**Part 4: The Automated External Defibrillator**

**Key Link in the Chain of Survival**

**Major Guidelines Changes**
Following are the major guidelines changes related to use of automated external defibrillators (AEDs) in basic life support:

1. Early defibrillation (shock delivery within 5 minutes of EMS call receipt) is a high-priority goal.
2. Healthcare providers with a duty to perform CPR should be trained, equipped, and authorized to perform defibrillation (Class IIa).
3. For in-hospital defibrillation:
   a. Early defibrillation capability, which is defined as having appropriate equipment and trained first responders, should be available throughout hospitals and affiliated outpatient facilities (Class IIa).
   b. The goal of early defibrillation by first responders is a collapse-to-shock interval, when appropriate, of <3 minutes in all areas of the hospital and ambulatory care facilities (Class I).
   c. Response time intervals for in-hospital resuscitation events are often inaccurate and must be corrected before documented times to defibrillation can be considered reliable (Class IIa).
4. Evidence supports establishment of public access defibrillation (PAD) programs in the following cases:
   a. The frequency of cardiac arrest events is such that there is a reasonable probability of one AED use in 5 years (estimated event rate of 1 sudden cardiac arrest per 1000 person-years).
   b. An EMS call–to–shock time interval of <5 minutes cannot be reliably achieved with conventional EMS services. In many communities, this EMS call–to–shock time interval can be achieved by training and equipping laypersons to:
      - Function as first responders in the community
      - Recognize cardiac arrest
      - Activate the EMS system (phoning 911 or another appropriate emergency response number) at appropriate times
      - Provide CPR
      - Attach/operate an AED safely.
   c. For BLS responders such as police, firefighters, security personnel, sports marshals, ski patrol members, ferryboat crews, and airline flight attendants (referred to as level 1 responders in this document), education in CPR and the use of an AED is a Class IIa recommendation. For level 2 targeted responders such as citizens at worksites or in public places, this is a Class Indeterminate recommendation. For level 3 responders (family and friends of persons at high risk) this is a Class Indeterminate recommendation.

5. Use of AEDs in children ≥8 years of age (approximately ≥25 kg body weight) is a Class IIb recommendation.
6. Use of AEDs in infants and children <8 years of age is not recommended (Class Indeterminate).
7. Biphasic waveform defibrillation with shocks ≥200 J is safe and has equivalent or higher efficacy for termination of ventricular fibrillation (VF) compared with higher-energy escalating monophasic-waveform shocks (Class IIa).

**Introduction**
Public access defibrillation, which places AEDs in the hands of trained laypersons, has the potential to be the single greatest advance in the treatment of VF cardiac arrest since the development of CPR.1–11 Time to defibrillation is the most important determinant of survival from cardiac arrest.1–16 PAD provides the opportunity to defibrillate victims of cardiac arrest within a few minutes, even at sites remote from traditional EMS responders. Extraordinary survival rates—as high as 49%—have been reported in PAD programs.17–24 These rates are twice those previously reported for the most effective EMS systems.25

AEDs are sophisticated, computerized devices that are reliable and simple to operate, enabling lay rescuers with minimal training to administer this lifesaving intervention.1–24,26 Flight attendants, security personnel, sports marshals, police officers, firefighters, lifeguards, family members, and many other trained laypersons have used AEDs successfully.15–24 AEDs are located in airports, airplanes, casinos, high-rise office buildings, housing complexes, recreational facilities, shopping malls, golf courses, and numerous other public locations.15,16,23,24,27–28 AEDs are also used by healthcare professionals in ambulances, hospitals, dental clinics, and physicians’ offices.29–34

With the inclusion of AED use as a BLS skill, BLS now encompasses the first 3 links in the Chain of Survival (early access, early CPR, and early defibrillation).35 AEDs widely used by the public and distributed throughout the community significantly advance the concept proposed more than 2 decades ago: the community should become the “ultimate coronary care unit.”36

**Principle of Early Defibrillation**
Early defibrillation is critical to survival from cardiac arrest for several reasons: (1) the most frequent initial rhythm in witnessed sudden cardiac arrest is VF; (2) the most effective treatment for VF is electrical defibrillation; (3) the probability of successful defibrillation diminishes rapidly over time; and...
ter implementation of early defibrillation programs by EMS personnel in 5 European regions, survival to discharge from VF cardiac arrest was as high as 27% to 55%.58

Clearly the earlier defibrillation occurs, the better the prognosis.38–58 Emergency personnel have only a few minutes after a victim’s collapse to reestablish a perfusing rhythm. CPR can sustain a patient for a short time but cannot directly restore an organized rhythm. Restoration of an adequate perfusing rhythm requires defibrillation and advanced cardiovascular care, which must be administered within a few minutes of the initial arrest.37 The use of AEDs increases the range of personnel who can use a defibrillator, shortening the time between collapse and defibrillation.47–51,53–56 This exciting prospect accounts for the addition of this intervention as an integral component of BLS.

Early defibrillation (shock within 5 minutes of EMS call receipt) is a high-priority goal of EMS care. Every community should assess its capability to provide this intervention and institute whatever measures are necessary to make this recommendation a reality.

**History of AEDs**

In a prophetic report of what was to follow in the next 2 decades, Diack and colleagues59 described experimental and clinical experience with the first AED. Subsequently, other studies provided supportive evidence for the potential role of such a device for widespread provision of rapid defibrillation.60–62

In the ensuing years, clinical studies have documented various aspects of AED performance, confirming the high sensitivity and specificity of the AED algorithms as well as the safety and efficacy of the devices.62–76

Another major advance in the use of AEDs was the development of a small (6.25-lb) AED specifically designed for home use. This AED delivered up to 3 nonescalating 180-J monophasic damped sinusoidal shocks and instructed the operator with easy-to-follow audible prompts. New AED models and manufacturers soon entered the field. Clinical evaluation confirmed the safety and efficacy of this AED in termination of out-of-hospital VF arrest.72,76,77 Home trials were conducted and reported, but the concept of home defibrillation for patients at high risk was not yet ready for acceptance.15,16,78–81

In the last few years there has been a significant increase in the use of AEDs in early defibrillation programs in a variety of settings, including EMS systems, police departments, casinos, airport terminals, and commercial aircraft, among others.12,13,17,18,20–24,82–84 In most of these settings, use of AEDs by BLS ambulance providers or first responders (PAD level 1 responders) in early defibrillation programs has been associated with a significant increase in survival rates. In some cases no benefit from such early defibrillation has been observed, usually in rural areas or systems in which EMS response is rapid enough to preclude benefit.14,85,86 Also, improved survival will not be likely when infrequent bystander CPR and delays in dispatch impose weaknesses in other aspects of the Chain of Survival.87 Long arrest-to-shock times (mean 23.8 minutes) and a low occurrence of bystander CPR (9%) were accompanied by a low survival rate (6%)
from VF after introduction of AEDs in a large Asian city. These and similar studies suggest that the introduction of AEDs into ambulance services may not significantly improve outcome unless other links in the Chain of Survival are optimized. Guidelines for implementation of early defibrillation programs have been published that emphasize the components that are likely to result in improved patient outcomes, especially the critical links in the Chain of Survival.

Advances in defibrillation waveform technology have been incorporated into AEDs, following the transition from monophasic to biphasic waveforms with implantable cardioverter-defibrillators (ICDs). Experimental and clinical evidence supporting the transition to biphasic waveforms in ICDs was abundant and consistent. The use of biphasic defibrillation waveforms permits a reduction in the size and weight of AEDs, a major consideration in many settings, such as aircraft. Recommendations for specifying algorithm performance and demonstrating the equivalence of alternative waveforms were published by the American Heart Association Subcommittee on AED Safety and Efficacy in 1997.

Contemporary AEDs

The term “AED” refers to an automated external defibrillator that incorporates a rhythm analysis system and a shock-advisory system. The AED “advises” a shock and the operator must take the final action (press the SHOCK button) to deliver the shock. Fully automated external defibrillators do not require pressing the SHOCK button, and they are available only for special situations.

Automated Analysis of Cardiac Rhythms

Current AEDs are highly sophisticated, microprocessor-based devices that analyze multiple features of the surface ECG signal, including frequency, amplitude, and some integration of frequency and amplitude, such as slope or wave morphology (Figure 2). Various filters check for QRS-like signals, radio transmission, or 50- or 60-cycle interference as well as loose electrodes and poor electrode contact. Some intermittent radio transmissions can produce an ECG artifact if a transmitter or receiver is used within 6 feet of a patient during rhythm analysis. Some devices are programmed to detect spontaneous movement by the patient or movement of the patient by others.

AEDs have been extensively tested, both in vitro against libraries of recorded cardiac rhythms and clinically in numerous field trials. Their accuracy in rhythm analysis is high. The rare errors noted in field trials have been almost solely errors of omission (sensitivity) in which the device failed to recognize certain varieties of VF or tachycardia or when operators failed to follow recommended operating procedures, such as avoidance of patient movement.

Inappropriate Shocks or Failure to Shock

Extensive clinical experience has revealed that AEDs are infrequently affected by movement of the patient (eg, seizures and agonal respirations), repositioning of the patient, or artifactual signals, although some rare difficulties have been reported. Failure to follow the manufacturer’s instructions for use of a fully automated external defibrillator has in rare instances resulted in delivery of inappropriate electrical countershocks. AEDs should be placed in the analysis mode only when full cardiac arrest has been confirmed and only when all movement, particularly patient transport, has ceased. Agonal respiration poses a problem because some devices may not be able to complete analysis cycles if the patient continues to have gasping respirations. Use of radio receivers and transmitters should be avoided during rhythm analysis. The major errors reported in clinical trials have been occasional failures to deliver shocks to rhythms that may benefit from electrical therapy, such as extremely fine or coarse VF. Occasionally the analysis and treatment cycles of implanted and automated defibrillators can conflict.

Ventricular Tachycardia

Although AEDs are not designed to deliver synchronized shocks, all AEDs will shock monomorphic and polymorphic ventricular tachycardia (VT) if the rate exceeds preset values. AEDs should be operated only on patients who are unresponsive, not breathing, and have no signs of circulation.

With this approach, the operator serves as a second verification system to confirm that the patient has suffered a cardiac arrest. In an apneic patient without signs of life, electrical shocks are indicated whether the rhythm is supraventricular tachycardia (SVT), VT, or VF. There have been rare reports of shocks delivered to responsive patients with perfusing ventricular or supraventricular arrhythmias. These are operator errors, not device errors, and are preventable when rescuers are well trained and possess good patient assessment skills.

Throughout this chapter, for laypersons the term “signs of circulation” means quickly evaluating the victim for normal breathing, coughing, or movement. For healthcare professionals, the term “signs of circulation” means quickly performing a pulse check while simultaneously evaluating the victim for breathing, coughing, or movement.
Waveforms and Energy Levels

The energy settings for defibrillators are designed to provide the lowest effective energy needed to terminate VF. If energy and current are too low, the shock will not terminate the arrhythmia; if energy and current are too high, myocardial damage may result. There is no clear relation between body size and energy requirements for defibrillation in adults. Modern AEDs fall into 2 broad categories of waveforms: monophasic and biphasic. Energy levels vary by type of device. Monophasic waveforms deliver current that is primarily of 1 polarity (ie, direction of current flow). They are further subdivided by the rate at which the current pulse decreases to zero; namely, either gradually (damped sinusoidal) or instantaneously (truncated exponential). The waveforms of biphasic defibrillators indicate a sequence of 2 current pulses; the polarity of the second is opposite that of the first.

In a prospective out-of-hospital study of monophasic manual defibrillators, defibrillation rates and the proportion of patients resuscitated and later discharged from the hospital were virtually identical in patients who received initial monophasic damped sine (MDS) waveform shocks of 175 J and 320 J. The recommended first-shock energy for monophasic waveform defibrillation is 200 J. For monophasic devices the recommended second shock is 200 to 300 J; the recommended third shock is 360 J. The intent of this escalating energy dosage protocol is to maximize shock success (termination of VF) while minimizing shock toxicity.

The first biphasic waveform for use in an AED was approved in the United States in 1996. This impedance-compensating biphasic truncated exponential (BTE) waveform was incorporated into an AED that discharged nonescalating 150-J shocks.

Impedance compensation was achieved by adjusting first-phase tilt, relative duration of the 2 phases, and total duration to a maximum of 20 ms. Experimental work in animals suggested the superiority of this waveform over monophasic truncated exponential (MTE) waveforms. In-hospital studies during ICD testing compared 115-J and 130-J shocks using the BTE waveform with MDS waveform shocks of 200 J and 360 J. This in-hospital data indicated that for short-duration VF, BTE shocks at low energy (115 J and 130 J) were as effective as the 200-J MDS shocks traditionally used for the first shock. Fewer ST-segment changes were observed after transthoracic defibrillation of short-duration VF with the 115- and 130-J BTE shocks compared with those after 200-J MDS shocks.

Another in-hospital study comparing an MDS waveform with a damped sinusoidal version of a biphasic waveform (“Gurvich”) concluded that this biphasic waveform was likewise superior to the MDS waveform in terminating short-duration VT and VF.

Early clinical experience with the 150-J, impedance-compensated BTE waveform for treatment of out-of-hospital long-duration VF was also positive. This experience, along with in-hospital clinical data, formed the basis for the AHA evidence-based review of this low-energy biphasic waveform defibrillation, which led to an initial Class IIb recommendation. Since then, cumulative experience with this waveform in 100 patients with VF was reported, confirming its efficacy in terminating VF arrest outside the hospital. The aggregate data with this waveform in VF arrest from one EMS system (Rochester, Minn) also affirmed the efficacy of this waveform for terminating VF. This experience was compared retrospectively with that of the MDS waveform in the same EMS system. The growing body of evidence is now considered sufficient to support a Class IIa recommendation for this low-energy, BTE waveform.

Other versions of biphasic waveforms have been introduced and have undergone initial evaluation during electrophysiology study and ICD implantation and testing. Experience with short-duration VF, in which a low-energy (120- to 170-J), constant-current, rectilinear biphasic waveform was used has recently been reported. This waveform has also been very effective in terminating atrial fibrillation during elective cardioversion with energies as low as 70 J. At this time no studies have reported experience with other biphasic waveforms in long-duration VF in out-of-hospital arrest. When such data becomes available, it will need to be assessed by the same evidence-evaluation process as used for the biphasic AED and this guidelines process.

The data indicates that biphasic waveform shocks of relatively low energy (≤200 J) are safe and have equivalent or higher efficacy for termination of VF compared with higher-energy escalating monophasic waveform shocks (Class IIa). The safety and efficacy data related to specific biphasic waveforms must be evaluated on an individual basis in both in-hospital (electrophysiology studies, ICD testing) and out-of-hospital settings.

Evaluation of Defibrillation Waveform Performance

The evaluation of defibrillation shock waveform efficacy requires the adoption of standard descriptors of defibrillation and postshock rhythms. Clinical investigators should uniformly apply such descriptors in the assessment of defibrillation waveforms. The term “defibrillation” means reversal of fibrillation and should not be confused with other resuscitation outcomes, such as restoration of a perfusing rhythm, admission to hospital, or discharge survival. These additional end points may occur during resuscitation as a consequence of many variables, including time from collapse to shock and other interventions, such as CPR and drug therapy.

In several recent studies, a successful defibrillatory shock was defined as the absence of VF 5 seconds after shock delivery. This definition of shock outcome was one of several considered by the 1999 Evidence Evaluation experts as acceptable to define “success” in evaluation of defibrillator waveforms. Thus, asystole or non-VF electrical activity at the postshock end point constitutes “success” because VF has been terminated. This is consistent with data from electrophysiological mapping studies confirming the time course of termination of VF after shock delivery, and clinically it is an easily measurable point in time after a shock. At this point the direct effect of the shock on VF is not influenced by many other interventions that may ensue after shock delivery,
such as chest compressions, ventilation, and administration of drugs, which themselves have an impact on cardiac rhythm after shocks. Examining the rhythm 5 seconds after each of the first series of shocks, before any drugs or other advanced life support interventions are initiated, will yield the most useful specific information about shock efficacy. In addition, tracking the postshock rhythm during the first minute after shock delivery will provide additional data, such as whether an organized rhythm is supraventricular or idioventricular and whether or not a perfusing rhythm accompanies restoration of organized electrical activity.

As new defibrillation waveforms evolve and are evaluated in out-of-hospital arrest, it is essential that standardized definitions of shock efficacy be accepted and uniformly applied by clinical investigators engaged in waveform research. The definitions proposed here help meet that need.

**Operation of the AED**

Before attaching the AED, the operator should first determine whether special situations exist that contraindicate the use of the AED or require additional actions before its use.

**Special Situations That May Require Additional Actions**

While preparing to use the AED, the operator must identify 4 possible circumstances (special situations) that may require rescuers to modify their actions before or during AED use. These situations include victims in water, those <8 years of age or <25 kg, those with transdermal medication patches, and those with implanted pacemakers or ICDs. Metal surfaces are not included as a special circumstance because they pose no shock hazard to either victim or rescuer.

**Water**

Water is a good conductor of electricity and may provide a pathway for energy from the AED to rescuers and bystanders treating the victim. There is a small possibility that rescuers or bystanders may receive shocks or minor burns if they are within such a pathway. Water on the skin of the chest can also provide a direct path of energy from one electrode pad to the other (arching) and can decrease the effectiveness of the shock delivered to the heart. It is critical to quickly remove the victim from freestanding water and dry the victim’s chest before using the AED. If the victim has a diving injury or other possible spinal injury, care should be taken to maintain cervical spine immobilization while moving the victim and performing resuscitation.

**Children**

Cardiac arrest is less common in children than adults, and its causes are more diverse. Approximately 50% of pediatric cardiac arrests occur in children <1 year old. Most of these are caused by sudden infant death syndrome and respiratory disease. Beyond the first 6 months of life, injuries and drowning are the major causes of cardiac arrest. The most common terminal rhythm observed in patients 17 years of age is asystole or pulseless electrical activity. When pediatric cardiac arrest rhythms are reported, estimates of VF range from 7% to 15%. In some studies, pediatric patients with VF who receive defibrillation at the scene have a higher initial resuscitation rate and are more likely to be discharged from the hospital with good neurological outcomes than pediatric patients who present with non-VF rhythms.

Experience with AEDs in children is very limited. The sensitivity and specificity for children of the AED algorithm need further study. The data suggests that AEDs can accurately detect VF in children of all ages (sensitivity), but there is inadequate data on the ability of AEDs to correctly identify nonshockable tachycardic rhythms in infants (specificity). Although the available data is encouraging, more data in larger pediatric populations is needed to define AED algorithm sensitivity and specificity.

More studies are also needed to determine AED energy doses that are safe and effective for children. In adults, clinical reports of biphasic waveform AED use have described energy doses as low as 120 J, with success rates equal to 200-J monophasic shocks for termination of VF; less postresuscitation myocardial dysfunction was observed after lower-energy shocks. Currently available AEDs deliver energy doses that exceed the recommended monophasic dose of 2 to 4 J/kg in most children <8 years of age. The median weight of children more than 8 years of age is typically >25 kg; therefore, the delivered initial dose from a monophasic or biphasic AED (150 to 200 J) will be <10 J/kg for this age group. Data from animals suggests that this may be a safe dose, although human pediatric data is extremely limited. At this time attempted defibrillation of VF/pulseless VT detected by an AED may be considered in older children (>8 years old, approximately >25 kg body weight), particularly in the out-of-hospital setting. A weight of 25 kg corresponds to a body length of approximately 50 in (128 cm) using a Broselow color-coded tape.

In summary, although VF is not a common arrhythmia in children, it is observed in as many as 15% of pediatric and adolescent arrests. In these patients rapid defibrillation may improve outcomes. Multicenter or controlled studies of AED algorithm sensitivity and specificity are needed, as well as a clearer definition of appropriate energy doses for children of all ages and sizes.

For these reasons, use of AEDs in children >8 years old (approximately >25 kg body weight) is a Class IIb recommendation. Use of AEDs in infants and children <8 years old is not recommended, primarily because of the lack of data concerning sensitivity, specificity, safety, and efficacy (Class Indeterminate). Healthcare providers who routinely care for children at risk for arrhythmias and cardiac arrest (eg, in-hospital settings) should continue to use defibrillators capable of appropriate energy adjustment. For infants and children <8 years old who are in cardiac arrest, the initial priorities continue to be support of the airway, oxygenation, and ventilation.

**Transdermal Medications**

AED electrodes should not be placed directly on top of a transdermal medication patch (eg, nitroglycerin, nicotine, analgesics, hormone replacements, antihypertensives), because the patch may block delivery of energy from the electrode pad to the heart and may cause small burns to the skin. The only problems reported with shocks over a
transdermal patch have involved patches with a metal backing. Metal backing for patches is no longer being used, so this potential problem has been eliminated. Medication patches should be removed and the area wiped clean before the AED electrode pad is attached.

**Implanted Pacemakers/ICDs**

Defibrillators that deliver a limited number of low-energy shocks directly to the myocardium have been implanted in selected patients with a history of malignant arrhythmias. These devices create a hard lump beneath the skin of the upper chest or abdomen (usually on the victim’s left side). The lump is about half the size of a pack of cards and usually has a small overlying scar. Placement of an AED electrode pad directly over an implanted medical device may reduce the effectiveness of defibrillation attempts. Instead, place the pad at least 1 inch (2.5 cm) away from the implanted device. Then follow the usual steps for operating an AED. However, if the ICD is delivering shocks to the patient (ie, the patient’s muscles contract in a manner like that observed during external defibrillation), allow 30 to 60 seconds for the ICD to complete the treatment cycle. Occasionally the analysis and shock cycles of automatic ICDs and AEDs will conflict. (See “Part 6, Section 2: Defibrillation” for guidelines for management of patients with ICDs.)

**The “Universal AED”: Common Steps to Operate All AEDs**

It is recommended that AEDs used in PAD programs (eg, large buildings, shopping malls, or homes) be stored next to a telephone. This allows the rescuer to activate the EMS system (by phoning 911 or another appropriate emergency telephone number) and retrieve the AED quickly. In some settings (eg, airports), security personnel or the local EMS system are automatically notified when the AED is retrieved from its storage case.

Position the AED close to the supine victim’s ear. Performing defibrillation protocols from the victim’s left side allows better access to the AED controls and easier placement of electrode pads. The left-side position also provides easier access to the AED controls and easier placement of electrode pads.

**Step 1: POWER ON the AED**

The first step in operating an AED is to turn the power on. This initiates voice prompts, which guide the operator through subsequent steps. To turn the AED on, press a power switch or lift the monitor cover or screen to the “up” position.

**Step 2: Attach electrode pads**

Quickly open and attach the self-adhesive monitor-defibrillator electrode pads directly to the skin of the victim’s chest. In some models the pads and cables are preconnected to the AED. Other devices may require a connection between the cable and AED or between the cable and electrode pads.

Place the electrode pads on the upper-right sternal border (directly below the clavicle) and lateral to the left nipple, with the top margin of the pad a few inches (approximately 7 cm) below the axilla (Figure 3). The correct position of the electrode pads is often illustrated on the pads themselves or another part of the AED. Stop CPR just before attaching the pads.

If the victim is noticeably diaphoretic, dry the chest with a cloth or towel before attaching the electrode pads.

If the victim has a hairy chest, the adhesive electrode pads may stick to the hair on the chest, preventing effective contact with the skin of the chest and causing transthoracic impedance to be high, leading to a “check electrodes” or “check electrode pads” message from the AED. This problem may be resolved by pressing firmly on each pad. If the error message continues, briskly remove the original pads (this will remove the hair under the pad) and apply a second set of electrodes. If the problem continues, shave the chest in the area of the pads before attaching a third set of electrodes. Alternatively, clip hair close to the chest or shave the chest hair before applying the second set of electrodes.

**Step 3: Analyze the rhythm**

Clear rescuers and bystanders from the victim and ensure that no one is touching the victim. To prevent artifactual errors, avoid all movement affecting the patient during rhythm analysis. In some devices the operator presses an ANALYZE button to initiate rhythm analysis. Other devices automatically begin analysis when the electrode pads are attached to the chest. Rhythm analysis requires from 5 to 15 seconds, depending on the brand of AED. If VF is present, the device will announce it through a displayed message, visual or auditory alarm, or voice-synthesized statement that a shock is indicated.

**Step 4: Clear the victim and press the SHOCK button**

Before pressing the SHOCK button, ensure that no one is touching the victim. Always loudly state a “Clear the patient”
message, such as “I’m clear, you’re clear, everybody clear” or simply “Clear.” At the same time perform a visual check to ensure that no one is in contact with the patient. In most devices, the capacitors charge automatically if a treatable rhythm is detected. A tone, voice-synthesized message, or light indicates that charging has started. Delivery of a shock should occur only after the victim is “cleared.” The shock will produce a sudden contraction of the patient’s musculature (like that seen with a conventional defibrillator). Therefore, after 3 shocks, check signs of circulation and continue compressions for 1 minute by performing CPR. If VF persists, deliver additional shocks, ie, after shocks 1 and 2, 4 and 5, 7 and 8, etc. After 60 seconds most devices will prompt a check for signs of circulation. If VF continues, deliver additional rounds of 3 “stacked” shocks after appropriate analysis. Provide sets of 3 stacked shocks followed by 1 minute of CPR until the AED gives a “no shock indicated” message or ACLS is available.

Do not check for signs of circulation between stacked shocks, ie, after shocks 1 and 2, 4 and 5, 7 and 8, etc. Checking for signs of circulation between shocks will delay rapid identification and shocking of persistent VF. The rapid sequence of shocks has the additional advantage of modestly reducing transthoracic impedance; this reduction will increase the effective energy delivered.

“No Shock Indicated” Message

Signs of Circulation Absent
When the AED gives a “no shock indicated” message, check for signs of circulation, and if there are no signs of circulation, resume CPR. Three “no shock indicated” messages suggest that there is a low probability that the rhythm can be successfully defibrillated. Therefore, rhythm analysis should be repeated only after 1- to 2-minute intervals of CPR. CPR should then be discontinued during rhythm analysis. No one should touch the victim during analysis.

Outcomes and Actions After Attempted Defibrillation

“Shock Indicated” Message: Recurrent VF
If signs of circulation do not return after 3 shocks, rescuers without immediate ACLS backup should resume CPR for 60 seconds. After 60 seconds most devices will prompt a check for signs of circulation. If VF persists, deliver additional rounds of 3 “stacked” shocks after appropriate analysis. Provide sets of 3 stacked shocks followed by 1 minute of CPR until the AED gives a “no shock indicated” message or ACLS is available.

AEDs can be left in place during transport of the patient in a moving vehicle. But never push the ANALYZE button while the patient is in transport, because the movement of the ambulance can interfere with rhythm assessment and artifact can simulate VF. Some devices continuously analyze the patient. If rhythm analysis is necessary during transport or if the AED prompts the rescuer to check the patient or recommends a shock, stop the vehicle, then reanalyze.

One Rescuer With an AED
In some situations, 1 rescuer with immediate access to an AED may respond to a cardiac arrest. The rescuer should quickly activate the EMS system or the emergency medical response system on the premises (eg, airport security personnel or the hospital resuscitation team) to summon ACLS providers. The recommended BLS rescue sequence for adults is as follows:

1. Verify unresponsiveness.
2. Activate EMS (or the emergency medical response system) at the appropriate time.
3. Open the airway, check breathing.
4. If the victim is not breathing, provide initial ventilations (2 in the United States; up to 5 in other countries).
5. Check for signs of circulation. If there are no signs of circulation, attach the AED and follow the AED treatment algorithm.

Reasonable variations in this sequence are acceptable.

Integration of CPR and AED Use
When arriving at the scene of a suspected cardiac arrest, rescuers must rapidly integrate CPR with use of the AED. In most out-of-hospital and in-hospital situations, rescuers will have the benefit of having 1 or more additional rescuers to assist with the multiple actions needed to resuscitate a victim of sudden cardiac death. In general, 3 actions must occur simultaneously at the scene of a cardiac arrest: (1) activation of the EMS system (or emergency medical response system, such as the hospital resuscitation team), (2) CPR, and (3) operation of the AED. When 2 or more rescuers are present, these functions can be initiated simultaneously. AED operators should be trained in scene leadership and team management to ensure timely and effective actions by multiple rescuers.

Care After Successful Defibrillation
When signs of circulation and breathing return, place the patient in a recovery position and leave the AED attached. Continue to monitor the victim. Many AEDs monitor rhythm continuously and advise the operator if fibrillation recurs. It is
important to check breathing and signs of circulation frequently.

AED programs should coordinate with the local EMS system to ensure seamless transfer of care after the arrival of BLS or ACLS healthcare providers.

The AED treatment algorithm (Figure 4) summarizes the approach to the cardiac arrest victim while using an AED.

Device Maintenance and Quality Assurance
Appropriate maintenance of the AED is vital for proper operation.150,151 AED manufacturers provide specific recommendations for maintenance and readiness, which should be followed carefully. Checklists have been developed to help identify and prevent maintenance deficiencies and suggest methods of uniform device testing. Use of these checklists will increase user familiarity with the equipment.152 Newer AED models require almost no maintenance. These devices conduct a self-check of operation and indicate “readiness to use.” Nonetheless, operators trained to use an AED must still ensure that the AED is ready to use at any time.

Medical Direction
Legislation and regulations regarding EMS authority and the use of AEDs vary from country to country and even from one
EMS system to another. In general, ambulance providers can perform some medical procedures in emergencies, but only with a physician’s medical authorization. The authorizing physician assumes medical direction and takes legal responsibility for the activity of BLS ambulance providers, including the use of AEDs. The authorizing physician for a PAD program oversees implementation of the program, issues standing orders for BLS personnel who operate AEDs, and monitors the system to ensure continuous quality improvement. In areas such as the United States, where AEDs are considered medical equipment, the rescuer must operate the AED under the authority of either the medical director or administrative codes of the state or commonwealth.

Case-by-Case Review
Ideally the medical director or designated representative should review every event in which an AED is used (or could have been used). This means every incident in which CPR was performed or an AED used should undergo a medical review to establish whether the patient was treated according to professional standards and local standing orders. Medical reviews should also determine whether VF and other rhythms were treated appropriately with defibrillation and BLS. Other dimensions of performance that can be evaluated include command of the scene, safety, efficiency, speed, professionalism, ability to troubleshoot, completeness of patient care, and interactions with other professionals and bystanders.

Quality Assurance
Organized collection and review of patient data can identify systemwide problems and allow assessment of each link in the Chain of Survival for the adult victim of sudden cardiac death. The Utstein Guidelines for reporting out-of-hospital cardiac arrest data present the recommended data to enable quality assurance monitoring for EMS and resuscitation programs (see also “Part 12: From Science to Survival”). This data collection constitutes quality assurance activities and as such should not expose clinical providers or organizations to increased risk of liability. Adult victims of witnessed cardiac arrest of presumed cardiac etiology caused by VF appear to be the best group on which to focus. A lower-than-expected hospital discharge rate in this group may be explained by long ambulance response times, delayed activation of EMS, infrequent witnessed arrests, rare bystander CPR, or slow on-scene times to defibrillation. Each of these problems can be addressed with a specific programwide effort. Continued systematic and uniform data collection will determine whether the new efforts succeed.

Emergency Cardiovascular Care Systems and the AED

The ECC Systems Concept
The term “Chain of Survival” provides a useful metaphor for the elements of the ECC systems concept, summarizing the best approach to treatment of persons in sudden cardiac arrest. The 4 links in the chain are early access to the EMS system, early CPR, early defibrillation, and early advanced cardiovascular life support. Epidemiological and clinical research have established that effective emergency cardiovascular care, whether in or out of hospital, requires that each of these links be strong, yet all are interconnected. The effectiveness of early defibrillation and PAD programs also depends on a strong Chain of Survival in the community.

Early Defibrillation
Early defibrillation with an AED has established benefit. The principle of early defibrillation suggests that the first person to arrive at the scene of a cardiac arrest should have a defibrillator. This principle is now internationally accepted. Healthcare providers with a duty to perform CPR should be trained, equipped, and authorized to attempt defibrillation (Class IIa). Healthcare providers who may be first responders include BLS ambulance providers, hospital-based healthcare providers, and trained laypersons in PAD programs.

Out-of-Hospital BLS Providers and AEDs
BLS emergency medical responders have different names in different countries, but BLS providers are the most common type of emergency responder in the world. These responders provide BLS but do not provide invasive interventions such as tracheal intubation, IV access, or IV medications. In Europe, BLS providers are often called “ambulance men,” “ambulance drivers,” or “ambulance personnel.” In the United States they are usually called “emergency medical technicians” (EMTs). In these Guidelines they are referred to as “BLS personnel,” “BLS rescuers,” “BLS providers,” or “BLS ambulance personnel.” Because BLS providers are typically the first emergency personnel to reach the scene of an out-of-hospital cardiac arrest, they can provide rapid defibrillation with an AED.

Early studies demonstrated a trend to superior survival rates with the use of AEDs in out-of-hospital cardiac arrest by BLS ambulance providers. These studies also established many practical advantages of AED use by BLS ambulance providers, including easy, brief, and inexpensive initial training and continuing education, as well as evidence that AEDs can be operated more quickly than conventional defibrillators. Subsequent studies have confirmed these findings, including AED accuracy, shorter times to defibrillation, faster application of subsequent ACLS interventions, and comparable survival. Taken together, these studies stand as powerful confirmation of the value of early defibrillation by out-of-hospital emergency personnel.

The clinical benefits and practical superiority of the AED are well established. Early defibrillation is recommended as a standard of care for EMS except in sparsely populated and remote settings, where the frequency of cardiac arrest is low and rescuer response times are excessively long.

In-Hospital Use of AEDs
An approach pioneered by William Kaye and others is now being used by many hospitals: general care nurses are being trained to use AEDs in resuscitation attempts. Hospital records were examined in several hospitals before AED placement to determine the average in-hospital time to first shock. This examination documented an unexpected and disturbing performance problem in many medical facilities:
long delays (5 to 10 minutes) before conventional in-hospital response teams first attempt defibrillation.\textsuperscript{176,177} Delayed defibrillation occurs infrequently in monitored beds and critical care units, but it occurs more often in unmonitored hospital beds and outpatient and diagnostic facilities, which hundreds of patients enter and leave each day. In such areas several minutes may elapse before centralized response teams arrive with a defibrillator, attach it, and deliver shocks.\textsuperscript{176} Resuscitation committees may inappropriately place more emphasis on arrival of the resuscitation team than on delivery of the first defibrillatory shock.\textsuperscript{30} As with out-of-hospital care, in-hospital practice must shift from a focus on CPR as the core of BLS care.\textsuperscript{30,178}

In recognition of the new AED technology, BLS has expanded to include CPR and defibrillation. An unacceptably high percentage of hospitals lack methods to assess resuscitation performance, underuse personnel in resuscitative efforts, and have not made significant attempts to improve the availability of early defibrillation by placing AEDs in non-critical care areas.\textsuperscript{179,180}

Several obstacles must be overcome before a quality early defibrillation program in which AEDs are used can be successfully implemented in the hospital. Nurses can be trained to use an AED and retain the skills needed for its safe and effective operation.\textsuperscript{30,181}

Strategic deployment of AEDs throughout hospital areas and authorization and training of first-responding personnel in their use is necessary to bring in-hospital use of AEDs up to the level of the out-of-hospital setting.\textsuperscript{32,33}

Documentation of in-hospital resuscitation events is often inaccurate and therefore unreliable in making quantitative assessments of such critical components as time to defibrillation and other interventions during resuscitation. This must be corrected before any data can be considered reliable enough to provide accurate assessment of resuscitation practices.

The absence of in-hospital early defibrillation programs is evident in the scarcity of data related to deployment of AEDs in hospital and its impact on patient outcome.\textsuperscript{52} Some studies have documented the components of a successful program such as acquisition and retention of skills in AED use by nurses, including a recommendation that AED use be incorporated into BLS training of all hospital personnel expected to respond to a cardiac arrest.\textsuperscript{30} Early defibrillation capability should be available in ambulatory care facilities as well as throughout hospital inpatient areas.

The International Liaison Committee on Resuscitation and the European Resuscitation Council have included in their guidelines formal recommendations for establishing in-hospital early defibrillation programs.\textsuperscript{59,90,182}

One regulatory organization is attempting to improve systemwide response to resuscitation. In the United States, the Joint Commission for the Accreditation of Healthcare Organizations (JCAHO) altered its standards for individual in-hospital resuscitation capabilities by evaluating the following characteristics: \textsuperscript{183}:

1. Appropriate policies, procedures, processes, or protocols for provision of resuscitation services

2. Appropriate equipment placed strategically throughout the hospital close to areas where patients are likely to need resuscitation services

3. Ongoing review of outcomes related to resuscitation in the aggregate to identify opportunities for improvement of resuscitative efforts

4. Appropriate staff trained and competent to recognize the need for and use of designated equipment in resuscitative efforts

5. Appropriate data collection related to the process and outcomes of resuscitation, particularly the ability to track trends and changes over several years

The AHA has established the National Registry of Cardiopulmonary Resuscitation to assist participating hospitals with systematic data collection of resuscitative efforts. The objectives of the registry are to develop a well-defined database documenting resuscitation performance of hospitals over time. This information can establish a hospital’s baseline performance, target problem areas, and identify opportunities for improvement in data collection and the resuscitation program in general. The registry is also the largest repository of information on in-hospital cardiopulmonary arrest. Patterned after the highly respected British Resuscitation Study (Bresus), the registry is based on the Utstein Guidelines for collecting and reporting information from in-hospital resuscitation events.\textsuperscript{184} Further guidelines for in-hospital resuscitation will emerge from future analyses of the large database provided by the registry. Participation in the registry will also allow hospitals to fully comply with the new JCAHO standards.

The capability to provide early defibrillation within patient-care areas is an obligation of the modern hospital. Early defibrillation is achieved by having defibrillators (including AEDs), ventilation equipment, and trained responders available throughout hospitals and affiliated outpatient facilities (Class IIA). The goal for all hospitals should be to have first responders provide early defibrillation to collapsed patients in VF in all areas of the hospital and ambulatory care facilities (Class I). The principle of early defibrillation should be “the earlier the better,” and evaluation and intervention should occur when prolonged collapse-to-shock intervals are documented. Experts at the international Guidelines 2000 Conference endorsed a goal of 3±1 minutes for the collapse-to-shock interval for a high percentage of in-hospital arrests.

When medical quality assurance monitoring is instituted, it is important to note that recorded response-time intervals for in-hospital resuscitation events are notoriously inaccurate. The most common methods used to time events are unsynchronized wristwatches and wall and bedside clocks. This asynchrony must be corrected before documentation of times to defibrillation will be consistently reliable. In many countries AEDs could easily be equipped with a timing mechanism that is synchronized with governmental atomic clock satellites. The AED clock could then become the gold standard for timing resuscitation events. Accurate time-interval data must be obtained because it is the key to future high-quality research (Class IIA).

Public Access Defibrillation

The concept of early defibrillation with AEDs was originally developed and explored by Douglas Chamberlain in Brigh-
tion, England, where AEDs were placed in train stations and commercial aircraft, and by Mickey Eisenberg in King County, Washington, who placed AEDs with families of high-risk patients. To develop strategies to implement programs of early defibrillation in the community, the AHA Task Force on Early Defibrillation hosted 2 conferences (in 1994 and 1997) on the subject of PAD.27,28

The recommendations that emerged from those conferences included the recognition that AEDs are the most promising method for achieving rapid defibrillation and that AEDs and training in their use should be accessible to the community.27,28 Advisory statements from ILCOR (1997)185 and the European Resuscitation Council (1998)182 affirmed the importance of early defibrillation programs.

Placement of AEDs in selected locations for immediate use by trained laypersons may be the key intervention to significantly increase survival from out-of-hospital cardiac arrest. The demonstrated safety and effectiveness of the AED make it an ideal source of early defibrillation by trained laypersons.52,62 Conceptually the AED and rescuer function as a sharp diagnostic and therapeutic probe searching for just 1 phenomenon—VF/pulseless (no circulation) VT—and providing a potentially lifesaving therapy over just a few seconds. AEDs are of no value for non-VF/pulseless VT arrest and provide no benefit after VF/pulseless VT has been terminated. Therefore, the rescuer must also be trained to open the airway and support ventilation and circulation with chest compressions as needed. For this reason, all persons who operate an AED still must be trained to recognize emergencies, including cardiac arrest, and to provide effective CPR.

PAD Rescuers
PAD implies expanded use of AEDs in the community to the broadest possible number of rescuers while maintaining safety and effectiveness.27,28,186 Within the next few years an increasing range of laypersons and healthcare professionals will learn the combined skills of CPR and AED use. These diverse groups can be roughly categorized into 3 levels of PAD responders, although the number and type of such responders change daily.

Level 1: Nontraditional Responders
Nontraditional responders are persons other than healthcare personnel, such as police, firefighters, security personnel, sports marshals, ski patrol members, ferryboat crews, and flight attendants, whose job duties require them to respond to an emergency. Traditionally, however, they have not been asked or expected to take any action other than to perform basic CPR.

Level 2: Targeted Responders
Targeted, or worksite, responders, who may also be called “citizen responders,” frequently participate in PAD programs. These responders are employees of companies, corporations, or public facilities with established PAD programs. Their location at the worksite (eg, central reception area staff) makes them a natural choice to be the primary responder with the AED. PAD programs can shorten the time to defibrillation and improve the chance of survival from sudden cardiac death in the workplace or community.

Level 3: Responders to Persons at High Risk
Family members and friends living with or visiting persons at high risk for cardiac emergencies are another potential category of responders. They often participate in early defibrillation programs and are taught CPR and use of an AED when a friend or loved one is at high risk for sudden cardiac death.

Deployment Strategies for PAD Programs
Before deploying AEDs, PAD program directors should determine whether the population in the geographic area covered by the program will be likely to benefit from it. Some PAD planners target locations with a large concentration of persons >50 years old, such as senior citizen centers.187 Implementation of AED programs in places where >10 000 people gather has been recommended for consideration.188 Ideally program planners should review communitywide cardiac arrest data, identify sites with the highest incidence of cardiac arrest, and target those locations for AED placement.

Location
Some data is available on the location and frequency of cardiac arrest events in metropolitan areas. In Seattle and King County, Washington, for example, the incidence of cardiac arrest is greatest at the international airport, then (in decreasing order of frequency) county correctional facilities, shopping malls, public sports venues, industrial sites, golf courses, shelters, ferries/train terminals, health clubs/gyms, and community/senior centers.189 The site-specific incidence and need for specific distribution of AEDs within those sites is likely to vary with each community. To optimize the benefit of limited healthcare resources in each community, program planners must provide AEDs and make trained rescuers available in locations with the highest incidence of cardiac arrest.

Accordingly, the evidence supports establishment of PAD programs at sites in which

1. The frequency of cardiac arrest events is such that there is a reasonable probability of AED use (an estimated event rate of 1 sudden cardiac arrest per 1000 person-years).
2. An EMS call–to–shock time interval of <5 minutes cannot be reliably achieved with conventional EMS services.
3. An EMS call–to–shock time interval of <5 minutes can be reliably achieved (in >90% of cases) by training and equipping laypersons to function as first responders in the community EMS system, recognizing cardiac arrest, phoning 911 (or another appropriate emergency telephone number), initiating CPR, and attaching/operating an AED.

For level 1 responders, such as police, firefighters, security personnel, ski patrol members, ferryboat crews, and flight attendants, this is a Class IIa recommendation. For level 2 targeted responders, such as citizens at worksites or in public places, this is a Class Indeterminate recommendation at this
time. It is hoped that data from a prospective, randomized multicenter trial regarding PAD will justify a change in this class of recommendation. For level 3 responders (family and friends of persons at high risk), the above recommendation is a Class Indeterminate recommendation.

Coordination With EMS Systems
PAD program planners should attempt to coordinate PAD programs with the local EMS system. This may include but is not limited to medical direction, assistance in planning AED deployment and AED protocols, training, continuous quality improvement, monitoring, and review of AED events. Integration with the local EMS dispatch system is important because many dispatch systems use phone-directed protocols to assist rescuers in the use of the AED if needed and will notify EMS en route that an AED is being used at the scene.

The American College of Emergency Physicians has issued a policy statement endorsing coordination with EMS systems to ensure medical direction of AED programs, including those in which bystanders use AEDs. Many other international organizations have issued similar recommendations.

Elements of Successful PAD Programs
Objective data on details of successful PAD programs is lacking. Nonetheless, rational conjecture plus data extrapolated from other sources have identified many elements as keys to successful PAD programs. There must be a strong Chain of Survival within the community. Innovative methods of providing effective, quality training to laypersons in the use of AEDs is important. Incorporating EMS dispatch into PAD programs allows dispatchers to direct a caller to the nearest AED location and provide instruction by telephone if needed. It also allows the EMS personnel to learn to operate specific types of AEDs in advance, enabling seamless patient care.

Careful planning, training, communication with the EMS system, and continuous quality improvement are vital to a successful PAD program. The program director should carefully select AED users who are motivated, available during the expected response period, and capable of performing their duties. A specific response plan should be implemented within each site, targeting a collapse-to-defibrillation time ≤4 to 5 minutes (eg, AEDs located throughout the facility so that the walk to retrieve an AED is no more than 1.5 minutes). Frequent unannounced practice drills and evaluations of performance and response time are recommended.

The most frequent cause of AED malfunction is lack of maintenance. Maintaining the device according to the manufacturer’s specifications is essential. Regular system evaluations should be conducted.

PAD program directors must also attend to the emotional needs of lay rescuers, who are not accustomed to providing lifesaving care in an emergency. Case-by-case review with laypersons and critical incident stress debriefing provide important support for PAD program participants. Medical direction includes responsibility for quality of training and medical care provided by PAD lay responders. PAD programs must comply with local or regional regulation and legislation.

Effectiveness of PAD Programs
Several studies have demonstrated the cost-effectiveness of AED use by BLS ambulance providers and PAD programs compared with other medical interventions. This data establishes the substantial survival benefits and attractive cost-effectiveness of a well-designed and well-implemented PAD program.

The National Heart, Lung, and Blood Institute (NHLBI), in partnership with the AHA and industry, has embarked on a multisite, controlled, prospective clinical trial to determine the efficacy and cost-effectiveness of placing AEDs in a variety of public settings. Such definitive scientific evidence is essential for decision making related to the potentially huge PAD initiative. Final results from the PAD trial are not expected for at least 3 years. The results of a large, controlled, randomized, multicenter, prospective clinical trial will eventually be needed for PAD to be considered a Class I recommendation.

Education and Training
Skills Maintenance
Survey results and experience in rural communities have demonstrated that emergency responders may go several years without treating a patient in cardiac arrest. Therefore, every program director must determine how to ensure correct performance of BLS and automated external defibrillation. Principles of adult education suggest that frequent practice of psychomotor skills such as use of an AED in a simulated cardiac arrest offers the best opportunity for skills maintenance.

Frequency of Practice
The frequency and content of these practice sessions have been established by several successful programs. At present many programs provide practice drills every 3 to 6 months and have found this interval satisfactory. Many EMS personnel and systems drill as often as once a month. The most successful long-term skills maintenance occurs when individual rescuers perform a quick check of the equipment frequently and regularly. This check includes a visual inspection of the defibrillator components and controls and a mental review of the steps to take and controls to operate during a cardiac arrest.

The AHA ECC Committee and international expert panels encourage routine skills review and practice sessions at least every 6 months.

Future of PAD
The future of PAD is likely to include further improvements in device design, making AEDs easier to use, lighter, and less expensive. Public access to AEDs is increasing, and implementation of AEDs in a diversity of settings is growing as well. Automated external defibrillation will continue to increase survival from VF if AED programs are well implemented and AEDs are used within the first few minutes after cardiac arrest.

References

Part 4: Automated External Defibrillator


Part 4: The Automated External Defibrillator: Key Link in the Chain of Survival

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