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European Resuscitation Council Guidelines for Resuscitation 2015 Section 2. Adult basic life support and automated external defibrillation

Gavin D. Perkins[a,b,*], Anthony J. Handley[c], Rudolph W. Koster[d], Maaret Castrén[e], Michael A. Smyth[a,f], Theresa Olasveengen[g], Koenraad G. Monsieurs[h,i], Violetta Raffay[j], Jan-Thorsten Gräsner[k], Volker Wenzel[l], Giuseppe Ristagno[m], Jasmeet Soar[n], on behalf of the Adult basic life support and automated external defibrillation section Collaborators[1]

[a] Warwick Medical School, University of Warwick, Coventry, UK
[b] Critical Care Unit, Heart of England NHS Foundation Trust, Birmingham, UK
[c] Hadstock, Cambridge, UK
[d] Department of Cardiology, Academic Medical Center, Amsterdam, The Netherlands
[e] Department of Emergency Medicine and Services, Helsinki University Hospital and Helsinki University, Finland
[f] West Midlands Ambulance Service NHS Foundation Trust, Dudley, UK
[g] Norwegian National Advisory Unit on Prehospital Emergency Medicine and Department of Anesthesiology, Oslo University Hospital, Oslo, Norway
[h] Faculty of Medicine and Health Sciences, University of Antwerp, Antwerp, Belgium
[i] Faculty of Medicine and Health Sciences, University of Ghent, Ghent, Belgium
[j] Municipal Institute for Emergency Medicine Novi Sad, Novi Sad, Serbia
[k] Department of Anaesthesia and Intensive Care Medicine, University Medical Center Schleswig-Holstein, Kiel, Germany
[l] Department of Anesthesiology and Critical Care Medicine, Medical University of Innsbruck, Innsbruck, Austria
[m] Department of Cardiovascular Research, IRCCS-Istituto di Ricerche Farmacologiche "Mario Negri", Milan, Italy
[n] Anaesthesia and Intensive Care Medicine, Southmead Hospital, Bristol, UK

Introduction

This chapter contains guidance on the techniques used during the initial resuscitation of an adult cardiac arrest victim. This includes basic life support (BLS: airway, breathing and circulation support without the use of equipment other than a protective device) and the use of an automated external defibrillator (AED). Simple techniques used in the management of choking (foreign body airway obstruction) are also included. Guidelines for the use of manual defibrillators and starting in-hospital resuscitation are found in the section Advanced Life Support Chapter.[1] A summary of the recovery position is included, with further information provided in the First Aid Chapter.[2]

The guidelines are based on the ILCOR 2015 Consensus on Science and Treatment Recommendations (CoSTR) for BLS/AED.[3] The ILCOR review focused on 23 key topics leading to 32 treatment recommendations in the domains of early access and cardiac arrest prevention, early, high-quality CPR, and early defibrillation. For these ERC guidelines the ILCOR recommendations were supplemented by focused literature reviews undertaken by Writing Group members in areas not reviewed by ILCOR. The writing group were cognisant of the costs and potential confusion created by changing guidance from 2010, and therefore sought to limit changes to those judged to be essential and supported by new evidence. Guidelines were drafted by Writing Group members, then reviewed by the full writing group and national resuscitation councils before final approval by the ERC Board.

Summary of changes since the ERC 2010 guidelines

Guidelines 2015 highlights the critical importance of the interactions between the emergency medical dispatcher, the bystander who provides CPR and the timely deployment of an automated external defibrillator. An effective, co-ordinated community response that draws these elements together is key to improving survival from out-of-hospital cardiac arrest (Fig. 2.1).

The emergency medical dispatcher plays an important role in the early diagnosis of cardiac arrest, the provision of dispatcher-assisted CPR (also known as telephone CPR), and the location and dispatch of an automated external defibrillator. The sooner the emergency services are called, the earlier appropriate treatment can be initiated and supported.

The knowledge, skills and confidence of bystanders will vary according to the circumstances, of the arrest, level of training and prior experience.

The ERC recommends that the bystander who is trained and able should assess the collapsed victim rapidly to determine if the victim

* Corresponding author.
E-mail address: g.d.perkins@warwick.ac.uk (G.D. Perkins).

[1] The members of the Adult basic life support and automated external defibrillation section Collaborators are listed in the Collaborators section.

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Fig. 2.1. The interactions between the emergency medical dispatcher, the bystander who provides CPR and the timely use of an automated external defibrillator are the key ingredients for improving survival from out of hospital cardiac arrest.

is unresponsive and not breathing normally and then immediately alert the emergency services.

Whenever possible, alert the emergency services without leaving the victim.

The victim who is unresponsive and not breathing normally is in cardiac arrest and requires CPR. Immediately following cardiac arrest blood flow to the brain is reduced to virtually zero, which may cause seizure-like episodes that may be confused with epilepsy. Bystanders and emergency medical dispatchers should be suspicious of cardiac arrest in any patient presenting with seizures and carefully assess whether the victim is breathing normally.

The writing group endorses the ILCOR recommendation that all CPR providers should perform chest compressions for all victims in cardiac arrest. CPR providers trained and able to perform rescue breaths should combine chest compressions and rescue breaths. The addition of rescue breaths may provide additional benefit for children, for those who sustain an asphyxial cardiac arrest, or where the emergency medical service (EMS) response interval is prolonged. Our confidence in the equivalence between chest compression-only and standard CPR is not sufficient to change current practice.

High quality cardiopulmonary resuscitation remains essential to improving outcomes. The ERC 2015 guideline for chest compression depth is the same as the 2010 guideline. CPR providers should ensure chest compressions of adequate depth (at least 5 cm but not more than 6 cm) with a rate of 100–120 compressions per minute. Allow the chest to recoil completely after each compression and minimise interruptions in compressions. When providing rescue breaths/ventilations spend approximately 1 s inflating the chest with sufficient volume to ensure the chest rises visibly. The ratio of chest compressions to ventilations remains 30:2. Do not interrupt chest compressions for more than 10 s to provide ventilations.

Defibrillation within 3–5 min of collapse can produce survival rates as high as 50–70%. Early defibrillation can be achieved through CPR providers using public access and on-site AEDs. Public access AED programmes should be actively implemented in public places that have a high density of citizens, such as airports, railway stations, bus terminals, sport facilities, shopping malls, offices and casinos. It is here that cardiac arrests are often witnessed, and trained CPR providers can be on-scene quickly. Placing AEDs in areas where one cardiac arrest per 5 years can be expected is considered cost-effective, and the cost per added life-year is comparable to other medical interventions. Past experience of the number of cardiac arrests in a certain area, as well as the neighbourhood characteristics, may help guide AED placement. Registration of public access AEDs allows dispatchers to direct CPR providers to a nearby AED and may help to optimise response.

The adult CPR sequence can be used safely in children who are unresponsive and not breathing normally. For CPR providers with additional training a modified sequence which includes providing 5 initial rescue breaths before starting chest compressions and delaying going for help in the unlikely situation that the rescuer is alone is even more suitable for the child and drowning victim. Chest compression depths in children should be at least one third of the depth of the chest (for infants that is 4 cm, for children 5 cm).

A foreign body causing severe airway obstruction is a medical emergency. It almost always occurs whilst the victim is eating or drinking and requires prompt treatment. Start by encouraging the victim to cough. If the victim has severe airway obstruction or begins to tire, give back blows and, if that fails to relieve the obstruction, abdominal thrusts. If the victim becomes unresponsive, start CPR immediately whilst help is summoned.

Cardiac arrest

Sudden cardiac arrest (SCA) is one of the leading causes of death in Europe. Depending how SCA is defined, about 55–113 per 100,000 inhabitants a year or 350,000–700,000 individuals a year are affected in Europe.[4–6] On initial heart-rhythm analysis, about 25–50% of SCA victims have ventricular fibrillation (VF), a percentage that has declined over the last 20 years.[7–13] It is likely that many more victims have VF or rapid ventricular tachycardia (VT) at the time of collapse, but by the time the first electrocardiogram (ECG) is recorded by emergency medical service personnel their rhythm has deteriorated to asystole.[14,15] When the rhythm is recorded soon after collapse, in particular by an on-site AED, the proportion of victims in VF can be as high as 76%.[16,17] More victims of SCA survive if bystanders act immediately while VF is still present. Successful resuscitation is less likely once the rhythm has deteriorated to asystole.

The recommended treatment for VF cardiac arrest is immediate bystander CPR and early electrical defibrillation. Most cardiac arrests of non-cardiac origin have respiratory causes, such as drowning (among them many children) and asphyxia. Rescue breaths as well as chest compressions are critical for successful resuscitation of these victims.

The chain of survival

The Chain of Survival summarises the vital links needed for successful resuscitation (Fig. 2.2). Most of these links apply to victims of both primary cardiac and asphyxial arrest.[18]

Early recognition and call for help

Chest pain should be recognised as a symptom of myocardial ischaemia. Cardiac arrest occurs in a quarter to a third of patients with myocardial ischaemia within the first hour after onset of chest pain.[19] Recognising the cardiac origin of chest pain, and calling the emergency services before a victim collapses, enables the emergency medical service to arrive sooner, hopefully before cardiac arrest has occurred, thus leading to better survival.[20–23]

Once cardiac arrest has occurred, early recognition is critical to enable rapid activation of the EMS and prompt initiation of bystander CPR. The key observations are **unresponsiveness** and **not breathing normally**. Emergency medical dispatchers can improve recognition by focusing on these keywords.

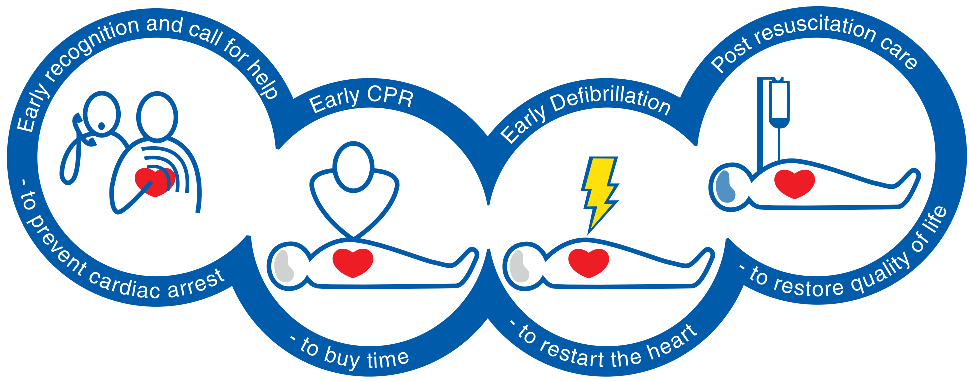


Fig. 2.2. The chain of survival.

Early bystander CPR

The immediate initiation of CPR can double or quadruple survival from cardiac arrest.[20,24–28] If able, bystanders with CPR training should give chest compressions together with ventilations. When a bystander has not been trained in CPR, the emergency medical dispatcher should instruct him or her to give chest-compression-only CPR while awaiting the arrival of professional help.[29–31]

Early defibrillation

Defibrillation within 3–5 min of collapse can produce survival rates as high as 50–70%. This can be achieved by public access and onsite AEDs.[13,17,32,33] Each minute of delay to defibrillation reduces the probability of survival to discharge by 10–12%. The links in the chain work better together: when bystander CPR is provided, the decline in survival is more gradual and averages 3–4% per minute delay to defibrillation.[20,24,34]

Early advanced life support and standardised post-resuscitation care

Advanced life support with airway management, drugs and correcting causal factors may be needed if initial attempts at resuscitation are un-successful. The quality of treatment during the post-resuscitation phase affects outcome and are addressed in the adult advanced life support and post resuscitation care chapters.[1,35]

The critical need for bystanders to act

In most communities, the median time from emergency call to emergency medical service arrival (response interval) is 5–8 min,[16,36–38] or 8–11 min to a first shock.[13,27] During this time the victim's survival depends on bystanders who initiate CPR and use an automated external defibrillator (AED).

Victims of cardiac arrest need immediate CPR. This provides a small but critical blood flow to the heart and brain. It also increases the likelihood that the heart will resume an effective rhythm and pumping power. Chest compressions are especially important if a shock cannot be delivered within the first few minutes after collapse.[39] After defibrillation, if the heart is still viable, its pacemaker activity resumes and produces an organised rhythm followed by mechanical contraction. In the first minutes after termination of VF, the heart rhythm may be slow, and the force of contractions weak; chest compressions must be continued until adequate cardiac function returns.

Use of an AED by lay CPR providers increases survival from cardiac arrest in public places.[16] AED use in residential areas is also increasing.[40] An AED uses voice prompts to guide the CPR provider, analyse the cardiac rhythm and instruct the CPR provider to deliver a shock if VF or rapid ventricular tachycardia (VT) is detected. They are accurate and will deliver a shock only when VF (or rapid VT) is present.[41,42]

Recognition of cardiac arrest

Recognising cardiac arrest can be challenging. Both bystanders and emergency call handlers (emergency medical dispatchers) have to diagnose cardiac arrest promptly in order to activate the chain of survival. Checking the carotid pulse (or any other pulse) has proved to be an inaccurate method for confirming the presence or absence of circulation.[43–47]

Agonal breaths are slow and deep breaths, frequently with a characteristic snoring sound. They originate from the brain stem, the part of the brain that remains functioning for some minutes even when deprived of oxygen. The presence of agonal breathing can be erroneously interpreted as evidence that there is a circulation and CPR is not needed. Agonal breathing may be present in up to 40% of victims in the first minutes after cardiac arrest, and if responded to as a sign of cardiac arrest, is associated with higher survival rates.[48] The significance of agonal breathing should be emphasised during basic life support training.[49,50] Bystanders should suspect cardiac arrest and start CPR if the victim is **unresponsive** and **not breathing normally**.

Immediately following cardiac arrest, blood flow to the brain is reduced to virtually zero, which may cause seizure-like episodes that can be confused with epilepsy. Bystanders should be suspicious of cardiac arrest in any patient presenting with seizures.[51,52] Although bystanders who have witnessed cardiac arrest events report changes in the victims' skin colour, notably pallor and bluish changes associated with cyanosis, these changes are not diagnostic of cardiac arrest.[51]

Role of the emergency medical dispatcher

The emergency medical dispatcher plays a critical role in the diagnosis of cardiac arrest, the provision of dispatcher assisted CPR (also known as telephone CPR), the location and dispatch of an automated external defibrillator and dispatch of a high priority EMS response. The sooner the emergency services are called, the earlier appropriate treatment can be initiated and supported.

Dispatcher recognition of cardiac arrest

Confirmation of cardiac arrest, at the earliest opportunity is critical. If the dispatcher recognises cardiac arrest, survival is more likely because appropriate measures can be taken.[53,54]

Enhancing dispatcher ability to identify cardiac arrest, and optimising emergency medical dispatcher processes, may be cost-effective solutions to improve outcomes from cardiac arrest.

Use of scripted dispatch protocols within emergency medical communication centres, including specific questions to improve cardiac arrest recognition may be helpful. Patients who are **unresponsive** and **not breathing normally** should be presumed to be in cardiac arrest. Adherence to such protocols may help improve cardiac arrest recognition,[9,55–57] whereas failure to adhere to protocols reduces rates of cardiac arrest recognition by dispatchers as well as the provision of telephone-CPR.[58–60]

Obtaining an accurate description of the victim's breathing pattern is challenging for dispatchers. Agonal breathing is often present, and callers may mistakenly believe the victim is still breathing normally.[9,60–68] Offering dispatchers additional education, specifically addressing the identification and significance of agonal breathing, can improve cardiac arrest recognition, increase the provision of telephone-CPR,[67,68] and reduce the number of missed cardiac arrest cases.[64]

Asking questions regarding the regularity or pattern of breathing may help improve recognition of abnormal breathing and thus identification of cardiac arrest. If the initial emergency call is for a person suffering seizures, the call taker should be highly suspicious of cardiac arrest, even if the caller reports that the victim has a prior history of epilepsy.[61,69]

Dispatcher assisted CPR

Bystander CPR rates are low in many communities. Dispatcher-assisted CPR (telephone-CPR) instructions have been demonstrated to improve bystander CPR rates,[9,56,70–72] reduce the time to first CPR,[56,57,68,72,73] increase the number of chest compressions delivered[70] and improve patient outcomes following out-of-hospital cardiac arrest (OHCA) in all patient groups.[9,29–31,57,71,74]

Dispatchers should provide telephone-CPR instructions in all cases of suspected cardiac arrest unless a trained provider is already delivering CPR. Where instructions are required for an adult victim, dispatchers should provide chest-compression-only CPR instructions.

If the victim is a child, dispatchers should instruct callers to provide both ventilations and chest compressions. Dispatchers should therefore be trained to provide instructions for both techniques.

Adult BLS sequence

The sequence of steps for the initial assessment and treatment of the unresponsive victim are summarised in Fig. 2.3. The sequence of steps takes the reader through recognition of cardiac arrest, calling EMS, starting CPR and using an AED. The number of steps has been reduced to focus on the key actions. The intent of the revised algorithm is to present the steps in a logical and concise manner that is easy for all types of rescuers to learn, remember and perform.

Fig. 2.4 presents the detailed step-by-step sequence for the trained provider. It continues to highlight the importance of ensuring rescuer, victim and bystander safety. Calling for additional help (if required) is incorporated in the alerting emergency services step below. For clarity the algorithm is presented as a linear sequence of steps. It is recognised that the early steps of checking response, opening the airway, checking for breathing and calling the emergency medical dispatcher may be accomplished simultaneously or in rapid succession.

Those who are not trained to recognise cardiac arrest and start CPR would not be aware of these guidelines and therefore require dispatcher assistance whenever they make the decision to call 112. These guidelines do not therefore include specific recommendations for those who are not trained to recognise cardiac arrest and start CPR.

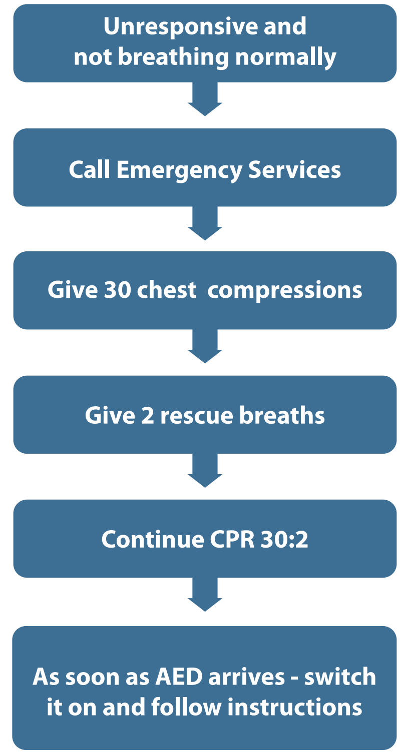


Fig. 2.3. The BLS/AED Algorithm.

The remainder of this section provides supplemental information on some of the key steps within the overall sequence.

Opening the airway and checking for breathing

The trained provider should assess the collapsed victim rapidly to determine if they are responsive and breathing normally.

Open the airway using the head tilt and chin lift technique whilst assessing whether the person is breathing normally. Do not delay assessment by checking for obstructions in the airway. The jaw thrust and finger sweep are no longer recommended for the lay provider. Check for breathing using the techniques described in Fig. 2.4 noting the critical importance of recognising agonal breathing described above.

Alerting emergency services

112 is the European emergency phone number, available everywhere in the EU, free of charge. It is possible to call 112 from fixed and mobile phones to contact any emergency service: an ambulance, the fire brigade or the police. Some European countries provide an alternative direct access number to emergency medical services, which may save time. Bystanders should therefore follow national guidelines on the optimal phone number to use.

Early contact with the emergency services will facilitate dispatcher assistance in the recognition of cardiac arrest, telephone instruction on how to perform CPR, emergency medical service/first responder dispatch, and on locating and dispatching of an AED.[75–78]

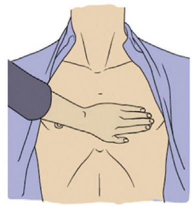
If possible, stay with the victim while calling the emergency services. If the phone has a speaker facility switch it to speaker as this will facilitate continuous dialogue with the dispatcher including (if required) CPR instructions.[79] It seems reasonable that CPR

SEQUENCE / Action		**Technical description**
SAFETY **Make sure you, the victim and any bystanders are safe**		
RESPONSE **Check the victim for a response**		Gently shake his shoulders and ask loudly: “Are you all right?" If he responds leave him in the position in which you find him, provided there is no further danger; try to find out what is wrong with him and get help if needed; reassess him regularly
AIRWAY **Open the airway**		Turn the patient onto his back if necessary Place your hand on his forehead and gently tilt his head back; with your fingertips under the point of the victim's chin, lift the chin to open the airway
BREATHING **Look, listen and feel for normal breathing**		In the first few minutes after cardiac arrest, a victim may be barely breathing, or taking infrequent, slow and noisy gasps. Do not confuse this with normal breathing. Look, listen and feel for **no more** than 10 seconds to determine whether the victim is breathing normally. If you have any doubt whether breathing is normal, act as if it is they are not breathing normally and prepare to start CPR
UNRESPONSIVE AND NOT BREATHING NORMALLY **Alert emergency services**		Ask a helper to call the emergency services (112) if possible otherwise call them yourself Stay with the victim when making the call if possible Activate speaker function on phone to aid communication with dispatcher
SEND FOR AED **Send someone to get AED**		Send someone to find and bring an AED if available. If you are on your own, do not leave the victim, start CPR

Fig. 2.4. Step by step sequence of actions for use by the BLS/AED trained provider to treat the adult cardiac arrest victim.

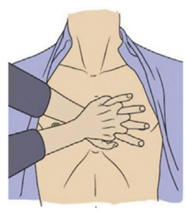
CIRCULATION

Start chest compressions



Kneel by the side of the victim

Place the heel of one hand in the centre of the victim's chest; (which is the lower half of the victim's breastbone (sternum))



Place the heel of your other hand on top of the first hand

Interlock the fingers of your hands and ensure that pressure is not applied over the victim's ribs

Keep your arms straight

Do not apply any pressure over the upper abdomen or the bottom end of the bony sternum (breastbone)

Position yourself vertically above the victim's chest and press down on the sternum approximately 5 cm (but not more than 6 cm)

After each compression, release all the pressure on the chest without losing contact between your hands and the sternum

Repeat at a rate of 100-120 min^{-1}

IF TRAINED AND ABLE

Combine chest compressions with rescue breaths

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 mouth to open, but maintain chin lift

Take a normal breath and place your lips around his mouth, making sure that you have a good seal

Blow steadily into the mouth while 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 effective rescue breaths. Do not interrupt compressions by more than 10 seconds to deliver two breaths. Then return your hands without delay to the correct position on the sternum and give a further 30 chest compressions

Fig. 2.4. (*Continued*).

		Continue with chest compressions and rescue breaths in a ratio of 30:2
IF UNTRAINED OR UNABLE TO DO RESCUE BREATHS **Continue compression only CPR**		Give chest compressions 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 on the AED and attach the electrode pads on the victim's bare chest If more than one rescuer is present, CPR should be continued while electrode pads are being attached to the chest
Follow the spoken/visual directions		Ensure that nobody is touching the victim while the AED is analysing the rhythm
If a shock is indicated, **deliver shock**		Ensure that nobody is touching the victim Push shock button as directed (fully automatic AEDs will deliver the shock automatically) Immediately restart CPR 30:2 Continue as directed by the voice / visual prompts
If no shock is indicated, continue CPR		Immediately resume CPR. Continue as directed by the voice/visual prompts

Fig. 2.4. (*Continued*).

IF NO AED IS AVAILABLE CONTINUE CPR Continue CPR		Do not interrupt resuscitation until: • a health professional tells you to stop • the victim is definitely waking up moving, opening eyes and breathing normally • you become exhausted
IF UNRESPONSIVE BUT BREATHING NORMALLY If you are certain the victim is breathing normally but is still unresponsive, place in the recovery position (see First aid chapter).		It is rare for CPR alone to restart the heart. Unless you are certain the person has recovered continue CPR Signs the victim has recovered • waking up • moving • opens eyes • normal breathing Be prepared to restart CPR immediately if patient deteriorates

Fig. 2.4. (*Continued*).

training should include how to activate the speaker phone.[80] Additional bystanders may be used to help call the emergency services.

Starting chest compressions

In adults needing CPR, there is a high probability of a primary cardiac cause. When blood flow stops after cardiac arrest, the blood in the lungs and arterial system remains oxygenated for some minutes. To emphasise the priority of chest compressions, it is recommended that CPR should start with chest compressions rather than initial ventilations. Manikin studies indicate that this is associated with a shorter time to commencement of CPR.[81–84]

When providing manual chest compressions:

1. Deliver compressions 'in the centre of the chest'.
2. Compress to a depth of at least 5 cm but not more than 6 cm.
3. Compress the chest at a rate of 100–120 min^{-1} with as few interruptions as possible.
4. Allow the chest to recoil completely after each compression; do not lean on the chest.

Hand position

Experimental studies show better haemodynamic responses when chest compressions are performed on the lower half of the sternum.[85–87] It is recommended that this location be taught in a simplified way, such as, "place the heel of your hand in the centre of the chest with the other hand on top". This instruction should be accompanied by a demonstration of placing the hands on the lower half of the sternum.[88,89]

Chest compressions are most easily delivered by a single CPR provider kneeling by the side of the victim, as this facilitates movement between compressions and ventilations with minimal interruptions. Over-the-head CPR for single CPR providers and straddle-CPR for two CPR providers may be considered when it is not possible to perform compressions from the side, for example when the victim is in a confined space.[90,91]

Compression depth

Fear of doing harm, fatigue and limited muscle strength frequently result in CPR providers compressing the chest less deeply than recommended. Four observational studies, published after the 2010 Guidelines, suggest that a compression depth range of 4.5–5.5 cm in adults leads to better outcomes than all other compression depths during manual CPR.[92–95] Based on an analysis of 9136 patients, compression depths between 40 and 55 mm with a peak at 46 mm, were associated with highest survival rates.[94] There is also evidence from one observational study suggesting that a compression depth of more than 6 cm is associated with an increased rate of injury in adults when compared with compression depths of 5–6 cm during manual CPR.[96] The ERC endorses the ILCOR recommendation that it is reasonable to aim for a chest compression of approximately 5 cm but not more than 6 cm in the average sized adult. In making this recommendation the ERC recognises that it can be difficult to estimate chest compression depth and that compressions that are too shallow are more harmful than compressions that are too deep. The ERC therefore decided to retain the 2010 guidance that chest compressions should be at least 5 cm but not more than 6 cm. Training should continue to prioritise achieving adequate compression depth.

Compression rate

Chest compression rate is defined as the actual rate of compressions being given at any one time. It differs from the number of chest compressions in a specific time period, which takes into account any interruptions in chest compressions.

Two studies, with a total of 13,469 patients, found higher survival among patients who received chest compressions at a rate of 100–120 min^{-1}, compared to >140, 120–139, <80 and 80–99 min^{-1}. Very high chest compression rates were associated with declining chest compression depths.[97,98] The ERC recommends, therefore, that chest compressions should be performed at a rate of 100–120 min^{-1}.

Minimising pauses in chest compressions

Delivery of rescue breaths, shocks, ventilations and rhythm analysis lead to pauses in chest compressions. Pre- and post-shock pauses of less than 10 s, and chest compression fractions >60% are associated with improved outcomes.[99–103] Pauses in chest compressions should be minimised, by ensuring CPR providers work effectively together.

Firm surface

CPR should be performed on a firm surface whenever possible. Air-filled mattresses should be routinely deflated during CPR.[104] The evidence for the use of backboards is equivocal.[105–109] If a backboard is used, take care to avoid interrupting CPR and dislodging intravenous lines or other tubes during board placement.

Chest wall recoil

Leaning on the chest preventing full chest wall recoil is common during CPR.[110,111] Allowing complete recoil of the chest after each compression results in better venous return to the chest and may improve the effectiveness of CPR.[110,112–114] CPR providers should, therefore, take care to avoid leaning after each chest compression.

Duty cycle

Optimal duty cycle (ratio of the time the chest is compressed to the total time from one compression to the next) has been studied in animal models and simulation studies with inconsistent results.[115–123] A recent human observational study has challenged the previously recommended duty cycle of 50:50 by suggesting compression phases >40% might not be feasible, and may be associated with decreased compression depth.[124] For CPR providers, the duty cycle is difficult to adjust, and is largely influenced by other chest compression parameters.[119,124] In reviewing the evidence, the ERC acknowledges there is very little evidence to recommend any specific duty cycle and, therefore, insufficient new evidence to prompt a change from the currently recommended ratio of 50%.

Feedback on compression technique

The use of CPR feedback and prompt devices during CPR in clinical practice is intended to improve CPR quality as a means of increasing the chances of ROSC and survival.[125,126] The forms of feedback include voice prompts, metronomes, visual dials, numerical displays, waveforms, verbal prompts, and visual alarms.

The effect of CPR feedback or prompt devices has been studied in two randomised trials[92,127] and 11 observational studies.[128–138] None of these studies demonstrated improved survival to discharge with feedback, and only one found a significantly higher ROSC rate in patients where feedback was used. However, in this study feedback was activated at the discretion of the physician and no details of the decision-making process to activate or not activate feedback were provided.[136] The use of CPR feedback or prompt devices during CPR should only be considered as part of a broader system of care that should include comprehensive CPR quality improvement initiatives,[138,139] rather than as an isolated intervention.

Rescue breaths

In non-paralysed, gasping pigs with unprotected, unobstructed airways, continuous-chest-compression CPR without artificial ventilation resulted in improved outcome.[140] Gasping may be present early after the onset of cardiac arrest in about one third of humans, thus facilitating gas exchange.[48] During CPR in intubated humans, however, the median tidal volume per chest compression was only about 40 mL, insufficient for adequate ventilation.[141] In witnessed cardiac arrest with ventricular fibrillation, immediate continuous chest compressions tripled survival.[142] Accordingly, continuous chest compressions may be most beneficial in the early, 'electric' and 'circulatory' phases of CPR, while additional ventilation becomes more important in the later, 'metabolic' phase.[39]

During CPR, systemic blood flow, and thus blood flow to the lungs, is substantially reduced, so lower tidal volumes and respiratory rates than normal can maintain effective oxygenation and ventilation.[143–146] When the airway is unprotected, a tidal volume of 1 L produces significantly more gastric inflation than a tidal volume of 500 mL.[147] Inflation durations of 1 s are feasible without causing excessive gastric insufflation.[148] Inadvertent hyperventilation during CPR may occur frequently, especially when using manual bag-valve-mask ventilation in a protected airway. While this increased intrathoracic pressure[149] and peak airway pressure,[150] a carefully controlled animal experiment revealed no adverse effects.[151]

From the available evidence we suggest that during adult CPR tidal volumes of approximately 500–600 mL (6–7 mL kg^{-1}) are delivered. Practically, this is the volume required to cause the chest to rise visibly.[152] CPR providers should aim for an inflation duration of about 1 s, with enough volume to make the victim's chest rise, but avoid rapid or forceful breaths. The maximum interruption in chest compression to give two breaths should not exceed 10 s.[153] These recommendations apply to all forms of ventilation during CPR when the airway is unprotected, including mouth-to-mouth and bag-mask ventilation, with and without supplementary oxygen.

Mouth-to-nose ventilation

Mouth-to-nose ventilation is an acceptable alternative to mouth-to-mouth ventilation.[154] It may be considered if the victim's mouth is seriously injured or cannot be opened, the CPR provider is assisting a victim in the water, or a mouth-to-mouth seal is difficult to achieve.

Mouth-to-tracheostomy ventilation

Mouth-to-tracheostomy ventilation may be used for a victim with a tracheostomy tube or tracheal stoma who requires rescue breathing.[155]

Compression–ventilation ratio

Animal data support a ratio of compression to ventilation of greater than 15:2.[156–158] A mathematical model suggests that a ratio of 30:2 provides the best compromise between blood flow and oxygen delivery.[159,160] A ratio of 30:2 was recommended in Guidelines 2005 and 2010 for the single CPR provider attempting resuscitation of an adult. This decreased the number of interruptions in compression and the no-flow fraction,[161,162] and reduced the likelihood of hyperventilation.[149,163] Several observational studies have reported slightly improved outcomes after implementation of the guideline changes, which included switching from a compression ventilation ratio of 15:2–30:2.[161,162,164,165] The ERC continues, therefore, to recommend a compression to ventilation ratio of 30:2.

Compression-only CPR

Animal studies have shown that chest-compression-only CPR may be as effective as combined ventilation and compression in the first few minutes after non-asphyxial arrest.[140,166] Animal and mathematical model studies of chest-compression-only CPR have also shown that arterial oxygen stores deplete in 2–4 min.[158,167] If the airway is open, occasional gasps and passive chest recoil may provide some air exchange.[48,141,168–170]

Observational studies, classified mostly as very low-quality evidence, have suggested equivalence of chest-compression-only CPR and chest compressions combined with rescue breaths in adults with a suspected cardiac cause for their cardiac arrest.[26,171–182]

The ERC has carefully considered the balance between potential benefit and harm from compression-only CPR compared to standard CPR that includes ventilation. Our confidence in the equivalence between chest-compression-only and standard CPR is not sufficient to change current practice. The ERC, therefore, endorses the ILCOR recommendations that all CPR providers should perform chest compressions for all patients in cardiac arrest. CPR providers trained and able to perform rescue breaths should perform chest compressions and rescue breaths as this may provide additional benefit for children and those who sustain an asphyxial cardiac arrest[175,183,184] or where the EMS response interval is prolonged.[179]

Use of an automated external defibrillator

AEDs are safe and effective when used by laypeople with minimal or no training.[185] AEDs make it possible to defibrillate many minutes before professional help arrives. CPR providers should continue CPR with minimal interruption of chest compressions while attaching an AED and during its use. CPR providers should concentrate on following the voice prompts immediately when they are spoken, in particular resuming CPR as soon as instructed, and minimizing interruptions in chest compression. Indeed, pre-shock and post-shock pauses in chest compressions should be as short as possible.[99,100,103,186] Standard AEDs are suitable for use in children older than 8 years.[187–189]

For children between 1 and 8 years paediatric pads should be used, together with an attenuator or a paediatric mode if available; if these are not available, the AED should be used as it is. There are a few case reports of successful use of AEDS in children ages less than 1 year.[190,191] The incidence of shockable rhythms in infants is very low except when there is cardiac disease.[187–189,192–195] In these rare cases, if an AED is the only defibrillator available, its use should be considered (preferably with a dose attenuator).

CPR before defibrillation

The importance of immediate defibrillation has always been emphasised in guidelines and during teaching, and is considered to have a major impact on survival from ventricular fibrillation. This concept was challenged in 2005 because evidence suggested that a period of up to 180 s of chest compression before defibrillation might improve survival when the EMS response time exceeded 4–5 min.[196,197] Three more recent trials have not confirmed this survival benefit.[198–200] An analysis of one randomised trial suggested a decline in survival to hospital discharge by a prolonged period of CPR (180 s) and delayed defibrillation in patients with a shockable initial rhythm.[200] Yet, for EMS agencies with higher baseline survival-to-hospital discharge rates (defined as >20% for an initial shockable rhythm), 180 s of CPR prior to defibrillation was more beneficial compared to a shorter period of CPR (30–60 s).[201] The ERC recommends that CPR should be continued while a defibrillator or AED is being brought on-site and applied, but defibrillation should not be delayed any longer.

Interval between rhythm checks

The 2015 ILCOR Consensus on Science reported that there are currently no studies that directly address the question of optimal intervals between rhythm checks, and their effect on survival: ROSC; favourable neurological or functional outcome; survival to discharge; coronary perfusion pressure or cardiac output.

In accordance with the ILCOR recommendation, and for consistency with previous guidelines, the ERC recommends that chest compressions should be paused every two minutes to assess the cardiac rhythm.

Voice prompts

It is critically important that CPR providers pay attention to AED voice prompts and follow them without any delay. Voice prompts are usually programmable, and it is recommended that they be set in accordance with the sequence of shocks and timings for CPR given above. These should include at least:

1. minimise pauses in chest compressions for rhythm analysis and charging;
2. a single shock only, when a shockable rhythm is detected;
3. a voice prompt for immediate resumption of chest compression after the shock delivery;
4. a period of 2 min of CPR before the next voice prompt to re-analyse the rhythm.

Devices measuring CPR quality may in addition provide real-time CPR feedback and supplemental voice/visual prompts.

The duration of CPR between shocks, as well as the shock sequence and energy levels are discussed further in the Advanced Life Support Chapter.[1]

In practice, AEDs are used mostly by trained rescuers, where the default setting of AED prompts should be for a compression to ventilation ratio of 30:2.

If (in an exception) AEDs are placed in a setting where such trained rescuers are unlikely to be available or present, the owner or distributor may choose to change the settings to compression only.

Fully-automatic AEDs

Having detected a shockable rhythm, a fully automatic AED will deliver a shock without further action from the CPR provider. One manikin study showed that untrained nursing students committed fewer safety errors using a fully automatic AED compared with a semi-automatic AED.[202] A simulated cardiac arrest scenario on a manikin showed that safety was not compromised when untrained lay CPR providers used a fully automatic AED rather than a semi-automatic AED.[203] There are no human data to determine whether these findings can be applied to clinical use.

Public access defibrillation (PAD) programmes

The conditions for successful resuscitation in residential areas are less favourable than in public areas: fewer witnessed arrests, lower bystander CPR rates and, as a consequence, fewer shockable rhythms than in public places. This limits the effectiveness of AED use for victims at home.[204] Most studies demonstrating a survival benefit from AED use were conducted with AEDs in public places.[32,205–208] More recent data from nationwide studies in Japan and the USA confirmed that when an AED was available, victims were defibrillated much sooner and with a better chance of survival.[16,209] However, an AED delivered a shock in only 3.7%[209] or 1.2%[16] of all cardiac arrests. There was a clear inverse relationship in the Japanese study between the number of AEDs available per square km and the interval between collapse and the first shock, leading to a positive relationship with survival.

Public access AED programmes should, therefore, be actively implemented in public places with a high density and movement of citizens such as airports, railway stations, bus terminals, sport facilities, shopping malls, offices and casinos where cardiac arrests are usually witnessed and trained CPR providers can quickly be on scene. The density and location of AEDs required for a sufficiently rapid response is not well established, especially when cost-effectiveness is a consideration. Factors such as expected incidence of cardiac arrest, expected number of life-years gained, and reduction in response time of AED-equipped CPR providers compared to that of traditional EMS should inform this decision. Placement of AEDs in areas where one cardiac arrest per 5 years can be expected is considered cost-effective and comparable to other medical interventions.[210–212] For residential areas, past experience may help guide AED placement, as may neighbourhood characteristics.[213,214] Registration of AEDs for public access, so that dispatchers can direct CPR providers to a nearby AED, may also help to optimise response.[215] Cost saving is also possible, as early defibrillation and on-site AED defibrillation may result in lower in-hospital cost.[216,217]

The full potential of AEDs has not yet been achieved, because they are mostly used in public settings, yet 60–80% of cardiac arrests occur at home. The proportion of patients found in VF is lower at home than in public places, however the absolute number of potentially treatable patients is higher at home.[204] Public access defibrillation (PAD) rarely reaches victims at home.[208] Different strategies, therefore, are required for early defibrillation in residential areas. Dispatched first responders, such as police and fire fighters will, in general, have longer response times, but they have the potential to reach the whole population.[17,36] The logistic problem for first responder programmes is that the CPR provider needs to arrive, not just earlier than the traditional ambulance, but within 5–6 min of the initial call, to enable attempted defibrillation in the electrical or circulatory phase of cardiac arrest.[39] With longer delays, the survival benefit decreases: a few minutes gain in time will have less impact when a first responder arrives more than 10 min after the call.[34,218] Dispatched lay CPR providers, local to the victim and directed to a nearby AED, may improve bystander CPR rates[33] and help reduce the time to defibrillation.[40]

When implementing an AED programme, community and programme leaders should consider factors such as development of a team with responsibility for monitoring, maintaining the devices, training and retraining individuals who are likely to use the AED, and identification of a group of volunteer individuals who are committed to using the AED for victims of cardiac arrest.[219] Funds must be allocated on a permanent basis to maintain the programme.

Programmes that make AEDs available in residential areas have only been evaluated for response time, not for survival benefit.[40] The acquisition of an AED for individual use at home, even for those considered at high risk of sudden cardiac arrest is not effective.[220]

The special circumstances chapter provides the evidence underpinning the ERC recommendation that AEDs should be mandatory on board all commercial aircraft in Europe, including regional and low-cost carriers.[221]

Universal AED signage

When a victim collapses an AED must be obtained rapidly: simple and clear signage indicating the location of an AED and the fastest way to it is important. ILCOR has designed such an AED sign that may be recognised worldwide and this is recommended.[222]

In-hospital use of AEDs

There are no published randomised trials comparing in-hospital use of AEDs with manual defibrillators. Two older, observational studies of adults with in-hospital cardiac arrest from shockable rhythms showed higher survival-to-hospital discharge rates when defibrillation was provided through an AED programme than with manual defibrillation alone.[223,224] A more recent observational study showed that an AED could be used successfully before the arrival of the hospital resuscitation team.[225] Three observational studies showed no improvements in survival to hospital discharge for in-hospital adult cardiac arrest when using an AED compared with manual defibrillation.[226–228] In one of these studies,[226] patients in the AED group with non-shockable rhythms had a lower survival-to-hospital discharge rate compared with those in the manual defibrillator group (15% vs. 23%; $P = 0.04$). Another large observational study of 11,695 patients from 204 hospitals also showed that in-hospital AED use was associated with a lower survival-to-discharge rate compared with no AED use (16.3% vs. 19.3%; adjusted rate ratio [RR], 0.85; 95% confidence interval [CI], 0.78–0.92; $P < 0.001$).[229] For non-shockable rhythms, AED use was associated with lower survival (10.4% vs. 15.4%; adjusted RR, 0.74; 95% CI, 0.65–0.83; $P < 0.001$), and a similar survival rate for shockable rhythms, (38.4% vs. 39.8%; adjusted RR, 1.00; 95% CI, 0.88–1.13; $P = 0.99$). This suggests that AEDs may cause harmful delays in starting CPR, or interruptions in chest compressions in patients with non-shockable rhythms.[230] Only a small proportion (less than 20%) of in-hospital cardiac arrests have an initial shockable rhythm.[229,231,232]

We recommend the use of AEDs in those areas of the hospital where there is a risk of delayed defibrillation,[233] because it will take several minutes for a resuscitation team to arrive, and first responders do not have skills in manual defibrillation. The goal is to attempt defibrillation within 3 min of collapse. In hospital areas where there is rapid access to manual defibrillation, either from trained staff or a resuscitation team, manual defibrillation should be used in preference to an AED. Whichever defibrillation technique is chosen (and some hospitals may choose to have defibrillators that offer both an AED and manual mode) an effective system for training and retraining should be in place.[232,234] Sufficient healthcare providers should be trained to enable the goal of providing the first shock within 3 min of collapse anywhere in the hospital. Hospitals should monitor collapse-to-first shock intervals and audit resuscitation outcomes.

Risks to the CPR provider and recipients of CPR

Risks to the victim who receives CPR who is not in cardiac arrest

Many CPR providers do not initiate CPR because they are concerned that delivering chest compressions to a victim who is not in cardiac arrest will cause serious complications. Three studies have investigated the risk of CPR in persons not in cardiac arrest.[235–237] Pooled data from these three studies, encompassing 345 patients, found an incidence of bone fracture (ribs and clavicle) of 1.7% (95% CI 0.4–3.1%), pain in the area of chest compression 8.7% (95% CI 5.7–11.7%), and no clinically relevant visceral injury. Bystander CPR extremely rarely leads to serious harm in victims who are eventually found not to be in cardiac arrest. CPR providers should not, therefore, be reluctant to initiate CPR because of concern of causing harm.

Risks to the victim who receives CPR who is in cardiac arrest

A systematic review of skeletal injuries after manual chest compression reports an incidence of rib fractures ranging from 13% to 97%, and of sternal fractures from 1% to 43%.[238] Visceral injuries (lung, heart, abdominal organs) occur less frequently and may or may not be associated with skeletal injury.[239] Injuries are more common when the depth of chest compression exceeds 6 cm in the average adult.[96]

Risks to the CPR provider during training and during real-life CPR

Observational studies of training or actual CPR performance and case reports have described rare occurrences of muscle strain, back symptoms, shortness of breath, hyperventilation, pneumothorax, chest pain, myocardial infarction and nerve injury.[240,241] The incidence of these events is very low, and CPR training and actual performance is safe in most circumstances.[242] Individuals undertaking CPR training should be advised of the nature and extent of the physical activity required during the training programme. Learners and CPR providers who develop significant symptoms (e.g. chest pain or severe shortness of breath) during CPR training should be advised to stop.

CPR provider fatigue

Several manikin studies have found that chest compression depth can decrease as soon as two minutes after starting chest compressions.[243] An in-hospital patient study showed that, even while using real-time feedback, the mean depth of compression deteriorated between 1.5 and 3 min after starting CPR.[244] It is therefore recommended that CPR providers change over about every two minutes to prevent a decrease in compression quality due to CPR provider fatigue. Changing CPR providers should not interrupt chest compressions.

Risks during defibrillation

Many studies of public access defibrillation showed that AEDs can be used safely by laypeople and first responders.[185] A systematic review identified eight papers that reported a total of 29 adverse events associated with defibrillation.[245] The causes included accidental or intentional defibrillator misuse, device malfunction and accidental discharge during training or maintenance procedures. Four single-case reports described shocks to CPR providers from discharging implantable cardioverter defibrillators (ICDs), in one case resulting in a peripheral nerve injury. No studies were identified which reported harm to CPR providers from attempting defibrillation in wet environments.

Although injury to the CPR provider from a defibrillator shock is extremely rare, it has been shown that standard surgical gloves do not provide adequate protection.[246–249] CPR providers, therefore, should not continue manual chest compressions during shock delivery, and victims should not be touched during ICD discharge. Direct contact between the CPR provider and the victim should be avoided when defibrillation is performed.

Psychological effects

One large, prospective trial of public access defibrillation reported few adverse psychological effects associated with CPR or AED use that required intervention.[242] Two large, retrospective, questionnaire-based studies found that bystanders who performed CPR regarded their intervention as a positive experience.[250,251] Family members witnessing a resuscitation attempt may also derive psychological benefit.[252–254] The rare occurrences of adverse psychological effects in CPR providers after performing CPR should be recognised and managed appropriately.

Disease transmission

The risk of disease transmission during training and actual CPR performance is extremely low.[255–257] Wearing gloves during CPR is reasonable, but CPR should not be delayed or withheld if gloves are not available.

Barrier devices for use with rescue breaths

Three studies showed that barrier devices decrease transmission of bacteria during rescue breathing in controlled laboratory settings.[258,259] No studies were identified which examined the safety, effectiveness or feasibility of using barrier devices (such as a face shield or face mask) to prevent victim contact when performing CPR. Nevertheless if the victim is known to have a serious infection (e.g. HIV, tuberculosis, hepatitis B or SARS) a barrier device is recommended.

If a barrier device is used, care should be taken to avoid unnecessary interruptions in CPR. Manikin studies indicate that the quality of CPR is superior when a pocket mask is used compared to a bag-valve mask or simple face shield.[260–262]

Foreign body airway obstruction (choking)

Foreign body airway obstruction (FBAO) is an uncommon but potentially treatable cause of accidental death.[263] As most choking events are associated with eating, they are commonly witnessed. As victims initially are conscious and responsive, there are often opportunities for early interventions which can be life saving.

Recognition

Because 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. FBAO usually occurs while the victim is eating or drinking. People at increased risk of FBAO include those with reduced conscious levels, drug and/or alcohol intoxication, neurological impairment with reduced swallowing and cough reflexes (e.g. stroke, Parkinson's disease), respiratory disease, mental impairment, dementia, poor dentition and older age.[264]

Fig. 2.5 presents the treatment algorithm for the adult with FBAO. Foreign bodies may cause either mild or severe airway obstruction. It is important to ask the conscious victim "Are you choking?" The victim that is able to speak, cough and breathe has mild obstruction. The victim that is unable to speak, has a weakening cough, is struggling or unable to breathe, has severe airway obstruction.

Treatment for mild airway obstruction

Coughing generates high and sustained airway pressures and may expel the foreign body. Aggressive treatment with back blows, abdominal thrusts and chest compressions, may cause harm and can worsen the airway obstruction. These treatments should be reserved for victims who have signs of severe airway obstruction. Victims with mild airway obstruction should remain under continuous observation until they improve, as severe airway obstruction may subsequently develop.

Treatment for severe airway obstruction

The clinical data on choking are largely retrospective and anecdotal. For conscious adults and children over one year of age

Action		Technical description
SUSPECT CHOKING **Be alert to choking particularly if victim is eating**		
ENCOURAGE TO COUGH **Instruct victim to cough**		
GIVE BACK BLOWS **If cough becomes ineffective give up to 5 back blows**		If the victim shows signs of severe airway obstruction and is conscious apply five back blows Stand to the side and slightly behind the victim Support the chest with one hand and lean the victim well forwards so that when the obstructing object is dislodged it comes out of the mouth rather than goes further down the airway Give five sharp blows between the shoulder blades with the heel of your other hand
GIVE ABDOMINAL THRUSTS **If back blows are ineffective give up to 5 abdominal thrutsts**		If five back blows fail to relieve the airway obstruction, give up to five abdominal thrusts as follows: Stand behind the victim and put both arms round the upper part of the abdomen Lean the victim forwards Clench your fist and place it between the umbilicus (navel) and the ribcage Grasp this hand with your other hand and pull sharply inwards and upwards Repeat up to five times If the obstruction is still not relieved, continue alternating five back blows with five abdominal thrusts

Fig. 2.5. Step by step sequence of actions for the treatment of the adult victim with foreign body airway obstruction.

START CPR

Start CPR If the victim becomes unresponsive

If the victim at any time becomes unresponsive:

- support the victim carefully to the ground
- immediately activate the ambulance service
- begin CPR with chest compressions

Fig. 2.5. (*Continued*).

with complete FBAO, case reports have demonstrated the effectiveness of back blows or ‘slaps’, abdominal thrusts and chest thrusts.[265] Approximately 50% of episodes of airway obstruction are not relieved by a single technique.[266] The likelihood of success is increased when combinations of back blows or slaps, and abdominal and chest thrusts are used.[265]

Treatment of foreign body airway obstruction in an unresponsive victim

A randomised trial in cadavers[267] and two prospective studies in anaesthetised volunteers[268,269] showed that higher airway pressures can be generated using chest thrusts compared with abdominal thrusts. Bystander initiation of chest compression for unresponsive or unconscious victims of FBAO was independently associated with good neurological outcome (odds ratio, 10.57; 95% CI, 2.472–65.059, $P < 0.0001$).[270] Chest compressions should, therefore, be started promptly if the victim becomes unresponsive or unconscious. After 30 compressions attempt 2 rescue breaths, and continue CPR until the victim recovers and starts to breathe normally.

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 afterwards for injury.

Resuscitation of children (see also Recognition of Cardiac Arrest section) and victims of drowning (see also The Chain of Survival section)

Many children do not receive resuscitation because potential CPR providers fear causing harm if they are not specifically trained in resuscitation for children. This fear is unfounded: it is far better to use the adult BLS sequence for resuscitation of a child than to do nothing. For ease of teaching and retention, laypeople should be taught that the adult sequence may also be used for children who are not responsive and not breathing normally. The following minor modifications to the adult sequence will make it even more suitable for use in children:

- Give 5 initial rescue breaths before starting chest compressions.
- Give CPR for 1 min before going for help in the unlikely event the CPR provider is alone.
- Compress the chest by at least one third of its depth; use 2 fingers for an infant under one year; use 1 or 2 hands for a child over 1 year as needed to achieve an adequate depth of compression.

The same modifications of 5 initial breaths and 1 min of CPR by the lone CPR provider before getting help, may improve outcome for victims of drowning. This modification should be taught only to those who have a specific duty of care to potential drowning victims (e.g. lifeguards).

Collaborators

Leo L. Bossaert, University of Antwerp, Antwerp, Belgium,
Antonio Caballero, Emergency Department, Hospital Universitario Virgen del Rocío, Sevilla, Spain,
Pascal Cassan, Global First Aid Reference Centre, International Federation of Red Cross and Red Crescent, Paris, France,
Cristina Granja, Emergency and Intensive Care Department, Hospital de Faro, Centro Hospitalar do Algarve, Porto, Portugal,
Claudio Sandroni, Department of Anaesthesiology and Intensive Care, Catholic University School of Medicine, Rome, Italy,
David A. Zideman, Imperial College Healthcare NHS Trust, London, UK,
Jerry P. Nolan, Department of Anaesthesia and Intensive Care Medicine, Royal United Hospital, Bath, UK,
Ian Maconochie, Paediatric Emergency Medicine and NIHR BRC, Imperial College, London, UK,
Robert Greif, Department of Anaesthesiology and Pain Medicine, University Hospital Bern and University Bern, Bern, Switzerland.

Conflicts of interest

Gavin D. Perkins	Editor Resuscitation
Jasmeet Soar	Editor Resuscitation
Anthony J. Handley	Medical advisor BA, Virgin, Places for people, Life saving Societies, Trading Company Secretary RCUK
Giuseppe Ristagno	Expert advice ZOLL: ECG interpretation
Maaret Castren	Medical advisory Board Falck Foundation
Rudolph W. Koster	Medical advisor Physio Control and HeartSine, Research grants PhysioControl, Philips, Zoll, Cardiac Science, Defibtech, Jolife
Volker Wenzel	Research grants, Medical advisor, Speakers honorarium “AOP Orphan” Pharma
Jan-Thorsten Gräsner	No conflict of interest reported
Koenraad G. Monsieurs	No conflict of interest reported
Michael A. Smyth	No conflict of interest reported
Theresa Mariero Olasveengen	No conflict of interest reported
Violetta Raffay	No conflict of interest reported

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