Fighting cardiac arrest: Automated external defibrillator

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Abstract

Ventricular tachyarrhythmias – Ventricular fibrillation (VF) and Ventricular tachycardia (VT) account for most of out-of-hospital sudden cardiac arrests. Defibrillation is the specific therapy for VF/pulseless VT. Time to defibrillation is the most important determinant of survival from these cardiac arrests. Automated external defibrillator (AED) has largely replaced the conventional defibrillator in Basic life support (BLS) programmes for out-of-hospital cardiac arrests. AED use by trained laypersons in the community as part of Public Access Defibrillation (PAD) programmes has significantly reduced time to defibrillation and increased survival. AED is now being stipulated for home use in people at high risk of sudden cardiac death. AED placement is also recommended in all areas of hospital. Physicians and Intensivists should strive to familiarize the medical fraternity in our country with AED use so that PAD programmes can be launched in the near future.

Key Words: Cardiac arrest, Defibrillation, Automated External Defibrillator, Public access defibrillation.

Introduction

Automated External Defibrillator (AED) has largely replaced the conventional defibrillator for providing early defibrillation as part of Basic Life Support (BLS) programmes in individuals experiencing a cardiac arrest.1-3 AED use for providing early defibrillation is an important link in the ‘Chain of survival’. ‘Chain of survival’ refers to a sequence of events, which, if carried out correctly and in rapid succession increase survival from cardiac arrest. These include – Early access to Emergency Medical Services, Early Cardiopulmonary Resuscitation (CPR), Early Defibrillation and Early Advanced Cardiac Life Support (ACLS).4,5 In this article we review the role of AED as a tool for providing early defibrillation.

Early defibrillation: crucial link in the chain of survival

The cardinal event in a cardiac arrest is an arrhythmia. Most patients with primary out-of-hospital sudden cardiac arrest exhibit ventricular tachyarrhythmias in form of Ventricular fibrillation (VF) or Ventricular tachycardia (VT) degenerating into VF (85%); the remaining demonstrate bradyarrhythmias or asystole.6,7 In its natural course VF converts to asystole within a few minutes. Defibrillation is the specific therapy for VF and pulseless VT. Defibrillation reestablishes normal cardiac rhythm. Successful defibrillation is defined as absence of VF five seconds after delivering the shock.8,9 Most cardiac arrest survivors are those who remain in VF when emergency personnel arrive.6,7 Cardiopulmonary Resuscitation (CPR) prolongs VF thereby preserving some circulation to brain and heart till a defibrillator is available; however CPR does not provide a means of defibrillation.10 Defibrillation should precede CPR when a defibrillator is available immediately for an out of hospital cardiac arrest due to VF/pulseless VT. CPR should precede defibrillation in all other cases.11 Long-term survival among patients who have undergone rapid defibrillation for an out-of-hospital cardiac arrest is comparable to those who did not have an out-of-hospital cardiac arrest with a quality of life which is similar to that of the general population.12
Time to defibrillation is the most important determinant of survival from cardiac arrest.\textsuperscript{13-15} A survival rate of 90\% has been reported amongst victims of witnessed ventricular fibrillation cardiac arrest when defibrillation is achieved within the first minute of collapse.\textsuperscript{16} The chances of survival decrease by 7-10\% for every minute that passes without defibrillation.\textsuperscript{17} Early defibrillation implies that defibrillation is carried out within five minutes of cardiac arrest by the trained rescuer who arrives first (first responder) at the scene of a cardiac arrest.\textsuperscript{1,5} Early defibrillation programmes with trained responders even without the backup of out-of-hospital Advanced Cardiac Life Support (ACLS) services have achieved time to defibrillation of less than five minutes and increased survival rates from an average of 5-10\% to 15-40\%.\textsuperscript{18-25}

**AED: Implementing early defibrillation**

**When and how to use an AED?**

A present day AED is a small, portable, user-friendly, microprocessor based, lithium battery operated device that is capable of delivering shocks to patients of cardiac arrest due to VF/VT. AED should be used only after confirming cardiac arrest. The patient should be unresponsive and without signs of circulation. In the absence of spontaneous breathing 2 – 5 rescue breaths are given to the patient before using an AED. In case the operator does not know how to feel for the pulse of the patient, the verification of unresponsiveness, absence of breathing and movement are sufficient indicators to go ahead with AED use.

The victim should be placed in a supine position. The AED should be placed next to the victim’s left ear. This position allows the first rescuer to operate the AED while a second rescuer provides CPR from the right. The operator switches on the device and attaches disposable electrodes of AED at specified positions (right infraclavicular and left infra-axillary area lateral to the left nipple) on the victim’s chest. He then plugs in the electrode cables into the AED. The AED registers and recognizes the arrhythmogenic rhythm in approximately 10 seconds. If the rhythm is a VF/VT warranting defibrillation, it instructs the operator (semi-automatic) to or automatically delivers a shock (automatic) to the victim. If the rhythm is a bradycardia or asystole not requiring defibrillation it instructs the operator not to shock the patient. Universal steps for AED operation are summarized in Box 1.

**What are the precautions to be taken while using an AED?**

Precautions to be taken while using AED are listed in Box 2.

**When should one not use an AED?**

AED use is contraindicated in a responsive patient, unresponsive patient with signs of circulation, children under 8 years (25 kgs) and when the victim is in water.

**What is its accuracy in arrhythmia detection?**

AED is highly accurate in arrhythmia detection.\textsuperscript{1,8,26-28} Several features of the surface ECG are used for analyzing the rhythm by AED. A high sensitivity is required for detection of shockable rhythms while a high specificity is required for detection of non-shockable rhythms. Errors can be machine or operator dependent. The AED may not detect certain shockable rhythms like an extremely fine or coarse VF, certain forms of VT, resulting in no shock being delivered. Non adherence to operating instructions can also result in missing shockable rhythms.\textsuperscript{29}

**How does it deliver the energy?**

**Monophasic vs. biphasic waveforms:**

AED delivers energy in a biphasic waveform. The conventional and early automated defibrillators provided energy in a monophasic waveform in which current flows in one direction only. Monophasic waveform can be further classified depending on the speed with which the

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**Box 1: The AED sequence**

- Switch ON the device
- ATTACH electrodes to patient and cable to device
- Wait for RHYTHM ANALYSIS
- SHOCK if indicated

**Box 2: Precautions while using AED**

1. Cervical spine is to be immobilized before shocking in case of suspected fracture
2. CPR is to be stopped before attaching pads
3. Chest should be wiped dry (water, sweat) before placing electrodes
4. Place and remove an electrode set on a hairy chest; then place a second set
5. Transdermal drug patch be removed if stuck over area required for electrodes
6. Do not place electrodes directly over an ICD or Pacemaker
7. No movement should occur during rhythm analysis (stretcher, ambulance)
8. Avoid fuel, oxygen, flammable anesthetic rich atmospheres
9. Do not use cell phones, two-way radio
10. All personnel should be clear of patient before shocking
waveform returns to zero voltage - as damped sinusoidal when there is a gradual return or truncated exponential when the voltage instantaneously drops to zero. Present day AED have various waveforms for defibrillation of which the biphasic truncated waveform has been studied extensively. In this waveform current flows in two directions - initially in a positive direction and subsequently in a negative direction. Biphasic waveforms use less energy thus allowing the defibrillator to be smaller, lighter, cheaper, requiring a low maintenance cost; thus making it handy to be used in early defibrillation programmes. The American Heart Association (AHA) has approved low energy defibrillation with biphasic waveform AED for VF/pulseless VT.

Impedance based adjustments

AED has the capacity to make impedance-based adjustments to current and voltage. This along with the biphasic waveform ensures that adequate amounts of defibrillation energy are delivered. Thus present day AED with biphasic waveform and impedance adjustments deliver lower amounts of energy whose efficacy is equivalent to higher energy levels delivered by conventional monophasic defibrillators. This also precludes the need for increasing energy levels in successive shocks as in conventional monophasic defibrillators.

Defibrillation versus Cardioversion

An AED delivers unsynchronized shocks (defibrillates) and does not have the ability for providing synchronized shocks (cardioversion). It is programmed to defibrillate all cases of monomorphic and polymorphic VT when the tachycardia rate exceeds programmed values (usually 180 bpm). Hence prior verification of pulselessness is an essential prerequisite to avoid inadvertent shocking of patient with signs of circulation.

Three - shock sequence

The AED is programmed to deliver a 3-shock sequence. This implies that the rhythm is analyzed after the first shock, if it is still amenable to shocks a second shock is advised, the rhythm is reanalyzed after the second shock, and if it is still amenable to shocks a third shock is advised. If at any point in this sequence the rhythm is not found to be amenable to shocks the AED will display a ‘no shock’ message and in that case CPR should be

<table>
<thead>
<tr>
<th>Algorithm for AED Use in Out-of-Hospital Primary Cardiac Arrest (Based on American Heart Association BLS Protocol)</th>
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<tbody>
<tr>
<td>VERIFY UNRESPONSIVENESS CALL FOR HELP WITH DEFIBRILLATOR</td>
</tr>
<tr>
<td>CHECK AIRWAY</td>
</tr>
<tr>
<td>CHECK BREATHING</td>
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<tr>
<td>2 RESCUE BREATHS IF BREATHING INADEQUATE OR ABSENT</td>
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<tr>
<td>CHECK SIGNS OF CIRCULATION</td>
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<tr>
<td>• ABSENT BREATHING, COUGHING &amp; SPONTANEOUS MOVEMENT IN RESPONSE TO RESCUE BREATHS FOR LAY RESCUERS</td>
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<td>• ABSENT PULSE FOR TRAINED RESCUERS</td>
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<td>SIGNS OF CIRCULATION ABSENT</td>
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<tr>
<td>AED AVAILABLE AT HAND</td>
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<td>AED NOT AT HAND</td>
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<tr>
<td>ATTACH AND DEFIBRILLATE IF VF/VT (SHOCK ADVISED)</td>
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<tr>
<td>CPR TILL AED ARRIVES</td>
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<tr>
<td>SHOCK-CPR SEQUENCE</td>
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<tr>
<td>IF NO VF/VT GIVE CPR TILL ACLS AVAILABLE</td>
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commenced. On completion of the 3-shock sequence pulselessness should be reconfirmed and CPR commenced. This 3-shock sequence provides the highest defibrillation rates and is recommended for best results.

**What is the amount of energy delivered?**

A monophasic AED is operated to deliver an escalating energy sequence of 200 J → 200-300 J → 360 J to increase success rate without increasing cardio-toxicity. A biphasic AED has a pre-configured automated protocol which can be manually overridden as is specified in the manufacturer’s instructions. It delivers a fixed non-escalating 3 shock sequence of 150 J or 200 J. All shocks are in quick succession with intermittent pauses just long enough to assess the rhythm. CPR should be resumed after the third shock. The effectiveness of first and successive low energy shocks with biphasic waveform is comparable or higher to the 200 J initial shock and 360 J repeated shocks of the monophasic waveform for persistent VF/pulseless VT. AED also delivers the first shock almost a minute faster than the conventional defibrillator. Thus energy delivered from biphasic waveform impedance compensated AED provide an effective means of defibrillation.

**How to assess response to defibrillation?**

Successful defibrillation is defined as absence of VF five seconds after delivering the shock. On completion of the 3 shock sequence the patient should be reassessed. If signs of circulation are present and patient is breathing spontaneously he should be placed in the recovery position. If circulation is present but there is no spontaneous breathing he should be given artificial breaths at the rate of 10-12 per minute. If signs of circulation are absent CPR should be resumed and continued for one minute after which the AED rhythm should be reanalyzed. If AED indicates that the rhythm is shockable the 3-shock sequence should be followed. If the AED gives a ‘no shock’ message CPR should be resumed and continued for one minute after which the AED rhythm should be reanalyzed. The 3 shock – CPR sequence should continue till ACLS is available or AED continuously displays ‘no shock’ message. Correct sequence of CPR and AED use results in increased survival. The AED automatically guides the operator through the 3-shock – CPR sequence. Newer AED have sensors in their electrodes which sense the rate and depth of chest compressions to assess efficacy of CPR, and the same is conveyed to the operator by audio prompts from the device. Integrating a CPR feedback protocol into an AED improves the quality of CPR.

**How safe is the device?**

AED is an extremely safe device in hands of trained personnel as well as untrained freshly acquainted personnel. The operating instructions are easy to understand and the device guides the operator through sequential steps of defibrillation and CPR by audio instructions. The rhythm recognition is highly accurate. Failure to follow the operating instructions rarely leads to accidental shocking (<0.1%). AED should meet the safety guidelines laid down by the American Heart Association Task Force on Automatic External Defibrillation, its Subcommittee on AED Safety and Efficacy, and the AED Manufacturers’ Panel.

**What are the problems encountered while using AED?**

Problems are minimal if the device has been maintained as per manufacturer’s instructions and standard operating instructions are followed. Most of the AED have a self check system and are programmed to carry out regular checks. Rhythm artifacts can arise due to movement of patient (stretcher, ambulance), agonal respiration, radio signals and other environmental features. An occasional failure to shock may be due to an inability to sense the rhythm. The potential for accidental shocking of responsive patients and bystanders will always exist. These problems can be minimized by strictly adhering to the operating instructions e.g. if AED has to be used in an ambulance the vehicle has to be stopped to prevent motion artifacts. The best defibrillation rates can only be obtained if all links in the Chain of survival should are strong. The device can also be misused. Problems may arise when the device is used in patients with an Implantable Cardioverter Defibrillator (ICD) and Permanent pacemaker. Placing AED electrodes on top of the ICD or pacemaker reduces the efficacy of defibrillation and increases the chances of malfunction of the implanted device. The AED electrodes should be placed at least 2.5 cm away from the implanted device. An ICD which is not functioning effectively should be disabled by placing a magnet over it. There may be a discordance between the AED and ICD rhythm analysis and shock cycles. The patient should not be shocked for at least 30-60 seconds after completion of the ICD shock cycle. AED is not a substi-
tute for an ICD. Individuals at high risk for ventricular arrhythmias benefit most from an ICD.44

Who should operate the AED?
AED should be operated by trained personnel. The trained personnel can be paramedics; or those employed in a job requiring handling of emergencies - police officers, security guards, firefighters, ambulance personnel, airline crews, lifeguards amongst others, the so called ‘nontraditional responders’; or personnel employed at locations covered under existing defibrillation programmes, the ‘targeted responders’; and family members of high risk patients.2,3,18

As the device is simple to use and knowledge of arrhythmia recognition is not required it can be operated efficiently by non-medical personnel. AED use is thus no longer restricted to the medical or paramedical fraternity. This concept of AED use by trained community personnel has significantly reduced time to defibrillation in out of hospital cardiac arrests.

Where should the AED be located?
Cardiac arrests can occur in an out-of-hospital or in-hospital setting. The former include community and home settings. Ideally an AED should be available at hand whenever an arrest occurs. However this is not a practical option because of the high cost of the device.

Community placement:
AED have been placed in public places to facilitate use by trained laypersons. This concept of AED use by trained laypersons in the community is called PUBLIC ACCESS DEFIBRILLATION (PAD). PAD utilizes the time wasted in waiting for emergency medical services to arrive and defibrillate. The role of paramedics is carried out by trained non-medical personnel. This significantly cuts down the time to defibrillation which is the most important determinant of survival from VF cardiac arrest. VF account for majority of out-of-hospital cardiac arrests. PAD has the ‘potential to be the single greatest advance in the treatment of VF cardiac arrest since the development of CPR’.13-15

AED have been placed in aircraft, airports, casinos, golf courses, government buildings, health care facilities, merchant vessels, oil rigs, passenger cruise liners, police cars, railway stations, shopping malls, tourist places amongst others and have significantly reduced time to defibrillation while enhancing survival from out-of-hospital VF cardiac arrest19,45,46 AED use by community responders is legally permitted in several countries by means of Good Samaritan laws.47 AED use by non-physician is still not legally permitted in other countries. Community studies have to be carried out to locate places where AED should be deployed. These include sites where there is a probability of one sudden cardiac arrest per 1000 adult population per year (or one AED use in five years), or places where the time to defibrillation by emergency medical services exceeds five minutes, and places where AED use by nontraditional responders will reduce time to defibrillation to less than five minutes.

PAD programmes have been implemented in several communities around the world with excellent results. Most have achieved a time to defibrillation of less than five minutes and increased survival rates from an average of 5-10% to 15-40%.18-25 These programmes run under the supervision of a Physician. Public awareness, health education, trained and motivated personnel, strategic AED deployment and regular practice are required to run a successful PAD programme. Several studies have documented cost effectiveness of properly implemented PAD programmes.

Home placement:
A majority of out-of-hospital cardiac arrests occur at home and most of these are witnessed by attendants.48,49 This has raised the possibility of placing AED in individual houses for use in case of a cardiac arrest. It is postulated that this placement will benefit patients with risk factors for Sudden Cardiac Death (SCD). However due to the absence of clinical trials defining patient sub-sets, recommendation of ICD use for patients at high risk for ventricular arrhythmias, physician and public unawareness of SCD and AED use, and high cost (Rs 2 lakh onwards) involved the home use of AED has not yet become popular.

Hospital use:
AED should be deployed in all hospital areas to provide for early defibrillation. This increases survival from cardiac arrests in hospital. The in-hospital defibrillation time should be 3+/-1 minute.50,51 Nurses should be trained as first responders. Ambulances should be equipped with
AED but this will improve survival only if time to defibrillation is short.\textsuperscript{42}

**AED: Cost factor**

In India the minimum cost of an AED is two lakh rupees. Newer devices which have a monitor, biphasic waveform defibrillator and facilities for transcutaneous pacing are costlier. The rationale of investing in an AED for treating a sudden cardiac arrest rather than in lifestyle modification for primary prevention has also been questioned.\textsuperscript{52}

**Pediatric defibrillation: Current perspectives**

Defibrillation is currently only recommended for children >8 years (>25 kgs) in VF cardiac arrest. Contrary to adults VF accounts for only 15% of cardiac arrests in children.\textsuperscript{53} The predominant rhythm in pediatric cardiac arrests is asystole or pulseless electrical activity. Data on AED use in children suggest that AED is highly sensitive in rhythm detection but further studies are needed to establish its specificity and optimal energy dose.\textsuperscript{54} Current AED deliver energy of 150-200 J which is much higher than the recommended monophasic waveform energy of 2-4 J/kg body weight for children.

**Applicability: Indian scenario**

In context of present day health scenario in India the role of AED may be limited to a small number of private medical providers with hospital based resuscitation teams which rush to the site of emergency on receiving a call. This entails valuable time lost during transportation from hospital to site of cardiac arrest essentially limiting the utility of early defibrillation. A concept similar to Public access defibrillation lacks applicability in our country due to low literacy levels and awareness levels amongst public, lack of knowledge on sudden cardiac arrest and AED among doctors, paucity of resuscitation training programmes, absence of organized emergency medical services and the expense involved.

It is recommended that AED use be taught to medical and paramedical staff with a view to further spread the knowledge to non-medical personnel. AED should be initially deployed in hospitals, ambulances, large institutions, public gatherings, and remote areas deprived of basic medical facilities. Public awareness about SCD and AED should be increased with regular health education programmes. It is the duty of medical fraternity to lead the way in this movement.

**Conclusion**

AED is an important advance in combating VF cardiac arrest. PAD programmes are important in reducing time to defibrillation and increasing survival. We should strive to popularize AED use in our country.

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