Section 2: Defibrillation

For a person in VF the probability of successful defibrillation and subsequent survival to hospital discharge is directly and negatively related to the time interval between onset of VF and delivery of the first shock. Early defibrillation by first responders is a rational implementation of the concept that the earlier defibrillation is performed, the better the rate of survival to hospital discharge. Early defibrillation has reversed VF cardiac arrest in a number of small case series (American Airlines, QANTAS Airlines, Chicago’s O’Hare Airport, and Las Vegas casinos). These dramatic examples of the effectiveness of early defibrillation by nontraditional responders have provided a driving force for PAD in the United States.

For more than a decade the AHA has recommended that every ambulance vehicle be equipped with a defibrillator and personnel trained in defibrillation. All healthcare providers with a duty to perform CPR should be trained, equipped, and encouraged to perform defibrillation. The Guidelines 2000 Conference recommends that early defibrillation be available throughout all hospital and outpatient medical facilities. The use of defibrillation now transcends both ACLS and BLS care. This section addresses use of standard defibrillators, including cardioversion, for the experienced healthcare provider in the ACLS environment. Early defibrillation, automated external defibrillation, and PAD are also discussed in “Part 4: The Automated External Defibrillator: Key Link in the Chain of Survival.”

Energy Requirements for Defibrillation

Defibrillation depends on the successful selection of energy to generate sufficient current flow through the heart (transmyocardial current) to achieve defibrillation while at the same time causing minimal electrical injury to the heart. A shock will not terminate the arrhythmia if the energy and current are too low. Functional and morphological damage may result if energy and current are too high. Selection of appropriate current also reduces the number of repetitive shocks and limits myocardial damage. There is no definite relationship between body size and energy requirements for defibrillation in adults. Transthoracic impedance does play an important role (see below).

Biphasic Waveform Defibrillators

Modern defibrillators, including AEDs, deliver energy or current in “waveforms.” Energy levels vary with the type of device and type of waveform. Several types of monophasic waveforms have been used in modern defibrillators. Biphasic waveforms have recently been developed and approved for marketing and clinical use. The body of evidence about the efficacy and safety of devices using biphasic waveforms has increased dramatically in the 4 years since the first such device was marketed. The first biphasic AED approved for use in the United States used a waveform set at a lower energy (150 to 175 J) than that recommended by the AHA (200 J) for the first shock. This device also was fixed-nonescalating, meaning the energy level of shocks could not be increased. In a recent review of evidence through 1997 for nonescalating low-energy biphasic waveforms in out-of-hospital arrest, the reviewers concluded that lower-energy biphasic shocks, delivered without an increase in energy, achieved clinical outcomes equivalent to those of monophasic shocks with increasing energy levels.

Monophasic waveforms deliver current in one direction. Monophasic defibrillators vary the speed and amount of waveform fall and the speed of the return to zero voltage point. If the monophasic waveform falls to zero gradually, the term damped sinusoidal is used. If the waveform falls instantaneously, the term truncated exponential is used. Biphasic waveforms, in contrast, deliver current that flows in a positive direction for a specified duration. The current then reverses and flows in a negative direction for the remaining milliseconds of the electrical discharge. Biphasic waveforms have proved superior to monophasic waveforms for defibrillation by nontraditional responders. Biphasic waveforms have proved superior to monophasic waveforms for defibrillation by implantable defibrillators. In 1996 the Food and Drug Administration approved the first AED that used a biphasic waveform. This was a biphasic truncated exponential (BTE) waveform with impedance compensation. This AED delivered only nonescalating 150-J shocks. Studies compared this waveform with conventional monophasic damped sinusoidal (MDS) waveform shocks at 200 and 360 J. These studies were conducted in electrophysiological stimulation suites during implantation of automatic implantable cardioverter-defibrillators (ICDs). In projects funded by defibrillator manufacturers, researchers observed that 150-J BTE shocks achieved first-shock defibrillation at the same rate as 200-J MDS shocks. BTE 150-J shocks also produced less ST-segment change than 200-J MDS shocks. Researchers have collected data both in-hospital (electrophysiological studies and ICD testing) and out of hospital. This research indicates that repetitive lower-energy biphasic waveform shocks (repeated shocks at 200 J) have equivalent or higher success for eventual termination of VF than defibrillators that increase the current (200, 300, 360 J) with successive shocks (escalating).

Biphasic Waveform Defibrillation

The optimal energies for biphasic defibrillation have not been determined. Importantly, the biphasic first-shock energy level

yielding the highest termination rate for VF is unknown. The percentage of patients who fail to respond to a first or successive biphasic shock at a constant energy of $\leq 200$ J remains unknown. Do patients in VF that is unresponsive to multiple “lower-energy” shocks then require higher-energy (escalating) biphasic shocks? Or will these patients require only repetition of low-energy biphasic shocks?

Research has not yet determined the optimal biphasic waveform. The potential advantages of new biphasic waveform variants, such as a rectilinear first pulse waveform, are also unknown. Researchers need to study the efficacy of “impedance compensation.” Compensation for patient-to-patient differences in impedance may be achieved by changes in duration and voltage of shocks or by releasing the residual membrane charge (called burping). Whether there is an optimal ratio of first-phase to second-phase duration and leading-edge amplitude is unclear. The threshold for the start and extent of cardiac damage from biphasic waveforms compared with monophasic waveforms remains a mystery. Finally, it will be important to determine whether a waveform more effective for immediate outcomes (defibrillation) and short-term outcomes (spontaneous circulation, admission to the hospital) results in better long-term outcomes (survival to hospital discharge, survival for 1 year). These are critical questions in communities in which the interval from collapse to first shock remains long.

**Shock Energies**

The traditional recommended energy for the first monophasic shock is 200 J.$^{20}$ The energy level for second and third shocks can be either the same (200 J) or as high as 360 J. Even a failed shock at one energy may be successful if simply repeated. Clinically the energy does not need to increase simply because the first shock failed to defibrillate. Any given energy has a constant probability to achieve defibrillation. Repeated shocks, even at the same energy level, add to the probability of successful defibrillation. This is not immediately obvious but can be clarified with a brief example. A waveform with a defibrillation rate of 80% will leave 20% of the victims in VF with each successive shock: of 100 people, first shock = 20 in VF; second shock = 4 in VF (20% of 20); third shock = 1 in VF (20% of 4). Thus, this waveform, with a 1-shock success rate of 80%, will achieve a 99% success rate if the 3 successive, nonescalating shocks are considered a single intervention.

Higher current flow will occur with subsequent shocks even at the same energy, because transthoracic impedance declines with repeated shocks.$^{21,22}$ These arguments favor repeating the second shock at the same energy level as the first if VF persists, but reductions in human transthoracic impedance are only modest.$^{21}$ A more predictable increase in current occurs when shock energy is increased. This supports second shocks of higher energy. A compromise between these positions is the use of a range of energies (200 to 300 J) for the second monophasic shock.

Increase the current/voltage and deliver a third shock of 360 J immediately if 2 monophasic shocks fail to defibrillate the heart. If VF is initially terminated by a shock but then recurs later in the arrest, deliver subsequent shocks at the previously successful energy level.

We cannot make a definitive recommendation for the energy for first and subsequent nonescalating biphasic defibrillation attempts. Current research confirms that biphasic shock energies $\leq 200$ J are safe and effective. Even though both escalating- and nonescalating-energy defibrillators are available, there is insufficient data to recommend one approach over another. Any claim of superiority at this time is unsupported. Nonescalating biphasic energies appear to have success rates for VF termination equivalent to or better than monophasic shocks (Class IIa) that increase in energy with each shock.

The most important determinant of survival in adult VF is rapid defibrillation. Give shocks as soon as a defibrillator is available.$^{1,2}$ If the first 3 shocks fail to achieve defibrillation immediately, continue CPR and follow the ACLS guidelines for sudden VF/VT: IV access, tracheal intubation, epinephrine; shock if still in VF; consider amiodarone or lidocaine.

**Cardioversion**

**Atrial Fibrillation**

The recommended initial energy for cardioversion of atrial fibrillation is 100 to 200 J MDS. Atrial flutter and paroxysmal supraventricular tachycardia (PSVT) generally require less energy. An initial energy of 50 to 100 J MDS is often sufficient, with stepwise increases in energy if initial shocks...
fail.23–25 Transthoracic cardioversion of atrial fibrillation with a low-energy (120-J), rectilinear, first-pulse biphasic waveform was superior to 200 J MDS in a recent controlled trial.26 Cardioversion with biphasic waveform is now available, but more data is needed before specific comparative recommendations can be made.

**Ventricular Tachycardia**

The amount of energy required for cardioversion of VT depends on the morphological characteristics and rate of the arrhythmia.27 Monomorphic VT (regular form and rate) with or without a pulse responds well to cardioversion shocks at initial energies of 100 J MDS. Polymorphic VT (irregular morphology and rate) responds similarly to VF. The initial shock energy should be 200 J MDS. Give stepwise increases if the first shock fails to cardiovert.27

**Transthoracic Impedance**

Defibrillation is accomplished by passage of sufficient electric current (amperes) through the heart. The energy chosen (joules) and the transthoracic impedance (ohms), or resistance to current flow, determine the current flow. Factors that determine transthoracic impedance include energy selected, electrode size, paddle-skin coupling material, number and time interval of previous shocks, phase of ventilation, distance between electrodes (size of the chest), and paddle electrode pressure.21,22,28 The average adult human impedance is approximately 70 to 80 Ω.13,21,22,29–31 When transthoracic impedance is too high, a low-energy shock will not generate enough current to achieve defibrillation.13,24,30 To reduce transthoracic impedance, the defibrillator operator should always press firmly on handheld electrode paddles and use a gel or cream or saline-soaked gauze pads between handheld electrode paddles and the chest. Self-adhesive monitor/defibrillator electrode pads do not require additional pressure. Use of “bare” handheld paddles without a coupling material between electrodes and the chest wall creates high transthoracic impedance.22 Male patients with a hirsute chest have poor electrode-to-chest contact plus air trapping. This results in high impedance, with occasional “arching.” (Although extremely rare, in oxygen-rich environments such as critical care units this arcing has been known to produce fires if an accelerant is present.) Rapid shaving of the area of intended pad placement may be necessary. The AHA textbook *Heartsaver AED for the Lay Rescuer and First Responder* contains an excellent description of successful approaches to removal of chest hair.

**Current-Based Defibrillation**

VF and other cardiac arrhythmias can be terminated by electric shock when sufficient current passes through the myocardium. A promising alternative approach to defibrillation is the use of electric current (amperes) instead of energy (joules). This approach would prevent attempts to deliver inappropriately low energy levels to a patient with high impedance. Current-based therapy would also prevent high-energy shocks to patients with low impedance, which result in excessive current flow, myocardial damage, and failure to defibrillate.13,24

Clinical studies using MDS waveform shocks have attempted to identify the range of current necessary to achieve defibrillation and cardioversion. The optimal current for ventricular defibrillation appears to be 30 to 40 A MDS.29–31 Comparable information on current dosage for biphasic waveform shocks is under investigation.

**Electrode Position**

Place electrodes in positions to maximize current flow through the myocardium. The standard placement is one electrode just to the right of the upper sternal border below the clavicle. Place the second electrode to the left of the nipple with the center of the electrode in the midaxillary line. An acceptable alternative is to place the “apex” paddle anterior, over the left precordium, and the other paddle (labeled “sternum”) posterior to the heart in the right infrascapular location.32,33 Take care that the electrodes are well separated and that paste or gel is not smeared on the chest between the paddles, because the current may follow a superficial pathway along the chest wall, “missing” the heart. Self-adhesive monitor/defibrillator electrode pads are also effective and can be used in any of these locations.31

When performing cardioversion or defibrillation in patients with permanent pacemakers or ICDs, do not place the electrodes near the device generator, because defibrillation can cause malfunction. A pacemaker or ICD also may block some current to the myocardium during defibrillation, delivering suboptimal energy to the heart. Finally, because some of the defibrillation current flows down the pacemaker leads, always reevaluate the pacing threshold after shock(s) to patients with permanent pacemakers.34 ICD function also should be evaluated.

**Electrode Size**

The Association for the Advancement of Medical Instrumentation recommends a minimum electrode size of 50 cm² for individual electrodes.35 The sum of the electrode areas should be a minimum of 150 cm². Larger electrodes have lower impedance, but excessively large electrodes may result in less transmyocardial current flow.26

For adult defibrillation, both handheld paddle electrodes and self-adhesive pad electrodes 8 to 12 cm in diameter are used and perform well.21,31,37 Even smaller pads have been found effective38 in VF of brief duration.

**Synchronized Cardioversion**

Delivered energy should be *synchronized* with the QRS complex to reduce the possibility of inducing VF, which can occur when a shock “hits” the relative refractory portion of the cardiac cycle.32 *Synchronization* to prevent this complication is recommended for hemodynamically stable wide-complex tachycardia requiring cardioversion, supraventricular tachycardia, atrial fibrillation, and atrial flutter. VF requires *unsynchronized* defibrillation mode. It is important to note that synchronization in VT may be difficult and misleading because of the wide-complex and variable forms of ventricular arrhythmia. The VT patient who is pulseless, unconscious, hypotensive, or in severe pulmonary edema should receive unsynchronized shocks to avoid the delay
associated with attempts to synchronize. The healthcare provider should be prepared to deliver another unsynchronized shock within seconds if VF or pulseless VT remains or recurs.

**Blind Defibrillation**

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

*“Occult” Versus “False” Asystole*

There is no evidence that attempting to “defibrillate” asystole is beneficial. In rare patients, however, coarse VF can be produced by technical errors (eg, no power, leads uncon- 

**Maintaining Defibrillators in a State of Readiness**

User checklists have been developed to reduce equipment malfunction and operator errors. Failure to properly maintain the defibrillator or power supply is responsible for the majority of reported malfunctions. Checklists are useful when designed to identify and prevent such deficiencies. Checklists help most when (1) users are trained in their proper use, (2) healthcare providers who actually use the defibrillators perform the check, and (3) checklists are completed with every change in personnel.

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Part 6: Advanced Cardiovascular Life Support: Section 2: Defibrillation

doi: 10.1161/01.CIR.102.suppl_1.I-90
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2000 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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