



# European Resuscitation Council Guidelines for Resuscitation 2005

## Section 3. Electrical therapies: Automated external defibrillators, defibrillation, cardioversion and pacing

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### Introduction

This section presents guidelines for defibrillation using both automated external defibrillators (AEDs) and manual defibrillators. All healthcare providers and lay responders can use AEDs as an integral component of basic life support. Manual defibrillation is used as part of advanced life support (ALS) therapy. In addition, synchronised cardioversion and pacing are ALS functions of many defibrillators and are also discussed in this section.

Defibrillation is the passage across the myocardium of an electrical current of sufficient magnitude to depolarise a critical mass of myocardium and enable restoration of coordinated electrical activity. Defibrillation is defined as the termination of fibrillation or, more precisely, the absence of ventricular fibrillation/ventricular tachycardia (VF/VT) at 5 s after shock delivery; however, the goal of attempted defibrillation is to restore spontaneous circulation.

Defibrillator technology is advancing rapidly. AED interaction with the rescuer through voice prompts is now established, and future technology may enable more specific instructions to be given by voice prompt. The ability of defibrillators to assess

the rhythm while CPR is in progress is required to prevent unnecessary delays in CPR. Waveform analysis may also enable the defibrillator to calculate the optimal time at which to give a shock.

### A vital link in the chain of survival

Defibrillation is a key link in the Chain of Survival and is one of the few interventions that have been shown to improve outcome from VF/VT cardiac arrest. The previous guidelines, published in 2000, rightly emphasised the importance of early defibrillation with minimum delay.<sup>1</sup>

The probability of successful defibrillation and subsequent survival to hospital discharge declines rapidly with time<sup>2,3</sup> and the ability to deliver early defibrillation is one of the most important factors in determining survival from cardiac arrest. For every minute that passes following collapse and defibrillation, mortality increases 7%–10% in the absence of bystander CPR.<sup>2–4</sup> EMS systems do not generally have the capability to deliver defibrillation through traditional paramedic responders within the first few minutes of a call, and the alternative use of trained lay responders

to deliver prompt defibrillation using AEDs is now widespread. EMS systems that have reduced time to defibrillation following cardiac arrest using trained lay responders have reported greatly improved survival-to-discharge rates,<sup>5–7</sup> some as high as 75% if defibrillation is performed within 3 min of collapse.<sup>8</sup> This concept has also been extended to in-hospital cardiac arrests where staff, other than doctors, are also being trained to defibrillate using an AED before arrival of the cardiac arrest team. When bystander CPR is provided, the reduction in survival rate is more gradual and averages 3%–4% per minute from collapse to defibrillation;<sup>2–4</sup> bystander CPR can double<sup>2,3,9</sup> or treble<sup>10</sup> survival from witnessed out-of-hospital cardiac arrest.

All healthcare providers with a duty to perform CPR should be trained, equipped, and encouraged to perform defibrillation and CPR. Early defibrillation should be available throughout all hospitals, outpatient medical facilities and public areas of mass gathering (see Section 2). Those trained in AED use should also be trained to deliver at least external chest compressions before the arrival of ALS providers, to optimise the effectiveness of early defibrillation.

### Automated external defibrillators

Automated external defibrillators are sophisticated, reliable computerised devices that use voice and visual prompts to guide lay rescuers and healthcare professionals to safely attempt defibrillation in cardiac arrest victims. Automated defibrillators have been described as "... the single greatest advance in the treatment of VF cardiac arrest since the development of CPR."<sup>11</sup> Advances in technology, particularly with respect to battery capacity, and software arrhythmia analysis have enabled the mass production of relatively cheap, reliable and easily operated portable defibrillators.<sup>12–15</sup> Use of AEDs by lay or non-healthcare rescuers is covered in Section 2.

### Automated rhythm analysis

Automated external defibrillators have microprocessors that analyse several features of the ECG, including frequency and amplitude. Some AEDs are programmed to detect spontaneous movement by the patient or others. Developing technology should soon enable AEDs to provide information about frequency and depth of chest compressions during CPR that may improve BLS performance by all rescuers.<sup>16,17</sup>

Automated external defibrillators have been tested extensively against libraries of recorded cardiac rhythms and in many trials in adults<sup>18,19</sup> and children.<sup>20,21</sup> They are extremely accurate in rhythm analysis. Although AEDs are not designed to deliver synchronised shocks, all AEDs will recommend shocks for VT if the rate and R-wave morphology exceed preset values.

### In-hospital use of AEDs

At the time of the 2005 Consensus 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 rhythms showed higher survival-to-hospital discharge rates when defibrillation was provided through an AED programme than with manual defibrillation alone.<sup>22,23</sup> A manikin study showed that use of an AED significantly increased the likelihood of delivering three shocks, but increased the time to deliver the shocks when compared with manual defibrillators.<sup>24</sup> In contrast, a study of mock arrests in simulated patients showed that use of monitoring leads and fully automated defibrillators reduced time to defibrillation when compared with manual defibrillators.<sup>25</sup>

Delayed defibrillation may occur when patients sustain cardiac arrest in unmonitored hospital beds and in outpatient departments. In these areas several minutes may elapse before resuscitation teams arrive with a defibrillator and deliver shocks.<sup>26</sup> 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 staff have no rhythm recognition skills or where they use defibrillators infrequently. An effective system for training and retraining should be in place. Adequate numbers of staff should be trained to enable achievement of 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 resuscitation outcomes.

### Strategies before defibrillation

#### Safe use of oxygen during defibrillation

In an oxygen-enriched atmosphere, sparking from poorly applied defibrillator paddles can cause a fire.<sup>27–32</sup> There are several reports of fires being caused in this way, and most have resulted in

significant burns to the patient. The risk of fire during attempted defibrillation can be minimised by taking the following precautions.

- Take off any oxygen mask or nasal cannulae and place them at least 1 m away from the patient's chest.
- Leave the ventilation bag connected to the tracheal tube or other airway adjunct. Alternatively, disconnect any bag-valve device from the tracheal tube (or other airway adjunct such as the laryngeal mask airway, combitube or laryngeal tube), and remove it at least 1 m from the patient's chest during defibrillation.
- If the patient is connected to a ventilator, for example in the operating room or critical care unit, leave the ventilator tubing (breathing circuit) connected to the tracheal tube unless chest compressions prevent the ventilator from delivering adequate tidal volumes. In this case, the ventilator is usually substituted for a ventilation bag, which can itself be left connected or detached and removed to a distance of at least 1 m. If the ventilator tubing is disconnected, ensure it is kept at least 1 m from the patient or, better still, switch the ventilator off; modern ventilators generate massive oxygen flows when disconnected. During normal use, when connected to a tracheal tube, oxygen from a ventilator in the critical care unit will be vented from the main ventilator housing well away from the defibrillation zone. Patients in the critical care unit may be dependent on positive end expiratory pressure (PEEP) to maintain adequate oxygenation; during cardioversion, when the spontaneous circulation potentially enables blood to remain well oxygenated, it is particularly appropriate to leave the critically ill patient connected to the ventilator during shock delivery.
- Minimise the risk of sparks during defibrillation. Theoretically, self-adhesive defibrillation pads are less likely to cause sparks than manual paddles.

### The technique for electrode contact with the chest

Optimal defibrillation technique aims to deliver current across the fibrillating myocardium in the presence of minimal transthoracic impedance. Transthoracic impedance varies considerably with body mass, but is approximately 70–80  $\Omega$  in adults.<sup>33,34</sup> The techniques described below aim to place external electrodes (paddles or self-adhesive pads) in an optimal position using techniques that minimise transthoracic impedance.

### Shaving the chest

Patients with a hairy chest have air trapping beneath the electrode and poor electrode-to-skin electrical contact. This causes high impedance, reduced defibrillation efficacy, risk of arcing (sparks) from electrode to skin and electrode to electrode and is more likely to cause burns to the patient's chest. Rapid shaving of the area of intended electrode placement may be necessary, but do not delay defibrillation if a shaver is not immediately available. Shaving the chest per se may reduce transthoracic impedance slightly and has been recommended for elective DC cardioversion.<sup>35</sup>

### Paddle force

If using paddles, apply them firmly to the chest wall. This reduces transthoracic impedance by improving electrical contact at the electrode–skin interface and reducing thoracic volume.<sup>36</sup> The defibrillator operator should always press firmly on handheld electrode paddles, the optimal force being 8 kg in adults<sup>37</sup> and 5 kg in children aged 1–8 years when using adult paddles<sup>38</sup>; 8-kg force may be attainable only by the strongest members of the cardiac arrest team, and therefore it is recommended that these individuals apply the paddles during defibrillation. Unlike self-adhesive pads, manual paddles have a bare metal plate that requires a conductive material placed between the metal and patient's skin to improve electrical contact. Use of bare metal paddles alone creates high transthoracic impedance and is likely to increase the risk of arcing and to worsen cutaneous burns from defibrillation.

### Electrode position

No human studies have evaluated the electrode position as a determinant of return of spontaneous circulation (ROSC) or survival from VF/VT cardiac arrest. Transmyocardial current during defibrillation is likely to be maximal when the electrodes are placed so that the area of the heart that is fibrillating lies directly between them, i.e., ventricles in VF/VT, atria in atrial fibrillation (AF). Therefore, the optimal electrode position may not be the same for ventricular and atrial arrhythmias.

More patients are presenting with implantable medical devices (e.g., permanent pacemaker, automatic implantable cardioverter defibrillator (AICD)). MedicAlert bracelets are recommended for such patients. These devices may be damaged during defibrillation if current is discharged through

electrodes placed directly over the device. Place the electrode away from the device or use an alternative electrode position as described below. On detecting VF/VT, AICD devices will discharge no more than six times. Further discharges will occur only if a new episode of VF/VT is detected. Rarely, a faulty device or broken lead may cause repeated firing; in these circumstances, the patient is likely to be conscious, with the ECG showing a relatively normal rate. A magnet placed over the AICD will disable the defibrillation function in these circumstances. AICD discharge may cause pectoral muscle contraction, but an attendant touching the patient will not receive an electric shock. AICD and pacing function should always be re-evaluated following external defibrillation, both to check the device itself and to check pacing/defibrillation thresholds of the device leads.

Transdermal drug patches may prevent good electrode contact, causing arcing and burns if the electrode is placed directly over the patch during defibrillation.<sup>39,40</sup> Remove medication patches and wipe the area before applying the electrode.

For ventricular arrhythmias, place electrodes (either pads or paddles) in the conventional sternal–apical position. The right (sternal) electrode is placed to the right of the sternum, below the clavicle. The apical paddle is placed in the mid-axillary line, approximately level with the V6 ECG electrode or female breast. This position should be clear of any breast tissue. It is important that this electrode is placed sufficiently laterally. Other acceptable pad positions include:

- each electrode on the lateral chest wall, one on the right and the other on the left side (bi-axillary);
- one electrode in the standard apical position and the other on the right or left upper back;
- one electrode anteriorly, over the left precordium, and the other electrode posterior to the heart just inferior to the left scapula.

It does not matter which electrode (apex/sternum) is placed in either position.

Transthoracic impedance has been shown to be minimised when the apical electrode is not placed over the female breast.<sup>41</sup> Asymmetrically shaped apical electrodes have a lower impedance when placed longitudinally rather than transversely.<sup>42</sup> The long axis of the apical paddle should therefore be orientated in a craniocaudal direction.

Atrial fibrillation is maintained by functional re-entry circuits anchored in the left atrium. As the left atrium is located posteriorly in the thorax, an anteroposterior electrode position may be more efficient for external cardioversion of atrial

fibrillation.<sup>43</sup> Most,<sup>44,45</sup> but not all,<sup>46,47</sup> studies have shown that anteroposterior electrode placement is more effective than the traditional antero-apical position in elective cardioversion of atrial fibrillation. Efficacy of cardioversion may be less dependent on electrode position when using biphasic impedance-compensated waveforms.<sup>48</sup> Either position is safe and effective for cardioversion of atrial arrhythmias.

### Respiratory phase

Transthoracic impedance varies during respiration, being minimal at end expiration. If possible, defibrillation should be attempted at this phase of the respiratory cycle. Positive end-expiratory pressure (PEEP) increases transthoracic impedance and should be minimised during defibrillation. Auto-PEEP (gas trapping) may be particularly high in asthmatics and may necessitate higher than usual energy levels for defibrillation.<sup>49</sup>

### Electrode size

The Association for the Advancement of Medical Instrumentation recommends a minimum electrode size of for individual electrodes and the sum of the electrode areas should be a minimum of 150 cm<sup>2</sup>.<sup>50</sup> Larger electrodes have lower impedance, but excessively large electrodes may result in less transmural current flow.<sup>51</sup> For adult defibrillation, both handheld paddle electrodes and self-adhesive pad electrodes 8–12 cm in diameter are used and function well. Defibrillation success may be higher with electrodes of 12-cm diameter compared with those of 8-cm diameter.<sup>34,52</sup>

Standard AEDs are suitable for use in children over the age of 8 years. In children between 1 and 8 years, use paediatric pads with an attenuator to reduce delivered energy, or a paediatric mode, if they are available; if not, use the unmodified machine, taking care to ensure that the adult pads do not overlap. Use of AEDs is not recommended in children less than 1 year.

### Coupling agents

If using manual paddles, gel pads are preferable to electrode pastes and gels because the latter can spread between the two paddles, creating the potential for a spark. Do not use bare electrodes without a coupling material, because this causes high transthoracic impedance and may increase the severity of any cutaneous burns. Do not use medical gels or pastes of poor electrical conductivity

(e.g., ultrasound gel). Electrode pads are preferred to electrode gel because they avoid the risk of smearing gel between the two paddles and the subsequent risk of arcing and ineffective defibrillation.

### **Pads versus paddles**

Self-adhesive defibrillation pads are safe and effective and are preferable to standard defibrillation paddles.<sup>52</sup> Consideration should be given to use of self-adhesive pads in peri-arrest situations and in clinical situations where patient access is difficult. They have a similar transthoracic impedance<sup>51</sup> (and therefore efficacy)<sup>53,54</sup> to manual paddles, and enable the operator to defibrillate the patient from a safe distance rather than leaning over the patient (as occurs with paddles). When used for initial monitoring of a rhythm, both pads and paddles enable quicker delivery of the first shock compared with standard ECG electrodes, but pads are quicker than paddles.<sup>55</sup>

When gel pads are used with paddles, the electrolyte gel becomes polarised and thus is a poor conductor after defibrillation. This can cause spurious asystole that may persist for 3–4 min when used to monitor the rhythm; a phenomenon not reported with self-adhesive pads.<sup>56,57</sup> When using a gel pad/paddle combination, confirm a diagnosis of asystole with independent ECG electrodes rather than the paddles.

### **Fibrillation waveform analysis**

It is possible to predict, with varying reliability, the success of defibrillation from the fibrillation waveform.<sup>58–77</sup> 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.

### **CPR versus defibrillation as the initial treatment**

Although the previous guidelines have recommended immediate defibrillation for all shockable rhythms, recent evidence has suggested that a period of CPR before defibrillation may be beneficial after prolonged collapse. In clinical studies where response times exceeded 4–5 min, a period of 1.5–3 min of CPR by paramedics or EMS physicians before shock delivery improved ROSC, survival to hospital discharge<sup>78,79</sup> and 1-year survival<sup>79</sup> for adults with out-of-hospital VF or VT, compared

with immediate defibrillation. In contrast, a single randomised study in adults with out-of-hospital VF or VT failed to show improvements in ROSC or survival following 1.5 min of paramedic CPR.<sup>80</sup> In animal studies of VF lasting at least 5 min, CPR before defibrillation improved haemodynamics and survival.<sup>81–83</sup> It may not be possible to extrapolate the outcomes achieved by paramedic-provided CPR, which includes intubation and delivery of 100% oxygen,<sup>79</sup> to those that may be achieved by laypeople providing relative poor-quality CPR with mouth-to-mouth ventilation.

It is reasonable for EMS personnel to give a period of about 2 min of CPR (i.e., about five cycles at 30:2) before defibrillation in patients with prolonged collapse (>5 min). The duration of collapse is frequently difficult to estimate accurately, and it may be simplest if EMS personnel are instructed to provide this period of CPR before attempted defibrillation in any cardiac arrest they have not witnessed. Given the relatively weak evidence available, individual EMS directors should determine whether to implement a CPR-before-defibrillation strategy; inevitably, protocols will vary depending on the local circumstances.

Laypeople and first responders using AEDs should deliver the shock as soon as possible.

There is no evidence to support or refute CPR before defibrillation for in-hospital cardiac arrest. We recommend shock delivery as soon as possible following in-hospital cardiac arrest (see Section 4b and c).

The importance of early uninterrupted external chest compression is emphasised throughout these guidelines. In practice, it is often difficult to ascertain the exact time of collapse and, in any case, CPR should be started as soon as possible. The rescuer providing chest compressions should interrupt chest compressions only for rhythm analysis and shock delivery, and should be prepared to resume chest compressions as soon as a shock is delivered. When two rescuers are present, the rescuer operating the AED should apply the electrodes while CPR is in progress. Interrupt CPR only when it is necessary to assess the rhythm and deliver a shock. The AED operator should be prepared to deliver a shock as soon as analysis is complete and the shock is advised, ensuring all rescuers are not in contact with the victim. The single rescuer should practice coordination of CPR with efficient AED operation.

### **One-shock versus three-shock sequence**

There are no published human or animal studies comparing a single-shock protocol with a three-

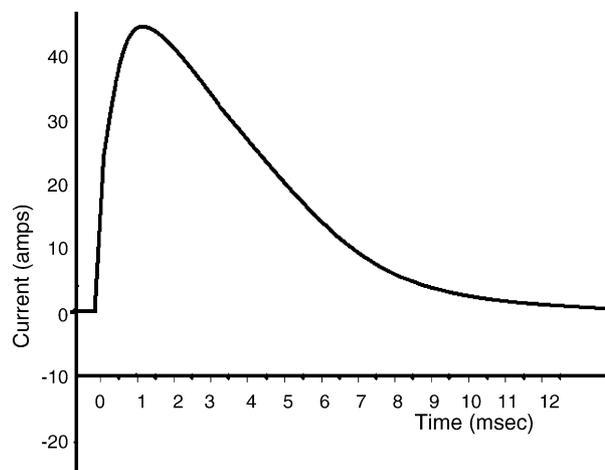
stacked-shock protocol for treatment of VF cardiac arrest. Animal studies show that relatively short interruptions in external chest compression to deliver rescue breaths<sup>84,85</sup> or perform rhythm analysis<sup>86</sup> are associated with post-resuscitation myocardial dysfunction and reduced survival. Interruptions in external chest compression also reduce the chances of converting VF to another rhythm.<sup>87</sup> Analysis of CPR performance during out-of-hospital<sup>16,88</sup> and in-hospital<sup>17</sup> cardiac arrest has shown that significant interruptions are common, with external chest compressions comprising no more than 51%<sup>16</sup> to 76%<sup>17</sup> of total CPR time.

In the context of a three-shock protocol being recommended in the 2000 guidelines, interruptions in CPR to enable rhythm analysis by AEDs were significant. Delays of up to 37s between delivery of shocks and recommencing chest compressions have been reported.<sup>89</sup> With first shock efficacy of biphasic waveforms exceeding 90%,<sup>90–93</sup> failure to cardiovert VF successfully is more likely to suggest the need for a period of CPR rather than a further shock. Thus, immediately after giving a single shock, and without reassessing the rhythm or feeling for a pulse, resume CPR (30 compressions:2 ventilations) for 2 min before delivering another shock (if indicated) (see Section 4c). Even if the defibrillation attempt is successful in restoring a perfusing rhythm, it is very rare for a pulse to be palpable immediately after defibrillation, and the delay in trying to palpate a pulse will further compromise the myocardium if a perfusing rhythm has not been restored.<sup>89</sup> In one study of AEDs in out-of-hospital VF cardiac arrest, a pulse was detected in only 2.5% (12/481) of patients with the initial post shock pulse check, though a pulse was detected sometime after the initial shock sequence (and before a second shock sequence) in 24.5% (118/481) of patients.<sup>93</sup> If a perfusing rhythm has been restored, giving chest compressions does not increase the chance of VF recurring.<sup>94</sup> In the presence of post-shock asystole chest compressions may induce VF.<sup>94</sup>

This single shock strategy is applicable to both monophasic and biphasic defibrillators.

### Waveforms and energy levels

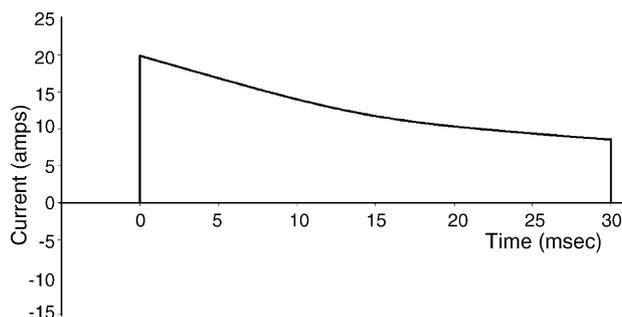
Defibrillation requires the delivery of sufficient electrical energy to defibrillate a critical mass of myocardium, abolish the wavefronts of VF and enable restoration of spontaneous synchronised electrical activity in the form of an organised rhythm. The optimal energy for defibrillation is that which achieves defibrillation while causing the minimum of myocardial damage.<sup>33</sup> Selection of an appropriate energy level also reduces the number



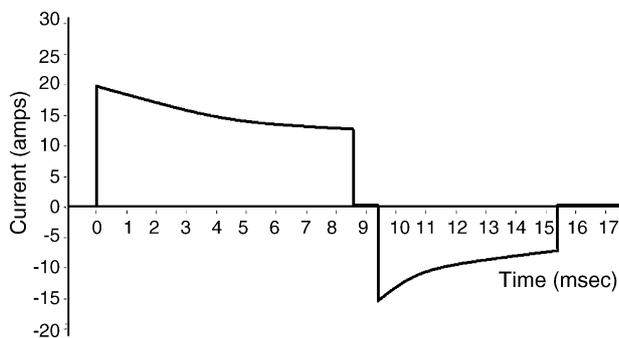
**Figure 3.1** Monophasic damped sinusoidal waveform (MDS).

of repetitive shocks, which in turn limits myocardial damage.<sup>95</sup>

After a cautious introduction a decade ago, defibrillators delivering a shock with a biphasic waveform are now preferred. Monophasic defibrillators are no longer manufactured, although many remain in use. Monophasic defibrillators deliver current that is unipolar (i.e., one direction of current flow). There are two main types of monophasic waveform. The commonest waveform is the monophasic damped sinusoidal (MDS) waveform (Figure 3.1) which gradually returns to zero current flow. The monophasic truncated exponential (MTE) waveform is electronically terminated before current flow reaches zero (Figure 3.2). Biphasic defibrillators, in contrast, deliver current that flows in a positive direction for a specified duration before reversing and flowing in a negative direction for the remaining milliseconds of the electrical discharge. There are two main types of biphasic waveform: the biphasic truncated exponential (BTE) (Figure 3.3) and rectilinear biphasic (RLB) (Figure 3.4). Biphasic defibrillators compensate for the wide variations in transthoracic impedance by electronically



**Figure 3.2** Monophasic truncated exponential waveform (MTE).

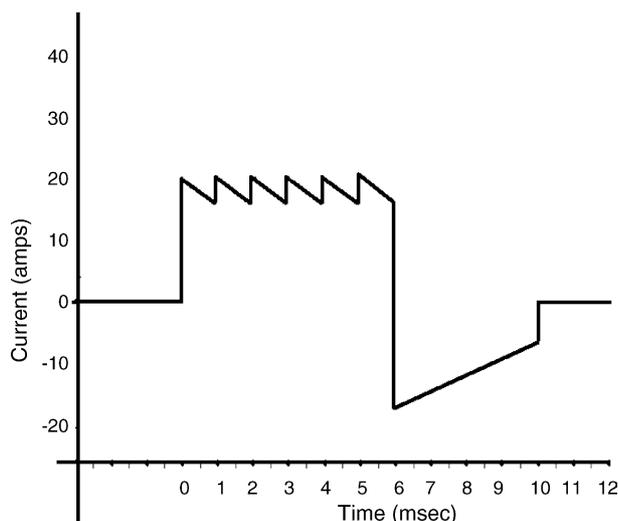


**Figure 3.3** Biphasic truncated exponential waveform (BTE).

adjusting the waveform magnitude and duration. The optimal ratio of first-phase to second-phase duration and leading-edge amplitude has not been established. Whether different waveforms have differing efficacy for VF of differing durations is also unknown.

All manual defibrillators and AEDs that allow manual override of energy levels should be labelled to indicate their waveform (monophasic or biphasic) and recommended energy levels for attempted defibrillation of VF/VT. First-shock efficacy for long-duration VF/VT is greater with biphasic than monophasic waveforms,<sup>96–98</sup> and therefore use of the former is recommended whenever possible. 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.

Although energy levels are selected for defibrillation, it is the transmural current flow that achieves defibrillation. Current correlates well with the successful defibrillation and cardioversion.<sup>99</sup>



**Figure 3.4** Rectilinear biphasic waveform (RLB).

The optimal current for defibrillation using a monophasic waveform is in the range of 30–40 A. Indirect evidence from measurements during cardioversion for atrial fibrillation suggest that the current during defibrillation using biphasic waveforms is in the range of 15–20 A.<sup>100</sup> Future technology may enable defibrillators to discharge according to transthoracic current: a strategy that may lead to greater consistency in shock success. Peak current amplitude, average current and phase duration all need to be studied to determine optimal values, and manufacturers are encouraged to explore further this move from energy-based to current-based defibrillation.

### First shock

First-shock efficacy for long-duration cardiac arrest using monophasic defibrillation has been reported as 54%–63% for a 200-J monophasic truncated exponential (MTE) waveform<sup>97,101</sup> and 77%–91% using a 200-J monophasic damped sinusoidal (MDS) waveform.<sup>96–98,101</sup> Because of the lower efficacy of this waveform, the recommended initial energy level for the first shock using a monophasic defibrillator is 360 J. Although higher energy levels risk a greater degree of myocardial injury, the benefits of earlier conversion to a perfusing rhythm are paramount. Atrioventricular block is more common with higher monophasic energy levels, but is generally transient and has been shown not to affect survival to hospital discharge.<sup>102</sup> Only 1 of 27 animal studies demonstrated harm caused by attempted defibrillation using high-energy shocks.<sup>103</sup>

There is no evidence that one biphasic waveform or device is more effective than another. First-shock efficacy of the BTE waveform using 150–200 J has been reported as 86%–98%.<sup>96,97,101,104,105</sup> First-shock efficacy of the RLB waveform using 120 J is up to 85% (data not published in the paper but supplied by personnel communication).<sup>98</sup> 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.

Manufacturers should display the effective waveform dose range on the face of the biphasic device. If the provider is unaware of the effective dose range of the device, use a dose of 200 J for the first shock. This 200 J default energy has been chosen because it falls within the reported range of selected doses that are effective for first and subsequent biphasic shocks and can be provided by every biphasic manual defibrillator available today. It is a consensus default dose and not a recommended ideal dose. If biphasic devices are clearly labelled

and providers are familiar with the devices they use in clinical care, there will be no need for the default 200 J dose. Ongoing research is necessary to firmly establish the most appropriate initial settings for both monophasic and biphasic defibrillators.

### Second and subsequent shocks

With monophasic defibrillators, if the initial shock has been unsuccessful at 360 J, second and subsequent shocks should all be delivered at 360 J. With biphasic defibrillators there is no evidence to support either a fixed or escalating energy protocol. Both strategies are acceptable; however, if the first shock is not successful and the defibrillator is capable of delivering shocks of higher energy, it is rational to increase the energy for subsequent shocks. If the provider is unaware of the effective dose range of the biphasic device and has used the default 200 J dose for the first shock, use either an equal or higher dose for second or subsequent shocks, depending on the capabilities of the device.

If a shockable rhythm (recurrent ventricular fibrillation) recurs after successful defibrillation (with or without ROSC), give the next shock with the energy level that had previously been successful.

## Other related defibrillation topics

### Defibrillation of children

Cardiac arrest is less common in children. Aetiology is generally related to hypoxia and trauma.<sup>106–108</sup> VF is relatively rare compared with adult cardiac arrest, occurring in 7%–15% of paediatric and adolescent arrests.<sup>108–112</sup> Common causes of VF in children include trauma, congenital heart disease, long QT interval, drug overdose and hypothermia. Rapid defibrillation of these patients may improve outcome.<sup>112,113</sup>

The optimal energy level, waveform and shock sequence are unknown but, as with adults, biphasic shocks appear to be at least as effective as, and less harmful than, monophasic shocks.<sup>114–116</sup> The upper limit for safe defibrillation is unknown, but doses in excess of the previously recommended maximum of  $4 \text{ J kg}^{-1}$  (as high as  $9 \text{ J kg}^{-1}$ ) have defibrillated children effectively without significant adverse effects.<sup>20,117,118</sup> The recommended energy level for manual monophasic defibrillation is  $4 \text{ J kg}^{-1}$  for the initial shock and for subsequent shocks. The same energy level is recommended for manual biphasic defibrillation.<sup>119</sup> As with adults, if a shockable rhythm recurs, use the energy level for defibrillation that had previously been successful.

### Blind defibrillation

Delivery of shocks without a monitor or an ECG rhythm diagnosis is referred to as “blind” defibrillation. Blind defibrillation is unnecessary. Handheld paddles with “quick-look” monitoring capabilities on modern manually operated defibrillators are widely available. AEDs use reliable and proven decision algorithms to identify VF.

### Spurious asystole and occult ventricular fibrillation

Rarely, coarse VF can be present in some leads, with very small undulations seen in the orthogonal leads, which is called occult VF. A flat line that may resemble asystole is displayed; examine the rhythm in two leads to obtain the correct diagnosis. Of more importance, one study noted that spurious asystole, a flat line produced by technical errors (e.g., no power, leads unconnected, gain set to low, incorrect lead selection, or polarisation of electrolyte gel (see above)), was far more frequent than occult VF.<sup>120</sup>

There is no evidence that attempting to defibrillate true asystole is beneficial. Studies in children<sup>121</sup> and adults<sup>122</sup> have failed to show benefit from defibrillation of asystole. On the contrary, repeated shocks will cause myocardial injury.

### Precordial thump

There are no prospective studies that evaluate use of precordial (chest) thump. The rationale for giving a thump is that the mechanical energy of the thump is converted to electrical energy, which may be sufficient to achieve cardioversion.<sup>123</sup> The electrical threshold of successful defibrillation increases rapidly after the onset of the arrhythmia, and the amount of electrical energy generated falls below this threshold within seconds. A precordial thump is most likely to be successful in converting VT to sinus rhythm. Successful treatment of VF by precordial thump is much less likely: in all the reported successful cases, the precordial thump was given within the first 10s of VF.<sup>123</sup> Although three case series<sup>124–126</sup> reported that VF or pulseless VT was converted to a perfusing rhythm by a precordial thump, there are occasional reports of thump causing deterioration in cardiac rhythm, such as rate acceleration of VT, conversion of VT into VF, complete heart block or asystole.<sup>125,127–132</sup>

Consider giving a single precordial thump when cardiac arrest is confirmed rapidly after a witnessed, sudden collapse and a defibrillator is not immediately to hand. These circumstances are

most likely to occur when the patient is monitored. Precordial thump should be undertaken immediately after confirmation of cardiac arrest and only by healthcare professionals trained in the technique. Using the ulnar edge of a tightly clenched fist, a sharp impact is delivered to the lower half of the sternum from a height of about 20 cm, followed by immediate retraction of the fist, which creates an impulse-like stimulus.

## 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.<sup>133</sup> Synchronisation can be difficult in VT because of the wide-complex and variable forms of ventricular arrhythmia. If synchronisation fails, give unsynchronised shocks to the unstable patient in VT to avoid prolonged delay in restoring sinus rhythm. Ventricular fibrillation or pulseless VT requires unsynchronised shocks. Conscious patients must be anaesthetised or sedated before attempting synchronised cardioversion.

## Atrial fibrillation

Biphasic waveforms are more effective than monophasic waveforms for cardioversion of AF<sup>100,134,135</sup>; when available, use a biphasic defibrillator in preference to a monophasic defibrillator.

## Monophasic waveforms

A study of electrical cardioversion for atrial fibrillation indicated that 360-J MDS shocks were more effective than 100-J or 200-J MDS shocks.<sup>136</sup> Although a first shock of 360-J reduces overall energy requirements for cardioversion, 360 J may cause greater myocardial damage than occurs with lower monophasic energy levels, and this must be taken into consideration. Commence cardioversion of atrial fibrillation using an initial energy level of 200 J, increasing in a stepwise manner as necessary.

## Biphasic waveforms

More data are needed before specific recommendations can be made for optimal biphasic energy levels. First-shock efficacy of a 70-J biphasic waveform has been shown to be significantly greater than that with a 100-monophasic waveform.<sup>100,134,135</sup> A

randomised study comparing escalating monophasic energy levels to 360 J and biphasic energy levels to 200 J found no difference in efficacy between the two waveforms.<sup>137</sup> An initial shock of 120–150 J, escalating if necessary, is a reasonable strategy based on current data.

## Atrial flutter and paroxysmal supraventricular tachycardia

Atrial flutter and paroxysmal SVT generally require less energy than atrial fibrillation for cardioversion.<sup>138</sup> Give an initial shock of 100-J monophasic or 70–120 J biphasic waveform. Give subsequent shocks using stepwise increases in energy.<sup>99</sup>

## Ventricular tachycardia

The energy required for cardioversion of VT depends on the morphological characteristics and rate of the arrhythmia.<sup>139</sup> Ventricular tachycardia with a pulse responds well to cardioversion using initial monophasic energies of 200 J. Use biphasic energy levels of 120–150 J for the initial shock. Give stepwise increases if the first shock fails to achieve sinus rhythm.<sup>139</sup>

## Pacing

Consider pacing in patients with symptomatic bradycardia refractory to anticholinergic drugs or other second-line therapy (see Section 4f). Immediate pacing is indicated, especially when the block is at or below the His–Purkinje level. If transthoracic pacing is ineffective, consider transvenous pacing. Whenever a diagnosis of asystole is made, check the ECG carefully for the presence of P waves, because this may respond to cardiac pacing. Do not attempt pacing for asystole; it does not increase short-term or long-term survival in or out of hospital.<sup>140–148</sup>

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