

2020 Korean Guidelines for Cardiopulmonary Resuscitation. Part 4. Adult advanced life support.

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Clin Exp Emerg Med Clin Exp Emerg Med 3081 ceem 101657493 CEEM Clinical and Experimental Emergency Medicine 2383-4625 The Korean Society of Emergency Medicine PMC8171171 PMC8171171.1 8171171 8171171 34034448 10.15441/ceem.21.023 ceem-21-023 1 Guideline 2020 Korean Guidelines for Cardiopulmonary Resuscitation. Part 4. Adult advanced life support Oh Jaehoon 1 <http://orcid.org/0000-0003-1818-2466> Cha Kyoung-Chul 2 Lee Jong-Hwan 3 Park Seungmin 4 Kim Dong-Hyeok 5 Lee Byung Kook 6 Park Jung Soo 7 Jung Woo Jin 2 Lee Dong Keon 3 Roh Young Il 2 Kim Tae Youn 2 Chung Sung Phil 8 Kim Young-Min 9 Park June Dong 9 Kim Han-Suk 10 Lee Mi Jin 11 Na Sang-Hoon 12 Cho Gyu Chong 13 Kim Ai-Rhan Ellen 14 Hwang Sung Oh 2 on behalf of the Steering Committee of the 2020 Korean Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care 1 Department of Emergency Medicine, Hanyang University College of Medicine, Seoul, Korea 2 Department of Emergency Medicine, Yonsei University Wonju College of Medicine, Wonju, Korea 3 Department of Anesthesiology and Pain Medicine, Sungkyunkwan University College of Medicine, Seoul, Korea 4 Department of Emergency Medicine, Seoul National University College of Medicine, Seoul, Korea 5 Department of Internal Medicine, Ewha Womans University College of Medicine, Seoul, Korea 6 Department of Emergency Medicine, Chonnam National University College of Medicine, Gwangju, Korea 7 Department of Emergency Medicine, Chungnam National University College of Medicine, Daejeon, Korea 8 Department of Emergency Medicine, Yonsei University College of Medicine, Seoul, Korea 9 Department of Emergency Medicine, The Catholic University of Korea College of Medicine, Seoul, Korea 10 Department of Pediatrics, Seoul National University College of Medicine, Seoul, Korea 11 Department of Emergency Medicine, Kyungpook National University College of Medicine, Daegu, Korea 12 Department of Internal Medicine, Seoul National University College of Medicine, Seoul, Korea 13 Department of Emergency Medicine, Hallym University College of Medicine, Seoul, Korea 14 Department of Pediatrics, Ulsan University College of Medicine, Seoul, Korea Correspondence to: Kyoung-Chul Cha Department of Emergency Medicine, Yonsei University Wonju College of Medicine, 20 Ilsan-ro, Wonju 26426, Korea E-mail: chaemp@yonsei.ac.kr 5 2021 21 5 2021 8 Suppl 383026 S26 S40 7 3 2021 7 3 2021 19 3 2021 21 05 2021 11 06 2021 24 08 2022 Copyright © 2021 The Korean Society of Emergency Medicine 2021 <https://creativecommons.org/licenses/by-nc/4.0/> This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0/>). Erratum to “2020 Korean Guidelines for Cardiopulmonary Resuscitation. Part 4. Adult advanced life support” 9 2 30 6 2022 162 163 Clinical and Experimental Emergency Medicine PMC9288876 35843620 pmc-status-qastatus 0 pmc-status-live yes pmc-status-embargo no pmc-status-released yes pmc-prop-open-access yes pmc-prop-olf no pmc-prop-manuscript no pmc-prop-legally-suppressed no pmc-prop-has-pdf yes pmc-prop-has-supplement no pmc-prop-pdf-only no pmc-prop-suppress-copyright no pmc-prop-is-real-version no pmc-prop-is-scanned-article no pmc-prop-preprint no pmc-prop-in-epmc yes pmc-license-ref CC BY-NC BACKGROUND OF THE 2020 GUIDELINES

FOR ADULT ADVANCED LIFE SUPPORT Adult advanced life support (ALS) is an important part of the chain of survival, promoting systemic circulation and oxygen supply during high-quality basic life support in patients with cardiac arrest. It includes advanced airway management, manual defibrillation, pharmacological therapy with vasopressors and antiarrhythmic agents, use of an extracorporeal circulation device, and other techniques to achieve return of spontaneous circulation (ROSC) [1 - 3].

Several milestone studies on ALS have been published since the publication of the 2015 Korean cardiopulmonary resuscitation (CPR) guidelines. These include a multicenter, randomized, double-blind, placebo-controlled study evaluating the effect of epinephrine in patients with out-of-hospital cardiac arrest (OHCA) as well as a comparative study on amiodarone, lidocaine, or placebo in patients with refractory shockable rhythm [4 , 5]. A study comparing the use of a supraglottic airway (SGA) device and endotracheal intubation for advanced airway management during OHCA has also been published [6].

Based on new research evidence, relevant contents of the 2015 CPR guidelines were revised in the 2020 Korean Adult ALS guidelines, with the addition of recommendations such as double sequential defibrillation, application of ultrasound, and monitoring of cerebral oxygen saturation during CPR [7 - 12]. In particular, the establishment of a rapid response team (RRT) or medical emergency team and the application of an early warning score were emphasized for preventing in-hospital cardiac arrest (IHCA) [13 - 19]. Specialized guidelines for the resuscitation of patients with confirmed or suspected coronavirus disease 2019 (COVID-19) have also been included [20 , 21].

High-quality CPR should be performed during all processes of ALS. The defibrillation pads or electrodes should be applied to the patient to monitor the electrocardiography (ECG) rhythm immediately after the ALS team arrives. Based on the ECG rhythm analysis, a team leader should decide on a treatment strategy as soon as possible. All team members should be proficient in the entire ALS algorithm so that it can be performed efficiently.

When an ALS team arrives at the scene, the defibrillation pads or electrodes should be attached to the patient to analyze the ECG rhythm immediately. To ensure high-quality CPR, newly arrived providers should perform chest compressions and ventilation in place of basic life support (BLS) providers. The chest compression-to-ventilation ratio should be 30:2 on 100% oxygen if an advanced airway has not been placed. Cardiac arrest rhythms are classified as shockable rhythms (ventricular fibrillation [VF] and pulseless ventricular tachycardia [pVT]) and non-shockable rhythms (asystole and pulseless electrical activity [PEA]). If the cardiac rhythm shows as a pVT or PEA, ALS providers should palpate the carotid artery to confirm the absence of a pulse. Since the ECG rhythm might change during CPR, providers should analyze it every 2 minutes and follow the treatment algorithm according to the analysis (Fig. 1).

Because VF and pVT can be terminated with defibrillation, they are also known as “shockable rhythms.” Providers should deliver a single shock (biphasic wave defibrillator: 120–200 J, monophasic wave defibrillator: 360 J) when a shockable rhythm is confirmed on the ECG monitor and resume CPR immediately for 2 minutes, beginning with chest compressions without a pulse check or ECG rhythm analysis. If the provider cannot identify the manufacturer’s recommended dose of the biphasic defibrillator, defibrillation (shock) should be conducted at 200 J. After the first shock is delivered, an intravenous (IV) or intraosseous (IO) route for drug administration should be established, and a 1 mg bolus of epinephrine should be administered, followed by a bolus of IV fluids. The IO route should be attempted only if the IV access is unsuccessful or not feasible. Administration of 1 mg epinephrine should be repeated every 3 to 5 minutes while ALS continues. After 2 minutes of CPR, the ECG rhythm should be checked. If a shockable rhythm persists, the provider should deliver another shock with equivalent or higher energy than the previous defibrillation and resume CPR immediately.

Meanwhile, another provider should consider performing advanced airway management and capnography. If an advanced airway is in place, it is reasonable to deliver 1 breath every 6 seconds (10 times/min) with continuous chest compressions. If endotracheal intubation has been performed, monitoring of the end-tidal carbon dioxide (ETCO₂) can assess the CPR quality and detect ROSC. If a shockable rhythm persists after 2 minutes of CPR, the provider should deliver another shock and resume CPR. Amiodarone or lidocaine can be prepared for refractory VF or pVT that is unresponsive to the second shock and may be administered immediately after the third shock. The recommended first dose is 300 mg for amiodarone or 1 to 1.5 mg/kg for lidocaine. If the VF or pVT persists, a second dose of amiodarone 150 mg or lidocaine 0.5 to 0.75 mg/kg can be administered. Based on the patient's cardiac arrest situation or medical history, immediate identification and treatment of the reversible causes of cardiac arrest may facilitate ROSC. Point-of-care ultrasound (POCUS), if available and not interfering with CPR, may be helpful to identify the cause of cardiac arrest. Extracorporeal CPR (eCPR) may be considered if ROSC is not achieved despite a high-quality CPR and if there is a potentially reversible cause of cardiac arrest that might benefit from temporary cardiorespiratory support.

As asystole and PEA do not require defibrillation during CPR, they are referred to as "non-shockable rhythms." Asystole is the absence of ventricular contraction regardless of the presence of atrial contraction. Meanwhile, PEA is a clinical condition defined by the absence of measurable blood pressure and palpable pulse despite the presence of sufficient electrical discharge and a heterogeneous group of pulseless rhythms, including pseudo-electromechanical dissociation, idioventricular rhythms, ventricular escape rhythms, and brady-asystolic rhythms. Patients with cardiac arrest with PEA can be treated if the reversible causes are identified and corrected, even though the survival rate of cardiac arrest patients with asystole is very low. If the ECG rhythm is nonshockable, chest compressions should be performed immediately for 2 minutes while the route (IV or IO) for drug administration is being established. Subsequently, a 1 mg bolus of epinephrine should be administered as soon as possible, along with an IV fluid push. Administration of 1 mg of epinephrine should be repeated every 3 to 5 minutes while ALS continues. After 2 minutes of CPR, the ECG rhythm should be analyzed. If the asystole or PEA persists, chest compressions should be continued, and advanced airway management should be performed. If a shockable rhythm is observed, the shock should be delivered according to the "shockable rhythm" algorithm. POCUS, if available and not interfering with CPR, can be helpful to identify the cause of cardiac arrest.

The adult ALS algorithm for OHCA is similar to that for IHCA. However, in OHCA, bag-mask ventilation (BMV) is preferably recommended for providers who are unfamiliar with advanced airway management. Using an SGA device is also preferred to endotracheal intubation for providers with little experience in endotracheal intubation. It is recommended to consider transferring the patient to the hospital after performing ALS on scene for 10 minutes if the emergency medical technicians (EMTs) participating in the resuscitation could perform ALS, including advanced airway management and epinephrine administration. In contrast, it is recommended to transfer the patient to the hospital after resuscitation for 6 minutes according to the BLS guidelines if the prehospital resuscitation team could not perform ALS. For example, in the case of a multitiered dispatch system, if the first EMT who arrives at the scene can perform ALS, the EMT should consider transferring the patient to the hospital after providing ALS for 10 minutes; otherwise, providing 6 minutes of CPR and then transferring the patient to the hospital would be appropriate. Scene time interval could be modified under direct medical oversight (Fig. 2).

Chest compressions, positive pressure ventilation, and securing an advanced airway can generate aerosols, which could increase the risk of transmission of COVID-19. It is essential that providers protect themselves and their colleagues from unnecessary exposure to both airborne and droplet particles. Members of the ALS team should wear appropriate personal protective equipment (PPE) with a minimum of Level D protection, including a mask (a minimum of N95 or FFP3) or powered air-purifying respirator, gloves, gown, and goggles or face shield before starting ALS. For patients with a poor prognosis, the provision of resuscitation should be reevaluated, and ALS should be started when resuscitation is deemed necessary. The ALS team should comprise the minimum

number of essential personnel. A mechanical CPR device can be used to minimize contact with the patient. For ECG rhythm check and defibrillation, a defibrillation pad should be used, if feasible. If advanced airway management is required, the provider should stop the chest compressions, perform endotracheal intubation with a cuffed tube, and connect the endotracheal tube with a high-efficiency particulate air filter, if available. Video laryngoscopy for endotracheal intubation should also be considered to reduce exposure to aerosol. If endotracheal intubation is delayed, the provider should consider attaching an SGA device or bag-valve mask to a high-efficiency particulate air filter with a tight seal. After completion of resuscitation, PPE should be disposed of according to the infection control guidelines and ALS providers should wash their hands thoroughly with soap and water or disinfect them with alcohol-based hand sanitizer as soon as possible, followed by a change of clothes (Fig. 3).

Using a feedback device and monitoring the patient can help optimize CPR quality and assess patient status during CPR [22]. However, it is not recommended to implement real time CPR feedback devices routinely because their use has no significant effect on resuscitation outcome compared with not using them at all [23 - 26]. Nevertheless, real time CPR feedback devices in medical systems can be used for monitoring CPR quality. No studies have proven the usefulness of checking the pulse to evaluate the effectiveness of chest compressions during CPR. However, the pulse can be checked as a method to confirm ROSC. Providers should check the pulse within 5 to 10 seconds to minimize chest compression interruption and, if there is no pulse, resume chest compressions immediately [27 - 29]. Advanced monitoring parameters such as ETCO₂ partial pressure, coronary perfusion pressure, and central venous oxygen saturation can be used as physiological monitoring indices during ALS. During cardiac arrest, ETCO₂ levels reflect the cardiac output generated by chest compressions. An ETCO₂ level of <10 mmHg despite high-quality CPR of >20 minutes has been associated with an extremely poor chance of ROSC and survival outcome. An abrupt increase of ETCO₂ during resuscitation may imply ROSC [30 - 34]. However, ETCO₂ partial pressure should not be used as a sole indicator of CPR quality and ROSC.

Measuring the ETCO₂ level from an SGA or bag-valve-mask airway cannot adequately predict the efficiency of chest compressions and resuscitation outcomes, but it is the most reliable method for confirming the correct placement of an endotracheal tube after intubation [35]. If the coronary perfusion pressure is <15 mmHg during CPR, the chance of ROSC is low [36]. However, coronary perfusion pressure is difficult to monitor because it is calculated from the arterial relaxation "diastolic" pressure and central venous pressure during CPR. If the central venous oxygen saturation (ScvO₂) has been monitored prior to cardiac arrest, or if catheterization is possible without interfering with resuscitation, providers can consider measuring the ScvO₂ to monitor CPR quality. Studies have shown that a ScvO₂ of <30% during CPR is associated with failure to restore spontaneous circulation; thus, providers should ensure high-quality CPR to maintain the ScvO₂ above 30% [37].

Pulse oximetry is not a suitable monitoring method because peripheral circulation is insufficient during cardiac arrest. Nevertheless, it can be used to evaluate proper oxygenation after ROSC [27]. Moreover, regional cerebral oxygen saturation monitoring using near-infrared spectroscopy during adult CPR can be easily applied noninvasively to help assess cerebral perfusion status and predict ROSC and prognosis [11 , 38].

When performing high-quality CPR and defibrillation, providers should be able to establish a route for drug administration. This procedure should not interfere with chest compressions [39 , 40]. The peripheral IV route is the traditional approach; it is reasonable that providers should first attempt IV access for drug administration during CPR [41 , 42]. A fluid bolus of 20 mL should be injected after drug administration to promote the entry of drugs into the central circulation. Lifting the arm during or after drug injection might theoretically promote the inflow of drug into the central circulation by gravity, although there is no evidence to support this. IO access, on the other hand, is safe and useful for infusion of fluids, administration of drugs, and blood sampling in patients of any age. However, two studies have shown that the rates of ROSC and survival to hospital discharge were

lower with using IO access than with using IV access during cardiac arrest [40 , 43]. IO access may nonetheless be considered if IV access is unsuccessful or not feasible. Another option is drug administration via a central venous catheter, which can achieve higher peak concentrations and more rapid circulation than peripheral IV administration [44 - 46]. Such a route may be considered by skilled providers when IV and IO access are unsuccessful or not feasible, although it may require interruption of CPR. An endotracheal tube may also be used, but drug delivery and pharmacological effects can be unpredictable with this route [47 , 48].

The alpha-adrenergic effect of epinephrine increases coronary artery perfusion pressure and cerebral perfusion pressure during CPR. In a study comparing the effects of epinephrine and placebo in patients with OHCA, the 3-month survival rate was higher in the group administered 1 mg of epinephrine at intervals of 3 to 5 minutes [4]. Therefore, it is recommended to administer 1 mg of epinephrine at intervals of 3 to 5 minutes to patients with cardiac arrest regardless of the cardiac arrest rhythm. Other studies with a very low level of evidence showed that high-dose epinephrine administration improved spontaneous circulation and survival to hospital admission compared with standard-dose administration (1 mg every 3 to 5 minutes in the form of a 1:1,000 ampule or 1:10,000 prefilled syringe formula) but did not improve survival to hospital discharge and neurological outcomes [49 , 50]. Therefore, routine administration of high doses of epinephrine is not recommended; however, an expert may deem it necessary [51].

The non-adrenergic peripheral vasoconstrictor, vasopressin, can also augment arterial blood pressure. A study comparing the effects of epinephrine and vasopressin found no difference in prognosis in patients with OHCA [52 , 53]. No differences were also found in the resuscitation outcomes in trials comparing vasopressin alone or vasopressin combined with epinephrine to epinephrine alone in cardiac arrest patients [54 , 55]. However, no studies have shown that the use of vasopressin alone or in combination with epinephrine worsens the prognosis of cardiac arrest patients [52 - 56]. Therefore, 40 units of vasopressin or vasopressin in combination with epinephrine may be administered as an alternative for the first or second dose of epinephrine.

Administration of amiodarone or lidocaine to OHCA patients with refractory VF or pVT improved survival to hospital admission but did not improve overall survival to hospital discharge or survival with good neurological outcome. The critical outcome of survival to hospital discharge was improved with amiodarone or lidocaine compared to placebo in patients with bystander-witnessed cardiac arrest; however, there was no difference between amiodarone and lidocaine with regard to ROSC, favorable neurological outcome, or survival to hospital discharge [5]. Additionally, the routine use of magnesium is not recommended in adult cardiac arrest patients [57]. When using amiodarone, the first dose is 300 mg IV or IO, and 150 mg can be added if the patient remains unresponsive. The first dose of lidocaine is 1 to 1.5 mg/kg IV or IO bolus, and then 0.5 to 0.75 mg/kg every 5 to 10 minutes; up to 3 mg/kg can be added [57 , 58]. Although lidocaine or beta-blockers may be considered for the prevention of arrhythmias immediately after ROSC in patients with refractory VF or pVT, their effectiveness remains uncertain [59 , 60].

Early defibrillation is crucial in patients with VF or pVT. Therefore, providers should deliver a shock immediately when the defibrillator is ready and a shockable rhythm is detected on ECG [61 - 65]. Biphasic waveform defibrillators are preferred over monophasic defibrillators because they are more safe and effective [66 , 67]. In unmonitored cardiac arrest, a single-shock strategy is suggested because the success rate of the first shock is around 90% and chest compression interruption is prolonged in stacked shocks [68 , 69]. Chest compressions should be performed even while the defibrillator is charging. The chest compression interruption before and after defibrillation should be within 10 s during the entire process of resuscitation [70 - 73]. For effective defibrillation, the shock should be delivered at the end of expiration to decrease transthoracic resistance, and it would be better to use defibrillation pads rather than paddles to ensure contact with the chest pads [74 - 76]. The usefulness of double sequential defibrillation for refractory VF or pVT has not been established [9 , 77].

Providers may use either BMV or an advanced airway strategy during ALS. However, in the case of advanced airway management in OHCA, EMTs without adequate training and experience in endotracheal intubation should use an SGA device. It is recommended that only experienced EMTs should try to perform endotracheal intubation [78 - 83]. For adult patients with IHCA, either an SGA device or endotracheal intubation may be considered.

The use of mechanical chest compression devices has not shown improvement in the critical outcomes in OHCA and IHCA [84 - 90]. However, the use of these devices may be considered in specific settings where high quality manual compressions are not possible or may harm the providers (e.g., limited personnel, in a moving ambulance, during coronary angiography, during prolonged CPR, during eCPR, or risk of exposure to infectious disease such as COVID-19) [20 , 91].

eCPR refers to venoarterial extracorporeal membrane oxygenation and cardiopulmonary bypass during the resuscitation of a cardiac arrest patient. Providers can consider applying eCPR to patients who have not achieved spontaneous circulation or have experienced repeated cardiac arrests despite receiving high quality CPR and patients who are expected to have a good neurological outcome. Highly trained medical staff and proper equipments and facilities are necessary for successful application of extracorporeal membrane oxygenation [92 , 93]. eCPR is recommended in patients aged <75 years and those with an initially shockable rhythm, a cardiac etiology or reversible cause of cardiac arrest, a no-flow time of <5 minutes, an unsuccessful resuscitation despite receiving ALS for >10 minutes, and a total collapse time of <60 minutes [94 - 107].

Based on previous CPR guidelines suggesting that a high oxygen level must be supplied during CPR and a study finding that the arterial partial pressure of oxygen was higher in resuscitated patients, it is recommended to supply 100% oxygen during CPR [108]. However, after ROSC, it is necessary to adjust the level of inhaled oxygen to maintain an oxygen saturation of 94% to 98% [109 - 111]. There is insufficient evidence for or against targeting mild hypercapnia compared with normocapnia in postcardiac arrest patients [109 , 110].

Since the ETCO₂ level reflects the cardiac output generated by chest compressions, it could be used to predict the patient's outcome during CPR. In intubated patients, ETCO₂ levels of <10 mmHg after 20 minutes of ALS were associated with poor outcomes, which can be a factor for deciding on whether to terminate resuscitation [32 , 112]. However, this parameter should not be used alone as a prediction tool for terminating resuscitation during CPR and should not be applied to patients who have not undergone endotracheal intubation.

Experienced physicians can use an ultrasound, if it does not interfere with CPR, to diagnose reversible causes of cardiac arrest such as cardiac tamponade, pulmonary thromboembolism (PTE), and myocardial infarction as well as to identify the existence of cardiac motility in patients with a PEA rhythm [10 , 113 - 115]. Ultrasound can also be used as an alternative to ETCO₂ capnography to confirm the correct placement of an endotracheal tube during CPR [116]. However, it should not be recommended as an independent predictor for terminating resuscitation.

Cardiac arrest due to PTE is the most dangerous complication of venous thromboembolism, and most cases of PTE are caused by deep vein thrombosis [117]. There is evidence of low certainty supporting the occurrence of intra-arrest thrombolysis in patients suspected with PTE [118 - 120]. There is also evidence of very low certainty supporting the performance of surgical embolization or percutaneous mechanical thrombectomy to resuscitate patients with cardiac arrest [121]. Therefore, thrombolysis is recommended in cardiac arrest patients suspected of PTE. Providers should also consider performing surgical embolectomy or percutaneous mechanical embolectomy in cardiac arrest patients diagnosed with PTE.

In pregnant women over 20 weeks of gestation, the cardiac output might be decreased by 30% to 40% as a result of compression of the inferior vena cava and aorta by the uterus, which reduces venous return [122]. In this case, the effectiveness of chest compressions may be reduced. The easiest method to avoid compressing the inferior vena cava or aorta is by lateral uterine displacement, which can be achieved by placing the patient in a supine position on a firm surface and moving the uterus to the patient's left by pushing it with one hand from the right side or pulling it with two hands from the left side [123 , 124].

When providing chest compressions, the provider may consider placing the chest compressions slightly higher than the center of the sternum, which is the standard position, to take account of the rise of the abdominal cavity and diaphragm during pregnancy [125 , 126]. However, there is still insufficient evidence about the proper positioning of chest compressions in pregnancy. Since there is no change in transthoracic impedance during pregnancy and there are no reports that defibrillation affects the fetal heart, defibrillation can be performed according to standard CPR guidelines.

If cardiac arrest is imminent or occurs in pregnant women, hysterotomy or cesarean section should be performed as soon as possible. Early delivery can improve the resuscitation outcomes by relieving compression of the aorta and vena cava [127]. Several studies of pregnant women with cardiac arrest showed that fetal survival rates were high when the cesarean section was performed successfully within 5 minutes of cardiac arrest [128]. Therefore, it is recommended to perform a cesarean section within 5 minutes when spontaneous circulation is not achieved even after performing CPR for the first 4 minutes in pregnant women who are at >20 weeks of gestation or whose uterus is palpable above the umbilicus.

"Early recognition and CPR team activation" constitute the first chain of survival from IHCA according to the 2000 Korean CPR guidelines. For successful resuscitation of patients with IHCA, an appropriate survival environment that includes operation of an RRT, training in ALS, establishment of a cardiac arrest treatment system, and quality improvement activities must be established [129 - 131].

An RRT is designed to detect patients who are deteriorating rapidly at an early stage and to respond appropriately [13]. The role of an RRT includes making decisions about transferring the patient to the intensive care unit, implementing a do-not-resuscitate order, performing intensive care including CPR, and planning care for a patient with terminal illness.

Most cases of IHCA exhibit a non-shockable rhythm at an early stage, which is generally preceded by respiratory failure or shock [81 , 132 , 133]. Therefore, the use of an early warning score can help the RRT detect a rapidly deteriorating patient. Hospital systems may use different early warning scores, but the NEWS (National Early Warning Score) and MEWS (Modified Early Warning Score) are well known [17].

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PMC7576326 2 Panchal AR Bartos JA Cabanas JG Part 3: Adult Basic and Advanced Life Support: 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Circulation 2020 142 16_suppl_2 S366 468 10.1161/CIR.0000000000000916 33081529 3 Morrison LJ Gent LM Lang E Part 2: Evidence Evaluation and Management of Conflicts of Interest: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Circulation 2015 132 18 Suppl 2 S368 82 26472990 10.1161/CIR.0000000000000253 4 Perkins GD Ji C Deakin CD A randomized trial of epinephrine in out-of-hospital cardiac arrest N Engl J Med 2018 379 711 21 30021076 10.1056/NEJMoa1806842 5 Kudenchuk PJ Brown SP Daya M Amiodarone, lidocaine, or placebo in out-of-hospital cardiac arrest N Engl J Med 2016 374 1711 22 27043165 10.1056/NEJMoa1514204 6 Bengler JR Kirby K Black S Effect of a strategy of a supraglottic airway device vs tracheal intubation during out-of-hospital cardiac arrest on functional outcome: the AIRWAYS-2 randomized clinical trial JAMA 2018 320 779 91 30167701 10.1001/jama.2018.11597 PMC6142999 7 Cabanas JG Myers JB Williams JG De Maio VJ Bachman MW Double sequential external defibrillation in out-of-hospital refractory ventricular fibrillation: a report of ten cases Prehosp Emerg Care 2015 19 126 30 25243771 10.3109/10903127.2014.942476 8 Ross EM Redman TT Harper SA Mapp JG Wampler DA Miramontes DA Dual defibrillation in out-of-hospital cardiac arrest: a retrospective cohort analysis Resuscitation 2016 106 14 7 27344928 10.1016/j.resuscitation.2016.06.011 9 Cheskes S Dorian P Feldman M Double sequential external defibrillation for refractory ventricular fibrillation: the DOSE VF pilot randomized controlled trial Resuscitation 2020 150 178 84 32084567 10.1016/j.resuscitation.2020.02.010 10 Gaspari R Weekes A Adhikari S Emergency department point-of-care ultrasound in out-of-hospital and in-ED cardiac arrest Resuscitation 2016 109 33 9 27693280 10.1016/j.resuscitation.2016.09.018 11 Engel TW 2nd Thomas C Medado P End tidal CO2 and cerebral oximetry for the prediction of return of spontaneous circulation during cardiopulmonary resuscitation Resuscitation 2019 139 174 81 30978377 10.1016/j.resuscitation.2019.04.006 12 Singer AJ Nguyen RT Ravishankar ST Cerebral oximetry versus end tidal CO2 in predicting ROSC after cardiac arrest Am J Emerg Med 2018 36 403 7 28847626 10.1016/j.ajem.2017.08.046 13 Maharaj R Raffaele I Wendon J Rapid response systems: a systematic review and meta-analysis Crit Care 2015 19 254 26070457 10.1186/s13054-015-0973-y PMC4489005 14 Park Y Ahn JJ Kang BJ Rapid response systems reduce in-hospital cardiopulmonary arrest: a pilot study and motivation for a nationwide survey Korean J Crit Care Med 2017 32 231 9 31723641 10.4266/kjccm.2017.00024 PMC6786727 15 Ko BS Lim TH Oh J The effectiveness of a focused rapid response team on reducing the incidence of cardiac arrest in the general ward Medicine (Baltimore) 2020 99 e19032 32150050 10.1097/MD.00000000000019032 PMC7478490 16 Brady PW Zix J Brilli R Developing and evaluating the success of a family activated medical emergency team: a quality improvement report BMJ Qual Saf 2015 24 203 11 10.1136/bmjqs-2014-003001 25516987 17 Smith GB Prytherch DR Meredith P Schmidt PE Featherstone PI The ability of the National Early Warning Score (NEWS) to discriminate patients at risk of early cardiac arrest, unanticipated intensive care unit admission, and death Resuscitation 2013 84 465 70 23295778 10.1016/j.resuscitation.2012.12.016 18 Subbe CP Kruger M Rutherford P Gemmel L Validation of a modified Early Warning Score in medical admissions QJM 2001 94 521 6 11588210 10.1093/qjmed/94.10.521 19 Subbe CP Davies RG Williams E Rutherford P Gemmell L Effect of introducing the Modified Early Warning score on clinical outcomes, cardio-pulmonary arrests and intensive care utilisation in acute medical admissions Anaesthesia 2003 58 797 802 12859475 10.1046/j.1365-2044.2003.03258.x 20 Edelson DP Sasson C Chan PS Interim Guidance for Basic and Advanced Life Support in Adults, Children, and Neonates With Suspected or Confirmed COVID-19: From the Emergency Cardiovascular Care Committee and Get With The Guidelines-Resuscitation Adult and Pediatric Task Forces of the American Heart Association Circulation 2020 141 e933 43 32270695 10.1161/CIRCULATIONAHA.120.047463 PMC7302067 21 Korean Society of Emergency Medicine A recommendation for in-hospital cardiopulmonary resuscitation in patient suspicious of coronavirus 19 infection Seoul Korean Society of Emergency Medicine 2020 22 Crowe C Bobrow BJ Vadeboncoeur TF Measuring and improving cardiopulmonary resuscitation quality inside the emergency department Resuscitation 2015 93 8 13 25963706 10.1016/j.resuscitation.2015.04.031 23 Smereka J Szarpak L Czekajlo M The TrueCPR device in the process of teaching cardiopulmonary resuscitation: a randomized simulation trial Medicine (Baltimore) 2019 98 e15995 31277091 10.1097/MD.00000000000015995 PMC6635263 24 Zhou XL Wang J Jin XQ Zhao Y Liu

RL Jiang C Quality retention of chest compression after repetitive practices with or without feedback devices: a randomized manikin study *Am J Emerg Med* 2020 38 73 8 31005392 10.1016/j.ajem.2019.04.025 25 Oh J Lim TH Cho Y Training a chest compression of 6-7 cm depth for high quality cardiopulmonary resuscitation in hospital setting: a randomised controlled trial *Yonsei Med J* 2016 57 505 11 26847307 10.3349/ymj.2016.57.2.505 PMC4740547 26 Lee S Oh J Kang H Proper target depth of an accelerometer-based feedback device during CPR performed on a hospital bed: a randomized simulation study *Am J Emerg Med* 2015 33 1425 9 26298053 10.1016/j.ajem.2015.07.010 27 Neumar RW Otto CW Link MS Part 8: adult advanced cardiovascular life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care *Circulation* 2010 122 18 Suppl 3 S729 67 20956224 10.1161/CIRCULATIONAHA.110.970988 28 Ochoa FJ Ramalle-Gomara E Carpintero JM Garcia A Saralegui I Competence of health professionals to check the carotid pulse *Resuscitation* 1998 37 173 5 9715777 10.1016/s0300-9572(98)00055-0 29 Mather C O'Kelly S The palpation of pulses *Anaesthesia* 1996 51 189 91 8779381 10.1111/j.1365-2044.1996.tb07713.x 30 Levine RL Wayne MA Miller CC End-tidal carbon dioxide and outcome of out-of-hospital cardiac arrest *N Engl J Med* 1997 337 301 6 9233867 10.1056/NEJM199707313370503 31 Pearce AK Davis DP Minokadeh A Sell RE Initial end-tidal carbon dioxide as a prognostic indicator for inpatient PEA arrest *Resuscitation* 2015 92 77 81 25939324 10.1016/j.resuscitation.2015.04.025 32 Ahrens T Schallom L Bettorf K End-tidal carbon dioxide measurements as a prognostic indicator of outcome in cardiac arrest *Am J Crit Care* 2001 10 391 8 11688606 33 Sandroni C De Santis P D'Arrigo S Capnography during cardiac arrest *Resuscitation* 2018 132 73 7 30142399 10.1016/j.resuscitation.2018.08.018 34 Paiva EF Paxton JH O'Neil BJ The use of end-tidal carbon dioxide (ETCO₂) measurement to guide management of cardiac arrest: a systematic review *Resuscitation* 2018 123 1 7 29217394 10.1016/j.resuscitation.2017.12.003 35 Grmec S Comparison of three different methods to confirm tracheal tube placement in emergency intubation *Intensive Care Med* 2002 28 701 4 12107674 10.1007/s00134-002-1290-x 36 Reynolds JC Salcido DD Menegazzi JJ Coronary perfusion pressure and return of spontaneous circulation after prolonged cardiac arrest *Prehosp Emerg Care* 2010 14 78 84 19947871 10.3109/10903120903349796 PMC2922866 37 Rivers EP Martin GB Smithline H The clinical implications of continuous central venous oxygen saturation during human CPR *Ann Emerg Med* 1992 21 1094 101 1514720 10.1016/s0196-0644(05)80650-x 38 Cournoyer A Iseppon M Chauny JM Denault A Cossette S Notebaert E Near-infrared spectroscopy monitoring during cardiac arrest: a systematic review and meta-analysis *Acad Emerg Med* 2016 23 851 62 27028004 10.1111/acem.12980 39 Kosciak C Pinawin A McGovern H Rapid epinephrine administration improves early outcomes in out-of-hospital cardiac arrest *Resuscitation* 2013 84 915 20 23523823 10.1016/j.resuscitation.2013.03.023 40 Feinstein BA Stubbs BA Rea T Kudenchuk PJ Intraosseous compared to intravenous drug resuscitation in out-of-hospital cardiac arrest *Resuscitation* 2017 117 91 6 28629995 10.1016/j.resuscitation.2017.06.014 41 Aitkenhead AR Drug administration during CPR: what route? *Resuscitation* 1991 22 191 5 1661024 10.1016/0300-9572(91)90011-m 42 Orlowski JP Porembka DT Gallagher JM Lockrem JD VanLente F Comparison study of intraosseous, central intravenous, and peripheral intravenous infusions of emergency drugs *Am J Dis Child* 1990 144 112 7 1688484 10.1001/archpedi.1990.02150250124049 43 Kawano T Grunau B Scheuermeyer FX Intraosseous vascular access is associated with lower survival and neurologic recovery among patients with out-of-hospital cardiac arrest *Ann Emerg Med* 2018 71 588 96 29310869 10.1016/j.annemergmed.2017.11.015 44 Barsan WG Levy RC Weir H Lidocaine levels during CPR: differences after peripheral venous, central venous, and intracardiac injections *Ann Emerg Med* 1981 10 73 8 10.1016/s0196-0644(81)80339-3 7224254 45 Kuhn GJ White BC Swetnam RE Peripheral vs central circulation times during CPR: a pilot study *Ann Emerg Med* 1981 10 417 9 7020494 10.1016/s0196-0644(81)80308-3 46 Emerman CL Pinchak AC Hancock D Hagen JF Effect of injection site on circulation times during cardiac arrest *Crit Care Med* 1988 16 1138 41 3273155 10.1097/00003246-198811000-00011 47 Hornchen U Schuttler J Stoeckel H Eichelkraut W Hahn N Endobronchial instillation of epinephrine during cardiopulmonary resuscitation *Crit Care Med* 1987 15 1037 9 3677746 10.1097/00003246-198711000-00009 48 Niemann JT Stratton SJ Cruz B Lewis RJ Endotracheal drug administration during out-of-hospital resuscitation: where are the survivors? *Resuscitation* 2002 53 153 7 12009218 10.1016/s0300-9572(02)00004-7 49 Callaham M Madsen CD Barton CW Saunders CE Pointer J A randomized clinical trial of high-dose epinephrine and norepinephrine vs standard-dose epinephrine

in prehospital cardiac arrest JAMA 1992 268 2667 72 1433686 50 Finn J Jacobs I Williams TA Gates S Perkins GD Adrenaline and vasopressin for cardiac arrest Cochrane Database Syst Rev 2019 1 CD003179 30653257 10.1002/14651858.CD003179.pub2 PMC6492484 51 Holmberg MJ Issa MS Moskowitz A Vasopressors during adult cardiac arrest: a systematic review and meta-analysis Resuscitation 2019 139 106 21 30980877 10.1016/j.resuscitation.2019.04.008 52 Stiell IG Hebert PC Wells GA Vasopressin versus epinephrine for in-hospital cardiac arrest: a randomized controlled trial Lancet 2001 358 105 9 11463411 10.1016/S0140-6736(01)05328-4 53 Aung K Htay T Vasopressin for cardiac arrest: a systematic review and meta-analysis Arch Intern Med 2005 165 17 24 15642869 10.1001/archinte.165.1.17 54 Callaway CW Hostler D Doshi AA Usefulness of vasopressin administered with epinephrine during out-of-hospital cardiac arrest Am J Cardiol 2006 98 1316 21 17134621 10.1016/j.amjcard.2006.06.022 55 Gueugniaud PY David JS Chanzy E Vasopressin and epinephrine vs. epinephrine alone in cardiopulmonary resuscitation N Engl J Med 2008 359 21 30 18596271 10.1056/NEJMoa0706873 56 Mukoyama T Kinoshita K Nagao K Tanjoh K Reduced effectiveness of vasopressin in repeated doses for patients undergoing prolonged cardiopulmonary resuscitation Resuscitation 2009 80 755 61 19446387 10.1016/j.resuscitation.2009.04.005 57 Panchal AR Berg KM Kudenchuk PJ 2018 American Heart Association Focused Update on Advanced Cardiovascular Life Support Use of Antiarrhythmic Drugs During and Immediately After Cardiac Arrest: An Update to the American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Circulation 2018 138 e740 9 30571262 10.1161/CIR.0000000000000613 PMC7324904 58 Soar J Nolan JP Bottiger BW European Resuscitation Council Guidelines for Resuscitation 2015: Section 3. Adult advanced life support Resuscitation 2015 95 100 47 26477701 10.1016/j.resuscitation.2015.07.016 59 Skrifvars MB Pettila V Rosenberg PH Castren M A multiple logistic regression analysis of in-hospital factors related to survival at six months in patients resuscitated from out-of-hospital ventricular fibrillation Resuscitation 2003 59 319 28 14659601 10.1016/s0300-9572(03)00238-7 60 Kudenchuk PJ Newell C White L Fahrenbruch C Rea T Eisenberg M Prophylactic lidocaine for post resuscitation care of patients with out-of-hospital ventricular fibrillation cardiac arrest Resuscitation 2013 84 1512 8 23743237 10.1016/j.resuscitation.2013.05.022 61 Bircher NG Chan PS Xu Y American Heart Association's Get With The Guidelines-Resuscitation Investigators Delays in cardiopulmonary resuscitation, defibrillation, and epinephrine administration all decrease survival in in-hospital cardiac arrest Anesthesiology 2019 130 414 22 30707123 10.1097/ALN.0000000000002563 62 Valenzuela TD Roe DJ Nichol G Clark LL Spaite DW Hardman RG Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos N Engl J Med 2000 343 1206 9 11071670 10.1056/NEJM200010263431701 63 White RD Asplin BR Bugliosi TF Hankins DG High discharge survival rate after out-of-hospital ventricular fibrillation with rapid defibrillation by police and paramedics Ann Emerg Med 1996 28 480 5 8909267 10.1016/s0196-0644(96)70109-9 64 Meier P Baker P Jost D Chest compressions before defibrillation for out-of-hospital cardiac arrest: a meta-analysis of randomized controlled clinical trials BMC Med 2010 8 52 20828395 10.1186/1741-7015-8-52 PMC2942789 65 Huang Y He Q Yang LJ Liu GJ Jones A Cardiopulmonary resuscitation (CPR) plus delayed defibrillation versus immediate defibrillation for out-of-hospital cardiac arrest Cochrane Database Syst Rev 2014 2014 CD009803 10.1002/14651858.CD009803.pub2 PMC6516832 25212112 66 Martens PR Russell JK Wolcke B Optimal Response to Cardiac Arrest study: defibrillation waveform effects Resuscitation 2001 49 233 43 11719116 10.1016/s0300-9572(01)00321-5 67 Wang CH Huang CH Chang WT Biphasic versus monophasic defibrillation in out-of-hospital cardiac arrest: a systematic review and meta-analysis Am J Emerg Med 2013 31 1472 8 24035505 10.1016/j.ajem.2013.07.033 68 Jost D Degrange H Verret C DEFI 2005: a randomized controlled trial of the effect of automated external defibrillator cardiopulmonary resuscitation protocol on outcome from out-of-hospital cardiac arrest Circulation 2010 121 1614 22 20351239 10.1161/CIRCULATIONAHA.109.878389 69 Berdowski J ten Haaf M Tijssen JG Chapman FW Koster RW Time in recurrent ventricular fibrillation and survival after out-of-hospital cardiac arrest Circulation 2010 122 1101 8 20805427 10.1161/CIRCULATIONAHA.110.958173 70 Edelson DP Abella BS Kramer-Johansen J Effects of compression depth and pre-shock pauses predict defibrillation failure during cardiac arrest Resuscitation 2006 71 137 45 16982127 10.1016/j.resuscitation.2006.04.008 71 Cheskes S Schmicker RH Christenson J Perishock pause: an independent predictor of survival from out-of-hospital shockable cardiac arrest Circulation 2011 124 58 66 21690495 10.1161/CIRCULATIONAHA.110.010736 PMC3138806 72 Cheskes S Schmicker RH Verbeek PR

The impact of peri-shock pause on survival from out-of-hospital shockable cardiac arrest during the Resuscitation Outcomes Consortium PRIMED trial Resuscitation 2014 85 336 42 24513129 10.1016/j.resuscitation.2013.10.014 PMC3944081 73 Sell RE Sarno R Lawrence B Minimizing pre- and post-defibrillation pauses increases the likelihood of return of spontaneous circulation (ROSC) Resuscitation 2010 81 822 5 20398991 10.1016/j.resuscitation.2010.03.013 74 Deakin CD McLaren RM Petley GW Clewlow F Dalrymple-Hay MJ Effects of positive end-expiratory pressure on transthoracic impedance: implications for defibrillation Resuscitation 1998 37 9 12 9667332 10.1016/s0300-9572(98)00049-5 75 Kerber RE Grayzel J Hoyt R Marcus M Kennedy J Transthoracic resistance in human defibrillation: influence of body weight, chest size, serial shocks, paddle size and paddle contact pressure Circulation 1981 63 676 82 7460251 10.1161/01.cir.63.3.676 76 Connell PN Ewy GA Dahl CF Ewy MD Transthoracic impedance to defibrillator discharge: effect of electrode size and electrode-chest wall interface J Electrocardiol 1973 6 313 M 4765325 10.1016/s0022-0736(73)80053-6 77 Kim HE Lee KJ Jo YH Refractory ventricular fibrillation treated with double simultaneous defibrillation: pilot study Emerg Med Int 2020 2020 5470912 32566304 10.1155/2020/5470912 PMC7273448 78 Chung SP Sakamoto T Lim SH The 2015 Resuscitation Council of Asia (RCA) guidelines on adult basic life support for lay rescuers Resuscitation 2016 105 145 8 27283062 10.1016/j.resuscitation.2016.05.025 79 Wang HE Schmicker RH Daya MR Effect of a strategy of initial laryngeal tube insertion vs endotracheal intubation on 72-hour survival in adults with out-of-hospital cardiac arrest: a randomized clinical trial JAMA 2018 320 769 78 30167699 10.1001/jama.2018.7044 PMC6583103 80 Jabre P Penaloza A Pinero D Effect of bag-mask ventilation vs endotracheal intubation during cardiopulmonary resuscitation on neurological outcome after out-of-hospital cardiorespiratory arrest: a randomized clinical trial JAMA 2018 319 779 87 29486039 10.1001/jama.2018.0156 PMC5838565 81 Andersen LW Holmberg MJ Berg KM Donnino MW Granfeldt A In-hospital cardiac arrest: a review JAMA 2019 321 1200 10 30912843 10.1001/jama.2019.1696 PMC6482460 82 Soar J Maconochie I Wyckoff MH 2019 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations: Summary From the Basic Life Support; Advanced Life Support; Pediatric Life Support; Neonatal Life Support; Education, Implementation, and Teams; and First Aid Task Forces Circulation 2019 140 e826 80 31722543 10.1161/CIR.0000000000000734 83 Andersen LW Granfeldt A Callaway CW Association between tracheal intubation during adult in-hospital cardiac arrest and survival JAMA 2017 317 494 506 28118660 10.1001/jama.2016.20165 PMC6056890 84 Perkins GD Lall R Quinn T Mechanical versus manual chest compression for out-of-hospital cardiac arrest (PARAMEDIC): a pragmatic, cluster randomised controlled trial Lancet 2015 385 947 55 25467566 10.1016/S0140-6736(14)61886-9 85 Rubertsson S Lindgren E Smekal D Mechanical chest compressions and simultaneous defibrillation vs conventional cardiopulmonary resuscitation in out-of-hospital cardiac arrest: the LINC randomized trial JAMA 2014 311 53 61 24240611 10.1001/jama.2013.282538 86 Wang HC Chiang WC Chen SY Video-recording and time-motion analyses of manual versus mechanical cardiopulmonary resuscitation during ambulance transport Resuscitation 2007 74 453 60 17386966 10.1016/j.resuscitation.2007.01.018 87 Hallstrom A Rea TD Sayre MR Manual chest compression vs use of an automated chest compression device during resuscitation following out-of-hospital cardiac arrest: a randomized trial JAMA 2006 295 2620 8 16772625 10.1001/jama.295.22.2620 88 Paradis NA Young G Lemeshow S Brewer JE Halperin HR Inhomogeneity and temporal effects in AutoPulse Assisted Prehospital International Resuscitation: an exception from consent trial terminated early Am J Emerg Med 2010 28 391 8 20466215 10.1016/j.ajem.2010.02.002 89 Tomte O Sunde K Lorem T Advanced life support performance with manual and mechanical chest compressions in a randomized, multicentre manikin study Resuscitation 2009 80 1152 7 19665833 10.1016/j.resuscitation.2009.07.001 90 Wik L Olsen JA Persse D Manual vs. integrated automatic load-distributing band CPR with equal survival after out of hospital cardiac arrest: the randomized CIRC trial Resuscitation 2014 85 741 8 24642406 10.1016/j.resuscitation.2014.03.005 91 Brooks SC Anderson ML Bruder E Part 6: Alternative Techniques and Ancillary Devices for Cardiopulmonary Resuscitation: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Circulation 2015 132 18 Suppl 2 S436 43 26472994 10.1161/CIR.0000000000000260 92 Panchal AR Berg KM Hirsch KG 2019 American Heart Association Focused Update on Advanced Cardiovascular Life Support: Use of Advanced Airways, Vasopressors, and Extracorporeal Cardiopulmonary Resuscitation During Cardiac Arrest: An

Update to the American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care *Circulation* 2019 140 e881 94 31722552

10.1161/CIR.0000000000000732 93 Holmberg MJ Geri G Wiberg S Extracorporeal cardiopulmonary resuscitation for cardiac arrest: a systematic review *Resuscitation* 2018 131 91 100 30063963 10.1016/j.resuscitation.2018.07.029 PMC6441971 94 Bartos JA Grunau B Carlson C Improved survival with extracorporeal cardiopulmonary resuscitation despite progressive metabolic derangement associated with prolonged resuscitation *Circulation* 2020 141 877 86 31896278 10.1161/CIRCULATIONAHA.119.042173 PMC7069385 95 Cesana F Avalli L Garatti L Effects of extracorporeal cardiopulmonary resuscitation on neurological and cardiac outcome after ischaemic refractory cardiac arrest *Eur Heart J Acute Cardiovasc Care* 2018 7 432 41 29064271 10.1177/2048872617737041 96 Choi DH Kim YJ Ryoo SM Extracorporeal cardiopulmonary resuscitation among patients with out-of-hospital cardiac arrest *Clin Exp Emerg Med* 2016 3 132 8 27752631 10.15441/ceem.16.145 PMC5065341 97 Han KS Kim SJ Lee EJ Lee SW The effect of extracorporeal cardiopulmonary resuscitation in re-arrest after survival event: a retrospective analysis *Perfusion* 2020 35 39 47 31146644 10.1177/0267659119850679 98 Hase M Tsuchihashi K Fujii N Early defibrillation and circulatory support can provide better long-term outcomes through favorable neurological recovery in patients with out-of-hospital cardiac arrest of cardiac origin *Circ J* 2005 69 1302 7 16247202 10.1253/circj.69.1302 99 Kim SJ Jung JS Park JH Park JS Hong YS Lee SW An optimal transition time to extracorporeal cardiopulmonary resuscitation for predicting good neurological outcome in patients with out-of-hospital cardiac arrest: a propensity-matched study *Crit Care* 2014 18 535 25255842 10.1186/s13054-014-0535-8 PMC4189722 100 Maekawa K Tanno K Hase M Mori K Asai Y Extracorporeal cardiopulmonary resuscitation for patients with out-of-hospital cardiac arrest of cardiac origin: a propensity-matched study and predictor analysis *Crit Care Med* 2013 41 1186 96 23388518 10.1097/CCM.0b013e31827ca4c8 101 Mandigers L Scholten E Rietdijk WJ Survival and neurological outcome with extracorporeal cardiopulmonary resuscitation for refractory cardiac arrest caused by massive pulmonary embolism: a two center observational study *Resuscitation* 2019 136 8 13 30572065 10.1016/j.resuscitation.2018.12.008 102 Matsuoka Y Ikenoue T Hata N Hospitals' extracorporeal cardiopulmonary resuscitation capabilities and outcomes in out-of-hospital cardiac arrest: a population-based study *Resuscitation* 2019 136 85 92 30668963 10.1016/j.resuscitation.2019.01.013 103 Siao FY Chiu CC Chiu CW Managing cardiac arrest with refractory ventricular fibrillation in the emergency department: conventional cardiopulmonary resuscitation versus extracorporeal cardiopulmonary resuscitation *Resuscitation* 2015 92 70 6 25936930 10.1016/j.resuscitation.2015.04.016 104 Venturini JM Retzer E Estrada JR Mechanical chest compressions improve rate of return of spontaneous circulation and allow for initiation of percutaneous circulatory support during cardiac arrest in the cardiac catheterization laboratory *Resuscitation* 2017 115 56 60 28377296 10.1016/j.resuscitation.2017.03.037 105 Yannopoulos D Bartos JA Raveendran G Coronary artery disease in patients with out-of-hospital refractory ventricular fibrillation cardiac arrest *J Am Coll Cardiol* 2017 70 1109 17 28838358 10.1016/j.jacc.2017.06.059 106 Chen YS Lin JW Yu HY Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis *Lancet* 2008 372 554 61 18603291 10.1016/S0140-6736(08)60958-7 107 Lin JW Wang MJ Yu HY Comparing the survival between extracorporeal rescue and conventional resuscitation in adult in-hospital cardiac arrests: propensity analysis of three-year data *Resuscitation* 2010 81 796 803 20413202 10.1016/j.resuscitation.2010.03.002 108 Spindelboeck W Gemes G Strasser C Arterial blood gases during and their dynamic changes after cardiopulmonary resuscitation: a prospective clinical study *Resuscitation* 2016 106 24 9 27328890 10.1016/j.resuscitation.2016.06.013 109 Young P Bailey M Bellomo R HyperOxic Therapy OR NormOxic Therapy after out-of-hospital cardiac arrest (HOT OR NOT): a randomised controlled feasibility trial *Resuscitation* 2014 85 1686 91 25261605 10.1016/j.resuscitation.2014.09.011 110 Jakkula P Reinikainen M Hastbacka J Targeting two different levels of both arterial carbon dioxide and arterial oxygen after cardiac arrest and resuscitation: a randomised pilot trial *Intensive Care Med* 2018 44 2112 21 30430209 10.1007/s00134-018-5453-9 PMC6280824 111 ICU-ROX Investigators and the Australian and New Zealand Intensive Care Society Clinical Trials Group Mackle D Bellomo R Conservative oxygen therapy during mechanical ventilation in the ICU *N Engl J Med* 2020 382 989 98 31613432 10.1056/NEJMoa1903297 112 Levin PD Pizov R End-tidal carbon dioxide and outcome of out-of-hospital cardiac arrest *N Engl J Med* 1997 337 1694 5 9411238 113 Clattenburg EJ Wroe P

Brown S Point-of-care ultrasound use in patients with cardiac arrest is associated prolonged cardiopulmonary resuscitation pauses: a prospective cohort study *Resuscitation* 2018 122 65 8 29175356 10.1016/j.resuscitation.2017.11.056 114 Chardoli M Heidari F Rabiee H Sharif-Alhoseini M Shokoohi H Rahimi-Movaghar V Echocardiography integrated ACLS protocol versus conventional cardiopulmonary resuscitation in patients with pulseless electrical activity cardiac arrest *Chin J Traumatol* 2012 15 284 7 23069099 115 Breitzkreutz R Price S Steiger HV Focused echocardiographic evaluation in life support and peri-resuscitation of emergency patients: a prospective trial *Resuscitation* 2010 81 1527 33 20801576 10.1016/j.resuscitation.2010.07.013 116 Chou HC Chong KM Sim SS Real-time tracheal ultrasonography for confirmation of endotracheal tube placement during cardiopulmonary resuscitation *Resuscitation* 2013 84 1708 12 23851048 10.1016/j.resuscitation.2013.06.018 117 Konstantinides SV Meyer G Becattini C 2019 ESC Guidelines for the diagnosis and management of acute pulmonary embolism developed in collaboration with the European Respiratory Society (ERS): the Task Force for the diagnosis and management of acute pulmonary embolism of the European Society of Cardiology (ESC) *Eur Respir J* 2019 54 1901647 31473594 10.1183/13993003.01647-2019 118 Bottiger BW Arntz HR Chamberlain DA Thrombolysis during resuscitation for out-of-hospital cardiac arrest *N Engl J Med* 2008 359 2651 62 19092151 10.1056/NEJMoa070570 119 Javaudin F Lascarrou JB Le Bastard Q Thrombolysis during resuscitation for out-of-hospital cardiac arrest caused by pulmonary embolism increases 30-day survival: findings from the French National Cardiac Arrest Registry *Chest* 2019 156 1167 75 31381884 10.1016/j.chest.2019.07.015 120 Yousuf T Brinton T Ahmed K Tissue plasminogen activator use in cardiac arrest secondary to fulminant pulmonary embolism *J Clin Med Res* 2016 8 190 5 26858790 10.14740/jocmr2452w PMC4737028 121 Fava M Loyola S Berton H Dougnac A Massive pulmonary embolism: percutaneous mechanical thrombectomy during cardiopulmonary resuscitation *J Vasc Interv Radiol* 2005 16 119 23 15640419 10.1097/01.RVI.0000146173.85401.BA 122 Chesnutt AN Physiology of normal pregnancy *Crit Care Clin* 2004 20 609 15 15388191 10.1016/j.ccc.2004.06.001 123 Humphries A Mirjalili SA Tarr GP Thompson JM Stone P The effect of supine positioning on maternal hemodynamics during late pregnancy *J Matern Fetal Neonatal Med* 2019 32 3923 30 29772936 10.1080/14767058.2018.1478958 124 Kundra P Khanna S Habeebullah S Ravishankar M Manual displacement of the uterus during Caesarean section Anaesthesia 2007 62 460 5 17448057 10.1111/j.1365-2044.2007.05025.x 125 Holmes S Kirkpatrick ID Zelop CM Jassal DS MRI evaluation of maternal cardiac displacement in pregnancy: implications for cardiopulmonary resuscitation *Am J Obstet Gynecol* 2015 213 401 25981849 10.1016/j.ajog.2015.05.018 126 Delgado C Dawson K Schwaegler B Zachariah R Einav S Bollag L Hand placement during chest compressions in parturients: a pilot study to identify the location of the left ventricle using transthoracic echocardiography *Int J Obstet Anesth* 2020 43 31 5 32574884 10.1016/j.ijoa.2020.05.003 127 Einav S Kaufman N Sela HY Maternal cardiac arrest and perimortem caesarean delivery: evidence or expert-based? *Resuscitation* 2012 83 1191 200 22613275 10.1016/j.resuscitation.2012.05.005 128 Beckett VA Knight M Sharpe P The CAPS Study: incidence, management and outcomes of cardiac arrest in pregnancy in the UK: a prospective, descriptive study *BJOG* 2017 124 1374 81 28233414 10.1111/1471-0528.14521 129 Chan PS Krumholz HM Nichol G Nallamothu BK American Heart Association National Registry of Cardiopulmonary Resuscitation Investigators Delayed time to defibrillation after in-hospital cardiac arrest *N Engl J Med* 2008 358 9 17 18172170 10.1056/NEJMoa0706467 130 Kang JY Kim YJ Shin YJ Huh JW Hong SB Kim WY Association between time to defibrillation and neurologic outcome in patients with in-hospital cardiac arrest *Am J Med Sci* 2019 358 143 8 31200920 10.1016/j.amjms.2019.05.003 131 Patel KK Spertus JA Khariton Y Association between prompt defibrillation and epinephrine treatment with longterm survival after in-hospital cardiac arrest *Circulation* 2018 137 2041 51 29279412 10.1161/CIRCULATIONAHA.117.030488 PMC5940568 132 Hessulf F Karlsson T Lundgren P Factors of importance to 30-day survival after in-hospital cardiac arrest in Sweden: a population-based register study of more than 18,000 cases *Int J Cardiol* 2018 255 237 42 29289346 10.1016/j.ijcard.2017.12.068 133 Nolan JP Soar J Smith GB Incidence and outcome of in-hospital cardiac arrest in the United Kingdom National Cardiac Arrest Audit *Resuscitation* 2014 85 987 92 24746785 10.1016/j.resuscitation.2014.04.002 Fig. 1. Adult advanced life support algorithm for in-hospital cardiac arrest. CPR, cardiopulmonary resuscitation; VF, ventricular fibrillation; pVT, pulseless ventricular tachycardia; IV, intravenous; IO, intraosseous; PEA, pulseless electrical activity; 5H, hypovolemia, hypoxia, hyperkalemia, hydrogen ion (acidosis),

and hypothermia; 5T, tension pneumothorax, tamponade (cardiac), toxin, thrombosis (pulmonary), and thrombosis (coronary); POCUS, point-of-care ultrasound; eCPR, extracorporeal cardiopulmonary resuscitation; ROSC, return of spontaneous circulation.

Adult 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; 5H, hypovolemia, hypoxia, hyperkalemia, hydrogen ion (acidosis), and hypothermia; 5T, tension pneumothorax, tamponade (cardiac), toxin, thrombosis (pulmonary), and thrombosis (coronary); ROSC, return of spontaneous circulation.

Adult advanced life support for cardiac arrest during the COVID-19 outbreak. PPE, personal protective equipment; CPR, cardiopulmonary resuscitation; VF, ventricular fibrillation; pVT, pulseless ventricular tachycardia; PEA, pulseless electrical activity; IV, intravenous; IO, intraosseous; 5H, hypovolemia, hypoxia, hyperkalemia, hydrogen ion (acidosis), and hypothermia; 5T, tension pneumothorax, tamponade (cardiac), toxin, thrombosis (pulmonary), and thrombosis (coronary); POCUS, point-of-care ultrasound; eCPR, extracorporeal cardiopulmonary resuscitation; ROSC, return of spontaneous circulation.