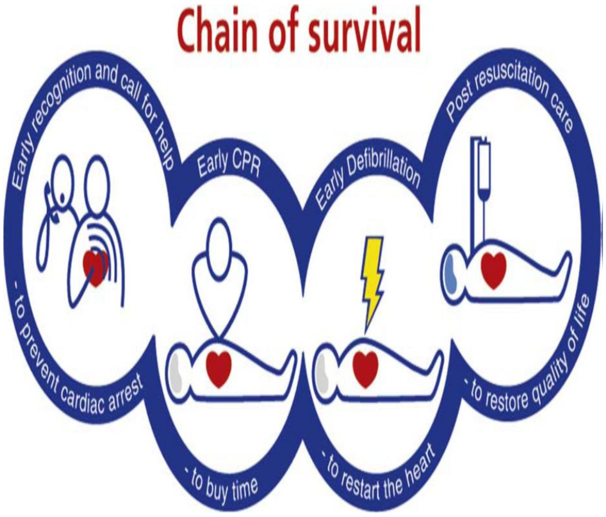
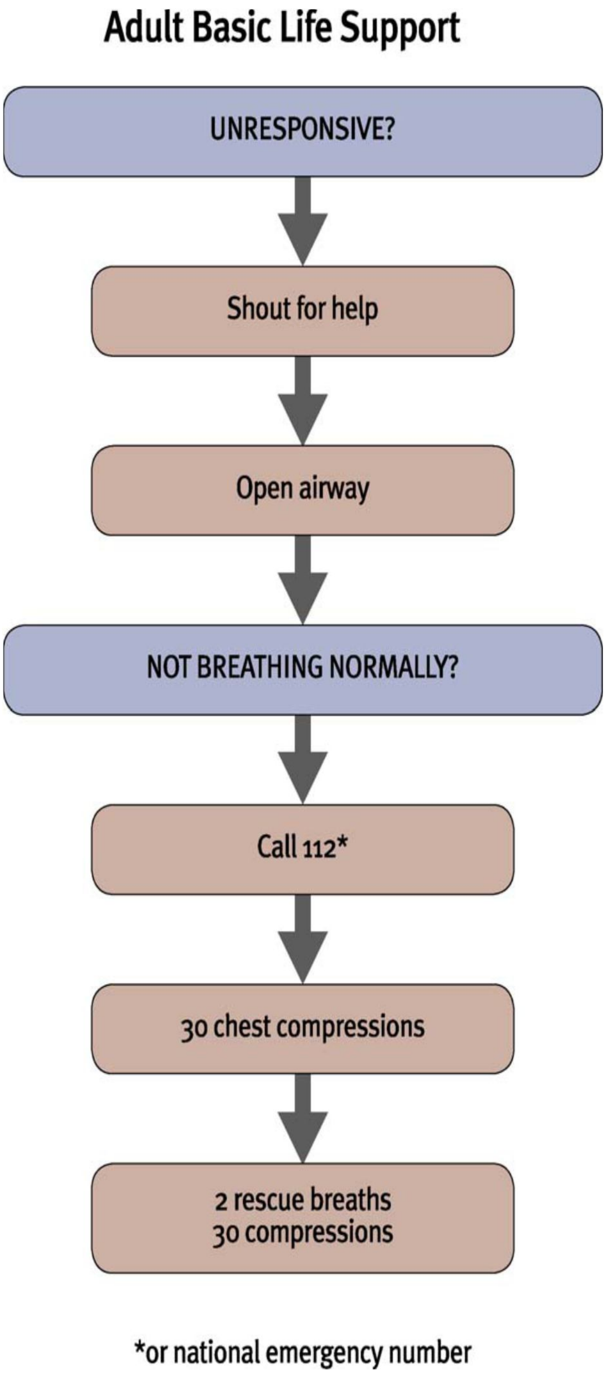
The Chain of Survival

The actions linking the victim of sudden cardiac arrest with survival are called the Chain of Survival (Fig. 1.1). The first link of this chain indicates the importance of recognising those at risk of cardiac arrest and calling for help in the hope that early treatment can prevent arrest. The central links depict the integration of CPR and defibrillation as the fundamental components of early resuscitation in an attempt to restore life. Immediate CPR can double or triple survival from VF OHCA.42–45 Performing chest-compressiononly CPR is better than giving no CPR at all.46,47 Following VF OHCA, cardiopulmonary resuscitation plus defibrillation within 3–5 min of collapse can produce survival rates as high as 49–75%.48–55 Each minute of delay before defibrillation reduces the probability of survival to discharge by 10–12%.42,56 The final link in the Chain of Survival, effective post-resuscitation care, is targeted at preserving function, particularly of the brain and heart. In hospital, the importance of early recognition of the critically ill patient and activation of a medical emergency or rapid response team, with treatment aimed at preventing cardiac arrest, is now well accepted.6 Over the last few years, the importance of the post-cardiac arrest phase of treatment, depicted in the fourth ring of the Chain of Survival, has been increasingly recognised.3 Differences in post-cardiac arrest treatment may account for some of the inter-hospital variability in outcome after cardiac arrest.57–63





Adult basic life support

Adult BLS sequence

Throughout this section, the male gender implies both males and females.

Basic life support comprises the following sequence of actions (Fig. 1.2).

1. Make sure you, the victim and any bystanders are safe.
2. Check the victim for a response:
• gently shake his shoulders and ask loudly: “Are you all right?“

3a. 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.

3b. If he does not respond:
• shout for help
◦ turn the victim onto his back and then open the airway using head; tilt and chin lift;
◦ 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.

4. Keeping the airway open, look, listen and feel for breathing:
• look for chest movement;
• listen at the victim’s mouth for breath sounds;
• feel for air on your cheek;
• decide if breathing is normal, not normal or absent.

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 s to determine whether the victim is breathing normally. If you have any doubt whether breathing is normal, act as if it is not normal.

5a. If he is breathing normally:

• turn him into the recovery position (see below);

• send or go for help – call 112 or local emergency number for an ambulance;

• continue to assess that breathing remains normal.

5b. If the breathing is not normal or absent:

• send someone for help and to find and bring an AED if available; or if you are on your own, use your mobile phone to alert the ambulance service – leave the victim only when there is no other option;

• start chest compression as follows:

◦ 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 sternum.

◦ position yourself vertically above the victim's chest and press down on the sternum at least 5 cm (but not exceeding 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 at least 100 min^{-1} (but not exceeding 120 min^{-1});

◦ compression and release should take equal amounts of time.

6a. Combine chest compression 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 s 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. The two breaths should not take more than 5 s in all. 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.

• Stop to recheck the victim only if he starts to wake up: to move, opens eyes and to breathe normally. Otherwise, do not interrupt resuscitation.

If your initial rescue breath does not make the chest rise as in normal breathing, then before your next attempt:

• look into the victim's mouth and remove any obstruction;

• recheck that there is adequate head tilt and chin lift;

• do not attempt more than two breaths each time before returning to chest compressions.

If there is more than one rescuer present, another rescuer should take over delivering CPR every 2min to prevent fatigue. Ensure that interruption of chest compressions is minimal during the changeover of rescuers.

6b. Chest-compression-only CPR may be used as follows:

• if you are not trained, or are unwilling to give rescue breaths, give chest compressions only;

• if only chest compressions are given, these should be continuous, at a rate of at least 100 min^{-1} (but not exceeding 120 min^{-1}).

7. Do not interrupt resuscitation until:

• professional help arrives and takes over; or

• the victim starts to wake up: to move, opens eyes and to breathe normally; or

• you become exhausted.

Recognition of cardiorespiratory arrest

Checking the carotid pulse (or any other pulse) is an inaccurate method of confirming the presence or absence of circulation, both for lay rescuers and for professionals.[64–66] Healthcare professionals, as well as lay rescuers, have difficulty determining the presence or absence of adequate or normal breathing in unresponsive victims.[67,68] This may be because the victim is making occasional (agonal) gasps, which occur in the first minutes after onset in up to 40% of cardiac arrests.[69] Laypeople should be taught to begin CPR if the victim is unconscious (unresponsive) and not breathing normally. It should be emphasised during training that the presence of agonal gasps is an indication for starting CPR immediately.

Initial rescue breaths

In adults needing CPR, the cardiac arrest is likely to have a primary cardiac cause – CPR should start with chest compression rather than initial ventilations. Time should not be spent checking the mouth for foreign bodies unless attempted rescue breathing fails to make the chest rise.

Ventilation
During CPR, the optimal tidal volume, respiratory rate and inspired oxygen concentration to achieve adequate oxygenation and CO_2 removal is unknown. During CPR, blood flow to the lungs is substantially reduced, so an adequate ventilation–perfusion ratio can be maintained with lower tidal volumes and respiratory rates than normal.[70] Hyperventilation is harmful because it increases intrathoracic pressure, which decreases venous return to the heart and reduces cardiac output. Interruptions in chest compression reduce survival.[71]

Rescuers should give each rescue breath over about 1 s, with enough volume to make the victim's chest rise, but to avoid rapid or forceful breaths. The time taken to give two breaths should not exceed 5 s. These recommendations apply to all forms of ventilation during CPR, including mouth-to-mouth and bag-mask ventilation with and without supplementary oxygen.

Chest compression
Chest compressions generate a small but critical amount of bloodflowto the brain and myocardium and increase the likelihood that defibrillation will be successful. Optimal chest compression technique comprises: compressing the chest at a rate of at least 100 min^{-1} and to a depth of at least 5 cm (for an adult), but not exceeding 6 cm; allowing the chest to recoil completely after each compression[72,73]; taking approximately the same amount of time for compression as relaxation. Rescuers can be assistedto achieve the recommended compression rate and depth by prompt/feedback devices that are either built into the AED or manual defibrillator, or are stand-alone devices.

Compression-only CPR
Some healthcare professionals as well as lay rescuers indicate that they would be reluctant to perform mouth-to-mouth ventilation, especially in unknown victims of cardiac arrest.[74,75] 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.[76,77] If the airway is open, occasional gasps and passive chest recoil may provide some air exchange, but this may result in ventilation of the dead space only.[69,78–80] Animal and mathematical model studies of chestcompression-only CPR have shown that arterial oxygen stores deplete in 2–4 min.[81,82] In adults, the outcome of chest compression without ventilation is significantly better than the outcome of giving no CPR at all in non-asphyxial arrest.[46,47] Several studies of

human cardiac arrest suggest equivalence of chest-compressiononly CPR and chest compressions combined with rescue breaths, but none of these studies exclude the possibility that chestcompression-only is inferior to chest compressions combined with ventilations.[47,83] Chest compression-only may be sufficient only in the first few minutes after collapse. Chest-compression-only CPR is not as effective as conventional CPR for cardiac arrests of non-cardiac origin (e.g., drowning or suffocation) in adults and children.[84,85] Chest compression combined with rescue breaths is, therefore, the method of choice for CPR delivered by both trained lay rescuers and professionals. Laypeople should be encouraged to perform compression-only CPR if they are unable or unwilling to provide rescue breaths, or when instructed during an emergency call to an ambulance dispatcher centre.

Risks to the rescuer

Physical effects

The incidence of adverse effects (muscle strain, back symptoms, shortness of breath, hyperventilation) on the rescuer from CPR training and actual performance is very low.[86] Several manikin studies have found that, as a result of rescuer fatigue, chest compression depth can decrease as little as 2 min after starting chest compressions.[87] Rescuers should change about every 2 min to prevent a decrease in compression quality due to rescuer fatigue. Changing rescuers should not interrupt chest compressions.

Risks during defibrillation

A large randomised trial of public access defibrillation showed that AEDs can be used safely by laypeople and first responders.[88] A systematic review identified only eight papers that reported a total of 29 adverse events associated with defibrillation.[89] Only one of these adverse events was published after 1997.[90]

Disease transmission

There are only very few cases reported where performing CPR has been linked to disease transmission. Three studies showed that barrier devices decreased transmission of bacteria in controlled laboratory settings.[91,92] Because the risk of disease transmission is very low, initiating rescue breathing without a barrier device is reasonable. If the victim is known to have a serious infection appropriate precautions are recommended.

Recovery position

There are several variations of the recovery position, each with its own advantages. No single position is perfect for all victims.[93,94] The position should be stable, near to a true lateral position with the head dependent, and with no pressure on the chest to impair breathing.[95]

Electrical therapies: automated external defibrillators, defibrillation, cardioversion and pacing

Automated external defibrillators

Automated external defibrillators (AEDs) are safe and effective when used by either laypeople or healthcare professionals (in- or out-of-hospital). Use of an AED by a layperson makes it possible to defibrillate many minutes before professional help arrives.

Sequence for use of an AED

The ERC AED algorithm is shown in Fig. 1.4.

1. Make sure you, the victim, and any bystanders are safe.
2. Follow the Adult BLS sequence:

- if the victim is unresponsive and not breathing normally, send someone for help and to find and bring an AED if available;
- if you are on your own, use your mobile phone to alert the ambulance service – leave the victim only when there is no other option.

3. Start CPR according to the adult BLS sequence. If you are on your own and the AED is in your immediate vicinity, start with applying the AED.
4. 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 immediately;
- ensure that nobody is touching the victim while the AED is analysing the rhythm.

5a. If a shock is indicated:

- ensure that nobody is touching the victim;
- push shock button as directed;
- immediately restart CPR 30:2;
- continue as directed by the voice/visual prompts.

5b. If no shock is indicated:

- immediately resume CPR, using a ratio of 30 compressions to 2 rescue breaths;
- continue as directed by the voice/visual prompts.

6. Continue to follow the AED prompts until:

- professional help arrives and takes over;
- the victim starts to wake up: moves, opens eyes and breathes normally;
- you become exhausted.

Public access defibrillation programmes

Automated external defibrillator programmes should be actively considered for implementation in public places such as airports,[52] sport facilities, offices, in casinos[55] and on aircraft,[53] where cardiac arrests are usually witnessed and trained rescuers are quickly on scene. Lay rescuer AED programmes with very rapid response times, and uncontrolled studies using police officers as first responders,[97,98] have achieved reported survival rates as high as 49–74%.

The full potential of AEDs has not yet been achieved, because they are used mostly in public settings, yet 60–80% of cardiac arrests occur at home. Public access defibrillation (PAD) and first responder AED programmes may increase the number of victims who receive bystander CPR and early defibrillation, thus improving survival from out-of-hospital SCA.[99] Recent data from nationwide studies in Japan and the USA[33,100] showed that when an AED was available, victims were defibrillated much sooner and with a better chance of survival. Programmes that make AEDs publicly available in residential areas have not yet been evaluated. The acquisition of an AED for individual use at home, even for those considered at high risk of sudden cardiac arrest, has proved not to be effective.[101]

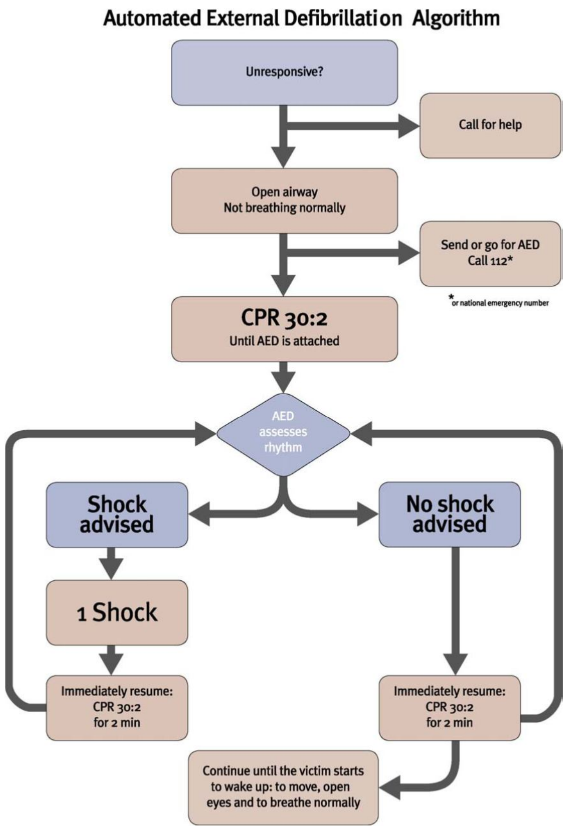
In-hospital use of AEDs

At the time of the 2010 Consensus on CPR Science Conference, there were no published randomised trials comparing in-hospital use of AEDs with manual defibrillators. Two lower-level studies of adults with in-hospital cardiac arrest from shockable rhythmsshowed higher survival-to-hospital discharge rates when defibrillation was provided through an AED programme than with manual defibrillation alone.[102,103] Despite limited evidence, AEDs should be considered for the hospital setting as a way to facilitate early defibrillation (a goal of <3 min from collapse), especially in areas where healthcare providers have no rhythm recognition skills or where they use defibrillators infrequently. An effective system for training and retraining should be in place.[104] Enough healthcare providers should be trained to enable the first shock to be given within 3min of collapse anywhere in the hospital. Hospitals should monitor collapse-to-first shock intervals and monitor resuscitation outcomes.

Shock in manual versus semi-automatic mode

Many AEDs can be operated in both manual and semi-automatic mode but few studies have compared these two options. The semiautomatic mode has been shown to reduce time to first shock when used both in-hospital[105] and pre-hospital[106] settings, and resultsin higher VF conversion rates,[106] and delivery of fewer inappropriate shocks.[107] Conversely, semi-automatic modes result in less time spent performing chest compressions,[107,108] mainly because

of a longer pre-shock pause associated with automated rhythm analysis. Despite these differences, no overall difference in ROSC, survival, or discharge rate from hospital has been demonstrated in any study.105,106,109 The defibrillation mode that affords the best
outcome will depend on the system, skills, training and ECG recognition skills of rescuers. A shorter pre-shock pause and lower total hands-off-ratio increases vital organ perfusion and the probability of ROSC.71,110,111 With manual defibrillators and some AEDs
it is possible to perform chest compressions during charging and thereby reduce the pre-shock pause to less than 5 s. Trained individuals may deliver defibrillation in manual mode but frequent team
training and ECG recognition skills are essential.



Strategies before defibrillation

Minimising the pre-shock pause

The delay between stopping chest compressions and delivery of
the shock (the pre-shock pause) must be kept to an absolute minimum; even 5–10 s delay will reduce the chances of the shock being successful.71,110,112 The pre-shock pause can easily be reduced to
less than 5 s by continuing compressions during charging of the defibrillator and by having an efficient team coordinated by a leader
who communicates effectively. The safety check to ensure that
nobody is in contact with the patient at the moment of defibrillation should be undertaken rapidly but efficiently. The negligible
risk of a rescuer receiving an accidental shock is minimised even

further if all rescuers wear gloves.[113] The post-shock pause is minimised by resuming chest compressions immediately after shock delivery (see below). The entire process of defibrillation should be achievable with no more than a 5 s interruption to chest compressions.

Pads versus paddles

Self-adhesive defibrillation pads have practical benefits over paddles for routine monitoring and defibrillation.[114–118] They are safe and effective and are preferable to standard defibrillation paddles.[119]

Fibrillation waveform analysis

It is possible to predict, with varying reliability, the success of defibrillation from the fibrillation waveform.[120–139] If optimal defibrillation waveforms and the optimal timing of shock delivery can be determined in prospective studies, it should be possible to prevent the delivery of unsuccessful high energy shocks and minimise myocardial injury. This technology is under active development and investigation but current sensitivity and specificity is insufficient to enable introduction of VF waveform analysis into clinical practice.

CPR before defibrillation

Several studies have examined whether a period of CPR prior to defibrillation is beneficial, particularly in patients with an unwitnessed arrest or prolonged collapse without resuscitation.

A review of evidence for the 2005 guidelines resulted in the recommendation that it was reasonable for EMS personnel to give a period of about 2min of CPR before defibrillation in patients with prolonged collapse (>5 min).[140] This recommendation was based on clinical studies, which showed that when response times exceeded 4–5 min, a period of 1.5–3 min of CPR before shock delivery improved ROSC, survival to hospital discharge[141,142] and 1 year survival[142] for adults with out-of-hospital VF or VT compared with immediate defibrillation.

More recently, two randomised controlled trials documented that a period of 1.5–3 min of CPR by EMS personnel before defibrillation did not improve ROSC or survival to hospital discharge in patients with out-of-hospital VF or pulseless VT, regardless of EMS response interval.[143,144] Four other studies have also failed to demonstrate significant improvements in overall ROSC or survival to hospital discharge with an initial period of CPR,[141,142,145,146] although one did show a higher rate of favourable neurological outcome at 30 days and 1 year after cardiac arrest.[145] Performing chest compressions while retrieving and charging a defibrillator has been shown to improve the probability of survival.[147]

In any cardiac arrest they have not witnessed, EMS personnel should provide good-quality CPR while a defibrillator is retrieved, applied and charged, but routine delivery of a specified period of CPR (e.g., 2 or 3 min) before rhythm analysis and a shock is delivered is not recommended. Some emergency medical services have already fully implemented a specified period of chest compressions before defibrillation; given the lack of convincing data either supporting or refuting this strategy, it is reasonable for them to continue this practice.

Delivery of defibrillation

One shock versus three-stacked shock sequence

Interruptions in external chest compression reduces the chances of converting VF to another rhythm.[71] Studies have shown a significantly lower hands-off-ratio with a one-shock instead of a three-stacked shock protocol[148] and some,[149–151] but not all,[148,152] have suggested a significant survival benefit from this single-shock strategy.

Whendefibrillation is warranted, give a single shock and resume chest compressions immediately following the shock. Do not delay CPR for rhythm analysis or a pulse check immediately after a shock. Continue CPR (30 compressions:2 ventilations) for 2min until rhythm analysis is undertaken and another shock given (if indicated) (see Advanced life support).[6]

If VF/VT occurs during cardiac catheterisation or in the early post-operative period following cardiac surgery (when chest compressions could disrupt vascular sutures), consider delivering up to three-stacked shocks before starting chest compressions (see Special circumstances).[10] This three-shock strategy may also be considered for an initial, witnessed VF/VT cardiac arrest if the patient is already connected to a manual defibrillator. Although there are no data supporting a three-shock strategy in any of these circumstances, it is unlikely that chest compressions will improve the already very high chance of return of spontaneous circulation when defibrillation occurs early in the electrical phase, immediately after onset of VF.

Waveforms

Monophasic defibrillators are no longer manufactured, and although many will remain in use for several years, biphasic defibrillators have now superseded them.

Monophasic versus biphasic defibrillation

Although biphasic waveforms are more effective at terminating ventricular arrhythmias at lower energy levels, have demonstrated greater first shock efficacy than monophasic waveforms, and have greater first shock efficacy for long duration VF/VT.[153–155] No randomised studies have demonstrated superiority in terms of neurologically intact survival to hospital discharge. Biphasic waveforms have been shown to be superior to monophasic waveforms for elective cardioversion of atrial fibrillation, with greater overall success rates, using less cumulative energy and reducing the severity of cutaneous burns,[156–159] and are the waveform of choice for this procedure.

Energy levels

Optimal energy levels for both monophasic and biphasic waveforms are unknown. The recommendations for energy levels are based on a consensus following careful review of the current literature.

First shock

There are no new published studies looking at the optimal energy levels for monophasic waveforms since publication of the 2005 guidelines. Relatively few studies on biphasic waveforms have been published in the past 5 years on which to refine the 2005 guidelines. There is no evidence that one biphasic waveform or device is more effective than another. First shock efficacy of the biphasic truncated exponential (BTE) waveform using 150–200 J has been reported as 86–98%.[153,154,160–162] First shock efficacy of the rectilinear biphasic (RLB) waveform using 120 J is up to 85% (data not published in the paper but supplied by personnel communication).[155] Two studies have suggested equivalence with lower and higher starting energy biphasic defibrillation.[163,164] Although human studies have not shown harm (raised biomarkers, ECG changes, ejection fraction) from any biphasic waveform up to 360 J,[163,165] several animal studies have suggested the potential for harm with higher energy levels.[166–169] The initial biphasic shock should be no lower than 120 J for RLB waveforms and 150 J for BTE waveforms. Ideally, the initial biphasic shock energy should be at least 150 J for all waveforms.

Second and subsequent shocks

The 2005 guidelines recommended either a fixed or escalating energy strategy for defibrillation and there is no evidence to change this recommendation.

Cardioversion

If electrical cardioversion is used to convert atrial or ventricular tachyarrhythmias, the shock must be synchronised to occur with the R wave of the electrocardiogram rather than with the T wave: VF can be induced if a shock is delivered during the relative refractory portion of the cardiac cycle.[170] Biphasic waveforms are more effective than monophasic waveforms for cardioversion of AF.[156–159] Commencing at high energy levels does not improve cardioversion rates compared with lower energy levels.[156,171–176] An initial synchronised shock of 120–150 J, escalating if necessary is a reasonable strategy based on current data. Atrial flutter and paroxysmal SVT generally require less energy than atrial fibrillation for cardioversion.[175] Give an initial shock of 100 J monophasic or 70–120 J biphasic. Give subsequent shocks using stepwise increases in energy.[177] The energy required for cardioversion of VT depends on the morphological characteristics and rate of the arrhythmia.[178] Use biphasic energy levels of 120–150 J for the initial shock. Consider stepwise increases if the first shock fails to achieve sinus rhythm.[178]

Pacing

Consider pacing in patients with symptomatic bradycardia refractory to anti-cholinergic drugs or other second line therapy (see Advanced life support).[6] Immediate pacing is indicated especially when the block is at or below the His-Purkinje level. If transthoracic pacing is ineffective, consider transvenous pacing.

Implantable cardioverter defibrillators

Implantable cardioverter defibrillators (ICDs) are implanted because a patient is considered to be at risk from, or has had, a lifethreatening shockable arrhythmia. On sensing a shockable rhythm, an ICD will discharge approximately 40 J through an internal pacing wire embedded in the right ventricle. On detecting VF/VT, ICD devices will discharge no more than eight times, but may reset if they detect a new period of VF/VT. Discharge of an ICD may cause pectoral muscle contraction in the patient, and shocks to the rescuer have been documented.[179] In view of the low energy levels discharged by ICDs, it is unlikely that any harm will come to the rescuer, but the wearing of gloves and minimising contact with the patient while the device is discharging is prudent.