

2025 Korean Guidelines for Cardiopulmonary Resuscitation: Part 4. Adult advanced life support

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The 2025 Korean advanced life support guidelines were updated using a structured evidence evaluation process informed by recent randomized controlled trials and systematic reviews. The guideline development group prioritized patient-important outcomes and assessed the certainty of the evidence to formulate graded recommendations. For drug administration during adult cardiac arrest, intravenous access is the preferred initial route, with intraosseous access recommended when intravenous access cannot be rapidly established. Epinephrine remains the recommended vasopressor. Routine administration of vasopressin, either alone or in combination with corticosteroids, is not recommended for in-hospital or out-of-hospital cardiac arrest. In the absence of specific indications, the routine use of buffering agents and calcium is discouraged owing to insufficient evidence of their benefits and potential harm. Defibrillation recommendations were refined based on emerging evidence. In adults with refractory ventricular fibrillation or pulseless ventricular tachycardia after multiple unsuccessful defibrillation attempts, vector change or double sequential defibrillation may be considered in selected settings when performed by experienced teams with appropriate equipment. Airway management guidelines recommend cricothyroidotomy as a rescue technique when conventional airway management strategies fail. For patients receiving cardiopulmonary resuscitation while on mechanical ventilation, specific ventilator settings during chest compressions are recommended to optimize ventilation and minimize interference with high-quality cardiopulmonary resuscitation. The guidelines also address cardiopulmonary resuscitation-induced consciousness, allowing the cautious use of sedatives and/or analgesic agents when awareness interferes with resuscitation quality or safety. Overall, the guidelines emphasize evidence-based practice and individualized clinical decision-making.

Keywords Cardiopulmonary resuscitation; Heart arrest; Advanced life support

Received: February 14, 2026
Accepted: February 25, 2026

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How to cite this article:

Kim TY, Ahn GJ, Cha KC, Kim DH, Sohn Y, Song Y, Shim G, Kim DK, Oh Y, Wi J, Youn CS, Lee ML, Lee MJ, Lee BK, Lee BH, Lee J, Lee CH, Lee H, Jang Y, Jang YS, Jung YH, Jung WJ, Chung SP, Cho GC, Heo JS, Hwang SO. 2025 Korean Guidelines for Cardiopulmonary Resuscitation: Part 4. Adult advanced life support. Clin Exp Emerg Med 2026;13(Suppl 1):S32-S60.
<https://doi.org/10.15441/ceem.26.073>

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MAJOR UPDATES IN THE 2025 ADULT ADVANCED LIFE SUPPORT GUIDELINES

Route of drug administration during cardiac arrest

In adult patients with cardiac arrest, intravenous access should be attempted first for drug administration rather than intraosseous access (weak recommendation, low certainty of evidence). If intravenous access cannot be established during cardiopulmonary resuscitation (CPR), intraosseous access may be considered as an alternative route (good practice statement).

Combined administration of vasopressin and corticosteroids during cardiac arrest

In adult patients with in-hospital cardiac arrest, the routine addition of vasopressin and corticosteroids to standard resuscitation therapy during CPR is not recommended (weak recommendation, low certainty of evidence). Similarly, the routine administration of vasopressin and corticosteroids is not recommended for adult patients with out-of-hospital cardiac arrest (weak recommendation, very low certainty of evidence).

Use of buffering agents during cardiac arrest

In the absence of specific indications, routine use of buffering agents, such as sodium bicarbonate, is not recommended during resuscitation of adult patients with out-of-hospital cardiac arrest (weak recommendation, low certainty of evidence). Similarly, in the absence of specific indications, routine administration of buffering agents is not recommended for the management of adult patients with in-hospital cardiac arrest (weak recommendation, very low certainty of evidence).

Calcium administration during cardiac arrest

Routine administration of calcium is not recommended for adult patients with out-of-hospital cardiac arrest (strong recommendation, moderate certainty of evidence). Similarly, the routine use of calcium is not recommended in adult patients with in-hospital cardiac arrest (weak recommendation, low certainty of evidence).

Vector change and double sequential defibrillation

In adult patients with cardiac arrest who remain in ventricular fibrillation (VF) or pulseless ventricular tachycardia (pVT) after three or more consecutive defibrillation attempts, vector change defibrillation (weak recommendation, very low certainty of evidence) or double sequential defibrillation (weak recommendation, low certainty of evidence) may be considered by an experienced physician, provided that appropriately trained personnel and ad-

ditional defibrillation pads or defibrillators are immediately available. When double sequential defibrillation is used, a single operator sequentially activates the defibrillators (good practice statement).

Cricothyroidotomy during CPR

If standard airway management strategies fail, cricothyroidotomy may be considered during CPR. Appropriately trained providers may attempt emergency cricothyroidotomy to establish a surgical airway (good practice statement).

Mechanical ventilator settings during CPR

When cardiac arrest occurs in patients receiving mechanical ventilation and mechanical ventilation is continued rather than manual ventilation during CPR, a volume-controlled ventilation mode may be considered during chest compression. The ventilator should be set to deliver a tidal volume of 6 to 8 mL/kg of the predicted body weight, or adjusted to achieve a visible chest rise. Oxygen should be administered at a fraction of inspired oxygen (FiO₂) of 1.0. The respiratory rate should be set at 10/min with an inspiratory time of 1 to 2 seconds. Positive end-expiratory pressure (PEEP) should be maintained at 0 to 5 cm H₂O, and the peak airway pressure alarm may be set at 60 to 70 cm H₂O. Flow triggering should be disabled. Effective ventilation should be confirmed; if adequate ventilation cannot be ensured, providers should switch to manual ventilation (good practice statement).

Consciousness during CPR

If a patient does not achieve return of spontaneous circulation (ROSC) but temporarily regains consciousness as a result of chest compressions, this interferes with the delivery of high-quality CPR or poses a risk to the patient or providers. Sedatives, analgesics, or a combination of both may be considered at the lowest effective dose to relieve pain and distress (good practice statement). Administration of neuromuscular blocking agents alone in conscious patients during CPR is not recommended (good practice statement). The optimal regimen for sedation and analgesia during CPR remains uncertain; therefore, medication selection may be guided by regimens commonly used in critical care practice and local institutional protocols (good practice statement).

ADULT ADVANCED LIFE SUPPORT ALGORITHMS

Adult advanced life support for in-hospital cardiac arrest

When an advanced life support (ALS) team arrives at the scene of an in-hospital cardiac arrest where basic life support (BLS) is underway, defibrillation pads or electrodes should be immediately applied to the patient to enable cardiac rhythm assessment. If sufficient personnel are available, providers should rotate roles for chest compressions and ventilation to maintain high-quality CPR. If an advanced airway has not been established, a chest compression to ventilation ratio of 30:2 should be maintained, and 100% oxygen should be administered during ventilation.

Cardiac arrest rhythms are classified as VF, pulseless ventricular tachycardia (pVT), asystole, and pulseless electrical activity (PEA). VF and pVT are classified as shockable rhythms because they are amenable to defibrillation, whereas asystole and PEA are classified as nonshockable rhythms as defibrillation is not indicated. In patients with pVT and PEA, the absence of a carotid pulse should be confirmed. Because electrocardiographic rhythms may change during CPR, appropriate treatment strategies should be selected according to the rhythm identified during ALS (Fig. 1).

Management of shockable rhythms (VF or pVT)

If a shockable rhythm is identified on electrocardiographic analysis, defibrillation should be immediately performed (biphasic defibrillator, 120–200 J; monophasic defibrillator, 360 J). Following defibrillation, CPR should be resumed immediately and continued for 2 minutes without rhythm analysis. If the manufacturer's recommended energy dose for a biphasic defibrillator is unknown, a defibrillation energy of 200 J should be used.

During CPR, intravenous or intraosseous access should be established, and a 1-mg bolus of epinephrine should be administered, followed by an intravenous fluid bolus to facilitate rapid delivery of the drug to the central circulation. Intravenous access should be attempted first, and intraosseous access should be considered if intravenous access cannot be established. Epinephrine should be administered every 3 to 5 minutes until ROSC is achieved or resuscitation efforts are terminated.

After 2 minutes of CPR, cardiac rhythm should be reassessed. If a shockable rhythm persists, defibrillation should be repeated using the same or higher energy level, followed immediately by continued CPR. If high-quality CPR is ongoing and epinephrine is administered appropriately, placement of an advanced airway may be considered. Once an advanced airway is in place, ventilation may be delivered without interruption of chest compressions

at a rate of one breath every 6 seconds.

If endotracheal intubation is performed, monitoring end-tidal carbon dioxide (ETCO₂) may assist in assessing the quality of CPR and in detecting ROSC. If advanced airway placement is unfamiliar or unsuccessful, bag-mask ventilation should be continued with a compression to ventilation ratio of 30:2.

If VF or pVT persists after 2 minutes of CPR following the second defibrillation, the patient is considered to have refractory VF or pVT, and preparation for the administration of amiodarone or lidocaine is recommended. After an additional 2 minutes of CPR, if a shockable rhythm persists, a third defibrillation should be delivered using the same or a higher energy level, followed immediately by 2 minutes of CPR. In cases of persistent refractory VF or pVT, defibrillation energy may be increased to the maximum available level.

Amiodarone or lidocaine should be administered during CPR. If the shockable rhythm persists, the above sequence should be repeated, and a single additional dose of amiodarone or lidocaine at half of the initial dose may be administered. The identification and early correction of reversible causes of cardiac arrest, based on the patient's clinical context and medical history, are essential for achieving ROSC. If it does not interfere with CPR, point-of-care ultrasound (POCUS) may assist in identifying reversible causes. If ROSC is not achieved despite high-quality CPR, extracorporeal CPR should be considered.

Management of nonshockable rhythms (asystole or PEA)

Asystole refers to the absence of ventricular contraction, regardless of the presence or absence of atrial activity. PEA is defined as the presence of organized electrical activity on electrocardiography without a detectable pulse or blood pressure on palpation or noninvasive monitoring. PEA encompasses a heterogeneous group of rhythms, including pseudo-electromechanical dissociation, idioventricular rhythms, ventricular escape rhythms, post-defibrillation idioventricular rhythms, and brady-asystolic rhythms.

Asystole and PEA do not require defibrillation during CPR and are, therefore, classified as nonshockable rhythms. PEA may result from reversible causes, and the identification and correction of these causes may lead to successful resuscitation. Survival rates in patients with asystole are extremely low, and the primary opportunity for successful resuscitation in nonshockable rhythms lies in identifying and correcting reversible causes.

When a nonshockable rhythm is identified on electrocardiography, CPR should be initiated immediately. Intravenous or intraosseous access should be established as quickly as possible, and a

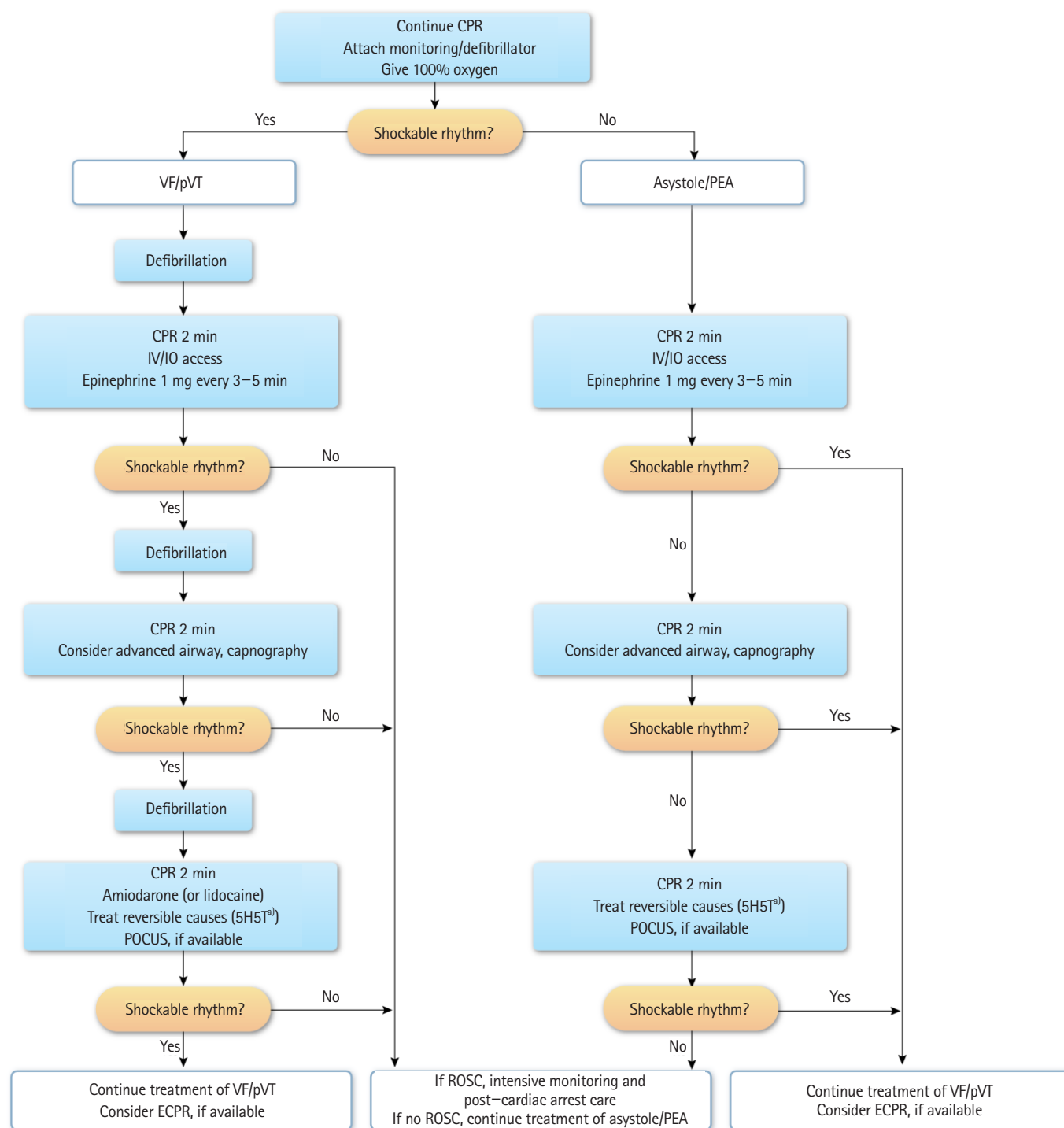


Fig. 1. Advanced life support algorithm for in-hospital cardiac arrest. CPR, cardiopulmonary resuscitation; VF, ventricular fibrillation; pVT, pulseless ventricular tachycardia; PEA, pulseless electrical activity; IV, intravenous; IO, intraosseous; POCUS, point-of-care ultrasound; ROSC, return of spontaneous circulation; ECPR, extracorporeal cardiopulmonary resuscitation. ³⁾The 5H indicates hypovolemia, hypoxia, hydrogen ion (acidosis), hyperkalemia/hypokalemia, and hypothermia, while the 5T indicates toxins, tamponade (cardiac), tension pneumothorax, thrombosis (coronary), and thrombosis (pulmonary).

1-mg bolus of epinephrine should be administered, followed by an intravenous fluid bolus. Epinephrine should be administered every 3 to 5 minutes until ROSC is achieved or resuscitation efforts are terminated.

After 2 minutes of CPR, cardiac rhythm should be reassessed. If a nonshockable rhythm persists, CPR should be continued, and placement of an advanced airway should be considered to allow ventilation without interruption of chest compressions. Once an advanced airway is in place, monitoring ETCO₂ may assist in evaluating CPR quality and detecting ROSC. If the rhythm remains nonshockable after reassessment, CPR should be continued, and efforts should focus on identifying and correcting the underlying cause of cardiac arrest, with POCUS when appropriate.

Post-cardiac arrest care

Patients who achieve ROSC after ALS should undergo intensive monitoring and integrated post-cardiac arrest care. Following ROSC, immediate management should include hemodynamic stabilization, optimization of ventilation and oxygenation, targeted temperature management, and consideration of coronary interventions for acute coronary syndrome. Post-cardiac arrest care is addressed in detail in Part 6.

Adult ALS for out-of-hospital cardiac arrest

The adult ALS for out-of-hospital cardiac arrest is largely similar to that for in-hospital cardiac arrest. However, for providers with limited experience in endotracheal intubation, bag-mask ventilation is preferred, and use of a supraglottic airway device is recommended as the initial advanced airway strategy. Providers who are unfamiliar with advanced airway placement should continue bag-mask ventilation.

In Korea, intraosseous access is not included within the scope of the practice of emergency medical technicians. Therefore, when emergency medical technicians perform ALS for out-of-hospital cardiac arrest, intraosseous access should not be attempted.

The duration of on-scene ALS should be determined under direct medical oversight. If the resuscitation team can provide ALS, including advanced airway placement and epinephrine administration, hospital transport may be considered after approximately 10 minutes of on-scene ALS. If the team is unable to provide ALS, hospital transport may be considered after approximately 6 minutes of CPR, in accordance with the BLS guidelines (Fig. 2).

Adult ALS during the COVID-19 pandemic

COVID-19 is transmitted through droplets and contact and has

an incubation period of 1 to 14 days (mean, 4–7 days), resulting in a high risk of person-to-person transmission. Although the evidence is indirect, chest compression and defibrillation may generate aerosols that increase the risk of infection among rescuers. Therefore, before initiating ALS in patients with confirmed or suspected COVID-19, rescuers should wear appropriate personal protective equipment (PPE) [1,2]. At a minimum, PPE should include level D full-body protective clothing or a waterproof long-sleeved gown, gloves, and eye protection (goggles or face shield), along with at least an N95 respirator (preferably a fold-type rather than a cup-type), an FFP3 respirator, or a powered air-purifying respirator.

For patients with a poor expected prognosis, the need for resuscitation should be reassessed, and ALS should be initiated only if resuscitation is deemed appropriate. The ALS team should consist of a minimum number of essential personnel, and the use of a mechanical chest compression device should be considered to minimize direct contact with the patient.

For rhythm assessment and defibrillation, pre-attached defibrillation pads should be used whenever possible. Ventilation should be provided using a bag-mask device with an attached high-efficiency particulate air (HEPA) filter. If an advanced airway has not been established, bag-mask ventilation performed by two experienced providers is more effective. A supraglottic airway device with an attached HEPA filter can be inserted to allow ventilation with minimal interruption of chest compressions.

If endotracheal intubation is attempted, a video laryngoscope should be used to minimize the proximity to the patient's airway, and the procedure should be performed by the most experienced provider to maximize the likelihood of first-pass success. Once an advanced airway is secured, ventilation should be provided with an attached HEPA filter.

After the termination of resuscitation efforts, PPE should be disposed of according to the infection control guidelines. Rescuers involved in resuscitation should wash their hands thoroughly with soap and water or disinfect them with alcohol-based hand sanitizers as soon as possible, and are advised to change their clothing. Local public health authorities should be contacted to determine the need for COVID-19 testing and self-isolation. The equipment and devices used during CPR should be cleaned or discarded according to manufacturer and institutional guidelines [3–5].

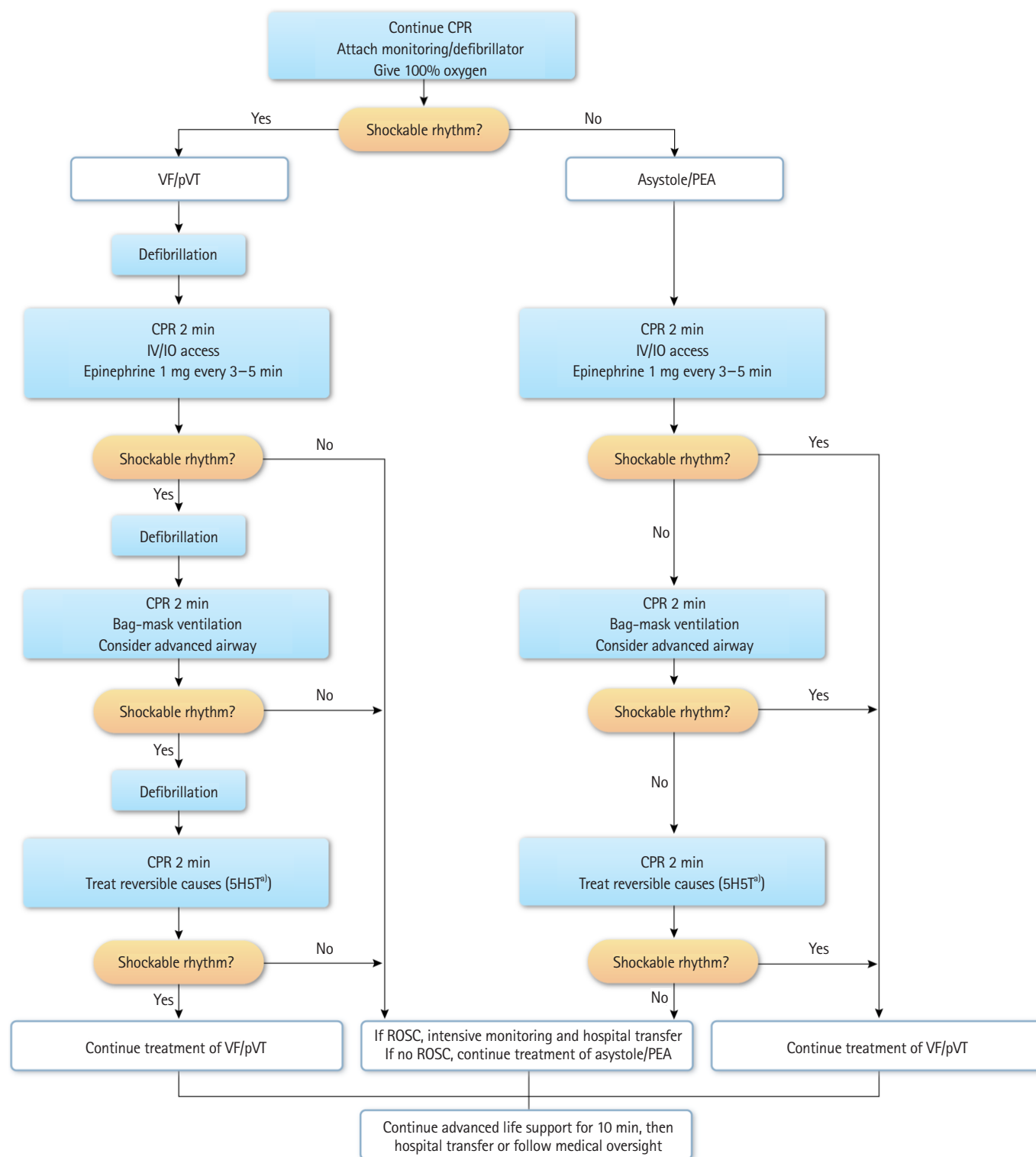


Fig. 2. Advanced life support algorithm for out-of-hospital cardiac arrest. CPR, cardiopulmonary resuscitation; VF, ventricular fibrillation; pVT, pulseless ventricular tachycardia; PEA, pulseless electrical activity; IV, intravenous; IO, intraosseous; ROSC, return of spontaneous circulation. ^{a)}The 5H indicates hypovolemia, hypoxia, hydrogen ion (acidosis), hyperkalemia/hypokalemia, and hypothermia, while the 5T indicates toxins, tamponade (cardiac), tension pneumothorax, thrombosis (coronary), and thrombosis (pulmonary).

ADULT ALS

Background for the revision of adult ALS in cardiac arrest

Adult ALS is a key component of the chain of survival in patients with cardiac arrest and aims to maintain effective systemic circulation and adequate oxygen delivery during high-quality BLS. It encompasses advanced airway management, vasopressor administration, defibrillation, use of antiarrhythmic agents, and circulatory support strategies, such as extracorporeal CPR, to restore circulation and support systemic perfusion. The 2025 Korean guidelines for adult ALS were developed through a structured review of scientific evidence addressing recommendations in the 2020 guidelines that were supported by limited evidence, insufficiently defined, or difficult to apply within the Korean healthcare system. Compared with the previous version, the 2025 guidelines provide more objective and explicit recommendations. The selection of key topics and the evidence review process are described in Part 1.

Since publication of the 2020 Korean Guidelines for Cardiopulmonary Resuscitation, several studies relevant to adult ALS have been reported. Randomized trials have evaluated epinephrine administration via intravenous versus intraosseous routes in adult cardiac arrest patients [6–8]. Additional randomized trials have compared combined administration of epinephrine, vasopressin, and corticosteroids with epinephrine alone in patients with in-hospital cardiac arrest [9]. Randomized trials evaluating the clinical effects of calcium administration in patients with out-of-hospital cardiac arrest have been reported [10]. Studies comparing conventional defibrillation with vector change defibrillation and double sequential defibrillation have been reported as have randomized trials evaluating extracorporeal CPR in out-of-hospital cardiac arrest [11,12]. Based on these newly published studies, the 2025 Korean guidelines for adult ALS revised relevant recommendations and introduced new recommendations. Updates include guidance on buffering agent administration during CPR, management of cardiac arrest caused by hyperkalemia, CPR in the prone position, management of patients who regain consciousness during CPR, ventilator settings during CPR in mechanically ventilated patients, and updated recommendations for ALS in patients with confirmed or suspected COVID-19.

Monitoring during CPR

During ALS, the use of monitoring devices that assess chest compression effectiveness and CPR quality and provide real-time feedback may help improve the quality of resuscitation [13]. ETCO₂, coronary perfusion pressure, diastolic arterial pressure, and

central venous oxygen saturation may be considered as representative physiological monitoring indicators during CPR. Among these, waveform ETCO₂ monitoring is recommended for assessing chest compression effectiveness during CPR, predicting the likelihood of ROSC, and confirming correct endotracheal tube placement [14–16].

Use of feedback devices during CPR

Feedback devices may be considered during CPR to monitor parameters, such as chest compression rate and depth and ventilation frequency to assess resuscitation quality. The simplest example is a metronome that provides auditory or visual cues to help maintain appropriate chest compression and ventilation rates. More advanced real-time CPR monitoring devices can measure chest compression rate, depth, recoil, pauses, and compression fraction and provide corresponding auditory or visual feedback [13]. However, evidence demonstrating that visual or auditory feedback devices or metronomes improves clinical outcomes in cardiac arrest remains insufficient. Therefore, routine use of feedback devices during CPR is not recommended. In clinical settings where real-time CPR feedback devices are already in use, continued use may be considered [17,18].

Physiological monitoring parameters during CPR

Few methods are available to directly assess hemodynamic status or CPR effectiveness during cardiac arrest. In addition to electrocardiographic rhythm analysis and pulse assessment, monitoring ETCO₂, coronary perfusion pressure, and central venous oxygen saturation can provide physiological information related to perfusion during CPR. These parameters correlate with cardiac output and myocardial blood flow during CPR, and may help predict the likelihood of ROSC.

(1) Measurement of ETCO₂ partial pressure

Capnography measures carbon dioxide produced by metabolism and transported to the lungs via circulating blood. Under normal circulatory conditions, ETCO₂ ranges from 35 to 40 mmHg. During cardiac arrest, carbon dioxide production continues, but the absence of circulation results in minimal pulmonary delivery and near-zero ETCO₂ levels. During CPR, pulmonary carbon dioxide delivery depends primarily on cardiac output generated by chest compressions. Low ETCO₂ levels generally indicate inadequate cardiac output, although low values may also result from bronchospasm, endotracheal tube obstruction or kinking, hyperventilation, use of a supraglottic airway device, or air leakage. The 2025 guidelines recommend ETCO₂ monitoring during CPR for

hemodynamic assessment, prediction of ROSC, and confirmation of correct endotracheal tube placement. Because ETCO_2 levels change proportionally with pulmonary perfusion during CPR, ETCO_2 monitoring is useful for assessing chest compression adequacy and predicting the likelihood of ROSC [15,16,19]. ETCO_2 monitoring may also confirm correct endotracheal tube placement after intubation [19]. If endotracheal intubation has been performed and ETCO_2 levels remain persistently low (< 10 mmHg) despite over 20 minutes of CPR, the likelihood of ROSC is low [15,20]. However, when a supraglottic airway device or bag-mask ventilation is used, the correlation between ETCO_2 monitoring and chest compression effectiveness remains insufficient [21]. ETCO_2 values should not be used as the sole indicator for assessing CPR quality or predicting ROSC. Monitoring ETCO_2 during CPR provides guidance for maintaining appropriate chest compression depth and rate and assists in identifying provider fatigue. A sudden and sustained increase in ETCO_2 levels indicates ROSC. Therefore, in intubated patients, waveform ETCO_2 monitoring may be considered during CPR to assess chest compression effectiveness and detect ROSC. If ETCO_2 levels remain below 10 mmHg, chest compressions should be adjusted to improve resuscitation quality. An abrupt rise to normal values (30–40 mmHg) should prompt evaluation for ROSC.

(2) Coronary perfusion pressure

During CPR, coronary perfusion pressure (CPP; defined as diastolic arterial pressure minus diastolic right atrial pressure) correlates with myocardial blood flow and ROSC. A CPP below 15 mmHg during CPR is associated with a low likelihood of achieving ROSC. However, routine CPP monitoring during CPR is clinically challenging as it requires simultaneous measurement of aortic and central venous pressures.

(3) Regional cerebral oxygen saturation

During CPR, regional cerebral oxygen saturation measured using near-infrared spectroscopy may be used as an indicator of cerebral perfusion. This noninvasive technique is easily applied and may help predict ROSC and neurological outcomes in patients under cardiac arrest [22,23].

(4) Physiology-guided CPR

Most clinical studies on physiology-guided CPR have been conducted in pediatric populations. In a cluster-randomized trial involving 18 pediatric intensive care units, a bundled intervention consisting of point-of-care physiology-focused CPR education and structured clinical event debriefing did not improve survival

to hospital discharge with favorable functional outcomes [24]. In that study, when invasive arterial blood pressure or ETCO_2 monitoring was available, clinicians targeted a systolic blood pressure ≥ 100 mmHg and an $\text{ETCO}_2 \geq 25$ mmHg in older children (excluding neonates and infants). Observational data from the same cohort showed higher survival to hospital discharge in older children when the mean diastolic blood pressure during CPR exceeded 30 mmHg [25].

In a study involving young adults, invasive arterial blood pressure was measured during CPR in 104 patients. Chest compression rates of 100 to 120 per minute and compression depths of 6 cm were associated with diastolic blood pressure values of approximately 30 mmHg measured at both the femoral and radial arteries [26]. Although a modest trend toward higher blood pressure with increasing compression depth was observed in individual patients, increased compression depth did not consistently result in higher blood pressure across all patients. In a more recent study, invasive blood pressure monitoring was performed in 80 adult patients with out-of-hospital cardiac arrest who received CPR by helicopter emergency medical service teams [27]. Analysis demonstrated that maximum, mean, and changes in maximum diastolic blood pressure from baseline were all significantly associated with ROSC. The optimal cutoff value of maximum diastolic blood pressure for predicting ROSC was identified as 35 mmHg (sensitivity, 94.1%; specificity, 58.7%), and for each 1-mmHg increase in maximum diastolic blood pressure, the odds of ROSC increased by an odds ratio of 1.05 (95% confidence interval, 1.03–1.08).

Based on these findings, the American Heart Association proposed several physiological targets during CPR through expert consensus, and the Korean guidelines for adult ALS suggest the same level of targets (expert consensus) [28].

- (1) In patients under cardiac arrest in whom both invasive arterial blood pressure monitoring and central venous catheterization are available, a target coronary perfusion pressure > 20 mmHg should be maintained.
- (2) In patients with cardiac arrest in whom only an arterial line is available, a target diastolic blood pressure ≥ 25 mmHg should be maintained.
- (3) In patients with cardiac arrest in whom only ETCO_2 monitoring is available, a target $\text{ETCO}_2 \geq 20$ mmHg should be achieved.

Route of drug administration during cardiac arrest

During cardiac arrest, high-quality CPR and early defibrillation are the primary interventions, with drug administration consid-

ered subsequently. After initiating CPR and performing defibrillation, intravenous or intraosseous access should be established for drug delivery. Establishing vascular access must not interfere with chest compressions. In patients with shockable cardiac arrest rhythms, epinephrine should be administered after defibrillation in the subsequent cycle. In patients with nonshockable rhythms, epinephrine should be administered as early as possible once chest compressions have begun and intravenous access has been secured [29].

Peripheral intravenous access

When drugs are administered via a peripheral intravenous route during resuscitation, a 20-mL fluid bolus should be administered after the drug bolus to facilitate rapid entry into the central circulation. Elevation of the extremity during or after drug administration may theoretically promote entry into the central circulation by gravity; however, no systematic studies support this practice.

Intraosseous access

Randomized controlled trials (RCTs) evaluating intraosseous drug administration during adult out-of-hospital cardiac arrest did not demonstrate superiority over intravenous access in terms of 30-day survival, favorable neurological outcome at 30 days or at hospital discharge, quality of life at 3 months, ROSC, survival to hospital discharge, 3-month survival, or favorable neurological survival at 3 months, and was instead associated with a lower likelihood of achieving sustained ROSC [6–8]. Therefore, intravenous access should be attempted first rather than intraosseous access for drug administration in adult patients under cardiac arrest (weak recommendation, low certainty of evidence). If intravenous access cannot be established during CPR, intraosseous access may be considered as an alternative route (good practice statement). In adults, commercially available intraosseous access devices are convenient to use.

Central venous access

In a small single-center study, patients randomized to femoral or internal jugular venous access showed higher rates of ROSC than those who received peripheral intravenous access; however, the study was limited by a high risk of bias [30]. Therefore, in adult patients under cardiac arrest, experienced physicians may consider central venous access when intravenous and intraosseous access are unsuccessful or not feasible (weak recommendation, low certainty of evidence).

Endotracheal drug administration

When neither intravenous nor intraosseous access can be established, epinephrine, vasopressin, and lidocaine may be administered via the endotracheal route, whereas amiodarone should not be administered by this route. Drugs administered endotracheally should be given at a dose 2 to 2.5 times the intravenous dose.

Medications administered during cardiac arrest

Vasopressors

Vasopressors administered during CPR increase the likelihood of ROSC in patients under cardiac arrest. Until recently, no large placebo-controlled randomized trials had evaluated their effect on long-term survival. A large RCT subsequently demonstrated that epinephrine significantly improved survival compared with placebo [31]. To date, no vasopressor has demonstrated superior survival outcomes compared with epinephrine.

(1) Epinephrine

In a large RCT of patients with out-of-hospital cardiac arrest, administration of epinephrine at a dose of 1 mg every 3 to 5 minutes was associated with higher 30-day and 3-month survival compared with placebo [31]. Long-term follow-up of the same cohort showed higher 6- and 12-month survival among patients who received epinephrine than those who received placebo [31,32]. Therefore, administration of 1 mg of epinephrine every 3 to 5 minutes is recommended for adult patients under cardiac arrest regardless of arrest rhythm (strong recommendation, moderate certainty of evidence). Although very low-certainty evidence suggests that high-dose epinephrine may improve ROSC and survival to hospital admission compared with standard dosing, it does not improve survival to hospital discharge or neurological outcomes. Therefore, routine administration of high-dose epinephrine is not recommended (strong recommendation, moderate certainty of evidence) [33]. High-dose epinephrine may be considered by experienced providers when deemed necessary.

During CPR in adult patients under cardiac arrest, epinephrine should be administered at a dose of 1 mg every 3 to 5 minutes using a 1:1,000 ampule or a commercially available 1:10,000 pre-filled syringe formulation [13,34]. Intravenous administration should be attempted first, with intraosseous administration considered when intravenous access is difficult. If neither route can be established, epinephrine may be administered via the endotracheal route at a dose of 2 to 2.5 mg. The timing of epinephrine administration depends on the initial arrest rhythm. In nonshockable rhythms, epinephrine should be administered as early as possible. In shockable rhythms, evidence supporting a specific

timing strategy is insufficient; in such cases, rapid defibrillation should be prioritized, followed by prompt epinephrine administration after defibrillation [29,35].

(2) Vasopressin

In one study, administration of vasopressin compared with placebo improved ROSC regardless of initial electrocardiographic rhythm and increased survival to hospital admission and discharge in patients with nonshockable rhythms [36]. However, systematic reviews and meta-analyses incorporating RCTs and observational studies have shown no significant survival benefit of vasopressin alone or in combination with epinephrine compared with epinephrine alone [36–38]. Therefore, routine administration of vasopressin, either alone or with epinephrine, during CPR in adult patients under cardiac arrest is not recommended (weak recommendation, moderate certainty of evidence).

(3) Combined administration of vasopressin and corticosteroids

The combined administration of vasopressin and corticosteroids (e.g., methylprednisolone) during cardiac arrest has been proposed based on physiological rationale, suggesting a potential improvement in hemodynamic stability during CPR and enhancement of ROSC and long-term survival [39]. However, recent RCTs and subsequent analyses have demonstrated that this combination therapy does not significantly improve clinical outcomes among patients under cardiac arrest [9,40,41]. Therefore, the routine addition of vasopressin and corticosteroids to standard resuscitation therapy during CPR is not recommended for patients with in-hospital cardiac arrest (weak recommendation, low certainty of evidence). Similarly, routine combined administration of vasopressin and corticosteroids is not recommended for patients with out-of-hospital cardiac arrest (weak recommendation, very low certainty of evidence).

Buffering agents

Buffering agents during cardiac arrest have been proposed to correct metabolic acidosis and acid-base imbalance during arrest, maintain myocardial function and vascular responsiveness, and facilitate ROSC. However, evidence demonstrating that the routine use of buffering agents improves survival or neurological outcomes in patients with cardiac arrest remains insufficient. RCTs have reported that the administration of buffering agents does not improve ROSC or survival upon hospital admission [31,42,43]. Therefore, in the absence of specific indications, routine use of buffering agents, such as sodium bicarbonate, is not recommended during the treatment of out-of-hospital cardiac

arrest (weak recommendation, low certainty of evidence). Similarly, in the absence of specific indications, the routine administration of buffering agents is not recommended during the management of in-hospital cardiac arrest (weak recommendation, very low certainty of evidence). This recommendation does not apply to special clinical situations, such as sodium channel blocker intoxication, tricyclic antidepressant overdose, or hyperkalemia.

Calcium

Recent RCTs demonstrated that calcium administration does not provide significant benefits in terms of survival or neurological outcomes among patients under cardiac arrest [10]. A recent large RCT was terminated early after the interim analysis because of a potential signal of harm in the calcium administration group, which showed significantly lower rates of functionally favorable survival at 90 days and at 1 year in patients who received calcium [44].

Accordingly, the routine administration of calcium is not recommended for adult patients with out-of-hospital cardiac arrest (strong recommendation, moderate certainty of evidence). Similarly, routine calcium use is not recommended for adult patients with in-hospital cardiac arrest (weak recommendation, low certainty of evidence).

However, to date, no RCTs have evaluated calcium administration in adult patients with in-hospital cardiac arrest, and most existing evidence is derived from studies involving out-of-hospital cardiac arrest patients. In addition, this recommendation does not apply to the following pathophysiological conditions: (1) hyperkalemia; (2) hypocalcemia; (3) calcium channel blocker overdose; (4) hypermagnesemia; (5) severe electrolyte abnormalities with a wide QRS complex; or (6) calcium deficiency due to massive hemorrhage.

Antiarrhythmic drugs

Evidence that amiodarone or lidocaine improves survival to hospital discharge or favorable neurological outcomes in patients with refractory VF or pVT remains limited. However, amiodarone has been shown to increase ROSC compared with lidocaine and to improve survival to hospital admission compared with placebo. Lidocaine has also been shown to increase ROSC and survival to hospital admission compared with placebo [45]. Therefore, the 2025 guidelines recommend administration of amiodarone or lidocaine in adult patients with refractory VF or pVT (weak recommendation, low certainty of evidence). In earlier guidelines up to 2011, magnesium sulfate was recommended for cardiac arrest caused by polymorphic ventricular tachycardia when hypomag-

neemia was suspected; however, the updated recommendations do not support routine use of magnesium in adult patients under cardiac arrest (strong recommendation, very low certainty of evidence) [46].

(1) Amiodarone

Amiodarone is indicated for VF or pVT that is refractory to CPR, defibrillation, and vasopressors. The initial dose is 300 mg administered intravenously or intraosseously, and if the rhythm remains refractory, a single additional dose of 150 mg may be administered [47].

(2) Lidocaine

Lidocaine may be considered for patients with refractory VF or pVT. The initial dose is 1 to 1.5 mg/kg administered intravenously, followed by additional doses of 0.5 to 0.75 mg/kg at intervals of 5 to 10 minutes, up to a maximum total dose of 3 mg/kg.

(3) Magnesium sulfate

Although magnesium sulfate was previously used in patients under cardiac arrest with polymorphic ventricular tachycardia when hypomagnesemia was suspected, updated recommendations do not support routine administration of magnesium sulfate in adult patients under cardiac arrest [46].

(4) Prophylactic use of antiarrhythmic drugs after ROSC

Prophylactic administration of lidocaine or β -blockers may be considered immediately after ROSC in patients with cardiac arrest due to refractory VF or pVT. However, evidence supporting their clinical usefulness remains insufficient. β -Blockers may reduce catecholamine-induced arrhythmias, stabilize the myocardial membrane, and reduce ischemic injury. However, their routine use is not recommended because they may cause hypotension or worsen heart failure in the immediate post-resuscitation period [48,49]. Lidocaine may suppress arrhythmias associated with myocardial infarction and prevent progression to ventricular arrhythmias without apparent harm; however, it does not improve survival outcomes. There is no evidence to support the prophylactic use of antiarrhythmic drugs in cardiac arrests caused by rhythms other than VF or ventricular tachycardia.

Defibrillation

Basic principles of defibrillation

In the absence of CPR, survival after defibrillation decreases by approximately 7% to 10% per minute. When bystander CPR is performed, the decline in defibrillation success is reduced to ap-

proximately 3% to 4% per minute. Therefore, performing CPR at the scene of cardiac arrest increases the probability of successful defibrillation by twofold to threefold compared with defibrillation without prior CPR. Bystander CPR also contributes to preservation of neurological function. When defibrillation is performed within 5 minutes of adult cardiac arrest, the neurological injury is minimal. However, CPR alone is unlikely to terminate VF.

Priority between defibrillation and CPR

Studies comparing CPR prior to defibrillation with immediate defibrillation after a delay from cardiac arrest have shown no difference in survival [50,51]. Therefore, in all patients with cardiac arrest, CPR should be initiated promptly. Once a defibrillator becomes available, electrocardiographic rhythm should be assessed immediately, and defibrillation should be performed without delay if indicated.

Initial single-shock defibrillation vs. stacked-shock defibrillation in the treatment of VF

The resumption of chest compressions immediately after defibrillation may induce VF recurrence; however, it may be beneficial to defibrillation efficacy at the next shock by providing myocardial blood flow [52,53]. During CPR, chest compressions are frequently interrupted for reasons, such as electrocardiographic rhythm analysis, ventilation, and intravenous access [54]. In a study involving patients with out-of-hospital cardiac arrest, when emergency medical personnel performed CPR using an automated external defibrillator, the actual proportion of time during which chest compressions were delivered was only 43% of the total resuscitation time [55]. Frequent interruptions in chest compressions decrease the success rate of defibrillation and the overall survival [56].

Before 2005, delivering three stacked shocks at the outset was recommended; however, stacked-shock defibrillation prolonged the duration of chest compression interruption. Since 2020, three stacked shocks have no longer been recommended. With biphasic waveform defibrillators, which are adopted in most automated defibrillators, the success rate of the first shock has been reported to be high (85%–98%) [57,58]. Accordingly, an initial single-shock strategy is recommended rather than three stacked shocks (weak recommendation, moderate certainty of evidence).

Defibrillation waveforms and energy levels

Currently used defibrillation waveforms include biphasic truncated exponential, rectilinear biphasic, and pulsed biphasic waveforms. No evidence has demonstrated that any specific waveform

is superior in terms of ROSC or survival outcomes in patients with cardiac arrest. However, biphasic waveform defibrillators can provide safe and effective defibrillation at lower energy levels [58–68]. When delivering the first defibrillation shock using a biphasic waveform defibrillator, an energy level of 120 to 200 J should be selected, according to the manufacturer's recommendations. If the manufacturer's recommended energy level is unknown, then the maximum available energy level may be considered. For monophasic waveform defibrillators, defibrillation should be performed at 360 J after the initial shock [69].

Defibrillation energy for consecutive shocks

When VF or pVT is not terminated by the first defibrillation attempt, the energy level for the second and subsequent defibrillation attempts may be repeated at the same level or increased, according to the manufacturer's recommendations [70,71]. If a manual defibrillator capable of energy escalation is available, the second or subsequent defibrillation attempts should be delivered at a higher energy level [47,72]. When refractory VF or pVT persists, defibrillation energy may be escalated up to the maximum available energy level.

Effective defibrillation strategies

(1) Selection of paddles vs. pads

The use of self-adhesive pads reduces interruptions in chest compressions before and after defibrillation and lowers the risk of electrical arcing, skin burns, and fire. Once applied, pads allow electrocardiographic rhythm analysis, defibrillation, synchronized cardioversion, and pacing. Compared with paddles, pads eliminate the need for conductive gel, repeated repositioning, and application of 10 to 12 kg of pressure to the chest during defibrillation. Accordingly, when available, pads should be considered rather than paddles.

(2) Strategies to minimize chest compression interruption before and after defibrillation

The interval between interruption of chest compressions and shock delivery should be minimized. Even brief interruptions of 5 to 10 seconds reduce defibrillation success [73–76]. Therefore, chest compressions should be continued while the defibrillator is charging, and pre-shock pauses should be minimized through clear team leadership and efficient resuscitation team coordination [77,78]. When using a manual defibrillator, total interruption of chest compressions before and after defibrillation should be limited to < 10 seconds.

(3) Safe use of oxygen during defibrillation

In oxygen-enriched environments, such as ambulances and hospitals, sparks from improperly attached defibrillation paddles can cause fires or severe burns [79–81]. Because fires or electrical arcing have not been reported with self-adhesive pads, their use is preferred over paddles whenever possible. During defibrillation, when oxygen is delivered via a nasal cannula, oxygen mask, or mechanical ventilator, precautions should be taken to prevent high concentrations of oxygen flowing across the patient's chest.

(4) Electrode placement

To minimize the transthoracic impedance and ensure that electrical current is delivered to the myocardium during defibrillation, the heart should be positioned between the two electrodes; therefore, the electrodes should be placed in the sternal-apical position (Fig. 3). The right sternal electrode (labeled "Sternum") should be placed to the right of the sternum below the clavicle. The left apical electrode (labeled "Apex") should be placed at the level of electrocardiographic lead V6 along the left mid-axillary line. Electrodes should not be placed over the breast tissue and should be positioned lateral to the breast whenever possible [82]. When using biphasic waveform defibrillators, the positions of the two electrodes labeled "Sternum" and "Apex" may be interchanged; therefore, electrode repositioning should not delay defibrillation or interrupt chest compressions. To minimize transthoracic impedance, the electrodes should be positioned vertically along the long axis of the chest [83].

(5) Respiratory cycle

To minimize transthoracic impedance, defibrillation should be attempted during the end-expiratory phase of the respiratory cycle, whenever possible. PEEP at the end of expiration increases transthoracic impedance. In patients with asthma, intrinsic PEEP may increase the energy requirements for successful defibrillation [84].

Double sequential defibrillation

Double sequential defibrillation is a technique that delivers two high-energy shocks in rapid sequence using two defibrillators. This has been proposed as a strategy to treat shockable rhythms that are refractory to repeated conventional defibrillation, and some studies have reported the potential benefits of this approach [11,85–88]. In particular, a randomized clinical trial comparing conventional defibrillation, vector change defibrillation (anteroposterior pad placement), and double sequential defibrillation reported that both the vector change and double sequential defibrillation groups had higher rates of favorable neurologi-

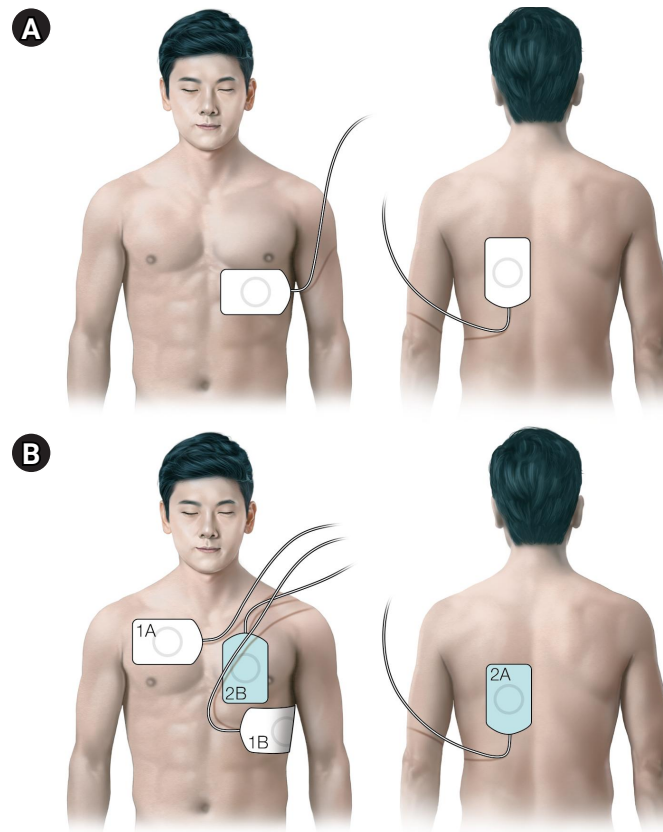


Fig. 3. Position of the pads in (A) vector change and (B) double sequential external defibrillation.

cal outcome at hospital discharge, survival to hospital discharge, and ROSC [11]. However, because this trial was conducted at a single center, it remains uncertain whether similar results would be reproduced in other settings, and the relative superiority of vector change defibrillation and double sequential defibrillation cannot be determined. However, further studies are required to confirm this hypothesis. Accordingly, the routine use of double sequential defibrillation in cardiac arrest with shockable rhythm is not currently recommended (weak recommendation, low certainty of evidence).

In adult patients with cardiac arrest in whom VF or pVT persists after three or more consecutive defibrillation attempts, vector change defibrillation (weak recommendation, very low certainty of evidence) or double sequential defibrillation (weak recommendation, low certainty of evidence) may be attempted at the discretion of an experienced physician, provided that trained personnel and additional pads or defibrillators are immediately available (weak recommendation, very low certainty of evidence) (Fig. 3). When double sequential defibrillation is performed, a single operator sequentially activates the defibrillators (good practice statement).

Advanced airway management

Airway management and ventilation during cardiac arrest includes mouth-to-mouth ventilation, mouth-to-mask ventilation, bag-mask ventilation, supraglottic airway devices, and endotracheal intubation. During prolonged cardiac arrest, chest compressions alone are insufficient to maintain adequate ventilation, and airway management is necessary to facilitate effective ventilation and reduce the risk of regurgitation and aspiration of gastric contents. However, it remains unclear which airway management strategy provides the greatest improvement in patient outcomes.

The 2015 Korean CPR guidelines recommended the use of bag-mask ventilation or advanced airway devices for oxygenation and ventilation during out-of-hospital or in-hospital cardiac arrest, based on the available evidence at that time [89]. Since 2015, three large RCTs evaluating advanced airway management during cardiac arrest have been published. Based on analyses incorporating these data, treatment recommendations from the International Liaison Committee on Resuscitation (ILCOR) and guidelines from the American Heart Association were revised and published in 2019 [90–94]. Accordingly, the 2025 guidelines established the following recommendations for advanced airway management:

- (1) Healthcare providers may use either bag-mask ventilation or the placement of an advanced airway device during CPR in adult patients under cardiac arrest (weak recommendation, moderate certainty of evidence). In adult out-of-hospital cardiac arrest, when an advanced airway is placed during CPR, supraglottic airway devices are recommended by emergency medical personnel who lack sufficient training and experience in endotracheal intubation, whereas endotracheal intubation should only be performed by emergency medical personnel with adequate training and experience in endotracheal intubation (weak recommendation, moderate certainty of evidence).
- (2) During CPR in adult patients with in-hospital cardiac arrest, either a supraglottic airway device or endotracheal intubation may be considered as an advanced airway management strategy (weak recommendation, moderate certainty of evidence).

Bag-mask ventilation

When bag-mask ventilation is performed during CPR, the ratio of chest compressions to ventilation should be maintained at 30:2. When a single rescuer uses a face mask, the rescuer should seal the mask to the patient's face with one hand while squeezing the bag with the other hand. Inadequate mask sealing may result in hypoventilation, and failure to maintain airway patency may cause air to enter the esophagus, leading to gastric inflation and an increased risk of aspiration. The two-person technique, in which one rescuer holds the face mask with both hands while the other squeezes the bag, is more effective. When endotracheal intubation is performed or a supraglottic airway device is inserted, chest compressions should be continued during ventilation and ventilation should be delivered at a rate of one breath every 6 seconds [47].

Supraglottic airway devices

During CPR, if advanced airway management is considered and the success rate of endotracheal intubation is expected to be low owing to factors, such as limited provider experience, the use of a supraglottic airway device is recommended. In contrast, in environments where the success rate of endotracheal intubation is high, such as emergency departments staffed by multiple providers with extensive experience in endotracheal intubation, either a supraglottic airway device or endotracheal intubation may be considered an advanced airway management strategy. Therefore, rescuers should receive sufficient training in the use of supraglottic airway devices and participate in regular practice to maximize insertion success rates and minimize complications.

Endotracheal intubation

An endotracheal tube maintains airway patency, allows suctioning of airway secretions, enables delivery of high concentrations of oxygen, and can be used as a route for the administration of certain medications. In addition, it facilitates ventilation and protects the airway from aspiration of gastric contents, as well as blood and secretions from the mouth and pharynx [95]. Despite the diverse patient conditions and environments encountered during resuscitation, repeated, safe, and effective endotracheal intubation requires substantial technical skill and experience.

(1) Endotracheal intubation in emergency situations

Endotracheal intubation offers several advantages over bag-mask ventilation. It allows ventilation without interrupting chest compressions and provides effective ventilation regardless of lung or chest wall compliance. In addition, it minimizes gastric inflation and regurgitation, and reduces the risk of pulmonary aspiration of gastric contents [96]. When deciding to perform endotracheal intubation, rescuers should consider its potential risks and benefits. Rescuers should be able to perform intubation without interrupting the chest compressions. Intubation may be deferred after ROSC to avoid interruption of chest compressions. If the chest compressions must be paused for intubation, the interruption should be limited to <5 seconds. If intubation is unsuccessful, bag-valve mask ventilation is recommended [47]. After intubation, the correct tube placement must be confirmed to reduce the risk of esophageal intubation.

(2) Assessment of correct endotracheal tube placement

ETCO₂ monitoring measures the partial pressure of carbon dioxide in the air exhaled from the lungs. The presence of a persistent ETCO₂ waveform after six ventilations indicates that the endotracheal tube is located in the airway. Waveform ETCO₂ monitoring has the highest sensitivity and specificity for confirming endotracheal intubation and continuously verifying the tube position in patients with out-of-hospital cardiac arrest. ETCO₂ monitoring should be used in conjunction with additional clinical assessments, such as auscultation and confirmation of the passage of the endotracheal tube through the vocal cords. Because waveform ETCO₂ monitoring alone cannot distinguish whether the tube is positioned in the trachea or mainstem bronchus, auscultation must be performed to reconfirm the tube position. Waveform ETCO₂ monitoring can be used to confirm endotracheal tube placement in all settings where advanced airway management is performed, including out-of-hospital environments, emergency departments, and in-hospital settings. The use of waveform ETCO₂

monitoring in conjunction with clinical judgment is strongly recommended for the confirmation of endotracheal intubation and continuous monitoring of tube position in patients under cardiac arrest [14,16,20,97–99].

(3) Post-endotracheal intubation management

After correct tube placement has been determined, the depth of the endotracheal tube at the level of the upper incisors should be recorded, and the tube should be secured using moisture-resistant tape or a commercial fixation device. After securing the tube, an oropharyngeal airway or bite block should be inserted following placement of the endotracheal tube or other advanced airway devices. Rescuers should reassess tube position after advanced airway placement and patient transport.

Cricothyroidotomy during CPR

If standard airway management strategies, such as oropharyngeal airway placement, bag-mask ventilation, supraglottic airway devices, or endotracheal intubation fail during cardiac arrest, inadequate airway maintenance and oxygen delivery may lead to fatal outcomes. However, in cardiac arrest with ongoing chest compressions, the use of monitoring indicators, such as oxygen saturation is limited, and failure of ventilation may be difficult to promptly recognize. In addition, no clinical studies specifically involving patients under cardiac arrest have been reported, and it is considered extremely difficult to design and conduct high-quality studies that directly address this question. Therefore, when standard airway management strategies fail, cricothyroidotomy may be considered, and appropriately trained rescuers may attempt to establish a surgical airway through cricothyroidotomy (good practice statement).

Mechanical ventilator settings during chest compressions

Two RCTs and two observational studies compared mechanical ventilation with bag ventilation during CPR [100–103]. The two RCTs were feasibility studies that compared volume-controlled ventilation (tidal volume, 6–7 mL/kg; respiratory rate, 10/min; and FiO_2 , 1.0) applied after establishing advanced airway with bag ventilation [100,101]. Each study enrolled 60 patients and no formal sample size calculations were performed. The results demonstrated that the use of mechanical ventilation during mechanical or manual chest compressions was feasible, and no significant differences were observed in oxygenation, ROSC, or survival rates. In a prospective observational study, mechanical ventilation was associated with reduced arterial PaCO_2 ; however, it did not affect ROSC, survival, or neurologically favorable survival

[102]. In addition, a retrospective study compared 298 patients who received mechanical ventilation using a CPR-specific ventilator mode with 2,268 patients who received bag ventilation and found that mechanical ventilation increased the rate of ROSC but did not affect neurologically favorable survival [103]. Overall, the available evidence suggests that mechanical ventilation during chest compressions is feasible; however insufficient evidence has demonstrated its superiority over manual bag ventilation or to recommend a specific ventilator mode.

Therefore, when cardiac arrest occurs in patients already receiving mechanical ventilation and ventilation is continued rather than converted to manual ventilation, a volume-controlled ventilation mode should be used during chest compressions. The ventilator should be set to deliver a tidal volume of 6 to 8 mL/kg predicted body weight or adjusted to achieve visible chest rise. Oxygen should be administered at the maximum concentration (FiO_2 , 1.0). The respiratory rate should be set to 10/min with an inspiratory time of 1 to 2 seconds. PEEP should be maintained at 0 to 5 cm H_2O , and the peak airway pressure alarm should be set to 60 to 70 cm H_2O . Flow triggering should be disabled. Effective mechanical ventilation should be confirmed, and if ventilation is ineffective, providers should switch to manual ventilation (expert consensus).

Mechanical CPR devices

Indications for mechanical CPR devices

Because current evidence does not demonstrate superiority of mechanical CPR devices over manual chest compressions, manual chest compressions are recommended as the standard method of CPR for cardiac arrest [104–114]. However, mechanical CPR devices may be a reasonable alternative when manual chest compressions are difficult to perform or when maintaining high-quality chest compressions becomes challenging, particularly during prolonged resuscitation.

Such situations include patient transport in confined spaces (e.g., elevator transfer in high-rise building), insufficient personnel to provide continuous chest compressions (e.g., during initiation of extracorporeal circulation), ambulance transport with unavoidable movement of providers or patients, hypothermic cardiac arrest with prolonged resuscitation and chest wall rigidity, or scenarios involving risk of exposure to infectious diseases [4,115]. In addition, during procedures such as coronary angiography or thrombectomy, mechanical CPR devices may reduce healthcare provider exposure to radiation while maintaining uninterrupted chest compressions.

Korean treatment recommendations

As evidence demonstrating the superiority of mechanical CPR devices over manual chest compressions is insufficient, routine replacement of manual CPR with mechanical CPR devices is not recommended for out-of-hospital cardiac arrest (weak recommendation, low certainty of evidence) or in-hospital cardiac arrest (weak recommendation, very low certainty of evidence).

Mechanical CPR devices may be considered when maintaining high-quality CPR is difficult or when provider safety is at risk (good practice statement). Acquisition of mechanical CPR devices involves cost, and users require appropriate training. Care should be taken to minimize interruptions in chest compressions during device application and removal. Delays in initiating CPR due to preparation for mechanical CPR devices should be avoided.

Extracorporeal CPR

Introduction to extracorporeal CPR

Extracorporeal CPR (ECPR) refers to the use of extracorporeal circulatory devices to maintain blood circulation in patients with cardiac arrest. An extracorporeal circulation device delivers oxygenated blood by circulating it outside the body through cannulas inserted into a vein and an artery. Once the extracorporeal circulation device is connected, the oxygenated blood can be circulated without chest compressions or artificial ventilation. The purpose of ECPR is to sustain life while treating the reversible causes of cardiac arrest. The implementation of extracorporeal circulation in patients with cardiac arrest requires highly trained personnel and specialized equipment. Successful treatment of cardiac arrest and patient recovery using ECPR requires close collaboration between the team performing extracorporeal circulation and the team responsible for critical care management.

In a recent systematic review, evidence was identified from four RCTs. Observational studies identified in previous systematic reviews were considered to have a high risk of bias and low reliability. Therefore, only results from RCTs were considered in this update of scientific evidence and recommendation levels. Four RCTs were identified for the prognostic analyses of survival (at hospital discharge, 30 days, and long-term) and favorable neurological outcomes (at hospital discharge, 30 days, and long-term) [12,116–118]. For all clinical outcomes, the certainty of evidence was assessed as low for out-of-hospital cardiac arrest and very low for in-hospital cardiac arrest. In a study enrolling 30 adult patients with out-of-hospital cardiac arrest, ECPR demonstrated benefits over standard treatment in terms of survival to hospital discharge, favorable neurological outcomes at discharge, and favorable neurological outcomes at 6 months [116]. In a study en-

rolling 15 adult patients with out-of-hospital cardiac arrest, ECPR showed no benefit compared with standard treatment in terms of survival to hospital discharge, favorable neurological outcomes at discharge, or favorable neurological outcomes at 3 months [117]. In a study enrolling 264 adult patients with out-of-hospital cardiac arrest, ECPR showed no benefit compared with standard treatment in terms of 30- or 180-day survival, or favorable neurological outcome at 180 days. However, ECPR demonstrated a benefit in favorable neurological outcome at 30 days compared with standard treatment [12]. In a study enrolling 134 adult patients with out-of-hospital cardiac arrest, ECPR showed no benefit compared to standard treatment in terms of survival to hospital discharge, favorable neurological outcomes at 30 days, or favorable neurological outcomes at 6 months [118].

Indications for ECPR

ECPR may be considered for patients with cardiac arrest due to potentially reversible causes who do not achieve ROSC with conventional CPR but are expected to recover neurologically if circulation is restored. Accordingly, ECPR may be considered in patients with refractory or recurrent cardiac arrest, provided irreversible neurological injury has not occurred. Because assessment of neurological recovery potential and arrest reversibility is challenging, uniform selection criteria are difficult to establish.

Previous studies have applied varying inclusion criteria. Commonly suggested characteristics include age <75 years, initial shockable rhythm, correctable or cardiac cause of arrest, witnessed arrest, no-flow time ≤5 minutes, failure to respond to ≥10 minutes of ALS, and total arrest duration ≤60 minutes [119–138].

Considerations for implementation

Implementation of ECPR requires immediate availability of trained personnel, equipment, and facilities. As the probability of recovery declines with increasing CPR duration, the interval from decision-making to initiation of extracorporeal circulation should be minimized. Healthcare providers or institutions intending to use ECPR should establish standardized protocols, training programs, and monitoring systems to facilitate early application in appropriately selected patients. Accordingly, ECPR may be considered as a selective rescue therapy for adult patients with out-of-hospital cardiac arrest or in-hospital cardiac arrest who do not achieve ROSC with conventional CPR, when available (weak recommendation, low or very low certainty of evidence).

Considerations during ALS

Oxygen administration during CPR

In a prospective multicenter observational study, arterial oxygen tension during CPR was higher in adult out-of-hospital cardiac arrest patients who survived to hospital admission [139]. Considering current recommendations and these findings, administration of the highest possible oxygen concentration (100%) during CPR is suggested. However, after ROSC, the FiO_2 should be titrated to maintain oxygen saturation between 94% and 98%.

Prognostic indicators during CPR

During cardiac arrest, the ETCO_2 reflects the cardiac output generated by chest compressions and can be used as a prognostic indicator. In adult patients with in-hospital or out-of-hospital cardiac arrest who have undergone endotracheal intubation, a persistently measured ETCO_2 value of ≤ 10 mmHg on waveform capnography after 20 minutes of resuscitation is associated with a very poor prognosis [14,20]. Accordingly, if ETCO_2 remains persistently at or below 10 mmHg after 20 minutes despite appropriate ALS, termination of resuscitation may be considered after taking other clinical factors into account.

However, ETCO_2 should not be used as the sole predictor of survival and this criterion should not be applied to patients who have not undergone endotracheal intubation. In addition, non-continuous, colorimetric ETCO_2 detectors used in the prehospital setting may be considered to confirm endotracheal tube placement but are not recommended for prognostication or as a basis for termination of CPR in the field.

Near-infrared spectroscopy monitoring of regional cerebral oxygen saturation during CPR may serve as an indicator of cerebral perfusion and can be applied noninvasively to assist in prognostic assessment and decisions regarding treatment termination. Therefore, although the data are limited, the measurement of regional cerebral oxygen saturation during CPR is suggested in adult patients with cardiac arrest as a reference for predicting ROSC and supporting clinical decision-making [3-5,22,23,140].

Use of ultrasound during CPR

The usefulness of ultrasound, including echocardiography, during CPR in adult patients has not yet been established. Although the data are limited, if an experienced ultrasound operator is available and ultrasound examination does not interfere with CPR, ultrasound may be helpful in diagnosing cardiac tamponade or other potential reversible causes of cardiac arrest and differentiating cardiac activity in patients with PEA [141,142]. In addition, ultrasound may be attempted as an alternative method to con-

tinuous ETCO_2 monitoring for confirmation of endotracheal tube placement during resuscitation [143]. However, recent systematic reviews have reported that no single ultrasound finding should be used as the sole criterion for the termination of resuscitation [144,145].

Therefore, the routine use of POCUS during CPR to diagnose reversible causes of cardiac arrest is not recommended (weak recommendation, very low certainty of evidence). If an experienced POCUS operator can perform ultrasound without interrupting CPR, it may be considered an adjunctive diagnostic tool when reversible causes of cardiac arrest are clinically suspected (weak recommendation, very low certainty of evidence). The use of POCUS during CPR should be carefully considered with awareness of the high risk of interrupting chest compressions and the potential for misinterpretation of ultrasound findings (good practice statement).

Return of consciousness during CPR

Return of consciousness during CPR, referred to as CPR-induced consciousness, has been increasingly reported. The experiences of rescuers and survivors encompassed diverse themes related to cardiac arrest, CPR, and recovery. The reported experiences included transcendent or mystical phenomena, visual and auditory perceptions, sensations of separation from the body, dream-like states, return of consciousness during CPR, and conscious experiences during recovery from a coma. In 2021, the ILCOR conducted a scoping review to describe reported experiences and evaluate whether interventions, such as the use of sedative agents, were implemented to prevent these experiences.

(1) Evidence review

Observational studies addressing consciousness and sedation during CPR were identified. In a study conducted in the United States involving 143 survivors of in-hospital or out-of-hospital cardiac arrest, no significant association was observed between administration of sedative or analgesic medications immediately before, during, or after CPR and the development of posttraumatic stress disorder [146]. In a study in the United Kingdom involving 140 survivors of in-hospital cardiac arrest, two patients reported clear conscious experiences with explicit recall of visual and auditory perceptions during resuscitation [147].

In interviews with 67 healthcare providers in Australia, including physicians, nurses, and paramedics, 59 respondents reported witnessing return of consciousness during CPR; in many cases, patients did not interfere with resuscitation. Among these events, respondents reported temporarily pausing CPR ($n = 10$), reassuring

the patient ($n = 7$), administering sedative agents or neuromuscular blockers ($n = 16$), or applying physical restraints ($n = 2$) [148]. In cases in which patient consciousness interfered with resuscitation efforts, such as attempts to block chest compressions or remove tubes or lines, 51 of 63 respondents reported such experiences; management included temporary pauses in CPR ($n = 7$), use of sedative agents or paralytics ($n = 23$), and application of physical restraints ($n = 7$). These findings highlight the need for clearer guidance on this issue.

In an observational study of 16,558 out-of-hospital cardiac arrest cases in Victoria, Australia (2008–2014), return of consciousness during CPR occurred in 112 cases (0.7%). Manifestations included eye opening (20.5%), verbalization (29.5%), physical movement (87.5%), or combinations thereof [149]. Sedative agents, such as midazolam, opioid analgesics, or neuromuscular blockers were administered in 42 patients (37.5%). Return of consciousness during CPR was associated with witnessed arrest, and outcomes were more favorable in patients who did not receive medications. In a separate study of 23,011 out-of-hospital cardiac arrest cases in Queensland, Australia (2007–2018), return of consciousness during CPR was reported in 52 cases (0.23%), most commonly presenting as agitation or aggressive behavior (34.6%) [150]. Return of consciousness during CPR was associated with witnessed arrest, emergency medical services–witnessed arrest, arrest occurring in a public place, and an initial shockable rhythm, all of which were linked to higher rates of ROSC and survival.

Since 1962, 24 case reports and case series describing 31 cases of return of consciousness during CPR have been published, with sedative agents used in approximately 30% of cases. Reported medications included ketamine, midazolam, and fentanyl, administered alone or in combination [151–174].

(2) Recommendations

In patients who do not achieve ROSC during CPR but temporarily regain consciousness due to chest compressions and interfere with high-quality CPR or pose a risk of harm to themselves or rescuers, administration of sedative agents or analgesics, alone or in combination, may be considered at the lowest effective dose to alleviate pain and distress (good practice statement). Administration of neuromuscular blocking agents alone to conscious patients during CPR is not recommended (good practice statement). Because the optimal sedation and analgesia regimen during CPR has not been established, medication selection may be guided by critical care practice and local institutional protocols (good practice statement).

In-hospital cardiac arrest

In-hospital cardiac arrest refers to any cardiac arrest occurring within a hospital setting. Survival depends on an effective system of care, including rapid response team operation, ALS education, organized cardiac arrest management, and continuous quality improvement. Early defibrillation and CPR have been associated with improved neurological outcomes in patients with in-hospital cardiac arrest [175–177]. Hospitalized patients often exhibit clinical deterioration hours to days before cardiac arrest [178]. In-hospital cardiac arrest in adult patients most commonly occurs within 2 days of hospital admission, with an incidence of approximately 1.5 to 2.8 per 1,000 hospitalized patients [179–184].

The survival outcomes after adult in-hospital cardiac arrest vary widely [185], which is attributed to differences in the level of medical care provided and adequacy of healthcare staff. Consequently, outcomes of in-hospital cardiac arrest are determined based on multiple factors. Some of these factors are modifiable, while others are not. Nonmodifiable factors included patient age, sex, comorbidities, and cause of cardiac arrest [186,187]. One of the most important modifiable factors is the location where cardiac arrest occurs. When cardiac arrest occurs in general wards, patients are often not adequately monitored, and the arrest may be unwitnessed, leading to poor outcomes [182,188]. In contrast, when cardiac arrest is recognized in settings, such as intensive care units or high-dependency units with appropriate monitoring and readily available personnel, response and outcomes may be improved. Therefore, each institution should establish rapid response teams capable of appropriately managing in-hospital cardiac arrest and implement systems for patient surveillance and triage using early warning scores.

Rapid response system

A rapid response system was designed to enable early identification and appropriate intervention for hospitalized patients whose clinical conditions rapidly deteriorate [189]. Interventions by a rapid response team include relatively simple treatments, such as the initiation of oxygen therapy and intravenous fluid administration, as well as complex decision-making processes, including transfer of the patient to the intensive care unit, decisions regarding do-not-resuscitate orders, determination of whether to escalate treatment stepwise to include CPR and other advanced interventions, and discussions regarding end-of-life care planning and terminal care.

The names of teams implementing rapid response systems vary between institutions, both domestically and internationally, in-

cluding rapid response teams, medical alert teams, and medical emergency teams. Despite differences in nomenclature, these teams serve the same fundamental function of identifying and treating patients at high risk of clinical deterioration to prevent cardiac arrest. Currently, controversy remains regarding whether rapid response systems have a definitive effect on improving patient survival and reducing the incidence of cardiac arrest. Nevertheless, the successful implementation of a rapid response system requires the establishment of an environment that ensures appropriate monitoring of hospitalized patients, early detection of clinical deterioration, and tailored responses [190].

Recent domestic and international studies have reported that the operation of rapid response systems is associated with reduced incidence of in-hospital cardiac arrest and decreased mortality [191–193].

A typical rapid response team is composed of physicians and nurses specializing in critical care, who respond to predefined calling criteria based on patient risk. These teams may completely replace or collaborate with traditional cardiac arrest response teams. A key element of an effective rapid response system is the role of all personnel involved in the care of hospitalized patients. These individuals should be empowered to request assistance for deteriorating patients and receive training in structured communication to facilitate effective information exchange [194–196]. Such training should include structured approaches, such as the ABCDE (airway, breathing, circulation, disability, and exposure) assessment for vital sign measurement, evaluation, and initial therapeutic intervention; structured communication tools, such as SBAR (situation, background, assessment, and recommendation); and appropriate methods for requesting help [197]. Through these measures, healthcare personnel can better recognize patients at risk, understand the clinical context, and identify when rapid response activation is required.

Individuals involved in patient care may include not only healthcare providers but also the patients themselves and their family members or caregivers, who may also be encouraged to activate the rapid response team [198–200].

Equipment preparation is essential for an effective and rapid response team performance. Hospitals should regularly manage and supervise resuscitation-related equipment and medications to ensure immediate access for prompt resuscitation. Missing equipment or device malfunctions may result in treatment delays [201,202].

Early warning scores

Rapid response systems and early warning scores may be effective

tools for appropriate responses to cardiac arrest in patients admitted to general wards. Most cases of in-hospital cardiac arrest initially present with nonshockable rhythms on electrocardiography, and signs of respiratory failure or shock typically precede cardiac arrest [93,182,184]. Therefore, early warning scores may assist rapid response teams in identifying critically ill patients.

To enable the early detection of clinical deterioration and development of critical illness, healthcare providers should measure patients' physiological parameters and document a vital sign monitoring plan, including the frequency of measurements. This can be facilitated by using standardized early warning scores. Commonly used early warning scoring systems include the National Early Warning Score (NEWS) and the Modified Early Warning Score (MEWS); however, the selection and implementation of a specific early warning scoring system may vary depending on institutional circumstances. In general, early warning scoring systems should align with national guidelines. For example, in the United Kingdom, the NEWS was approved for use by the National Institute for Health and Care Excellence [197,203].

The components of the early warning scores typically include seven parameters: respiratory rate, oxygen saturation, use of supplemental oxygen, body temperature, systolic blood pressure, heart rate, and level of consciousness, as assessed using the AVPU (alert, verbal, pain, unresponsive) scale. For example, the NEWS includes all seven parameters, whereas the MEWS, commonly used in Korea, consists of five parameters: systolic blood pressure, heart rate, respiratory rate, body temperature, and level of consciousness, assessed using the AVPU scale. Each parameter was assigned a score ranging from 0 to 3 [204]. A total MEWS score of ≤ 4 was classified as low risk and warrants observation; a score of ≥ 5 was classified as moderate risk and should prompt consultation with the rapid response team regarding further management; and a score of ≥ 7 was classified as high risk, indicating a need for intensive care and proactive intervention with the formulation of an ongoing treatment plan.

Although no RCTs have specifically evaluated early warning scores for prevention of adult in-hospital cardiac arrest, observational studies suggest an association between elevated scores and cardiac arrest risk [205,206]. Emerging approaches, including machine learning-based models, are under investigation to enhance early detection of clinical deterioration.

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Conceptualization: SOH; Funding acquisition: SPC; Investigation: all authors; Project administration: SPC; Writing—original draft: TYK, GJA; Writing—review & editing: all authors. All authors read and approved the final manuscript.

Conflicts of interest

Chun Song Youn, Mi Jin Lee, Byung Kook Lee, Jisook Lee, Sung Phil Chung, 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.

Funding

This work was supported by the Korea Disease Control and Prevention Agency (No. 2024100BE7B-00) and the Korean Association of Cardiopulmonary Resuscitation.

Data availability

Data sharing is not applicable as no new data were created or analyzed in this study.

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