RESUSCITATION 161 (2021) 98 –114

Available online at www.sciencedirect.com

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

European Resuscitation Council Guidelines 2021: Basic Life Support

Theresa M. Olasveengen [a,*], Federico Semeraro [b], Giuseppe Ristagno [c,d], Maaret Castren [e], Anthony Handley [f], Artem Kuzovlev [g], Koenraad G. Monsieurs [h], Violetta Raffay [i], Michael Smyth [j,k], Jasmeet Soar [l], Hildigunnur Svavarsdottir [m,n], Gavin D. Perkins [o,p]

[a] Department of Anesthesiology, Oslo University Hospital and Institute of Clinical Medicine, University of Oslo, Norway
[b] Department of Anaesthesia, Intensive Care and Emergency Medical Services, Maggiore Hospital, Bologna, Italy
[c] Department of Anesthesiology, Intensive Care and Emergency, Fondazione IRCCS Ca' Granda, Ospedale Maggiore Policlinico, Milano, Italy
[d] Department of Pathophysiology and Transplantation, University of Milan, Italy
[e] Emergency Medicine, Helsinki University and Department of Emergency Medicine and Services, Helsinki University Hospital, Helsinki, Finland
[f] Hadstock, Cambridge, United Kingdom
[g] Federal Research and Clinical Center of Intensive Care Medicine and Rehabilitology, V.A. Negovsky Research Institute of General Reanimatology, Moscow, Russia
[h] Department of Emergency Medicine, Antwerp University Hospital and University of Antwerp, Belgium
[i] Department of Medicine, School of Medicine, European University Cyprus, Nicosia, Cyprus
[j] Warwick Clinical Trials Unit, Warwick Medical School, University of Warwick, Coventry CV4 7AL, United Kingdom
[k] West Midlands Ambulance Service and Midlands Air Ambulance, Brierly Hill, West Midlands DY5 1LX, United Kingdom
[l] Southmead Hospital, North Bristol NHS Trust, Bristol, United Kingdom
[m] Akureyri Hospital, Akureyri, Iceland
[n] Institute of Health Science Research, University of Akureyri, Akureyri, Iceland
[o] Warwick Clinical Trials Unit, Warwick Medical School, University of Warwick, Coventry CV4 7AL, United Kingdom
[p] University Hospitals Birmingham, Birmingham B9 5SS, United Kingdom

Abstract

The European Resuscitation Council has produced these basic life support guidelines, which are based on the 2020 International Consensus on Cardiopulmonary Resuscitation Science with Treatment Recommendations. The topics covered include cardiac arrest recognition, alerting emergency services, chest compressions, rescue breaths, automated external defibrillation (AED), CPR quality measurement, new technologies, safety, and foreign body airway obstruction.

Keywords: Guidelines, Basic Life support, Cardiopulmonary Resuscitation, Chest compression, Ventilation, Rescue breaths, Automated External Defibrillator, Emergency Medical Services, Emergency Medical Dispatch

Introduction and scope

These guidelines are based on the International Liaison Committee on Resuscitation (ILCOR) 2020 Consensus on Science and Treatment Recommendations (CoSTR) for BLS.[1] For these ERC Guidelines the ILCOR recommendations were supplemented by focused literature reviews undertaken by the ERC BLS Writing Group for those topics not reviewed in the 2020 ILCOR CoSTR. When required, the guidelines

* Corresponding author.
E-mail address: t.m.olasveengen@medisin.uio.no (T.M. Olasveengen).

https://doi.org/10.1016/j.resuscitation.2021.02.009

were informed by the expert consensus of the writing group membership.

The BLS writing group prioritised consistency with previous guidelines to build confidence and encourage more people to act when a cardiac arrest occurs. Failing to recognise cardiac arrest remains a barrier to saving more lives. The terminology used in the ILCOR CoSTR,[5] is to start CPR in any person who is "unresponsive with absent or abnormal breathing". This terminology has been included in the BLS 2021 guidelines. Those learning or providing CPR are reminded that slow, laboured breathing (agonal breathing) should be considered a sign of cardiac arrest. The recovery position is included in the first aid section of the ERC guidelines 2021. The first aid guidelines highlight that the recovery position should only be used for adults and children with a decreased level of responsiveness due to medical illness or non-physical trauma. The guidelines emphasise that it should only be used in people who do NOT meet the criteria for the initiation of rescue breathing or chest compressions (CPR). Anyone placed in the recovery position should have their breathing continuously monitored. If at any point their breathing becomes absent or abnormal, roll them on to their back and start chest compressions. Finally, the evidence informing the treatment of foreign body airway obstruction has been comprehensively updated, but the treatment algorithms remain the same.

The ERC has also produced guidance on cardiac arrest for patients with coronavirus disease 2019 (COVID-19),[2] which is based on an ILCOR CoSTR and systematic review.[3,4] Our understanding of the optimal treatment of patients with COVID-19 and the risk of virus transmission and infection of those providing CPR is poorly understood and evolving. Please check ERC and national guidelines for the latest guidance and local policies for both treatment and rescuer precautions.

These guidelines were drafted and agreed by the Basic Life Support Writing Group members. The methodology used for guideline development is presented in the Executive summary.[4a] The guidelines were posted for public comment in October 2020. The feedback was reviewed by the writing group and the guidelines was updated where relevant. The Guideline was presented to and approved by the ERC General Assembly on 10th of December 2020.

Key messages from this section are presented in Fig. 1.

Fig. 1 – BLS infographic summary.

Concise guideline for clinical practice

The BLS algorithm is presented in Fig. 2 and step by step instructions are provided in Fig. 3.

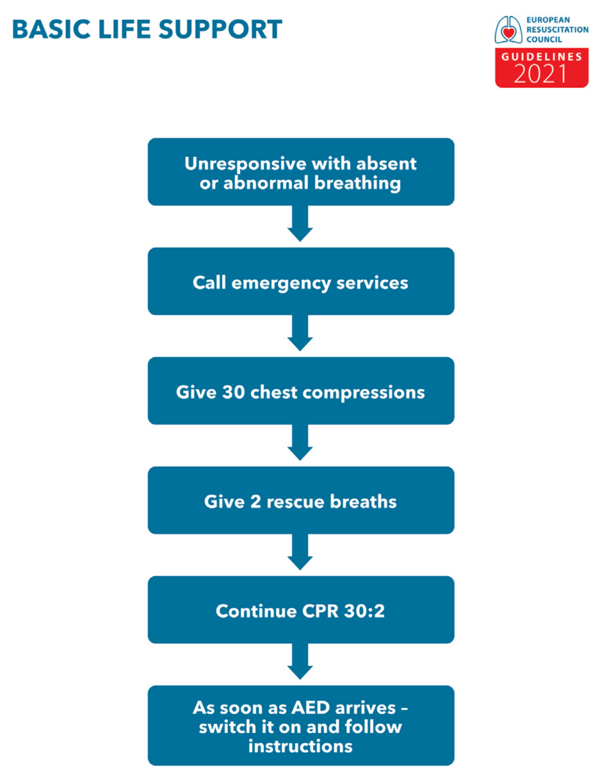


Fig. 2 – BLS algorithm.

How to recognise cardiac arrest

- Start CPR in any unresponsive person with absent or abnormal breathing.
- Slow, laboured breathing (agonal breathing) should be considered a sign of cardiac arrest.
- A short period of seizure-like movements can occur at the start of cardiac arrest. Assess the person after the seizure has stopped: if unresponsive and with absent or abnormal breathing, start CPR.

How to alert the emergency services

- Alert the emergency medical services (EMS) immediately if a person is unconscious with absent or abnormal breathing.
- A lone bystander with a mobile phone should dial the EMS number, activate the speaker or another hands-free option on the mobile phone and immediately start CPR assisted by the dispatcher.
- If you are a lone rescuer and you have to leave a victim to alert the EMS, activate the EMS first and then start CPR.

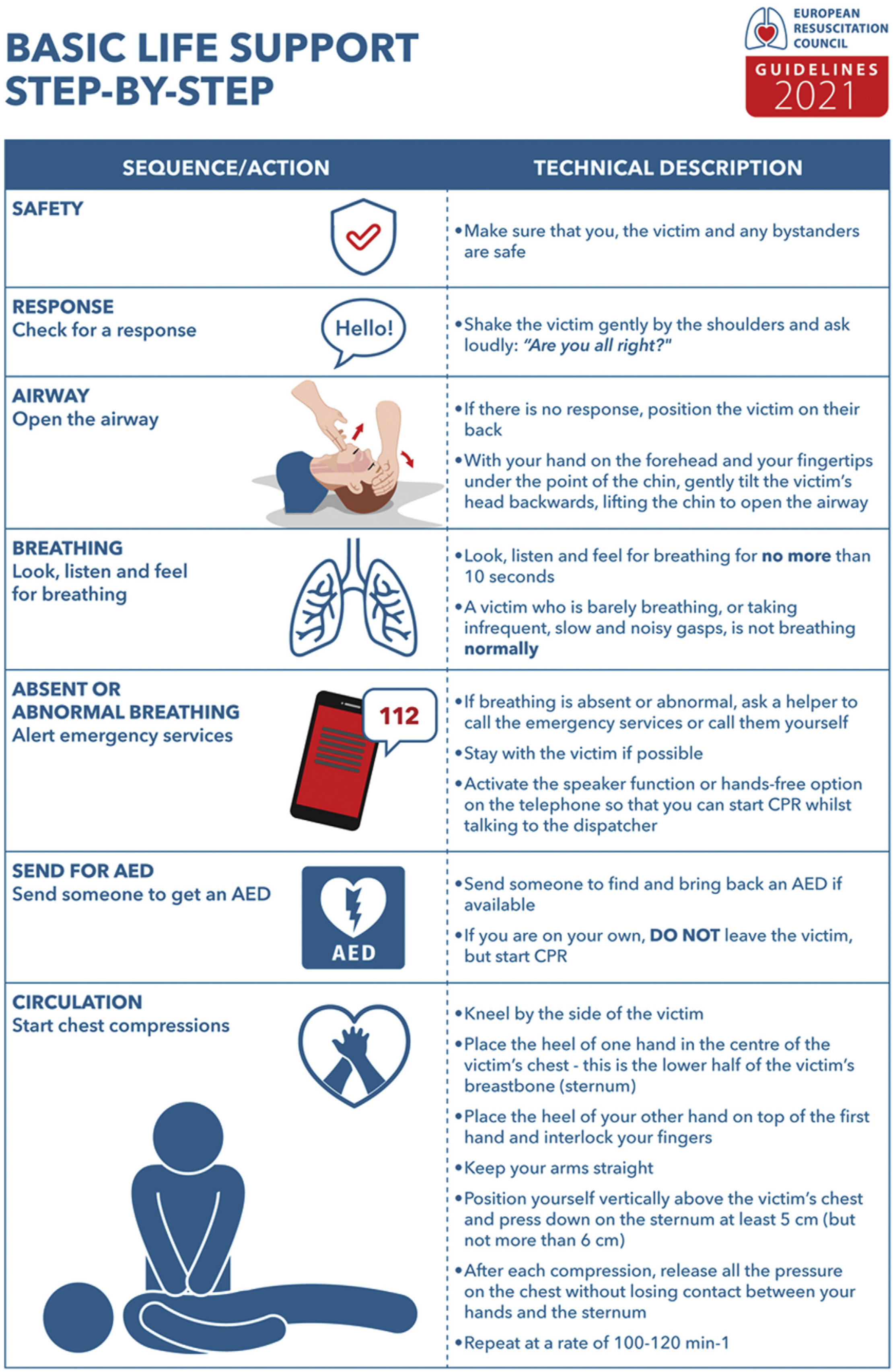


Fig. 3 – BLS step by step instructions.

BASIC LIFE SUPPORT STEP-BY-STEP

EUROPEAN RESUSCITATION COUNCIL
GUIDELINES 2021

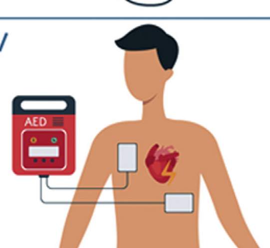
SEQUENCE/ACTION	TECHNICAL DESCRIPTION
COMBINE RESCUE BREATHING WITH CHEST COMPRESSIONS 	• **If you are trained to do so,** after 30 compressions, open the airway again, using head tilt and chin lift • Pinch the soft part of the nose closed, using the index finger and thumb of your hand on the forehead • Allow the victim's mouth to open, but maintain chin lift • Take a normal breath and place your lips around the victim's mouth, making sure that you have an airtight seal • Blow steadily into the mouth whilst watching for the chest to rise, taking about 1 second as in normal breathing. This is an effective rescue breath • Maintaining head tilt and chin lift, take your mouth away from the victim and watch for the chest to fall as air comes out • Take another normal breath and blow into the victim's mouth once more to achieve a total of two rescue breaths • Do not interrupt compressions by more than 10 seconds to deliver the two breaths even if one or both are not effective • Then return your hands without delay to the correct position on the sternum and give a further 30 chest compressions • Continue with chest compressions and rescue breaths in a ratio of 30:2
COMPRESSION-ONLY CPR 	• **If you are untrained, or unable to give rescue breathes,** give chest-compression-only CPR (continuous compressions at a rate of 100-120 min-1)
WHEN AED ARRIVES Switch on the AED and attach the electrode pads 	• As soon as the AED arrives switch it on and attach the electrode pads to the victim's bare chest • If more than one rescuer is present, CPR should be continued whilst the electrode pads are being attached to the chest
FOLLOW THE SPOKEN/ VISUAL DIRECTIONS 	• Follow the spoken and visual directions given by the AED • **If a shock is advised**, ensure that neither you nor anyone else is touching the victim • Push the shock button as directed • Then **immediately** resume CPR and continue as directed by the AED

Fig. 3 – (*continued*).

BASIC LIFE SUPPORT STEP-BY-STEP

EUROPEAN RESUSCITATION COUNCIL
GUIDELINES 2021

SEQUENCE/ACTION	TECHNICAL DESCRIPTION
IF NO SHOCK IS ADVISED Continue CPR 	• **If no shock is advised,** immediately resume CPR and continue as directed by the AED

IF NO AED IS AVAILABLE
Continue CPR

	• If no AED is available, **OR** whilst waiting for one to arrive, continue CPR
	• Do not interrupt resuscitation until:
	  • A health professional tells you to stop OR
	  • The victim is definitely waking up, moving, opening eyes, and breathing normally
	  • OR
	  • You become exhausted
	• It is rare for CPR alone to restart the heart. Unless you are certain that the victim has recovered continue CPR
	• Signs that the victim has recovered
	  • Waking-up
	  • Moving
	  • Opening eyes
	  • Breathing normally

IF UNRESPONSIVE BUT BREATHING NORMALLY Place in the Recovery Position 	• If you are certain that the victim is breathing normally but still unresponsive, place them in the recovery position **SEE FIRST AID SECTION** • Be prepared to restart CPR immediately if the victim becomes unresponsive, with absent or abnormal breathing

Fig. 3 – (*continued*).

High quality chest compressions

- Start chest compressions as soon as possible.
- Deliver compressions on the lower half of the sternum ('in the centre of the chest').

  Compress to a depth of at least 5 cm but not more than 6 cm.
- Compress the chest at a rate of 100–120 min^{-1} with as few interruptions as possible.
- Allow the chest to recoil completely after each compression; do not lean on the chest.
- Perform chest compressions on a firm surface whenever feasible.

Rescue breaths

- Alternate between providing 30 compressions and 2 rescue breaths.
- If you are unable to provide ventilations, give continuous chest compressions.

AED

How to find an AED

- The location of an AED should be indicated by clear signage.

When and how to use an AED

- As soon as the AED arrives, or if one is already available at the site of the cardiac arrest, switch it on.
- Attach the electrode pads to the victim's bare chest according to the position shown on the AED or on the pads.
- If more than one rescuer is present, continue CPR whilst the pads are being attached.
- Follow the spoken (and/or visual) prompts from the AED.
- Ensure that nobody is touching the victim whilst the AED is analysing the heart rhythm.
  If a shock is indicated, ensure that nobody is touching the victim.
- Push the shock button as prompted. Immediately restart CPR with 30 compressions.
- If no shock is indicated, immediately restart CPR with 30 compressions.
- In either case, continue with CPR as prompted by the AED. There will be a period of CPR (commonly 2 min) before the AED prompts for a further pause in CPR for rhythm analysis.

Compressions before defibrillation

- Continue CPR until an AED (or other defibrillator) arrives on site and is switched on and attached to the victim.
- Do not delay defibrillation to provide additional CPR once the defibrillator is ready.

Fully automatic AEDs

- If a shock is indicated, fully automatic AEDs are designed to deliver a shock without any further action by the rescuer. The safety of fully automatic AEDs have not been well studied.

Safety of AEDs

- Many studies of public access defibrillation have shown that AEDs can be used safely by bystanders and first responders. Although injury to the CPR provider from a shock by a defibrillator is extremely rare, do not continue chest compression during shock delivery.

Safety

- Make sure you, the victim and any bystanders are safe.
- Laypeople should initiate CPR for presumed cardiac arrest without concerns of harm to victims not in cardiac arrest.
- Lay people may safely perform chest compressions and use an AED as the risk of infection during compressions and harm from accidental shock during AED use is very low.
- Separate guidelines have been developed for resuscitation of victims with suspected or confirmed acute respiratory syndrome coronavirus 2 (SARS-CoV-2). See www.erc.edu/covid.

How technology can help

- EMS systems should consider the use of technology such as smartphones, video communication, artificial intelligence and drones to assist in recognising cardiac arrest, to dispatch first responders, to communicate with bystanders to provide dispatcher-assisted CPR and to deliver AEDs to the site of cardiac arrest.

Foreign body airway obstruction

- Suspect choking if someone is suddenly unable to speak or talk, particularly if eating.
- Encourage the victim to cough.
- If the cough becomes ineffective, give up to 5 back blows:
  - Lean the victim forwards.
  - Apply blows between the shoulder blades using the heel of one hand

- If back blows are ineffective, give up to 5 abdominal thrusts:
  - Stand behind the victim and put both your arms around the upper part of the victim's abdomen.
  - Lean the victim forwards.
  - Clench your fist and place it between the umbilicus (navel) and the ribcage.
  - Grasp your fist with the other hand and pull sharply inwards and upwards.

- If choking has not been relieved after 5 abdominal thrusts, continue alternating 5 back blows with 5 abdominal thrusts until it is relieved, or the victim becomes unconscious.
- If the victim becomes unconscious, start CPR

Evidence informing the guidelines

How to recognise cardiac arrest

The practical, operational definition of cardiac arrest is when a person is unresponsive with absent or abnormal breathing.[5] Earlier guidelines included the absence of a palpable pulse as a criterion, but reliably detecting peripheral pulses in stressful medical emergencies proved difficult for professionals and lay people alike.[6–10] Unresponsiveness and abnormal breathing obviously overlap with other potentially life-threatening medical emergencies, but have very high sensitivity as diagnostic criteria for cardiac arrest. Using these criteria will moderately overtriage for cardiac arrest, but the risk of starting CPR in an unresponsive individual with absent or abnormal breathing and not in cardiac arrest is believed to be far outweighed by the increased mortality associated with delayed CPR for cardiac arrest victims.[1]

Agonal breathing

Agonal breathing is an abnormal breathing pattern observed in about 50% of cardiac arrest victims. It indicates the presence of brain function and is associated with improved outcomes.[11,12] Agonal breathing is commonly misinterpreted as a sign of life, presenting a challenge to lay people and emergency medical dispatchers. Common terms used by lay people to describe agonal breathing include: gasping, barely or occasionally breathing, moaning, sighing, gurgling, noisy, groaning, snorting, heavy or laboured breathing.[11,13,14] Agonal breathing remains the biggest barrier to recognition of OHCA.[15–22] Early recognition of agonal breathing is a prerequisite for early CPR and defibrillation, and failure by dispatchers to recognise cardiac arrest during emergency calls is associated with decreased survival.[18,23]

When focusing on the recognition of agonal breathing for both lay rescuer and professional CPR providers, it is important to underline that the risk of delaying CPR for a cardiac arrest victim far outweighs any risk from performing CPR on a person not in cardiac arrest. (See also Safety section) The misinterpretation of agonal breathing as a sign of life may prompt bystanders to erroneously place cardiac arrest victims in the recovery position instead of starting CPR.

Seizures

Seizure-like movements of short duration among patients in cardiac arrest pose another important barrier to recognition of cardiac arrests. Seizures are common medical emergencies and are reported to constitute about 3–4% of all emergency medical calls.[24–26] Only 0.6–2.1% of these calls are also cardiac arrest.[25,27] A recent observational study including 3502 OHCAs identified 149 (4.3%) victims with seizure-like activity.[28] Patients presenting with seizure-like activity were younger (54 vs. 66 years old; $p < 0.05$), were more likely to have a witnessed arrest (88% vs. 45%; $p < 0.05$), more likely to present with an initial shockable rhythm (52% vs. 24%; $p < 0.05$), and more likely to survive to hospital discharge (44% vs. 16%; $p < 0.05$). Similar to agonal respiration, seizures complicate the recognition of cardiac arrest for both lay people and professionals (median time to dispatcher identification of the cardiac arrest; 130 s vs. 62 s; $p < 0.05$).[28]

Recognising cardiac arrest after a seizure episode when the victim remains unresponsive with abnormal breathing is important to prevent delayed CPR. The risk of delaying CPR for a cardiac arrest victim far outweighs any risk from performing CPR on a person not in cardiac arrest. (See also Safety section)

Alert emergency services

The practical question of whether to 'call first' or do 'CPR first' has been debated and is particularly relevant when a phone is not immediately available in a medical emergency. As mobile phones have become the dominant form of telecommunication, calling the emergency services does not necessarily mean delaying CPR. After evaluating and discussing the results of a recent systematic review, ILCOR made a recommendation that lone bystanders with a mobile phone dial EMS, activate the speaker or other hands-free option on the mobile phone and immediately start CPR.[1] This recommendation was based on expert consensus and very-low certainty evidence drawn from a single observational study.[29] The observational study from Japan included 5446 OHCAs and compared outcomes between patients treated with a 'CPR first' or 'call first' strategy. Overall survival rates were very similar between 'call first' and 'CPR first' strategies, but adjusted analyses performed on various subgroups suggested improved survival with a favourable neurological outcome with a 'CPR first' strategy compared with a 'call first' strategy. Improved outcomes were observed in subgroups of non-cardiac aetiology (adjusted odds ratio (aOR) 2.01 [95% CI 1.39–2.9]); under 65 years of age (aOR 1.38 [95% CI 1.09–1.76]); under 20 years of age (aOR 3.74 [95% CI 1.46–9.61]) and; both under 65 years of age and non-cardiac aetiology together (aOR 4.31 [95% CI 2.38–8.48]).[29]

The observational study supporting a 'CPR first' strategy was limited by only including cases where lay people witnessed the OHCA and spontaneously performed CPR (without the need for dispatcher assistance), and the groups compared were different with respect to age, gender, initial rhythm, bystander CPR characteristics and EMS intervals. Despite the very low certainty evidence, ILCOR made a discordant strong recommendation to emphasise the importance of early bystander CPR.

Despite widespread availability of mobile phones, there are situations where a lone rescuer might have to leave a victim to alert emergency services. Choosing to either start CPR or alert EMS first would be dependent on exact circumstances, but it would be reasonable to prioritise prompt activation of EMS before returning to the victim to initiate CPR.

High quality chest compressions

Chest compressions are the key component of effective CPR as the widely available means to provide organ perfusion during cardiac arrest. The effectiveness of chest compressions is dependent on correct hand position and chest compression depth, rate, and degree of chest wall recoil. Any pauses in chest compressions mean pauses in organ perfusion, and consequently need to be minimised to prevent ischaemic injury.

Hand position during compressions

The evidence for optimal hand position was reviewed by ILCOR in 2020.[1] Although the recommendations for hand position during compressions have been modified over time, these changes have been based solely on low- or very-low-certainty evidence, with no data demonstrating that a specific hand position was optimal in terms of patient survival. In the most recent systematic review, no studies reporting critical outcomes such as favourable neurologic outcome, survival, or ROSC were identified.

Three very-low-certainty studies investigated effect of hand position on physiological end points.[30–32] One crossover study in 17 adults with prolonged resuscitation from non-traumatic cardiac arrest documented improved peak arterial pressure during compression systole and $ETCO_2$ when compressions were performed over the lower third of the sternum compared with the centre of the chest.[31] Similar results were observed in a crossover study in 10 children when compressions were performed on the lower third of the sternum compared with the middle of the sternum, with higher peak systolic pressure and higher mean arterial pressure.[30] A third crossover study in 30 adults with cardiac arrest documented no difference in $ETCO_2$ values resulting from changes in hand placement.[32]

Imaging studies were excluded from the ILCOR systematic review as they do not report clinical outcomes for patients in cardiac arrest, but they do provide some supportive background information on the optimal position for compressions based on the anatomical structures underlying the recommended and alternative hand positions. Evidence from recent imaging studies indicates that, in most adults and children, the maximal ventricular cross-sectional area underlies the lower third of the sternum/xiphisternal junction, while the ascending aorta and left ventricular outflow tract underlie the centre of the chest.[33–39] There are important differences in anatomy between individuals and depend on age, body mass index, congenital cardiac disease and pregnancy, and thus one specific hand placement strategy might not provide optimal compressions across a range of persons.[34,38,40]

These findings led ILCOR to retain their current recommendation and continue to suggest performing chest compressions on the lower half of the sternum in adults in cardiac arrest (weak recommendation, very-low-certainty evidence). Consistent with the ILCOR treatment recommendations, the ERC recommends teaching that chest compressions should be delivered 'in the centre of the chest', whilst demonstrating hand position on the lower half of the sternum.

Chest compression depth, rate and recoil

This guideline is based on ILCOR recommendations,[1] informed by an ILCOR scoping review[41] and the previous 2015 ERC BLS Guidelines.[42] The ILCOR BLS Task Force scoping review related to chest compression rate, chest compression depth, and chest wall recoil. It aimed to identify any recently published evidence on these chest compression components as discrete entities and to assess whether studies have reported interactions among these chest compression components.

In addition to the 14 studies identified in the 2015 ERC BLS guidelines,[42] 8 other studies[43–50] published after 2015 were identified so that a total of 22 studies evaluated compression depth rate and recoil. Five observational studies examined both chest compression rate and chest compression depth.[48,49,51,52] One RCT,[44] one crossover trial,[53] and 6 observational studies[45,50,54–57] examined chest compression rate only. One RCT[58] and 6 observational studies examined chest compression depth only,[59–64] and 2 observational studies examined chest wall recoil.[43,46] No studies were identified that examined different measures of leaning.

While this scoping review highlighted significant gaps in the research evidence related to interactions between chest compression components, it did not identify sufficient new evidence that would justify conducting a new systematic review or reconsideration of current resuscitation treatment recommendations.

ILCOR's treatment recommendations for chest compression depth, rate and recoil are therefore unchanged from 2015.[42] ILCOR recommends a manual chest compression rate of 100 to 120 min^{-1} (strong recommendation, very-low-certainty evidence), a chest compression depth of approximately 5 cm (2 in) (strong recommendation, low-certainty evidence) while avoiding excessive chest compression depths (greater than 6 cm [greater than 2.4 in] in an average adult) during manual CPR (weak recommendation, low-certainty evidence) and suggest that people performing manual CPR avoid leaning on the chest between compressions to allow full chest wall recoil (weak recommendation, very-low-certainty evidence).

Consistent with the ILCOR Treatment Recommendations, the ERC recommends a chest compression rate of 100 to 120 min^{-1} and a compression depth of 5–6 cm while avoiding leaning on the chest between compressions. The recommendation to compress 5–6 cm is a compromise between observations of poor outcomes with shallow compressions and increased incidence of harm with deeper compressions.[42]

Firm surface

ILCOR updated the Consensus on Science and Treatment Recommendation for performing CPR on a firm surface in 2020.[1,65] When CPR is performed on a soft surface (e.g. a mattress), both the chest wall and the support surface are compressed.[66] This has the potential to diminish effective chest compression depth. However, effective compression depths can be achieved even on a soft surface, providing the CPR provider increases overall compression depth to compensate for mattress compression.[67–73]

The ILCOR systematic review identified twelve manikin studies evaluating the importance of a firm surface during CPR.[65] These studies were further grouped into evaluations of mattress type,[70,74–76] floor compared with bed,[75–78] and backboard.[69,70,79–83] No human studies were identified. Three RCTs evaluating mattress type did not identify a difference in chest compression depth between various mattress types.[70,74–76] Four RCTs evaluating floor compared with bed found no effect on chest compression depth.[75–78] Of the seven RCTs evaluating use of backboard, six could be meta-analysed and showed increased compression depth using a backboard with a mean difference of 3 mm (95% CI, 1 to 4).[69,70,79–82] The clinical relevance of this difference was debated, although statistically significant–the actual increase in compression depth was small.

These findings led ILCOR to suggest performing manual chest compressions on a firm surface when possible (weak recommendation, very low certainty evidence). ILCOR also suggested that when a bed has a CPR mode that increases mattress stiffness, it should be activated (weak recommendation, very-low-certainty evidence), but suggested against moving a patient from a bed to the floor to improve chest compression depth in the hospital setting (weak recommendation, very-low-certainty evidence). The confidence in effect estimates is so low that ILCOR was unable to make a recommendation about the use of a backboard strategy.

Consistent with the ILCOR Treatment Recommendations, the ERC suggests performing chest compressions on a firm surface whenever possible. For the in-hospital setting, moving a patient from the bed to the floor is NOT recommended. The ERC does not recommend using a backboard.

Rescue breaths

Compression-ventilation (CV) ratio

ILCOR updated the Consensus on Science and Treatment Recommendations for compression-ventilation (CV) ratio in 2017.[84] The supporting systematic review found evidence from two cohort studies ($n = 4877$) that a ratio of compressions to ventilation of 30:2 compared with 15:2 improved favourable neurological outcome in adults (risk difference 1.72% (95% CI 0.5–2.9%).[85] Meta-analysis of six cohort studies ($n = 13,962$) found that more patients survived with a ratio of 30:2 compared with 15:2 (risk difference 2.48% (95% CI 1.57–3.38). A similar pattern of better outcomes was observed in a small cohort study ($n = 200$, shockable rhythms) when comparing a ratio of 50:2 with 15:2 (risk difference 21.5 (95% CI 6.9–36.06).[86] The ILCOR treatment recommendation, which suggests a CV ratio of 30:2 compared with any other CV ratio in patients with cardiac arrest (weak recommendation, very-low-quality evidence), remains valid and forms the basis for the ERC guidelines to alternate between providing 30 compressions and 2 ventilation.

Compression-only CPR

The role of ventilation and oxygenation in the initial management of cardiac arrest remains debated. ILCOR performed systematic reviews of compression-only versus standard CPR in both lay rescuer and professional or EMS settings.[85,87]

In the lay rescuer setting, six very-low-certainty observational studies compared chest compression-only with standard CPR using a CV ratio of 15:2 or 30:2.[18,88–92] In a meta-analysis of two studies, there was no significant difference in favourable neurological outcome in patients who received compression-only CPR compared with patients who received CPR at a CV ratio of 15:2 (RR, 1.34 [95% CI, 0.82–2.20]; RD, 0.51 percentage points [95% CI, −2.16 to 3.18]).[18,90] In a meta-analysis of three studies, there was no significant difference in favourable neurological outcome in patients who received compression-only CPR compared with patients who received compressions and ventilations during a period when the CV ratio changed from 15:2 to 30:2 (RR, 1.12 [95% CI, 0.71–1.77]; RD, 0.28 percentage points

[95% CI, −2.33 to 2.89]).[89,91,92] In one study, patients receiving compression-only CPR had worse survival compared with patients who received CPR at a CV ratio of 30:2 (RR, 0.75 [95% CI, 0.73−0.78]; RD, −1.42 percentage points [95% CI, −1.58 to −1.25]).[88] Lastly, one study examined the influence of nationwide dissemination of compression-only CPR recommendations for lay people and showed that, although bystander CPR rates and nationwide survival improved, patients who received compression-only CPR had lower survival compared with patients who received chest compressions and ventilations at a CV ratio of 30:2 (RR, 0.72 [95% CI, 0.69−0.76]; RD, −0.74 percentage points [95% CI, −0.85 to 0.63]).[88] Based on this review, ILCOR suggests that bystanders who are trained, able, and willing to give rescue breaths and chest compressions do so for all adult patients in cardiac arrest (weak recommendation, very-low-certainty evidence).

In the EMS setting, a high-quality RCT included 23,711 patients. Those randomised to bag-mask ventilation, without pausing for chest compressions, had no demonstrable benefit for favourable neurological outcome (RR, 0.92 [95% CI, 0.84−1.00]; RD, −0.65 percentage points [95% CI, −1.31 to 0.02]) compared with patients randomised to conventional CPR with a CV ratio of 30:2.[93] ILCOR recommends that EMS providers perform CPR with 30 compressions to 2 ventilations (30:2 ratio) or continuous chest compressions with positive pressure ventilation delivered without pausing chest compressions until a tracheal tube or supraglottic device has been placed (strong recommendation, high-certainty evidence).

Consistent with the ILCOR treatment recommendations, the ERC recommends alternating between providing 30 compressions and 2 ventilations during CPR in both lay rescuer and professional settings.

Automated external defibrillator

An AED (automated external defibrillator or, less commonly termed, automatic external defibrillator) is a portable, battery-powered device with adhesive pads that are attached to a patient's chest to detect the heart rhythm following suspected cardiac arrest. Occasionally it may be necessary to shave the chest if very hairy and/or the electrodes will not stick firmly. If the rhythm is ventricular fibrillation (or ventricular tachycardia), an audible or audible-and-visual prompt is given to the operator to deliver a direct current electric shock. For other heart rhythms (including asystole and a normal rhythm), no shock is advised. Further prompts tell the operator when to start and stop CPR. AEDs are very accurate in their interpretation of the heart rhythm and are safe and effective when used by laypeople.

The probability of survival after OHCA can be markedly increased if victims receive immediate CPR and a defibrillator is used. AEDs make it possible for laypeople to attempt defibrillation following cardiac arrest many minutes before professional help arrives; each minute of delay decreases the chance of successful resuscitation by about 3−5%.[94]

The ILCOR Consensus on Science and Treatment Recommendations (2020) made a strong recommendation in support of the implementation of public-access defibrillation programmes for patients with OHCA based on low-certainty evidence.[1] The ILCOR Scientific Statement on Public Access Defibrillation addresses key interventions (early detection, optimising availability, signage, novel delivery methods, public awareness, device registration, mobile apps for AED retrieval and public access defibrillation) which should be considered as part of all public access defibrillation programmes.

Compressions before defibrillation

ILCOR updated the Consensus on Science and Treatment Recommendation for CPR before defibrillation in 2020.[1] Five RCTs were identified comparing a shorter with a longer interval of chest compressions before defibrillation.[95−99] Outcomes assessed varied from 1-year survival with favourable neurological outcome to ROSC. No clear benefit from CPR before defibrillation was found in a meta-analysis of any of the critical or important outcomes. In a meta-analysis of four studies, there was no significant difference in favourable neurological outcome in patients who received a shorter period of CPR before defibrillation compared with a longer period of CPR (RR, 1.02 [95% CI, −0.01−0.01]; 1 more patient/1000 (−29 to 98).[95,96,98,99] In a meta-analysis of five studies, there was no significant difference in survival to discharge in patients who received a shorter period of CPR before defibrillation compared with a longer period of CPR (RR, 1.01 [95% CI, −0.90−1.15]; 1 more patient/1000 (−8 to 13).[95−99]

ILCOR suggests a short period of CPR until the defibrillator is ready for analysis and/or defibrillation in unmonitored cardiac arrest. Consistent with the ILCOR Treatment Recommendations, the ERC recommends CPR be continued until an AED arrives on site, is switched on and attached to the victim, but defibrillation should not be delayed any longer for additional CPR.

Electrode positioning

ILCOR completed a scoping review on AED paddle size and placement in 2020, searching for any available evidence to guide optimal pad placement and size.[1] No new evidence that directly addressed these questions was identified, and the scoping review from the ILCOR BLS task force is therefore limited to expert discussion and consensus. These discussions highlighted studies that showed that antero-posterior electrode placement is more effective than the traditional antero-lateral or antero-apical position in elective cardioversion of atrial fibrillation (AF), while most studies have failed to demonstrate any clear advantage of any specific electrode position. Transmyocardial current during defibrillation is likely to be maximal when the electrodes are placed so that the area of the fibrillating heart lies directly between them (i.e. ventricles in VF/pulseless VT, atria in AF). Therefore, the optimal electrode position may not be the same for ventricular and atrial arrhythmias. ILCOR continues to suggest that pads be placed on the exposed chest in an antero-lateral position. An acceptable alternative position is antero-posterior. In large-breasted individuals, it is reasonable to place the left electrode pad lateral to or underneath the left breast, avoiding breast tissue. Consideration should be given to the rapid removal of excessive chest hair before the application of pads, but emphasis must be on minimising delay in shock delivery. There is insufficient evidence to recommend a specific electrode size for optimal external defibrillation in adults. It is, however, reasonable to use a pad size greater than 8 cm.[100,101] Consistent with the ILCOR Treatment Recommendations and to avoid confusion for the person using the AED, the ERC BLS writing group recommends attaching the electrode pads to the victim's bare chest using the antero-lateral position as shown on the AED.

CPR feedback devices

To improve CPR quality, key CPR metrics need to be measured. CPR quality data can be presented to the rescuer in real-time and/or provided in a summary report at the end of a resuscitation. Measuring

CPR performance to improve resuscitation systems is addressed in the Systems Saving Lives chapter.[102] Real-time feedback devices for CPR providers will be discussed in this section.

ILCOR updated the Consensus on Science and Treatment Recommendation for feedback for CPR quality in 2020.[1] Three types of feedback devices were identified: (1) digital audio-visual feedback including corrective audio prompts; (2) analogue audio and tactile 'clicker' feedback for chest compression depth and release; and (3) metronome guidance for chest compression rate. There is considerable clinical heterogeneity across studies with respect to the type of devices used, the mechanism of CPR quality measurement, the mode of feedback, patient types, locations (e.g. in-hospital and out-of-hospital), and baseline (control group) CPR quality.

Digital audio-visual feedback including corrective audio prompts

One cluster RCT[103] and four observational studies[47,104–106] evaluated the effects of these devices on favourable neurological outcome. The low-certainty cluster RCT found no difference in favourable neurological outcome (relative risk 1.02; 95% CI 0.76−1.36; $p = 0.9$).[103] While one of the observational studies found an association with improved favourable neurological outcome (adjusted odds ratio 2.69; 95% CI 1.04−6.94),[106] the other three did not.[47,104,105]

One cluster RCT[103] and six observational studies[48,52,104,106,107] evaluated the effects of these devices on survival to hospital discharge or 30-day survival. Neither the low-certainty cluster RCT (relative risk 0.91; 95% CI 0.69−1.19; $p = 0.5$),[103] nor the observational studies found any benefit associated with these devices.[48,52,104,106–108]

The potential benefit from real-time audio-visual feedback would be their ability to improve CPR quality. While the low-certainty cluster RCT showed improved chest compression rate (difference of 4.7 per minute; 95% CI −6.4−3.0), chest compression depth (difference of 1.6 mm; 95% CI 0.5−2.7 mm) and chest compression fraction (difference of 2%; 66% vs. 64%, $p = 0.016$), the clinical significance of these relatively small differences in CPR metrics is debated.[103]

Five very-low-certainty observational studies compared various CPR metrics.[47,52,104,106,107] One observational study showed no difference in chest compression rates with and without feedback.[107] The other four observational studies[47,52,104,106] showed lower compression rates in the group with CPR feedback with differences ranging from −23 to −11 compressions per minute. One observational study showed no difference in chest compression depth with and without feedback.[107] Three observational studies showed significantly deeper chest compressions ranging from 0.4 to 1.1 cm.[47,52,106] Two studies reported statistically significant increases in CPR fraction associated with feedback[104,107] and three studies did not observe a statistically or clinically important difference.[47,52,106] The Couper study demonstrated an increase in compression fraction from 78% (8%) to 82% (7%), $p = 0.003$.[104] This increase is of questionable clinical significance. The Bobrow study demonstrated an increase in chest compression fraction from 66% (95% CI 64 to 68) to 84% (95% CI 82 to 85).[106] Two major caveats with this study include a concern that the observed difference may have not been related to the feedback device, as there were other training interventions and use of an imputed data set. None of the studies showed any improvement in ventilation rates.[47,52,103,104,106,107]

Analogue audio and tactile clicker feedback

The standalone analogue clicker device, designed to be placed on the patient's chest under the hands of a CPR provider, involves a mechanism that produces a clicking noise and sensation when enough pressure is applied. It provides tactile feedback on correct compression depth and complete release between chest compressions.

One very-low-certainty RCT evaluated the effect of a clicker device on survival to hospital discharge and found significantly improved outcome in the group treated with the clicker device (relative risk 1.90; 95% CI 1.60−2.25; $p < 0.001$).[109] Two very-low-certainty RCTs evaluated the effect of a clicker device on ROSC, and found significantly improved outcome in the group treated with the clicker device (relative risk 1.59; 95% CI 1.38−1.78; $p < 0.001$ and relative risk 2.07; 95% CI 1.20−3.29, $p < 0.001$).[109,110]

Metronome rate guidance

One very-low-certainty observational study evaluated the effect of a metronome to guide chest compression rate during CPR before ambulance arrival found no benefit in 30 day survival (relative risk 1.66; 95% CI −17.7−14.9, $p = 0.8$) One very-low-certainty observational study evaluated the effect of a metronome on 7-day survival and found no difference (3/17 vs. 2/13; $p = 0.9$).[111] Two observational studies evaluated the effect of a metronome on ROSC, and found no difference in outcome (adjusted relative risk 4.97; 95% CI −21.11 −11.76, $p = 0.6$ and 7/13 vs. 8/17, $p = 0.7$).[108,111]

Taking these data together ILCOR suggested the use of real-time audio visual feedback and prompt devices during CPR in clinical practice as part of a comprehensive quality improvement programme for cardiac arrest designed to ensure high-quality CPR delivery and resuscitation care across resuscitation systems, but suggested against the use of real-time audiovisual feedback and prompt devices in isolation (ie, not part of a comprehensive quality improvement programme).[112]

Safety

Harm to people providing CPR

This guideline is based on an ILCOR scoping review,[112] the previous 2015 ERC BLS Guidelines[42] and the recently published ILCOR consensus on science, treatment recommendations and task force insights,[3] ILCOR systematic review,[4] and ERC COVID-19 guidelines.[2]

The ILCOR BLS Task Force performed a scoping review related to harm to people providing CPR to identify any recent published evidence on risk to CPR providers. This scoping review was completed before the COVID-19 pandemic. In this review, very few reports of harm from performing CPR and defibrillation were identified. Five experimental studies and one case report published since 2008 were reviewed. The five experimental studies reported perceptions in experimental settings during shock administration for elective cardioversion. In these studies, the authors also measured current flow and the average leakage current in different experiments to assess rescuer safety. Despite limited evidence evaluating safety, there was broad agreement within the ILCOR BLS Task Force and ERC BLS writing group that the lack of published evidence supports the interpretation that the use of an AED is generally safe. Consistent with ILCOR treatment recommendations, the ERC recommends that lay rescuers perform chest compressions and use an AED as the risk of damage from accidental shock during AED use is low.[1,42,112]

As the SARS CoV-2 infection rates have continued to rise throughout the world, our perception of safety during CPR has changed profoundly. A recent systematic review on transmission of SARS CoV-2 during resuscitation performed by ILCOR identified eleven studies: two cohort studies, one case control study, five case reports, and three manikin RCTs. The review did not identify any evidence that CPR or defibrillation generated aerosol or transmitted infection, but the certainty of evidence was very low for all outcomes.[4] Based on the findings in this systematic review, yet still erring on the side of caution, ILCOR published Consensus on Science and Treatment Recommendations aimed at balancing the benefits of early resuscitation with the potential for harm to care providers during the COVID-19 pandemic. The resulting recommendations are for lay people to consider chest compressions and public-access defibrillation during the current COVID-19 pandemic. However, ILCOR clearly recommends that healthcare professionals use personal protective equipment for all aerosol-generating procedures. The following ERC guidelines have emphasised the need to follow current advice given by local authorities, as infection rates vary between areas. For the lay rescuer, it is important to follow instructions given by the emergency medical dispatcher. The ERC has published guidelines for modified BLS in suspected or confirmed COVID-19.[2] The most important changes relate to the use of personal protection equipment, assessing breathing without getting close to the victim's nose and mouth, and recognising ventilation as a potential aerosol generating procedure with greater risk of disease transmission. Details can be found in the ERC COVID-19 guidelines. (www.erc.edu/COVID)

Harm from CPR to victims not in cardiac arrest

Lay people may be reluctant to perform CPR on an unresponsive person with absent or abnormal breathing because of concern that delivering chest compressions to a person who is not in cardiac arrest could cause serious harm. The evidence for harm from CPR to victims not in cardiac arrest was reviewed by ILCOR in 2020.[1] This systematic review identified four very-low-certainty observational studies enrolling 762 patients who were not in cardiac arrest but received CPR by lay people outside the hospital. Three of the studies reviewed the medical records to identify harm,[113−115] and one included follow-up telephone interviews.[113] Pooled data from the first three studies, including 345 patients, found an incidence of rhabdomyolysis of 0.3% (one case), bone fracture (ribs and clavicle) of 1.7% (95% CI, 0.4 −3.1%), pain in the area of chest compression of 8.7% (95% CI, 5.7 −11.7%), and no clinically relevant visceral injury. The fourth study relied on fire department observations at the scene, and there were no reported injuries in 417 patients.[116] Case reports and case series of serious harm to persons receiving CPR who are not in cardiac arrest are likely to be published because they are of general interest to a broad group of healthcare providers. The few reports of harm published, strengthens the arguments that harm is likely very rare and desirable effects will far outweigh undesirable effects.

Despite very-low-certainty evidence, ILCOR recommends that laypersons initiate CPR for presumed cardiac arrest without concerns of harm to patients not in cardiac arrest. The ERC guidelines are consistent with the ILCOR Treatment Recommendations.

How technology can help

Technology is used for many lifestyle comforts, from our smartphones to innovative applications in medicine. Several researchers are working on different areas of implementation. For BLS, the main areas of interest are applications to locate AEDs, smartphones and smartwatches as an aid for first responder and providers to reach the patients, and CPR feedback in real-time and video communication for video dispatch. The new 'sci-fi' technology describes the potential impact of drones and artificial intelligence on the chain of survival.

AED locator apps

In the case of OHCA, early defibrillation increases the chances of survival, but retrieving an AED during an emergency can be challenging because the rescuer needs to know where the AED is located. Thanks to built-in global positioning systems (GPS) in smartphones, numerous apps have been developed to locate the user and display the nearest AEDs. Moreover, such apps enable users to add new AEDs that become available, or to update details of existing ones throughout communities. As a result, apps to locate AEDs may help build and maintain an updated registry of AEDs in the community that could be used and integrated by emergency dispatch centres. Usually, this kind of app provides a list of nearby AEDs that can immediately display the route to reach the location with a navigation app. Data on location, access, availability time, photo of installation, and contacts of owner or person in charge of the AED are commonly provided. Users also have the possibility to report malfunctioning or missing AEDs. The role of mobile phone technology as a tool to locate AEDs is described in detail in the Systems Saving Lives chapter.[102]

Smartphones and smartwatches

There is growing interest among researchers in integrating smartphones and smartwatches in education and training in cardiopulmonary resuscitation and defibrillation, and for improving the response to OHCA with dedicated apps. Initially, apps were developed to provide educational content on resuscitation. Following the technological evolution of the last years, smartphone apps have been used to provide feedback on CPR quality by exploiting the built-in accelerometer. Such systems can provide real-time audio-visual feedback to the rescuer through the speakers and the screen. Although current real-time feedback devices tested in professional settings have had limited effect on patient outcomes, new technology could improve the quality of CPR. As technology has evolved, the same concept has been applied to smartwatches, devices particularly suitable to be used as feedback devices thanks to their small size and their wearability. A systematic review found conflicting results on the role of smart devices. In one randomised simulation study that evaluated the effectiveness of one of these apps, the quality of CPR significantly improved by using a smartwatch-based app with real-time audio-visual feedback in simulated OHCA.[117] Similarly, a higher proportion of chest compressions of adequate depth was observed when using a smartphone.[118] The current body of evidence is still limited, but smartwatch-based systems might be an important strategy to provide CPR feedback with smart devices.

During telephone CPR, dispatchers can locate and alert first-responder citizens who are in the immediate vicinity of an OHCA through a text message system or a smartphone app and guide them to the nearest AED. This strategy has been studied and been shown to increase the proportion of patients receiving CPR before ambulance arrival and improve survival.[119−122] The role of mobile phone technology as a tool to activate first responders is also described in the Systems Saving Lives chapter.[102]

Video communication

Smartphone and video communication play an important role in modern society. Traditionally, dispatchers give audio-only CPR instructions; newly developed technology enables dispatchers to provide video CPR instructions through the caller's mobile phone. A recent systematic review and meta-analysis identified nine papers evaluating video instructions for simulated OHCA. Compression rates were better with video-instructions, and there was a trend towards better hand-placement. No difference was observed in compression depth or time to first ventilation, and there was a slight increase in the time it took to start CPR with video instructions.[123] In a more recent retrospective study of adult OHCA a total of 1720 eligible OHCA patients (1489 and 231 in the audio and video groups, respectively) were evaluated. The median instruction time interval (ITI) was 136 s in the audio group and 122 s in the video group ($p = 0.12$). The survival to discharge rates were 8.9% in the audio group and 14.3% in the video groups ($p < 0.01$). Good neurological outcome occurred in 5.8% and 10.4% in the audio and video groups, respectively ($p < 0.01$).[124] In a prospective clinical study of OHCAs in nursing homes the application of video communication to guide advanced cardiac life support by paramedics was evaluated in 616 consecutive cases. Survival among the third that received video-instructed ALS was 4.0% compared to 1.9% without video instructions ($p = 0.078$), and survival with good neurological outcome was 0.5% vs. 1.0%, respectively.[125]

Artificial intelligence

Artificial intelligence (AI) is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans. The term AI is often used to describe machines (or computers) that mimic cognitive functions associated with the human mind, such as learning and problem solving.

Artificial intelligence (AI) has been applied to health conditions demonstrating that a computer can help with clinical decision-making.[126,127] The use of AI as a tool to improve the key components of the chain of survival is under evaluation. Recently, a machine-learning approach was used to recognise OHCA from unedited recordings of emergency calls to an emergency medical dispatch centre, and the performance of the machine-learning framework was subsequently assessed.[128] The study included 108,607 emergency calls, of which 918 (0.8%) were out-of-hospital cardiac arrest calls eligible for analysis. Compared with medical dispatchers, the machine-learning framework had a significantly higher sensitivity (72.5% vs. 84.1%, $p < 0.001$) with a slightly lower specificity (98.8% vs. 97.3%, $p < 0.001$). The machine-learning framework had a lower positive predictive value compared with dispatchers (20.9% vs. 33.0%, $p < 0.001$). Time to recognition was significantly shorter for the machine-learning framework compared with the dispatchers (median 44 s vs. 54 s, $p < 0.001$). Another application of AI in terms of recognition of OHCA is integrated software home assistant devices. Widespread adoption of smartphones and smart speakers presents a unique opportunity to identify this audible biomarker (agonal breathing) and link unwitnessed cardiac arrest victims to EMS or lay people. A recent study hypothesised that existing commodity devices (e.g., smartphones and smart speakers) could be used to identify OHCA-associated agonal breathing in a domestic setting. The researchers developed a specific algorithm that recognises agonal breathing through a dataset from EMS. Using real-world labelled EMS audio of cardiac arrests, the research team trained AI software to classify agonal breathing. The results obtained an overall sensitivity and specificity of 97.24% (95% CI: 96.86−97.61%) and 99.51% (95% CI: 99.35−99.67%). The false positive rate was between 0 and 0.14% over 82 h (117,985 audio segments) of polysomnographic sleep lab data that includes snoring, hypopnea, and central, and obstructive sleep apnoea events.[129]

The last example of the potential use of AI is as a tool to predict survival. Two studies reported the use of AI as a deep-learning-based prognostic system and a machine-learning algorithm to discover potential factor influencing outcomes and predict neurological recovery and discharge alive from hospital.[130,131] Further research is needed to understand the potential of this new AI technology as a tool to support human clinical decisions.

Drones

Despite the increasing number of AEDs in communities, an AED is still rarely available on site during OHCA. Increasing access to AEDs and reducing time to first defibrillation are critical for improving survival after an OHCA. Drones or unmanned aerial vehicles have the potential to speed up the delivery of an AED, and mathematical modelling can be used to optimise the location of drones to improve the emergency response in OHCA.

In the last years, several studies have investigated the feasibility of delivering AEDs with drones to a simulated OHCA scene. Studies have demonstrated how delivering AEDs through a drone is feasible without issues during drone activation, take-off, landing, or bystander retrieval of the AED from the drone, and confirmed that they could be expected to arrive earlier by drone than by ambulance.[132,133] A study conducted in Toronto (Canada) estimated that the AED arrival time could be reduced by almost 7 min in an urban area and by more than 10 min in a rural area.[133] Such reduction in time of AED arrival could translate to shorter time to first defibrillation, which may ultimately improve survival. Drones for AED delivery might also play a more important role in areas with a low density of population and AEDs, and in mountain and rural areas.[134] A study that investigated the bystander experience in retrieving an AED from a drone found that interacting with a drone in simulated OHCA was perceived to be safe and feasible by laypeople.[135]

The effect of the impact of technologies on recognition and performance during cardiac arrests or on patient outcomes is unknown. Further research is needed to understand how different technologies could affect the recognition of cardiac arrest (e.g. artificial intelligence and video communication), the rate of bystander CPR (e.g. AED locator apps, smartphones and smartwatches) and survival (e.g. drones). Measuring the implementation and consequences of these technologies into resuscitation programmes would be useful to inform future practices.

Foreign body airway obstruction

Foreign body airway obstruction (FBAO) is a common problem, with many cases being relieved easily without the need to involve healthcare providers. Foreign body airway obstruction, however, is an important cause of accidental death.[136] It can affect all ages but is most common in young children and older adults.[136a,136b]

As most choking events are associated with eating, they are commonly witnessed and potentially treatable. Victims are initially conscious and responsive, so there are often opportunities for early intervention, which can be lifesaving. For every case leading to hospitalisation or death there are many more that are treated effectively by first aid in the community.

Recognition

Recognition of airway obstruction is the key to successful outcome. It is important not to confuse this emergency with fainting, myocardial infarction, seizure or other conditions that may cause sudden respiratory distress, cyanosis or loss of consciousness. Factors which place individuals at risk of FBAO include psychotropic medication, alcohol intoxication, neurological conditions producing reduced swallowing and cough reflexes, mental impairment, developmental disability, dementia, poor dentition and older age.[138,139] Foreign bodies most commonly associated with airway obstruction are solids such as nuts, grapes, seeds, vegetables, meat and bread.[137,138] Children, in particular, may put all sorts of objects in their mouths.[137]

A foreign body can lodge in the upper airway, trachea or lower airway (bronchi and bronchioles).[140] Airway obstruction may be partial or complete. In partial airway obstruction, air may still pass around the obstruction, allowing some ventilation and the ability to cough. Complete airway obstruction occurs when no air can pass around the obstruction. Left untreated, complete airway obstruction will rapidly cause hypoxia, loss of consciousness and cardiac arrest within a few minutes. Prompt treatment is critical.

It is important to ask the conscious victim “Are you choking?” A victim who is able to speak, cough and breathe has mild obstruction; one who is unable to speak, has a weakening cough, is struggling or unable to breathe, has severe airway obstruction.

Treatment of foreign body airway obstruction

The guidelines for the treatment of FBAO, informed by the ILCOR systematic review and CoSTR,[112,141] highlight the importance of early bystander intervention.[142,143]

Conscious patient with foreign body airway obstruction

A person who is conscious and able to cough, should be encouraged to do so as coughing generates high and sustained airway pressures and may expel the foreign body.[142,144,145] Aggressive treatment with back blows, abdominal thrusts and chest compressions carry the risk of injury and can even worsen the obstruction. These procedures, particularly abdominal thrusts, are reserved for victims who have signs of severe airway obstruction, such as inability to cough or fatigue. If coughing fails to clear the obstruction or the victim starts to show signs of fatigue, give up to 5 back blows. If these are ineffective, give up to 5 abdominal thrusts. If both of these interventions are unsuccessful, further series of 5 back blows followed by 5 abdominal thrusts are continued.

Unconscious victim with foreign body airway obstruction

If at any point, the victim becomes unconscious with absent or abnormal breathing, chest compressions are started in accordance with the standard BLS resuscitation algorithm and continued until the victim recovers and starts to breathe normally, or emergency services arrive. The rationale for this is that chest compressions generate higher airway pressures than abdominal thrusts and may potentially alleviate the obstruction, whilst also providing some cardiac output.[146–148]

Approximately 50% of episodes of FBAO are not relieved by a single technique.[144] The likelihood of success is increased when combinations of back blows and abdominal thrusts and, if necessary, chest thrusts are used.

A blind finger sweep as a means of removing unseen solid material may worsen airway obstruction or cause soft tissue injury.[1] Attempt a finger sweep only when an obstruction can be clearly seen in the mouth.

The use of a Magill's forceps by trained healthcare professionals falls outside the scope of the intended audience for the ERC BLS guidelines and is therefore not included in these guidelines.

Alternative techniques

In recent years, manual suction airway clearance devices to remove foreign bodies have become commercially available. The ERC adopts a similar approach to ILCOR in suggesting that further evidence is needed in relation to the safety, efficacy and training requirements of such devices before any recommendations for or against their use can be made.[1] Similarly, interventions such as the Table[149] and chair manoeuvres,[150] lack sufficient evidence for their introduction into the guidelines at the present time.

Aftercare and referral for medical review

Following successful treatment of FBAO, foreign material may nevertheless remain in the upper or lower airways and cause complications later. Victims with a persistent cough, difficulty swallowing, or the sensation of an object being still stuck in the throat should, therefore, be referred for a medical opinion. Abdominal thrusts and chest compressions can potentially cause serious internal injuries and all victims successfully treated with these measures should be examined by a qualified practitioner.

Conflict of interest

TO declares research funding from Laerdal Foundation and Zoll Foundation. JS declares his role as an editor of Resuscitation; he declares institutional research funding for the Audit-7 project. MS reports unspecified institutional research funding. GR declares his role of consultant for Zoll; he reports research grant from Zoll for the AMSA trial and other Institutional grants: EU Horizon 2020 support for ESCAPE-NET, Fondazione Sestini support for the project “CPArtrial”, EU Horizon 2020 and Coordination and support for the action “iProcureSecurity”.GDP reports funding from Elsevier for his role as an editor of the journal Resuscitation. He reports research funding from the National Institute for Health Research in relation to the PARAMEDIC2 trial and the RESPECT project and from the Resuscitation Council UK and British Heart Foundation for the OHCAO Registry. AH declared his role of Medical advisor British Airways and Medical Director of Places for People.

Acknowledgement

The Writing Group acknowledges the contributions by Tommaso Scquizzato in drafting the “How technology can help” section. GDP is supported by the by the National Institute for Health Research (NIHR) Applied Research Collaboration (ARC) West Midlands. The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care.

REFERENCES

1. Olasveengen T. Adult basic life support. 2020 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Resuscitation 2020;156(November):A23–34.
2. Nolan JP, Monsieurs KG, Bossaert L, et al. European Resuscitation Council COVID-19 guidelines executive summary. Resuscitation 2020;153:45–55.

3. Perkins GD, Morley PT, Nolan JP, et al. International Liaison Committee on Resuscitation: COVID-19 consensus on science, treatment recommendations and task force insights. Resuscitation 2020;151:145–7.
4. Couper K, Taylor-Phillips S, Grove A, et al. COVID-19 in cardiac arrest and infection risk to rescuers: a systematic review. Resuscitation 2020;151:59–66.
4a. Perkins GD, Graesner JT, Semeraro F, et al. European Resuscitation Council Guidelines 2021 – Executive summary. Resuscitation 2021;161.
5. Koster RW, Sayre MR, Botha M, et al. Part 5: Adult basic life support: 2010 International consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Resuscitation 2010;81(Suppl. 1): e48–70.
6. Bahr J, Klingler H, Panzer W, Rode H, Kettler D. Skills of lay people in checking the carotid pulse. Resuscitation 1997;35:23–6.
7. Ruppert M, Reith MW, Widmann JH, et al. Checking for breathing: evaluation of the diagnostic capability of emergency medical services personnel, physicians, medical students, and medical laypersons. Ann Emerg Med 1999;34:720–9.
8. Perkins GD, Stephenson B, Hulme J, Monsieurs KG. Birmingham assessment of breathing study (BABS). Resuscitation 2005;64: 109–13.
9. Handley AJ, Koster R, Monsieurs K, Perkins GD, Davies S, Bossaert L. European Resuscitation Council guidelines for resuscitation 2005. Section 2. Adult basic life support and use of automated external defibrillators. Resuscitation 2005;67(Suppl. 1): S7–S23.
10. Anonymous. Part 3: adult basic life support. European Resuscitation Council. Resuscitation 2000;46:29–71.
11. Clark JJ, Larsen MP, Culley LL, Graves JR, Eisenberg MS. Incidence of agonal respirations in sudden cardiac arrest. Ann Emerg Med 1992;21:1464–7.
12. Debaty G, Labarere J, Frascone RJ, et al. Long-term prognostic value of gasping during out-of-hospital cardiac arrest. J Am Coll Cardiol 2017;70:1467–76.
13. Bang A, Herlitz J, Martinell S. Interaction between emergency medical dispatcher and caller in suspected out-of-hospital cardiac arrest calls with focus on agonal breathing. A review of 100 tape recordings of true cardiac arrest cases. Resuscitation 2003;56: 25–34.
14. Riou M, Ball S, Williams TA, et al. 'She's sort of breathing': What linguistic factors determine call-taker recognition of agonal breathing in emergency calls for cardiac arrest? Resuscitation 2018;122:92–8.
15. Dami F, Heymann E, Pasquier M, Fuchs V, Carron PN, Hugli O. Time to identify cardiac arrest and provide dispatch-assisted cardio-pulmonary resuscitation in a criteria-based dispatch system. Resuscitation 2015;97:27–33.
16. Bohm K, Rosenqvist M, Hollenberg J, Biber B, Engerstrom L, Svensson L. Dispatcher-assisted telephone-guided cardiopulmonary resuscitation: an underused lifesaving system. Eur J Emerg Med 2007;14:256–9.
17. Fukushima H, Imanishi M, Iwami T, et al. Abnormal breathing of sudden cardiac arrest victims described by laypersons and its association with emergency medical service dispatcher-assisted cardiopulmonary resuscitation instruction. Emerg Med 2015;32: 314–7.
18. Berdowski J, Beekhuis F, Zwinderman AH, Tijssen JG, Koster RW. Importance of the first link: description and recognition of an out-of-hospital cardiac arrest in an emergency call. Circulation 2009;119:2096–102.
19. Travers S, Jost D, Gillard Y, et al. Out-of-hospital cardiac arrest phone detection: those who most need chest compressions are the most difficult to recognize. Resuscitation 2014;85:1720–5.
20. Vaillancourt C, Verma A, Trickett J, et al. Evaluating the effectiveness of dispatch-assisted cardiopulmonary resuscitation instructions. Acad Emerg Med 2007;14:877–83.
21. Brinkrolf P, Metelmann B, Scharte C, Zarbock A, Hahnenkamp K, Bohn A. Bystander-witnessed cardiac arrest is associated with reported agonal breathing and leads to less frequent bystander CPR. Resuscitation 2018;127:114–8.
22. Hardeland C, Sunde K, Ramsdal H, et al. Factors impacting upon timely and adequate allocation of prehospital medical assistance and resources to cardiac arrest patients. Resuscitation 2016;109: 56–63.
23. Viereck S, Moller TP, Ersboll AK, et al. Recognising out-of-hospital cardiac arrest during emergency calls increases bystander cardiopulmonary resuscitation and survival. Resuscitation 2017;115:141–7.
24. Feldman MJ, Verbeek PR, Lyons DG, Chad SJ, Craig AM, Schwartz B. Comparison of the medical priority dispatch system to an out-of-hospital patient acuity score. Acad Emerg Med 2006;13:954–60.
25. Sporer KA, Johnson NJ. Detailed analysis of prehospital interventions in medical priority dispatch system determinants. West J Emerg Med 2011;12:19–29.
26. Clawson J, Olola C, Scott G, Heward A, Patterson B. Effect of a Medical Priority Dispatch System key question addition in the seizure/convulsion/fitting protocol to improve recognition of ineffective (agonal) breathing. Resuscitation 2008;79:257–64.
27. Dami F, Rossetti AO, Fuchs V, Yersin B, Hugli O. Proportion of out-of-hospital adult non-traumatic cardiac or respiratory arrest among calls for seizure. Emerg Med 2012;29:758–60.
28. Schwarzkoph M, Yin L, Hergert L, Drucker C, Counts CR, Eisenberg M. Seizure-like presentation in OHCA creates barriers to dispatch recognition of cardiac arrest. Resuscitation 2020;156:230–6.
29. Kamikura T, Iwasaki H, Myojo Y, Sakagami S, Takei Y, Inaba H. Advantage of CPR-first over call-first actions for out-of-hospital cardiac arrests in nonelderly patients and of noncardiac aetiology. Resuscitation 2015;96:37–45.
30. Orlowski JP. Optimum position for external cardiac compression in infants and young children. Ann Emerg Med 1986;15:667–73.
31. Cha KC, Kim HJ, Shin HJ, Kim H, Lee KH, Hwang SO. Hemodynamic effect of external chest compressions at the lower end of the sternum in cardiac arrest patients. J Emerg Med 2013;44:691–7.
32. Qvigstad E, Kramer-Johansen J, Tomte O, et al. Clinical pilot study of different hand positions during manual chest compressions monitored with capnography. Resuscitation 2013;84:1203–7.
33. Park M, Oh WS, Chon SB, Cho S. Optimum chest compression point for cardiopulmonary resuscitation in children revisited using a 3D coordinate system imposed on CT: a retrospective, cross-sectional study. Pediatr Crit Care Med 2018;19:e576–84.
34. Lee J, Oh J, Lim TH, et al. Comparison of optimal point on the sternum for chest compression between obese and normal weight individuals with respect to body mass index, using computer tomography: a retrospective study. Resuscitation 2018;128:1–5.
35. Nestaas S, Stensaeth KH, Rosseland V, Kramer-Johansen J. Radiological assessment of chest compression point and achievable compression depth in cardiac patients. Scand J Trauma Resusc Emerg Med 2016;24:54.
36. Cha KC, Kim YJ, Shin HJ, et al. Optimal position for external chest compression during cardiopulmonary resuscitation: an analysis based on chest CT in patients resuscitated from cardiac arrest. Emerg Med 2013;30:615–9.
37. Papadimitriou P, Chalkias A, Mastrokostopoulos A, Kapniari I, Xanthos T. Anatomical structures underneath the sternum in healthy adults and implications for chest compressions. Am J Emerg Med 2013;31:549–55.
38. Holmes S, Kirkpatrick ID, Zelop CM, Jassal DS. MRI evaluation of maternal cardiac displacement in pregnancy: implications for cardiopulmonary resuscitation. Am J Obstet Gynecol 2015213: 401e1–e5.
39. Catena E, Ottolina D, Fossali T, et al. Association between left ventricular outflow tract opening and successful resuscitation after cardiac arrest. Resuscitation 2019;138:8–14.

40. Park JB, Song IK, Lee JH, Kim EH, Kim HS, Kim JT. Optimal chest compression position for patients with a single ventricle during cardiopulmonary resuscitation. Pediatr Crit Care Med 2016;17:303–6.
41. Considine J, Gazmuri RJ, Perkins GD, et al. Chest compression components (rate, depth, chest wall recoil and leaning): a scoping review. Resuscitation 2020;146:188–202.
42. Perkins GD, Handley AJ, Koster RW, et al. European Resuscitation Council guidelines for resuscitation 2015: Section 2. Adult basic life support and automated external defibrillation. Resuscitation 2015;95:81–99.
43. Cheskes S, Common MR, Byers AP, Zhan C, Silver A, Morrison LJ. The association between chest compression release velocity and outcomes from out-of-hospital cardiac arrest. Resuscitation 2015;86:38–43.
44. Hwang SO, Cha KC, Kim K, et al. A randomized controlled trial of compression rates during cardiopulmonary resuscitation. J Korean Med Sci 2016;31:1491–8.
45. Kilgannon JH, Kirchhoff M, Pierce L, Aunchman N, Trzeciak S, Roberts BW. Association between chest compression rates and clinical outcomes following in-hospital cardiac arrest at an academic tertiary hospital. Resuscitation 2017;110:154–61.
46. Kovacs A, Vadeboncoeur TF, Stolz U, et al. Chest compression release velocity: association with survival and favorable neurologic outcome after out-of-hospital cardiac arrest. Resuscitation 2015;92:107–14.
47. Riyapan S, Naulnark T, Ruangsomboon O, et al. Improving quality of chest compression in Thai emergency department by using real-time audio-visual feedback cardio-pulmonary resuscitation monitoring. J Med Assoc Thail 2019;102:245–51.
48. Sainio M, Hoppu S, Huhtala H, Eilevstjonn J, Olkkola KT, Tenhunen J. Simultaneous beat-to-beat assessment of arterial blood pressure and quality of cardiopulmonary resuscitation in out-of-hospital and in-hospital settings. Resuscitation 2015;96:163–9.
49. Sutton RM, Case E, Brown SP, et al. A quantitative analysis of out-of-hospital pediatric and adolescent resuscitation quality—a report from the ROC epistry-cardiac arrest. Resuscitation 2015;93:150–7.
50. Sutton RM, Reeder RW, Landis W, et al. Chest compression rates and pediatric in-hospital cardiac arrest survival outcomes. Resuscitation 2018;130:159–66.
51. Edelson DP, Abella BS, Kramer-Johansen J, et al. Effects of compression depth and pre-shock pauses predict defibrillation failure during cardiac arrest. Resuscitation 2006;71:137–45.
52. Kramer-Johansen J, Myklebust H, Wik L, et al. Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective interventional study. Resuscitation 2006;71:283–92.
53. Kern KB, Sanders AB, Raife J, Milander MM, Otto CW, Ewy GA. A study of chest compression rates during cardiopulmonary resuscitation in humans: the importance of rate-directed chest compressions. Arch Intern Med 1992;152:145–9.
54. Idris AH, Guffey D, Pepe PE, et al. Chest compression rates and survival following out-of-hospital cardiac arrest. Crit Care Med 2015;43:840–8.
55. Idris AH, Guffey D, Aufderheide TP, et al. Relationship between chest compression rates and outcomes from cardiac arrest. Circulation 2012;125:3004–12.
56. Abella BS, Sandbo N, Vassilatos P, et al. Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. Circulation 2005;111:428–34.
57. Ornato JP, Gonzalez ER, Garnett AR, Levine RL, McClung BK. Effect of cardiopulmonary resuscitation compression rate on end-tidal carbon dioxide concentration and arterial pressure in man. Crit Care Med 1988;16:241–5.
58. Bohn A, Weber TP, Wecker S, et al. The addition of voice prompts to audiovisual feedback and debriefing does not modify CPR quality or outcomes in out of hospital cardiac arrest—a prospective, randomized trial. Resuscitation 2011;82:257–62.
59. Stiell IG, Brown SP, Nichol G, et al. What is the optimal chest compression depth during out-of-hospital cardiac arrest resuscitation of adult patients? Circulation 2014;130:1962–70.
60. Vadeboncoeur T, Stolz U, Panchal A, et al. Chest compression depth and survival in out-of-hospital cardiac arrest. Resuscitation 2014;85:182–8.
61. Hellevuo H, Sainio M, Nevalainen R, et al. Deeper chest compression – more complications for cardiac arrest patients? Resuscitation 2013;84:760–5.
62. Stiell IG, Brown SP, Christenson J, et al. What is the role of chest compression depth during out-of-hospital cardiac arrest resuscitation? Crit Care Med 2012;40:1192–8.
63. Babbs CF, Kemeny AE, Quan W, Freeman G. A new paradigm for human resuscitation research using intelligent devices. Resuscitation 2008;77:306–15.
64. Sutton RM, French B, Niles DE, et al. 2010 American Heart Association recommended compression depths during pediatric in-hospital resuscitations are associated with survival. Resuscitation 2014;85:1179–84.
65. Holt J, Ward A, Mohamed TY, et al. The optimal surface for delivery of CPR: a systematic review and meta-analysis. Resuscitation 2020;155:159–64.
66. Perkins GD, Kocierz L, Smith SC, McCulloch RA, Davies RP. Compression feedback devices over estimate chest compression depth when performed on a bed. Resuscitation 2009;80:79–82.
67. Beesems SG, Koster RW. Accurate feedback of chest compression depth on a manikin on a soft surface with correction for total body displacement. Resuscitation 2014;85:1439–43.
68. Nishisaki A, Maltese MR, Niles DE, et al. Backboards are important when chest compressions are provided on a soft mattress. Resuscitation 2012;83:1013–20.
69. Sato H, Komasawa N, Ueki R, et al. Backboard insertion in the operating table increases chest compression depth: a manikin study. J Anesth 2011;25:770–2.
70. Song Y, Oh J, Lim T, Chee Y. A new method to increase the quality of cardiopulmonary resuscitation in hospital. Conf Proc IEEE Eng Med Biol Soc 2013 2013;469–72.
71. Lee S, Oh J, Kang H, et al. 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.
72. Oh J, Song Y, Kang B, et al. The use of dual accelerometers improves measurement of chest compression depth. Resuscitation 2012;83:500–4.
73. Ruiz de Gauna S, Gonzalez-Otero DM, Ruiz J, Gutierrez JJ, Russell JK. A feasibility study for measuring accurate chest compression depth and rate on soft surfaces using two accelerometers and spectral analysis. Biomed Res Int 2016;2016:6596040.
74. Oh J, Chee Y, Song Y, Lim T, Kang H, Cho Y. A novel method to decrease mattress compression during CPR using a mattress compression cover and a vacuum pump. Resuscitation 2013;84:987–91.
75. Perkins GD, Benny R, Giles S, Gao F, Tweed MJ. Do different mattresses affect the quality of cardiopulmonary resuscitation? Intensive Care Med 2003;29:2330–5.
76. Tweed M, Tweed C, Perkins GD. The effect of differing support surfaces on the efficacy of chest compressions using a resuscitation manikin model. Resuscitation 2001;51:179–83.
77. Jantti H, Silfvast T, Turpeinen A, Kiviniemi V, Uusaro A. Quality of cardiopulmonary resuscitation on manikins: on the floor and in the bed. Acta Anaesthesiol Scand 2009;53:1131–7.
78. Ahn HJ, Cho Y, You YH, et al. Effect of using a home-bed mattress on bystander chest compression during out-of-hospital cardiac arrest. Hong Kong J Emerg Med 2019.
79. Andersen LO, Isbye DL, Rasmussen LS. Increasing compression depth during manikin CPR using a simple backboard. Acta Anaesthesiol Scand 2007;51:747–50.
80. Fischer EJ, Mayrand K, Ten Eyck RP. Effect of a backboard on compression depth during cardiac arrest in the ED: a simulation study. Am J Emerg Med 2016;34:274–7.

81. Perkins GD, Smith CM, Augre C, et al. Effects of a backboard, bed height, and operator position on compression depth during simulated resuscitation. Intensive Care Med 2006;32:1632–5.
82. Sanri E, Karacabey S. The impact of backboard placement on chest compression quality: a mannequin study. Prehosp Disaster Med 2019;34:182–7.
83. Putzer G, Fiala A, Braun P, et al. Manual versus mechanical chest compressions on surfaces of varying softness with or without backboards: a randomized, crossover manikin study. J Emerg Med 201650: 594–600e1.
84. Olasveengen TM, de Caen AR, Mancini ME, et al. 2017 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations summary. Resuscitation 2017;121:201–14.
85. Ashoor HM, Lillie E, Zarin W, et al. Effectiveness of different compression-to-ventilation methods for cardiopulmonary resuscitation: a systematic review. Resuscitation 2017;118: 112–25.
86. Garza AG, Gratton MC, Salomone JA, Lindholm D, McElroy J, Archer R. Improved patient survival using a modified resuscitation protocol for out-of-hospital cardiac arrest. Circulation 2009;119:2597–605.
87. Olasveengen TM, de Caen AR, Mancini ME, et al. 2017 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations summary. Circulation 2017;136:e424–40.
88. Ma MH, Lu TC, Ng JC, et al. Evaluation of emergency medical dispatch in out-of-hospital cardiac arrest in Taipei. Resuscitation 2007;73:236–45.
89. Bohm K, Stalhandske B, Rosenqvist M, Ulfvarson J, Hollenberg J, Svensson L. Tuition of emergency medical dispatchers in the recognition of agonal respiration increases the use of telephone assisted CPR. Resuscitation 2009;80:1025–8.
90. Roppolo LP, Westfall A, Pepe PE, et al. Dispatcher assessments for agonal breathing improve detection of cardiac arrest. Resuscitation 2009;80:769–72.
91. Dami F, Fuchs V, Praz L, Vader JP. Introducing systematic dispatcher-assisted cardiopulmonary resuscitation (telephone-CPR) in a non-Advanced Medical Priority Dispatch System (AMPDS): implementation process and costs. Resuscitation 2010;81:848–52.
92. Lewis M, Stubbs BA, Eisenberg MS. Dispatcher-assisted cardiopulmonary resuscitation: time to identify cardiac arrest and deliver chest compression instructions. Circulation 2013;128: 1522–30.
93. Nichol G, Leroux B, Wang H, et al. Trial of continuous or interrupted chest compressions during CPR. N Engl J Med 2015;373:2203–14.
94. Gold LS, Fahrenbruch CE, Rea TD, Eisenberg MS. The relationship between time to arrival of emergency medical services (EMS) and survival from out-of-hospital ventricular fibrillation cardiac arrest. Resuscitation 2010;81:622–5.
95. Wik L, Hansen TB, Fylling F, et al. Delaying defibrillation to give basic cardiopulmonary resuscitation to patients with out-of-hospital ventricular fibrillation: a randomized trial. JAMA 2003;289: 1389–95.
96. Baker PW, Conway J, Cotton C, et al. Defibrillation or cardiopulmonary resuscitation first for patients with out-of-hospital cardiac arrests found by paramedics to be in ventricular fibrillation? A randomised control trial. Resuscitation 2008;79:424–31.
97. Jacobs IG, Finn JC, Oxer HF, Jelinek GA. CPR before defibrillation in out-of-hospital cardiac arrest: a randomized trial. EMA – Emerg Med Aust 2005;17:39–45.
98. Ma MH, Chiang WC, Ko PC, et al. A randomized trial of compression first or analyze first strategies in patients with out-of-hospital cardiac arrest: results from an Asian community. Resuscitation 2012;83:806–12.
99. Stiell IG, Nichol G, Leroux BG, et al. Early versus later rhythm analysis in patients with out-of-hospital cardiac arrest. N Engl J Med 2011;365:787–97.
100. Sunde K, Jacobs I, Deakin CD, et al. Part 6: Defibrillation: 2010 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Resuscitation 2010;81(Suppl. 1):e71–85.
101. Jacobs I, Sunde K, Deakin CD, et al. Part 6: Defibrillation: 2010 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Circulation 2010;122:S325–37.
102. Semeraro F. European Resuscitation Council guidelines systems saving lives 2020 resuscitation. 2020.
103. Hostler D, Everson-Stewart S, Rea TD, et al. Effect of real-time feedback during cardiopulmonary resuscitation outside hospital: prospective, cluster-randomised trial. BMJ 2011;342:d512.
104. Couper K, Kimani PK, Abella BS, et al. The system-wide effect of real-time audiovisual feedback and postevent debriefing for in-hospital cardiac arrest: the cardiopulmonary resuscitation quality improvement initiative. Crit Care Med 2015;43:2321–31.
105. Sainio M, Kamarainen A, Huhtala H, et al. Real-time audiovisual feedback system in a physician-staffed helicopter emergency medical service in Finland: the quality results and barriers to implementation. Scand J Trauma Resusc Emerg Med 2013;21:50.
106. Bobrow BJ, Vadeboncoeur TF, Stolz U, et al. The influence of scenario-based training and real-time audiovisual feedback on out-of-hospital cardiopulmonary resuscitation quality and survival from out-of-hospital cardiac arrest. Ann Emerg Med 201362: 47–56e1.
107. Abella BS, Edelson DP, Kim S, et al. CPR quality improvement during in-hospital cardiac arrest using a real-time audiovisual feedback system. Resuscitation 2007;73:54–61.
108. Agerskov M, Hansen MB, Nielsen AM, Moller TP, Wissenberg M, Rasmussen LS. Return of spontaneous circulation and long-term survival according to feedback provided by automated external defibrillators. Acta Anaesthesiol Scand 2017;61:1345–53.
109. Goharani R, Vahedian-Azimi A, Farzanegan B, et al. Real-time compression feedback for patients with in-hospital cardiac arrest: a multi-center randomized controlled clinical trial. J Intensive Care 2019;7:5.
110. Vahedian-Azimi A, Hajiesmaeili M, Amirsavadkouhi A, et al. Effect of the Cardio First Angel device on CPR indices: a randomized controlled clinical trial. Crit Care 2016;20:147.
111. Chiang WC, Chen WJ, Chen SY, et al. Better adherence to the guidelines during cardiopulmonary resuscitation through the provision of audio-prompts. Resuscitation 2005;64:297–301.
112. Olasveengen TM, Mancini ME, Perkins GD, et al. Adult basic life support: international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Resuscitation 2020;156:A35–79.
113. White L, Rogers J, Bloomingdale M, et al. Dispatcher-assisted cardiopulmonary resuscitation: risks for patients not in cardiac arrest. Circulation 2010;121:91–7.
114. Haley KB, Lerner EB, Pirrallo RG, Croft H, Johnson A, Uihlein M. The frequency and consequences of cardiopulmonary resuscitation performed by bystanders on patients who are not in cardiac arrest. Prehosp Emerg Care 2011;15:282–7.
115. Moriwaki Y, Sugiyama M, Tahara Y, et al. Complications of bystander cardiopulmonary resuscitation for unconscious patients without cardiopulmonary arrest. J Emerg Trauma Shock 2012;5: 3–6.
116. Tanaka Y, Nishi T, Takase K, et al. Survey of a protocol to increase appropriate implementation of dispatcher-assisted cardiopulmonary resuscitation for out-of-hospital cardiac arrest. Circulation 2014;129:1751–60.
117. Lu TC, Chang YT, Ho TW, et al. Using a smartwatch with real-time feedback improves the delivery of high-quality cardiopulmonary resuscitation by healthcare professionals. Resuscitation 2019;140:16–22.
118. Park SS. Comparison of chest compression quality between the modified chest compression method with the use of smartphone application and the standardized traditional chest compression method during CPR. Technol Health Care 2014;22:351–8.

119. Ringh M, Rosenqvist M, Hollenberg J, et al. Mobile-phone dispatch of laypersons for CPR in out-of-hospital cardiac arrest. N Engl J Med 2015;372:2316–25.
120. Lee SY, Shin SD, Lee YJ, et al. Text message alert system and resuscitation outcomes after out-of-hospital cardiac arrest: a before-and-after population-based study. Resuscitation 2019;138:198–207.
121. Scquizzato T, Pallanch O, Belletti A, et al. Enhancing citizens response to out-of-hospital cardiac arrest: a systematic review of mobile-phone systems to alert citizens as first responders. Resuscitation 2020;152:16–25.
122. Andelius L, Malta Hansen C, Lippert FK, et al. Smartphone activation of citizen responders to facilitate defibrillation in out-of-hospital cardiac arrest. J Am Coll Cardiol 2020;76:43–53.
123. Lin YY, Chiang WC, Hsieh MJ, Sun JT, Chang YC, Ma MH. Quality of audio-assisted versus video-assisted dispatcher-instructed bystander cardiopulmonary resuscitation: a systematic review and meta-analysis. Resuscitation 2018;123:77–85.
124. Lee SY, Song KJ, Shin SD, Hong KJ, Kim TH. Comparison of the effects of audio-instructed and video-instructed dispatcher-assisted cardiopulmonary resuscitation on resuscitation outcomes after out-of-hospital cardiac arrest. Resuscitation 2020;147:12–20.
125. Kim C, Choi HJ, Moon H, et al. Prehospital advanced cardiac life support by EMT with a smartphone-based direct medical control for nursing home cardiac arrest. Am J Emerg Med 2019;37:585–9.
126. Gulshan V, Peng L, Coram M, et al. Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. JAMA 2016;316:2402–10.
127. Rajkomar A, Oren E, Chen K, et al. Scalable and accurate deep learning with electronic health records. NPJ Digit Med 2018;1:18.
128. Blomberg SN, Folke F, Ersboll AK, et al. Machine learning as a supportive tool to recognize cardiac arrest in emergency calls. Resuscitation 2019;138:322–9.
129. Chan J, Rea T, Gollakota S, Sunshine JE. Contactless cardiac arrest detection using smart devices. NPJ Digit Med 2019;2:52.
130. Kwon JM, Jeon KH, Kim HM, et al. Deep-learning-based out-of-hospital cardiac arrest prognostic system to predict clinical outcomes. Resuscitation 2019;139:84–91.
131. Al-Dury N, Ravn-Fischer A, Hollenberg J, et al. Identifying the relative importance of predictors of survival in out of hospital cardiac arrest: a machine learning study. Scand J Trauma Resusc Emerg Med 2020;28:60.
132. Claesson A, Backman A, Ringh M, et al. Time to delivery of an automated external defibrillator using a drone for simulated out-of-hospital cardiac arrests vs emergency medical services. JAMA 2017;317:2332–4.
133. Boutilier JJ, Brooks SC, Janmohamed A, et al. Optimizing a drone network to deliver automated external defibrillators. Circulation 2017;135:2454–65.
134. Vogele A, Strohle M, Paal P, Rauch S, Brugger H. Can drones improve survival rates in mountain areas, providing automated external defibrillators? Resuscitation 2020;146:277–8.
135. Sanfridsson J, Sparrevik J, Hollenberg J, et al. Drone delivery of an automated external defibrillator – a mixed method simulation study of bystander experience. Scand J Trauma Resusc Emerg Med 2019;27:40.
136. Fingerhut LA, Cox CS, Warner M. International comparative analysis of injury mortality. Findings from the ICE on injury statistics. International Collaborative Effort on Injury Statistics. Adv Data 1998;1–20.
136a. Statista.com. Number of deaths due to choking in the United States from 1945 to 2018. Statista (https://www.statista.com/statistics/527321/deaths-due-to-choking-in-the-us/).
136b. Office for National Statistics. Choking related deaths in England and Wales, 2014 to 2018. Office for National Statistics (https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/10785chokingrelateddeathsinenglandandwales2014to2018).
137. Foltran F, Ballali S, Passali FM, et al. Foreign bodies in the airways: a meta-analysis of published papers. Int J Pediatr Otorhinolaryngol 2012;76(Suppl. 1):S12–9.
138. Hemsley B, Steel J, Sheppard JJ, Malandraki GA, Bryant L, Balandin S. Dying for a meal: an integrative review of characteristics of choking incidents and recommendations to prevent fatal and nonfatal choking across populations. Am J Speech Lang Pathol 2019;28:1283–97.
139. Wong SC, Tariq SM. Cardiac arrest following foreign-body aspiration. Respir Care 2011;56:527–9.
140. Igarashi Y, Norii T, Sung-Ho K, et al. New classifications for Life-threatening foreign body airway obstruction. Am J Emerg Med 2019;37:2177–81.
141. Couper K, Abu Hassan A, Ohri V, et al. Removal of foreign body airway obstruction: a systematic review of interventions. Resuscitation 2020;156:174–81.
142. Igarashi Y, Yokobori S, Yoshino Y, Masuno T, Miyauchi M, Yokota H. Prehospital removal improves neurological outcomes in elderly patient with foreign body airway obstruction. Am J Emerg Med 2017;35:1396–9.
143. Kinoshita K, Azuhata T, Kawano D, Kawahara Y. Relationships between pre-hospital characteristics and outcome in victims of foreign body airway obstruction during meals. Resuscitation 2015;88:63–7.
144. Redding JS. The choking controversy: critique of evidence on the Heimlich maneuver. Crit Care Med 1979;7:475–9.
145. Vilke GM, Smith AM, Ray LU, Steen PJ, Murrin PA, Chan TC. Airway obstruction in children aged less than 5 years: the prehospital experience. Prehosp Emerg Care 2004;8:196–9.
146. Langhelle A, Sunde K, Wik L, Steen PA. Airway pressure with chest compressions versus Heimlich manoeuvre in recently dead adults with complete airway obstruction. Resuscitation 2000;44:105–8.
147. Guildner CW, Williams D, Subitch T. Airway obstructed by foreign material: the Heimlich maneuver. JACEP 1976;5:675–7.
148. Ruben H, Macnaughton FI. The treatment of food-choking. Practitioner 1978;221:725–9.
149. Blain H, Bonnafous M, Grovalet N, Jonquet O, David M. The table maneuver: a procedure used with success in four cases of unconscious choking older subjects. Am J Med 2010123: 1150e7–e9.
150. Pavitt MJ, Swanton LL, Hind M, et al. Choking on a foreign body: a physiological study of the effectiveness of abdominal thrust manoeuvres to increase thoracic pressure. Thorax 2017;72:576–8.