01 mg/kg (0.1 mL/kg of a 1:10,000 solution) via IV or IO routes. If IV access is difficult to secure or IO administration is not possible and endotracheal intubation has been performed, administer epinephrine 0.1 mg/kg (0.1 mL/kg of a 1:1,000 solution) via the endotracheal tube. If bradycardia does not improve, administration can be repeated every 3 to 5 minutes. In cases of bradycardia caused by increased vagal tone or anticholinergic drug toxicity, administer atropine at a dose of 0.02 mg/kg via IV or IO routes or at a dose of 0.04 to 0.06 mg/kg via the endotracheal tube.

#### *Cardiac pacing*

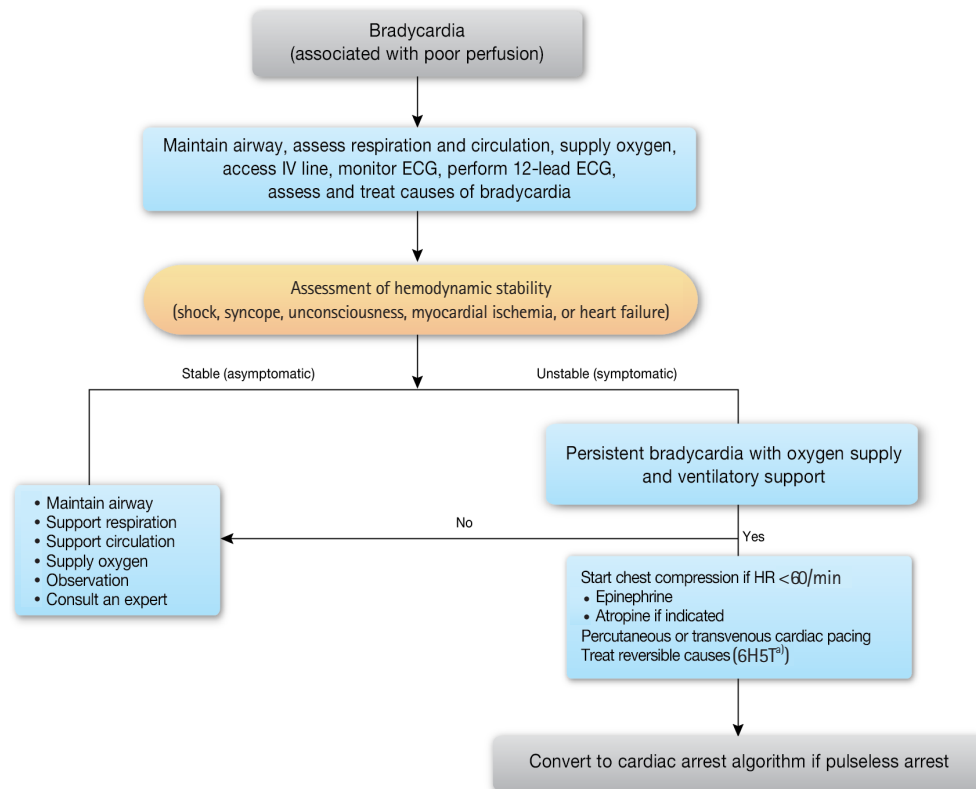
If bradycardia is caused by complete atrioventricular block or sinus node dysfunction and fails to respond to conventional treatments, including ventilation, oxygenation, and medications, emergency transcutaneous cardiac pacing may be lifesaving, especially in patients with congenital or acquired heart disease. However, cardiac pacing is not effective for asystole or bradycardia associated with respiratory failure or hypoxic-ischemic myocardial injury following cardiac arrest.

### Treatment of tachycardia

In patients with tachycardia and a palpable pulse, check for other causes that could lead to hemodynamic changes and evaluate the circulatory status while maintaining the airway, providing respiratory support, administering oxygen, attaching a monitor and defibrillator, and securing vascular access. Perform a 12-lead ECG and assess the QRS interval on the ECG. Treatment of tachycardia depends on the type, and it can be classified based on the QRS interval into narrow (QRS interval  $\leq 0.09$  seconds) and wide QRS tachycardia (QRS interval  $> 0.09$  seconds) (Fig. 4, Table 4). Narrow QRS tachycardia is further divided into sinus tachycardia and SVT for management.

#### *Sinus tachycardia*

Most cases can be diagnosed through the patient's history, such



**Fig. 3.** Algorithm for treatment of pediatric bradycardia with poor perfusion signs. IV, intravenous; ECG, electrocardiography; HR, heart rate. <sup>a</sup>6H (hypothermia, hypoxia, hypovolemia, hypokalemia/hyperkalemia, hypoglycemia, and hydrogen ion-acidosis) and 5T (cardiac tamponade, thrombosis-pulmonary or cardiac, toxin, tension pneumothorax, and trauma).

**Table 3.** Reference chart of the treatment algorithm for pediatric bradycardia with poor perfusion

| Drug        | Detail                                                                                                                                         |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| Atropine    | IV or IO administration, 0.02 mg/kg<br>Endotracheal administration, 0.04 to 0.06 mg/kg                                                         |
| Epinephrine | IV or IO administration, 0.01 mg/kg (0.1 mL/kg of 1:10,000 solution)<br>Endotracheal administration, 0.1 mg/kg (0.1 mL/kg of 1:1,000 solution) |

IV, intravenous; IO, intraosseous.

as fever, respiratory distress, dehydration, hypovolemia, or pain. The underlying cause should be corrected.

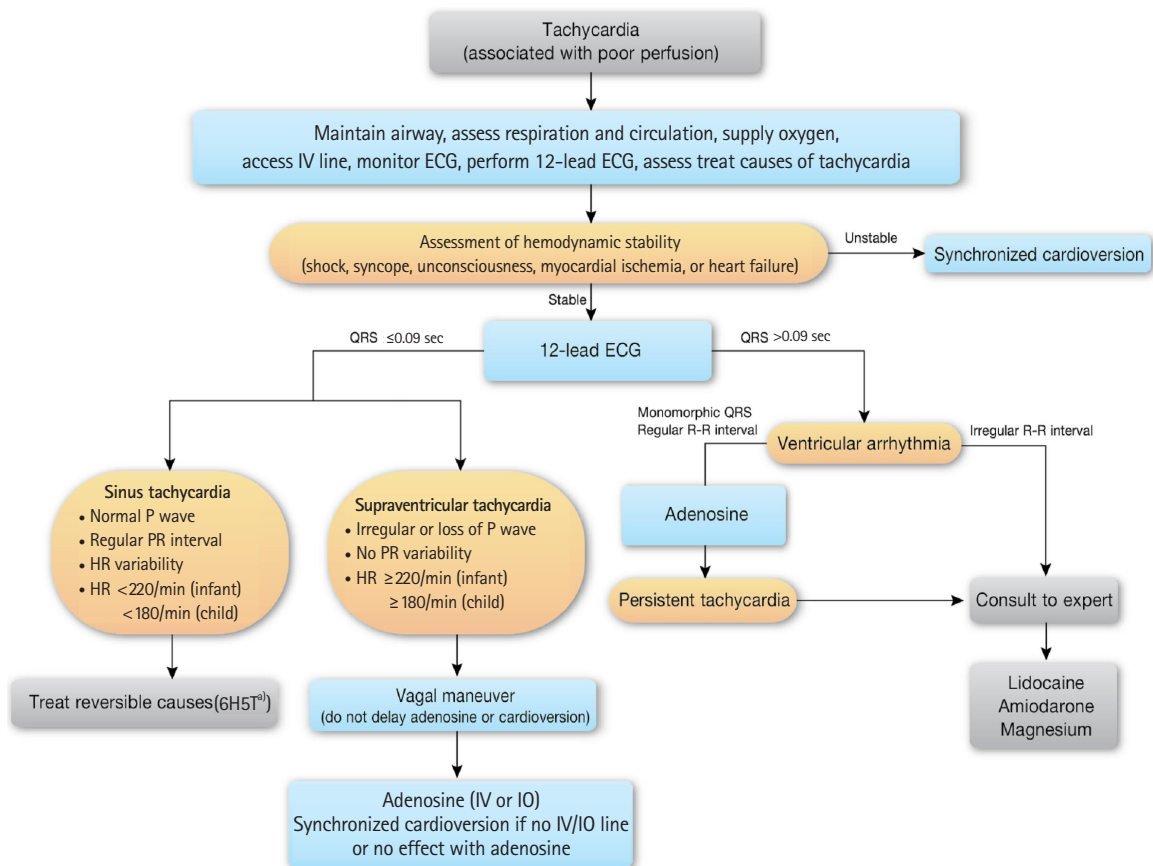
#### Supraventricular tachycardia

If IV or IO access is secured, adenosine 0.1 mg/kg (maximum, 6 mg) can be administered. If there is no response, the second administration of adenosine 0.2 mg/kg (maximum, 12 mg) can be given. If possible, two syringes should be connected with a T-connector or stopcock, and adenosine should be administered quickly through the first syringe, followed by a rapid flush of 5 to 10 mL of normal saline via the second syringe. In children older than 1 year with SVT that does not respond to adenosine, administration

of verapamil at a dose of 0.1 to 0.3 mg/kg via IV or IO access may be considered. However, because verapamil may induce myocardial depression, hypotension, or cardiac arrest, it is advisable to consider administration only after consultation with a pediatric cardiologist. If the patient is hemodynamically unstable, IV or IO access is not secured, or adenosine is ineffective, electrical synchronized cardioversion should be attempted. In conscious children, sedatives should be administered beforehand, and cardioversion should initially be started at an energy dose of 0.5 to 1 J/kg. If a normal sinus rhythm is not restored, the dose may be increased (up to 2 J/kg). If a second electrical cardioversion fails or tachycardia recurs rapidly, amiodarone administration may be considered before the third cardioversion, and consultation with a pediatric cardiologist is recommended. Monitor the ECG and blood pressure while administering amiodarone 5 mg/kg slowly over 20 to 60 minutes.

#### Wide QRS tachycardia

Wide QRS tachycardia is commonly caused by VT, but it may also have a supraventricular origin. Since all arrhythmia treatments can cause severe side effects, it is advisable to consult with a specialist



**Fig. 4.** Algorithm for treatment of pediatric tachycardia with poor perfusion signs. IV, intravenous; ECG, electrocardiography; HR, heart rate; IO, intraosseous. <sup>a</sup>6H (hypothermia, hypoxia, hypovolemia, hypokalemia/hyperkalemia, hypoglycemia, and hydrogen ion-acidosis) and 5T (cardiac tamponade, thrombosis-pulmonary or cardiac, toxin, tension pneumothorax, and trauma).

**Table 4.** Reference chart of the treatment algorithm for pediatric tachycardia with poor perfusion

| Treatment                | ECG                                                                             | Dose                                                                                                                                                    |
|--------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| Electrical cardioversion | Any QRS with hemodynamic compromise                                             | Start from 0.5–1.0 J/kg<br>Increase 2 J/kg if no effect<br>Do not delay<br>Sedate if necessary                                                          |
| Drug                     |                                                                                 |                                                                                                                                                         |
| Adenosine                | Stable, regular, narrow or wide QRS tachycardia                                 | First dose: 0.1 mg/kg IV bolus (maximum, 6 mg), then normal saline > 5 mL<br>Second dose: 0.2 mg/kg IV bolus (maximum, 12 mg) then normal saline > 5 mL |
| Amiodarone               | Stable, regular, narrow or wide QRS tachycardia<br>Stable, wide QRS tachycardia | IV or IO infusion, 5 mg/kg over 20–60 min<br>Daily maximum, 300 mg                                                                                      |

ECG, electrocardiogram; IV, intravenous; IO, intraosseous.

before treating hemodynamically stable pediatric patients with arrhythmia. For hemodynamically unstable patients, synchronized cardioversion should be initiated with an initial dose of 0.5 to 1 J/kg, and if unsuccessful, the dose should be increased to 2 J/kg. If the patient is conscious, sedation should be considered before cardioversion. If the patient is hemodynamically stable (without hypotension or signs of shock) and the rhythm is regular with a monomor-

phic QRS morphology, adenosine administration may be considered. The first dose should be 0.1 mg/kg (maximum, 6 mg), and if there is no response, the second dose should be increased to 0.2 mg/kg (maximum, 12 mg). However, adenosine should be avoided in patients with pre-excitation syndrome who present with wide QRS tachycardia. Adenosine can be used to differentiate between VT and SVT, and it can be used to convert a wide QRS tachycardia of

supraventricular origin to a normal sinus rhythm. Adenosine may be considered only if the rhythm is regular and the QRS morphology is monomorphic. Consult with a pediatric cardiologist to consider pharmacological cardioversion using amiodarone or procainamide. Amiodarone should be administered at a dose of 5 mg/kg via slow IV infusion over 20 to 60 minutes under continuous ECG and blood pressure monitoring; if hypotension occurs or the QRS interval widens, the infusion should be slowed or discontinued. Avoid the simultaneous administration of amiodarone and procainamide unless directed by a pediatric cardiologist.

## ECPR USING ECMO

Resuscitation using ECMO refers to the use of venoarterial ECMO in patients who do not achieve ROSC after cardiac arrest. Because CPR using ECPR requires substantial resources and multidisciplinary collaboration, the application of ECPR should be limited to hospitals with appropriate facilities (weak recommendation, low certainty). While some studies suggest that ECPR improves outcomes after cardiac arrest, evidence remains insufficient to support its routine use in all cardiac arrest cases [72–85]. In pediatric cases with IHCA, ECPR may be considered when conventional CPR fails to achieve ROSC. Some studies report that the use of ECPR in pediatric patients who underwent more than 10 min of CPR due to IHCA improved hospital discharge rates and neurologic survival rates [76]. In pediatric cases with IHCA, ECPR can be beneficial when implemented in settings with established protocols, specialized expertise, and appropriate equipment [86]. Therefore, in pediatric patients with IHCA who are unresponsive to conventional CPR, ECPR may be considered for a selected patient population (e.g., cardiac disease) if a facility capable of providing ECMO-facilitated CPR is available (e.g., an established ECPR protocol, trained personnel, and appropriate equipment) (weak recommendation, very low certainty). However, in cases of cardiac arrest not of cardiac origin, especially in OHCA, evidence for applying ECPR as part of routine CPR treatment remains insufficient [59,87,88].

## RESUSCITATION IN SPECIAL SITUATIONS

### Septic shock

Early aggressive fluid resuscitation is considered a cornerstone of treatment for pediatric septic shock; however, its effectiveness remains a subject of controversy, and the certainty of evidence for this approach is currently very low. Many existing treatment guidelines recommend a rapid bolus of crystalloid fluid 20 mL/kg

during the initial phase [89,90]. The 2020 Surviving Sepsis Campaign International Guidelines recommend repeated 10–20 mL/kg boluses within the first hour, up to a total of 40–60 mL/kg. However, in patients without hypotension or in settings where intensive care is unavailable, rapid fluid boluses are not recommended [91]. Rapid fluid boluses increase the risk of mortality and the need for mechanical ventilation [92–96]; although they may transiently improve circulation, these effects are not sustained [97]. Two systematic reviews published since 2015 identified no clinical benefits of rapid fluid bolus therapy [98,99]. In summary, for infants and children with suspected septic shock, 10–20 mL/kg boluses should be administered over 10 minutes, with the total volume not exceeding 40–60 mL/kg (weak recommendation, very low certainty of evidence). Conversely, routine rapid fluid boluses are not suggested for infants and children with febrile illness in the absence of hypotension (weak recommendation, very low certainty of evidence). As it is clinically challenging to distinguish volume-responsive shock from cardiogenic shock in infants and children, patients must be assessed for signs of fluid responsiveness and fluid overload after each bolus (strong recommendation, very low certainty of evidence). A 2015 systematic review found no difference in the effectiveness of crystalloid and colloid solutions [100]. There is ongoing controversy regarding the difference between the therapeutic efficacies of balanced crystalloid solutions, represented by lactated Ringer's, and unbalanced crystalloids, such as normal saline. Among the studies conducted since 2015, two failed to demonstrate the benefits of balanced crystalloid solutions [101,102], whereas one study reported that their use improved survival rates [103]. Moreover, normal saline is known to cause hyperchloremic metabolic acidosis, which can adversely affect patient prognosis. In summary, balanced crystalloid solutions are recommended as the first-line agent for rapid bolus therapy; however, normal saline and colloid solutions, such as albumin, may be used as alternatives (weak recommendation, low certainty of evidence). If the patient's condition fails to improve despite multiple fluid boluses, vasoactive agents or inotropes should be initiated early. In cases of shock refractory to vasoactive agents or inotropes, administration of stress-dose corticosteroids may be considered.

### Trauma and trauma-induced hemorrhagic shock

In cases of hemorrhagic shock, rapid boluses of crystalloid solutions should be minimized, and early blood transfusion should be considered [104–109]. In cases of severe circulatory failure, transfusion of plasma, platelets, fibrinogen, clotting factors, or whole blood should be considered to enhance hemostatic function

[110–112]. Fluid therapy should be guided by clinical endpoints, including mean arterial pressure (MAP), lactate, hemoglobin, clinical assessment, pH, and coagulopathy, to maintain adequate tissue perfusion while avoiding fluid overload [113]. Although based on adult data, excessive fluid administration is known to be associated with poorer outcomes; therefore, permissive hypotension, targeting a MAP at the lower end of the fifth percentile for the age group, should be considered [114,115]. However, permissive hypotension should be avoided in cases of potential traumatic brain injury, as it may exacerbate secondary brain damage. In pediatric patients with severe hemorrhage requiring transfusion, tranexamic acid should be administered within 3 hours of the initial injury. Tranexamic acid should also be considered for patients with suspected moderate traumatic brain injury (Glasgow Coma Scale score, 9–13) who exhibit normal pupillary reactivity. Administer a loading dose of tranexamic acid 15–20 mg/kg (maximum, 1 g) via rapid IV infusion, followed by a maintenance infusion of 2 mg/kg/hr for at least 8 hours or until hemorrhage is controlled [116].

### Cardiac arrest due to myocarditis and dilated cardiomyopathy

Patients with acute myocarditis exhibiting high-risk ECG changes, such as arrhythmias, atrioventricular block, or ST-segment deviations, are at high risk for cardiac arrest; therefore, continuous, close monitoring in the ICU is mandatory [117]. In patients with reduced cardiac output due to myocarditis or dilated cardiomyopathy, early initiation of extracorporeal life support may help prevent cardiac arrest; however, the supporting evidence remains limited [118–120]. Considering that successful resuscitation is extremely challenging in these patients, early transfer to a center capable of providing extracorporeal life support, such as extracorporeal CPR or ventricular assist device support, is suggested (weak recommendation, very low certainty of evidence).

## MONITORING OF PATIENTS DURING RESUSCITATION

### Electrocardiography

Continuous ECG monitoring is recommended during resuscitation to evaluate responses to pharmacological interventions and other clinical therapies.

### Pulse oximetry

During cardiac arrest, the profound decrease in cardiac output results in insufficient peripheral pulsatile blood flow; consequent-

ly, pulse oximetry is not an appropriate method for monitoring oxygen saturation during CPR.

### Blood pressure

Two observational studies conducted in the setting of IHCA, involving patients with invasive arterial blood pressure monitoring at the time of cardiac arrest, examined the relationship between DBP and cardiac arrest outcomes. Research indicates that during the first 10 minutes of CPR, maintaining a DBP of at least 25 mmHg in infants under 1 year of age and at least 30 mmHg in children 1 year and older is associated with higher rates of ROSC, survival to hospital discharge, and favorable neurologic outcomes compared to those with lower DBP [121,122]. Therefore, in pediatric patients with preexisting arterial access during cardiac arrest, it is suggested to maintain DBP above 25 mmHg for infants under 1 year and above 30 mmHg for children 1 year and older (weak recommendation, very low certainty of evidence). Due to insufficient evidence comparing outcomes and prognosis between patient groups monitored with a specific SBP target versus those without, it is difficult to recommend a specific SBP target during cardiac arrest.

### End-tidal carbon dioxide

Continuous monitoring of end-tidal carbon dioxide (ETCO<sub>2</sub>) is helpful in evaluating the adequacy of chest compressions during resuscitation. During resuscitation, if the ETCO<sub>2</sub> level is consistently below 10 mmHg, efforts should be made to increase cardiac output through more effective chest compressions; simultaneously, caution should be exercised to ensure that hyperventilation is not occurring during manual breaths. A rapid and sustained increase in ETCO<sub>2</sub> levels (above 30 mmHg) can be considered an indicator of ROSC. Monitoring ETCO<sub>2</sub> may serve as a more immediate indicator for identifying ROSC as compared to interrupting chest compressions for a pulse check [123]. The administration of vasoconstrictors, such as epinephrine, may decrease pulmonary blood flow and lead to a reduction in ETCO<sub>2</sub>. Conversely, ETCO<sub>2</sub> may increase following the administration of sodium bicarbonate, so clinicians must carefully account for these pharmacological effects during assessment [124,125]. A recent prospective multicenter pediatric ICU CPR study demonstrated that ETCO<sub>2</sub> of above 20 mmHg during resuscitation was not associated with survival to hospital discharge or ROSC rates, showing no significant difference in ETCO<sub>2</sub> levels between survivors and nonsurvivors [126]. However, this study was limited to a small cohort of critically ill patients and analyzed measurements obtained during the first 10 minutes of resuscitation. Given the potential confounding effects

of ventilation status and medication administration, further research is required to evaluate the utility of  $\text{ETCO}_2$  measurement in pediatric CPR.

## POST-RESUSCITATION BUNDLE OF CARE

It is recommended that pediatric patients who achieve ROSC be managed in the ICU. Respiratory and cardiovascular management should be implemented to maintain adequate ventilation and oxygenation. Clinicians must actively address issues such as respiratory failure and shock, and in cases of coma, targeted temperature management (TTM) may be considered.

### Targeted temperature management

A systematic review was conducted, incorporating two randomized clinical trials and eight cohort studies involving comatose pediatric patients who achieved ROSC. The study compared neurologic outcomes, survival rates, and adverse effects in 2,060 patients and found no significant differences between TTM at 32 to 34 °C and either TTM at 36 to 37.5 °C or no active temperature control [127]. In a subgroup analysis focusing on pediatric patients with OHCA, TTM at 32 to 34 °C was found to improve short-term (30 days) and medium-term (6 months) survival rates when compared to TTM at 36 to 37.5 °C or no active temperature control [128]. In pediatric patients with IHCA, TTM at 32 to 34 °C was associated with lower survival rates and poorer neurologic outcomes at 3 to 6 months [129]. In an analysis based on the cause of cardiac arrest, TTM at 32 to 34 °C was associated with improved short-term (30 days) and medium-term (6 months) survival rates compared to TTM at 36 to 37.5 °C or no active temperature control in pediatric patients with asphyxial cardiac arrest [128]. However, in cases of drowning or cardiogenic cardiac arrest, there were no significant differences in survival rates or neurologic outcomes. Based on this evidence, there is insufficient support to recommend a specific range for TTM (32–34 °C vs. 36–37.5 °C) in pediatric cardiac arrest patients after ROSC. However, studies indicate that post-cardiac arrest hyperthermia is common and significantly associated with poor neurologic outcomes. The implementation of TTM is expected to play a role in actively treating and preventing hyperthermia. Therefore, in comatose pediatric patients after ROSC, active temperature monitoring is essential to prevent hyperthermia, regardless of whether TTM is implemented. When TTM is applied, setting the target temperature within either 32 to 34 or 36 to 37.5 °C is suggested (weak recommendation, very low certainty of evidence). While optimal methods for cooling and rewarming have yet to be es-

tablished, unless there is another reason for rapid rewarming, the temperature during rewarming should not increase by more than 0.5 °C every 2 hours.

### Respiratory management

There are no randomized controlled trials comparing survival and neurologic outcomes based on specific target levels for  $\text{PaO}_2$  and  $\text{PaCO}_2$  after pediatric resuscitation. However, observational studies with low certainty of evidence indicated that while hyperoxemia or hypoxemia was not significantly associated with prognosis, hypercapnia and hypocapnia were linked to lower survival rates [130–133]. Therefore, it is recommended to maintain normoxia and normocapnia in pediatric patients after ROSC unless there are specific contraindications (weak recommendation, low certainty of evidence).

### Cardiovascular management

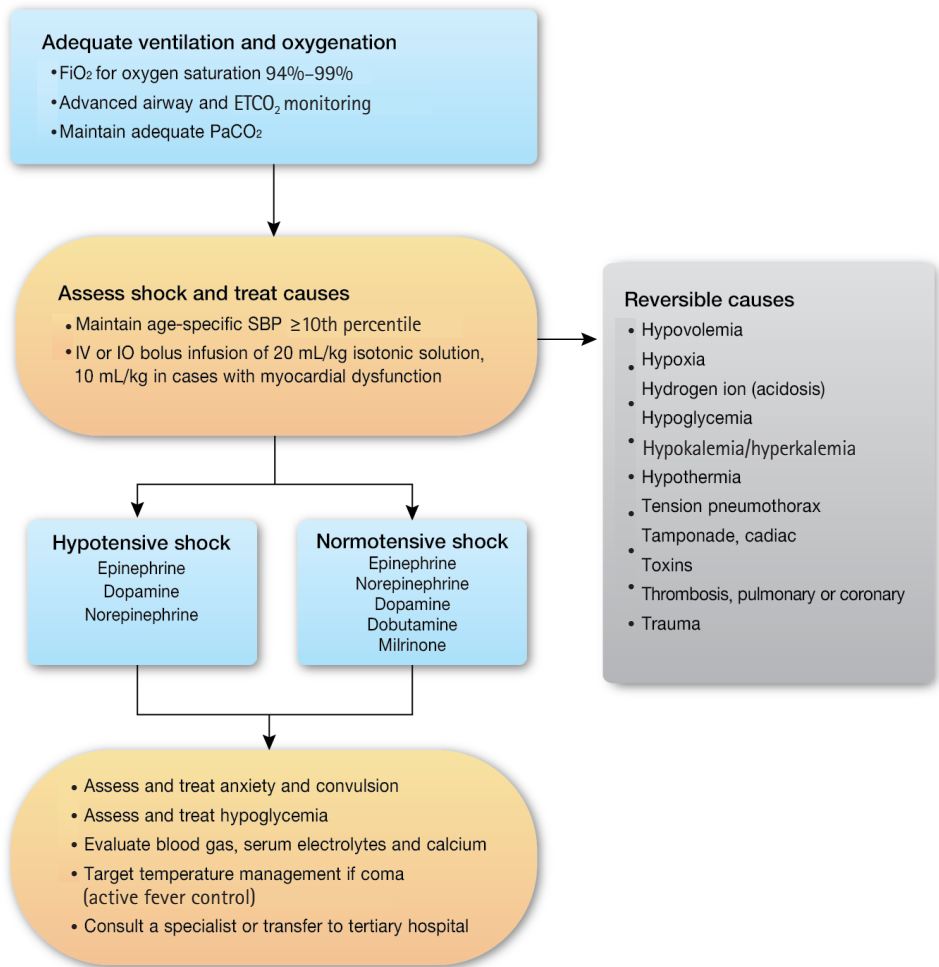
In patients with persistent cardiovascular instability, invasive arterial pressure monitoring via an indwelling arterial catheter should be implemented whenever possible. In four observational studies involving pediatric patients with IHCA and OHCA, those with SBP above the fifth percentile for age during the first 6 hours after ROSC demonstrated better survival rates compared to those with SBP at or below the fifth percentile. Furthermore, in an observational study analyzing SBP above versus below the 10th percentile for age, the group with SBP above the 10th percentile showed superior survival rates [134–138]. Hypotension is common during the post-ROSC period and is significantly associated with poor outcomes [139–141]. In pediatric patients with ROSC, SBP should be maintained at or above the 10th percentile for age during the first 6 hours; to achieve this outcome, the administration of IV fluids or inotropes is recommended (weak recommendation, very low certainty of evidence).

In cases of hypotension, unless cardiac function is impaired, an initial bolus of crystalloid fluid 20 mL/kg should be administered. If hypotensive shock persists, the administration of epinephrine, dopamine, or norepinephrine should be considered. While evaluating the shock state, clinicians should identify and manage reversible causes (6H and 5T) simultaneously with resuscitative efforts. If the patient has normal blood pressure but remains in shock after the bolus, vasopressor administration may be considered. When an IO access is in place, the IO needle should be removed only after a secure central venous line has been established. If the patient remains comatose after ROSC, TTM should be considered. When consulting with specialists, smaller health-care facilities should prepare to transfer the patient to a tertiary

care center (Fig. 5). The medications used to maintain cardiac output are listed in Table 5.

### Neurologic management

Nonconvulsive seizures and nonconvulsive status epilepticus are common after pediatric cardiac arrest and difficult to detect without electroencephalographic monitoring [142,143]. EEG



**Fig. 5.** Algorithm for the treatment of shock in children. FiO<sub>2</sub>, fraction of inspired oxygen; ETCO<sub>2</sub>, end-tidal carbon dioxide; SBP, systolic blood pressure; IV, intravenous; IO, intraosseous.

**Table 5.** Medications for maintenance and stabilization of the cardiac output

| Drug           | Dose                                                                                  | Detail                                                                               |
|----------------|---------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Epinephrine    | 0.1–1 µg/kg/min IV/IO infusion                                                        | Inotrope, chronotrope, vasodilation at low doses, and vasoconstriction at high doses |
| Dopamine       | 2–20 µg/kg/min IV/IO infusion                                                         | Renal and splanchnic vasodilation at low doses and vasoconstriction at high doses    |
| Dobutamine     | 2–20 µg/kg/min IV/IO infusion                                                         | Inotrope, vasodilator                                                                |
| Norepinephrine | 0.1–2 µg/kg/min IV/IO infusion                                                        | Vasoconstrictor                                                                      |
| Amrinone       | 0.75–1 mg/kg IV/IO over 5 min (may repeat up to two times); then 5–10 µg/kg/min       | Inodilator                                                                           |
| Milrinone      | Loading: 50 µg/kg IV/IO over 10–60 min followed by 0.25–0.75 µg/kg/min IV/IO infusion | Inodilator                                                                           |
| Nitroprusside  | Initial: 0.5–1 µg/kg/min; then titrate up to 8 µg/kg/min as needed                    | Vasodilator, dilute with D5W                                                         |

IV, intravenous; IO, intraosseous.

monitoring within 1 week after cardiac arrest helps assess neurologic outcomes [143–147]. Additionally, it may be helpful in detecting seizures in patients receiving ECMO. However, further research is needed to determine whether this monitoring improves neurologic outcomes.

There are no pediatric studies evaluating whether prophylactic anticonvulsant administration after ROSC improves neurologic outcomes. Moreover, referencing adult studies, there is insufficient evidence to recommend the routine use of prophylactic anticonvulsants. It is recommended that prophylactic anticonvulsants not be used routinely after resuscitation (good practice statement). Similarly, no pediatric studies have evaluated whether treating seizures after resuscitation improves neurologic outcomes. Convulsive status epilepticus and nonconvulsive status epilepticus are associated with poor prognosis [142]. Therefore, treatment of clinical seizures is recommended when present (good practice statement) [146,148].

## PROGNOSTIC FACTORS AFTER ROSC

Predicting the prognosis of pediatric patients who survive cardiac arrest is complex and challenging. Studies have been conducted using clinical examination findings, blood biomarkers, electrophysiologic tests such as EEG, and imaging studies such as brain CT or MRI to predict prognosis. Clinicians must exercise caution when selecting prognostic factors for poor neurologic outcomes. Prognostic factors for poor neurologic outcomes with a high false-positive rate should not be used to justify discontinuing life-sustaining treatment in pediatric patients who may later survive or exhibit favorable neurologic outcomes. To date, no studies have specifically repeated investigations on individual post-resuscitation prognostic factors. The field of identifying tools to predict neurologic outcomes is relatively new; however, studies to date have been limited by small numbers of studies and patients, substantial heterogeneity, and a high risk of bias. Therefore, neurologic outcomes in pediatric patients after ROSC should be carefully evaluated using multiple modalities. Repeated neurologic examinations, serum biomarkers, EEG, and imaging tests such as CT or MRI should be performed and considered in combination (strong recommendation, low certainty).

### Neurologic examination

After ROSC, repeated assessment of pupillary reflexes is recommended, and the results should be used as indicators for predicting favorable or poor neurologic outcomes (good practice statement). However, due to the limited evidence, research findings

should be interpreted in conjunction with other assessment criteria.

Three studies evaluated the presence of bilateral pupillary reflexes within 12 hours of ROSC. According to the results, the sensitivity for identifying favorable neurologic outcomes (Pediatric Cerebral Performance Category [PCPC], 1–2 or 1–3) in patients with bilateral pupillary responses was high, and the false-positive rate was low [149–151]. However, beyond 24 hours after ROSC, although the sensitivity of bilateral pupillary responses remained high, the false-positive rate was also elevated, suggesting insufficient reliability for predicting neurologic outcomes [147,150,152–155]. Therefore, bilateral pupillary responses assessed more than 24 h after cardiac arrest are less reliable, and at any time point, pupillary response alone is insufficient to predict neurologic outcomes.

Three studies evaluated whether loss of pupillary reflexes at 48 and 72 hours after ROSC predicted poor neurologic outcomes. These studies reported a false-positive rate of less than 1%, but with wide confidence intervals and low sensitivity [150,154,156]. Despite the very low false-positive rate, the low sensitivity suggests that this measure is only a reliable prognostic indicator when used in conjunction with other prognostic factors for neurologic outcomes. Therefore, if normal pupillary reflexes are present within 12 hours after ROSC, favorable neurologic outcomes can be predicted. If pupillary reflexes are absent between 48 and 72 hours after ROSC, poor neurologic outcomes can be predicted.

### Serum biomarker

If serum lactate levels are below 2 mmol/L within 12 hours after ROSC, the sensitivity for predicting favorable neurologic outcomes ranges from 16% to 28%, and the false-positive rate is very low, making it a reliable prognostic factor [157–159]. In contrast, lactate levels below 2 mmol/L at 24 and 48 hours after ROSC, or below 5 mmol/L at 1 and 24 hours after ROSC, were associated with a high false-positive rate, rendering them insufficient as prognostic factors for predicting neurologic outcomes [157,160].

S100B, NSE, myelin basic protein, neurofilament light, ubiquitin C-terminal hydrolase-L1, glial fibrillary acidic protein, and tau have been studied at various time points after ROSC; however, reliable findings have not yet been established [152,161–163].

Therefore, when interpreted in conjunction with other prognostic criteria, plasma lactate levels below 2 mmol/L within 12 hours after ROSC in pediatric patients may be used to predict favorable neurologic outcomes (expert consensus recommendation). However, there is insufficient evidence to recommend or

limit the use of blood biomarkers such as S100B and NSE for predicting neurologic outcomes, regardless of the timing after ROSC.

### Electroencephalography

It is recommended to use EEG for up to 72 hours after ROSC to assess neurologic outcomes (expert consensus recommendation). Several studies have analyzed the associations among EEG examinations performed at various time points after cardiac arrest. In studies evaluating EEG conducted 6–12 and 24 hours after ROSC, the false-positive rate for favorable neurologic outcomes was below 29%, and sensitivity ranged widely [143,147,155,164–s166]. In studies analyzing EEG findings at 48 and 72 hours after ROSC, the false-positive rate for favorable neurologic outcomes was reported to vary widely [152,154,165,167]. Therefore, when interpreted alongside other prognostic criteria, continuous or normal background activity on EEG within the first 72 hours after ROSC may be used as evidence supporting favorable neurologic outcomes. In some studies, sleep architecture at 6–12 hours and sleep spindle appearance at 24 hours showed a higher-than-threshold false-positive rate and moderately high sensitivity for predicting favorable neurologic outcomes, respectively [147,155]. In two studies, EEG reactivity observed at 6–12 and 24 hours after ROSC was associated with a false-positive rate below 27% and a sensitivity ranging from 53% to 63% for predicting favorable neurologic outcomes [143,146]. However, at 48 hours, EEG reactivity was not reliable for predicting favorable neurologic outcomes because of a high false-positive rate [143]. Therefore, when interpreted in conjunction with other prognostic criteria, the appearance of sleep spindles or stage 2 sleep patterns on EEG performed between 12 and 24 hours after cardiac arrest can be used for predicting favorable neurologic outcomes. Additionally, the presence of EEG reactivity on EEG performed between 6 and 24 hours after cardiac arrest in infants and children may be used to predict favorable neurologic outcomes.

Three studies found that the presence of persistent seizures at 24–72 hours after ROSC predicted poor neurologic outcomes with a very low false-positive rate (0%) [154,166,167]. However, at 4–6 and 6–12 hours, the false-positive rate was higher and sensitivity was low [146,164]. The presence of burst suppression, burst attenuation, or generalized periodic epileptiform discharges within 24 hours after ROSC showed a wide range of false-positive rates and low sensitivity in predicting poor neurologic outcomes [143,155,164,168]. Three studies reported a low false-positive rate for predicting poor neurologic outcomes at 48–72 hours after ROSC, with a widely varying sensitivity [149,154,167]. Therefore, when interpreted alongside other prognostic factors,

the presence of persistent seizures, burst suppression, burst attenuation, or generalized periodic epileptiform discharges on EEG performed at 24–72 hours after cardiac arrest may be considered indicators of poor neurologic outcomes.

### Neuroimaging

Performing neuroimaging in patients after ROSC is useful for identifying the cause of cardiac arrest and assessing the extent of brain injury. CT and MRI findings change over time after cardiac arrest; therefore, the timing of neuroimaging studies should be considered when interpreting these findings. Moreover, these findings should be used in conjunction with other prognostic factors.

In three studies, the absence of diffusion restriction or any abnormal findings on MRI was associated with a low false-positive rate and a wide range of sensitivity for predicting favorable neurologic outcomes [154,169,170]. On average, 4 days after ROSC, an apparent diffusion coefficient above a specific threshold in more than 93% of the brain volume predicted favorable neurologic outcomes with high sensitivity and a relatively low false-positive rate [171]. In some studies, the absence of abnormal findings in specific localized areas showed very high sensitivity for favorable neurologic outcomes, but the false-positive rate was also very high [156,172]. In three studies, the presence of a high ischemic burden involving more than 10% of brain volume at a mean of 4 days after ROSC predicted poor neurologic outcomes with moderate sensitivity and a low false-positive rate [168,171,173]. Therefore, when interpreted alongside other prognostic factors, normal MRI findings obtained between 72 hours and 2 weeks after cardiac arrest can be used to predict favorable neurologic outcomes, and abnormal MRI findings demonstrating a high ischemic burden obtained at 72 hours after cardiac arrest may be used to predict poor neurologic outcomes (expert consensus recommendation).

One study analyzed CT findings obtained within 24 hours after cardiac arrest in 78 pediatric patients. Loss of gray-white matter differentiation on CT was associated with a very low false-positive rate and moderate sensitivity for predicting poor neurologic outcomes (PCPC > 3) at hospital discharge; however, the study was not blinded [174]. In two studies, the absence of gray-white matter differentiation on CT within 24 hours after ROSC was associated with a wide range of sensitivity and false-positive rates for predicting favorable neurologic outcomes at hospital discharge. The absence of other abnormal CT findings defined by the researchers showed high sensitivity for predicting favorable neurologic outcomes, but the false-positive rate was also high and

variable [174,175]. Therefore, when interpreted alongside other prognostic factors, loss of gray-white matter differentiation observed on CT within 24 hours after cardiac arrest is recommended as an indicator of poor neurologic outcomes (expert consensus recommendation). However, normal brain CT findings obtained within the first 48 hours after cardiac arrest are not recommended for use as an indicator of favorable neurologic outcomes (expert consensus recommendation).

## TERMINATION OF RESUSCITATION ATTEMPTS IN PEDIATRIC PATIENTS

There is no universal indicator to guide the decision on when to discontinue resuscitation attempts. In patients with OHCA, the likelihood of effective resuscitation increases when the event is witnessed, when resuscitation is performed immediately by a lay rescuer, or when professional rescuers arrive quickly after collapse. However, duration of resuscitation, cause of cardiac arrest, preexisting conditions, age, location of the arrest, or whether the event was witnessed is not directly correlated with prognosis [176,177]. The decision to terminate resuscitation attempts should be made by comprehensively considering all factors for each case.

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### Conflicts of interest

Jisook Lee, Sung Phil Chung, Chun Song Youn, Mi Jin Lee, and Sung Oh Hwang are editorial board members of this journal, but were not involved in the peer reviewer selection, evaluation, or decision process of this article. The authors have no other conflicts of interest to declare.

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