Cardiac Defibrillators

Introduction:

Defibrillators are devices used to supply a strong electric shock to a patient in an effort to convert excessively fast and ineffective heart rhythm disorders to slower rhythms that allow the heart to pump more blood. Defibrillators have been in common use for many decades for emergency treatment of life-threatening cardiac rhythms as well as for elective treatment of less threatening rapid rhythms.

The most serious arrhythmia treated by a defibrillator is ventricular fibrillation. Without rapid treatment using a defibrillator, ventricular fibrillation (see figure 1) causes complete loss of cardiac function and death within minutes. Atrial fibrillation and the more organized rhythms of atrial flutter and ventricular tachycardia can be treated on a less emergent basis. Although they do not cause immediate death, their shortening of the interval between contractions can impair filling of the heart chambers and thus decrease cardiac output. Conventionally, treatment of ventricular fibrillation is called defibrillation, whereas treatment of the other tachycardia's is called cardioversion.

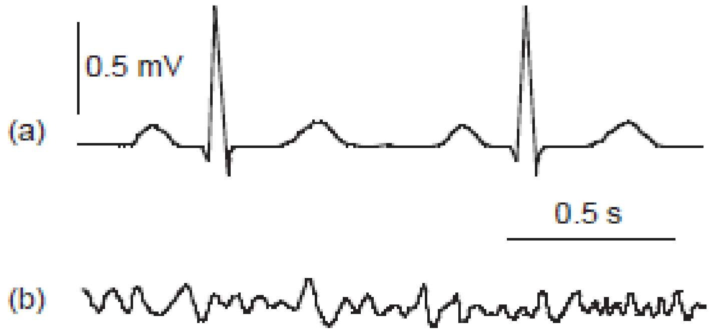


Figure 1. (a) A normal electrocardiogram (ECG). (b) The ECG during fibrillation.

SA node: (SA stands for sinoatrial) The SA node is the heart's natural pacemaker. The SA node consists of a cluster of cells that are situated in the upper part of the wall of the right atrium (the right upper chamber of the heart). The electrical impulses are generated there. The SA node is also called the sinus node

AV node : AV stands for Atrioventricular The AV node, which controls the heart rate, is one of the major elements in the cardiac conduction system. The AV node serves as an electrical relay station, slowing the electrical current sent by the sinoatrial (SA) node before the signal is permitted to pass down through to the ventricles.

Fibrillation

Fibrillation is the rapid, irregular, and unsynchronized contraction of muscle fibers.

There are two major classes of cardiac fibrillation: Atrial Fibrillation and Ventricular Fibrillation.

Atrial fibrillation: is an irregular and uncoordinated contraction of the cardiac muscle of atria.

Ventricular Fibrillation: is an irregular and uncoordinated contraction of the cardiac muscle of ventricles.

Defibrillation: is a process in which an electronic device sends an electric shock to the heart to stop an extremely rapid, irregular heartbeat, and restore the normal heart rhythm.

Defibrillation should be performed with in the first 8 minutes after cardiac arrest. Ideally, the sooner, the better.

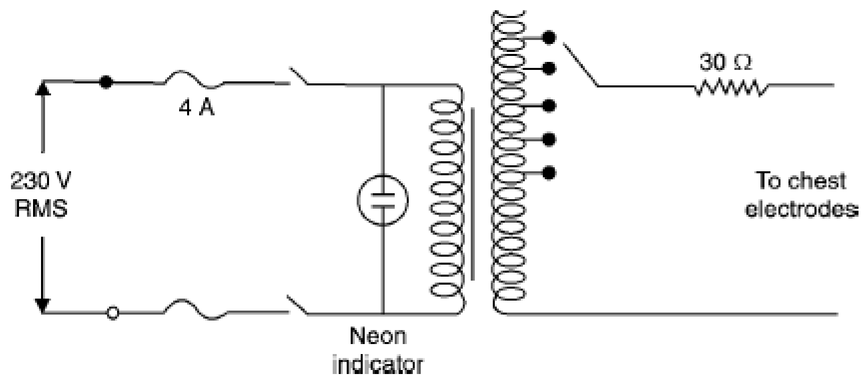
AC

Defibrillator:

Early A.C. Defibrillators needs 2 Amps on exposed heart and 5 Amps on closed heart, (50, 90 ohms), 60 Hz current, 100–300 V, and the recommended duration ¼ second only. Energy delivered = 500 watts per second.

AC defibrillator replaced by various DC defibrillators because:

1. DC signal has less deleterious effect on the heart than AC pulse.
2. DC has a diminished convulsive effect on skeletal muscles.
3. Can be used in the conversion of atrial arrhythmia as well.



AC Defibrillator circuit diagram

DC Defibrillator:

In almost all present day trans-thoracic defibrillators, an energy storage capacitor is charged at a relatively slow rate form AC line by means of step up transformer and rectifier arrangement, or from a battery and DC to DC converter arrangement. During trans-thoracic defibrillation the energy stored in the capacitor is then delivered at a relatively rapid rate (in order of milliseconds) to the chest of the subject. For effective defibrillation, it's advantageous to adopt some shaping of the discharge current pulse. The simplest arrangement involves the discharge of the capacitor energy through the patient's own resistance (R), this yields an exponential discharge typical of and RC circuit, if the discharge is truncated so that the ratio of the duration of the shock to the time constant of decay of the exponential waveform is small, the pulse of the current delivered to the chest has an nearly rectangular shape. For a somewhat larger ratio, the pulse of the current appears nearly trapezoidal rectangular and trapezoidal waveforms have also been found to be effective in the trans-thoracic defibrillation and such waveforms have been employed in defibrillators designed for clinical use.

The basic circuit diagram of a DC defibrillator is shown in figure 2. A variable auto-transformer T1 forms the primary of a high voltage transformer T2. The output voltage of the transformer is

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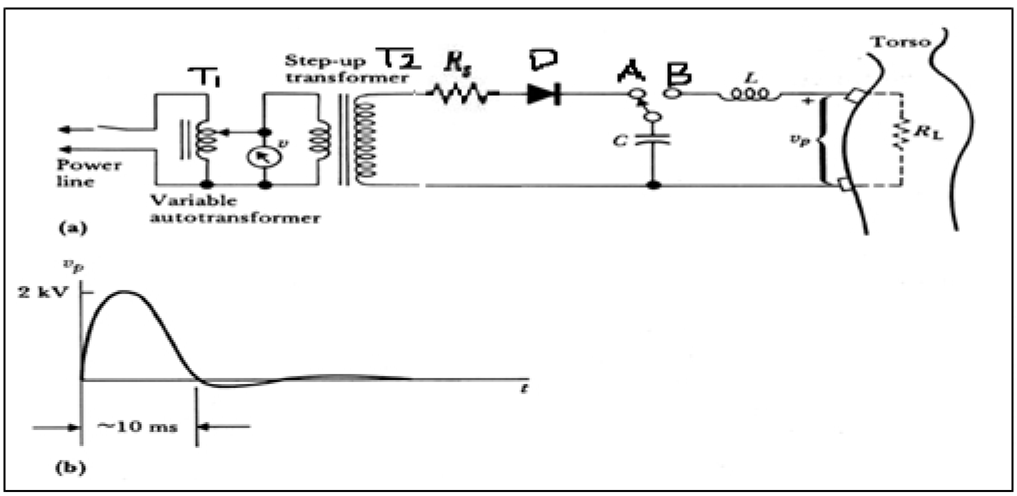
rectified by a diode rectifier and is connected to a vacuum type high voltage change-over switch. A series resistance Rs limits the charging current to protect the circuit components, and also helps to determine the time necessary to achieve a full charge on capacitor. In position a. the switch is connected to one end of an oil-filled 16 micro-farad capacitor. In this position, the capacitor charges to a voltage set by the positioning of the auto-transformer. When the shock is to be delivered to the patient, a foot switch or push button mounted on the handle of the electrode is operated. The high voltage switch changes over to position B and the capacitor is discharged across the heart through the electrodes.

In a defibrillator, an enormous voltage (about 4000V) is initially applied to the patient. The high current required impairs the contractility of the ventricles. This is overcome by inserting a current limiting inductor in series with the patient circuit. The disadvantage of using an inductor is that any practical inductor will have its own resistance and dissipates part of the energy during the discharge process. In practice, a 100 mH inductor will have a resistance of about 20 ohm. The energy delivered to the patient will, therefore, be only 71% of the stored energy.

The inductor also slows down the discharge from the capacitor by the induced counter voltage. This gives the output pulse a physiologically favorable shape, the shape of the waveform that appears across electrodes will depend upon the value of the capacitor and inductor used in the circuit.



a) Basic circuit diagram for a capacitive–discharge type of cardiac defibrillator. (b) A typical waveform of the discharge pulse. The actual waveshape is strongly dependent on the values of *L*, *C*, and the torso resistance *R*L

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It has been found experimentally that the success of defibrillation correlates better with amount of energy stored in the capacitor that with the value of the voltage used. It is for this reason that the output of a DC defibrillator is always calibrated in term of watt-seconds or joules as a measure of the electrical energy stored in the capacitor. The instrument usually provides output form 0-400 Ws and this range provides sufficient energy for both external and internal defibrillation.

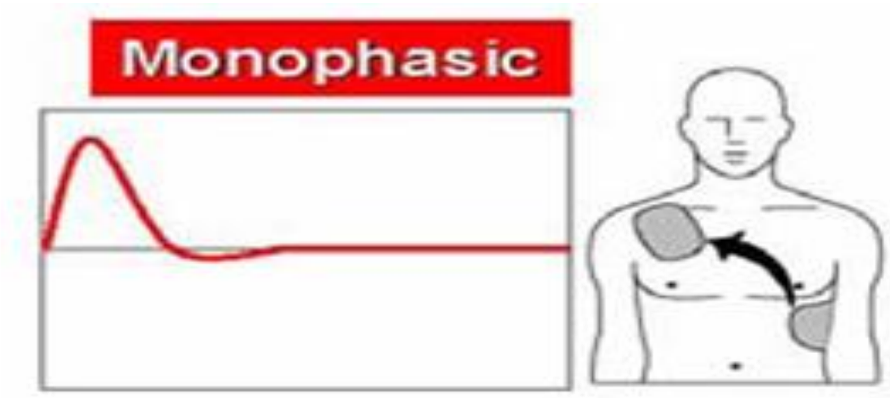
Energy in watt seconds is equal to, $E = 0.5\ CV^2$.If a 16 microfarad capacitor is used, then for the full output of 400 Ws to be available, the capacitor has to b charged to 7000 V.

<u>**Classification of Waveform**</u>

There are two general classes of waveforms:

1-Monophasic Waveform

A monophasic type, give a high-energy shock, up to 10 to 360 joules due to which increased cardiac injury and in burns the chest around the shock pad site**s**

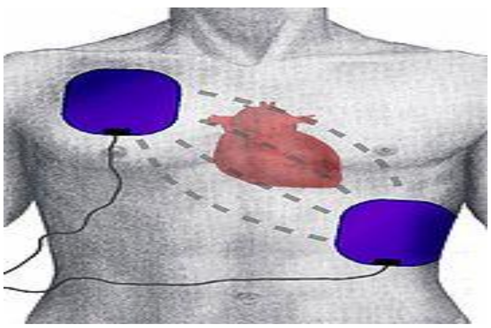


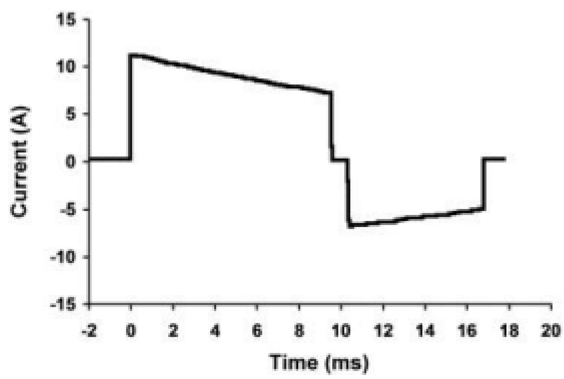
2-Biphasic Waveform

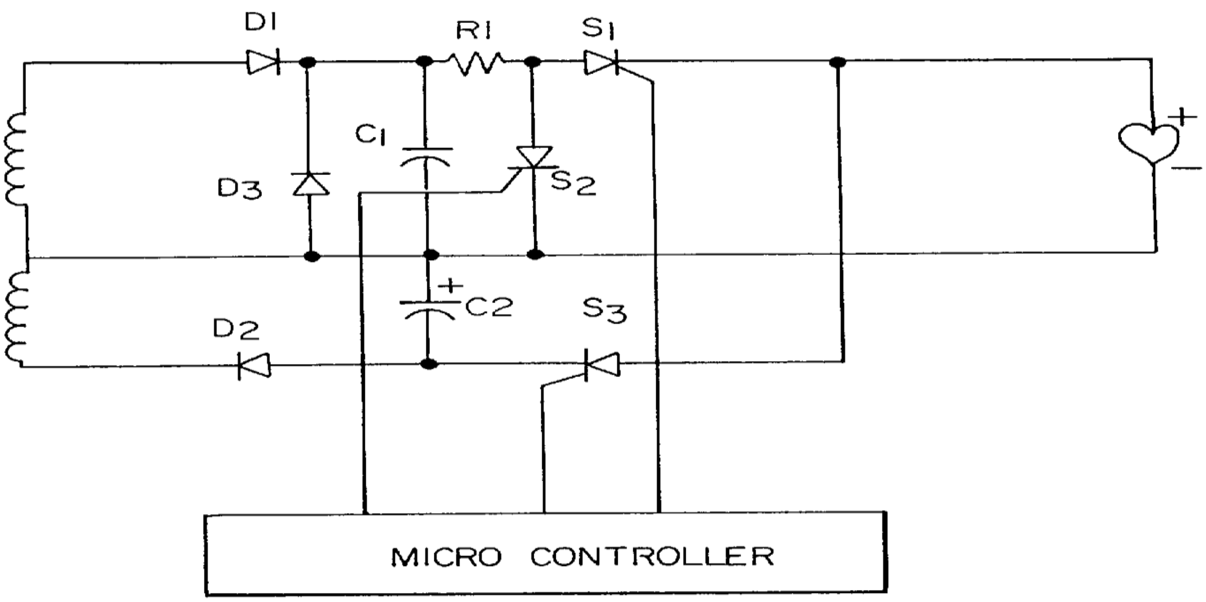
A biphasic type, give two sequential lower-energy shocks of 5 - 200 joules, with each shock moving in an opposite polarity between the pads.

Low energy biphasic shocks may be as effective as high energy monophasic shocks.

Biphasic waveform defibrillation used in implantable cardioverter defibrillator (ICD) and automatic external defibrillators.







b) circuit diagram of biphasic defibrillator

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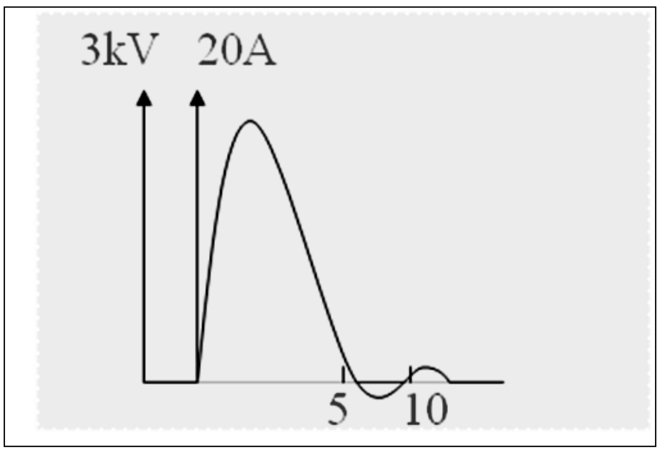
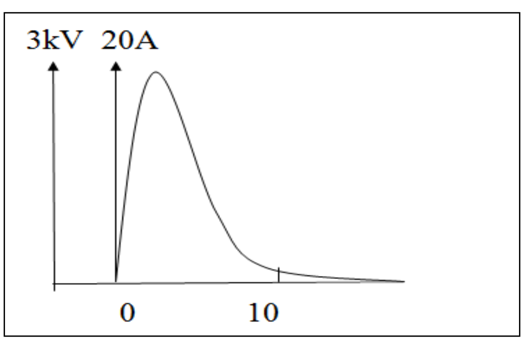
Monophasic waveforms:

1) The Lown waveform: shows the voltage and the current applied to the patient's chest plotted against time.

The current will rise very rapidly to about 20A, under the influence of slightly less than 3KV.the waveform then decays back to zero within 5msec duration. The charge delivered to the patient is stored in a capacitor and is produced by a high voltage DC power supply. The operator can set the charge level using the set energy knob on front panel. This knob controls the DC voltage produced by the high voltage power supply, so can set the maximum charge on the capacitor.



2) mono pulse waveform: this wave is created by a circuit similar to the circuit of lown waveform but without inductor to create the negative second pulse. Consequently, the wave form decays to zero in the exponential manner expected of an R-C network.



3) tapered delay: this waveform differs from the two previous pulses in that it uses a lower amplitude and longer duration to achieve the energy level. The energy transferred is

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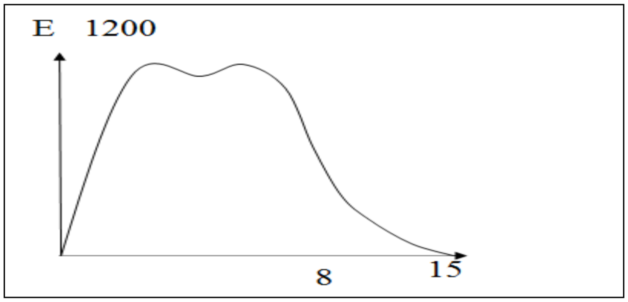
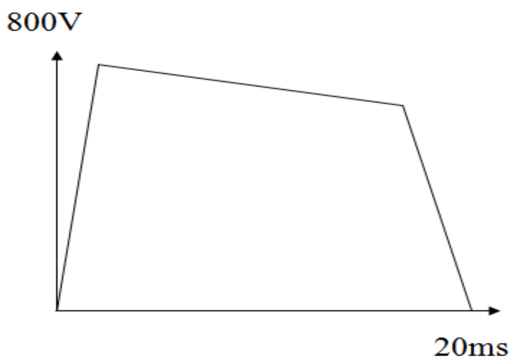
proportional to the area under the square of the curve. The double-humped waveform characteristic of tapered delay machines is achieved by placing two L-C section such as L/C in cascade with each other.



4) trapezoidal waveform:

is another low voltage-long duration shape. The initial output potential is about 800V, which drops continuously for about 20msec until it reaches 500V.



<u>Types of Defibrillator</u>

1-Internal Defibrillator

An implantable cardioverter-defibrillator (often called an ICD) is a device that briefly passes an electric current through the heart.

1. It is "implanted," or put in your body surgically.
2. It includes a pulse generator and one or more leads.
3. The pulse generator constantly watches your heartbeat.

External Defibrillator

Electrodes placed directly on the chest.

e.g., AED (Automatic External Defibrillator)

External Electrodes of defibrillator:

The electrodes for external defibrillations are usually metal discs about 3-5 cm in diameters and attached to highly insulated handles, for internal defibrillation large spoon shaped electrodes are used. Some of the external electrode contains safety switches inside the housings and the capacitor is discharged only when the electrodes are making a good and firm contact with the chest of the patient.

Electrode gel is usually used to reduce contact impedance.

Pre-gelled and self adhesive electrodes have been introduced to meet the requirements of good and firm contact.

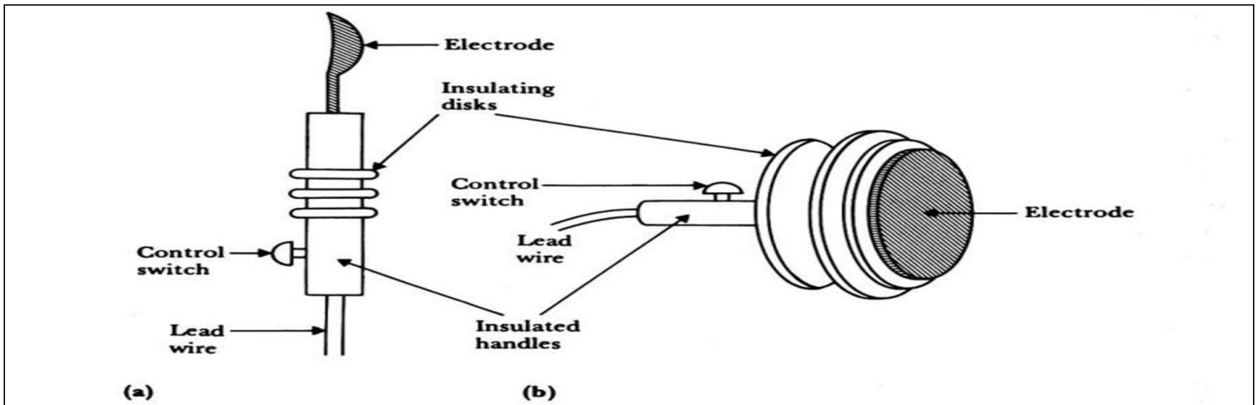


Figure Electrodes used in cardiac defibrillation (a) A spoon-shaped internal electrode that is applied directly to the heart. (b) A paddle-type electrode that is applied against the anterior chest wall.

- **Types of defibrillator electrodes:-**
  - a) Spoon Shaped Electrode

    Applied directly to the heart.
  - b) Paddle type electrode

    Applied against the chest wall
  - c) Pad Type Electrode

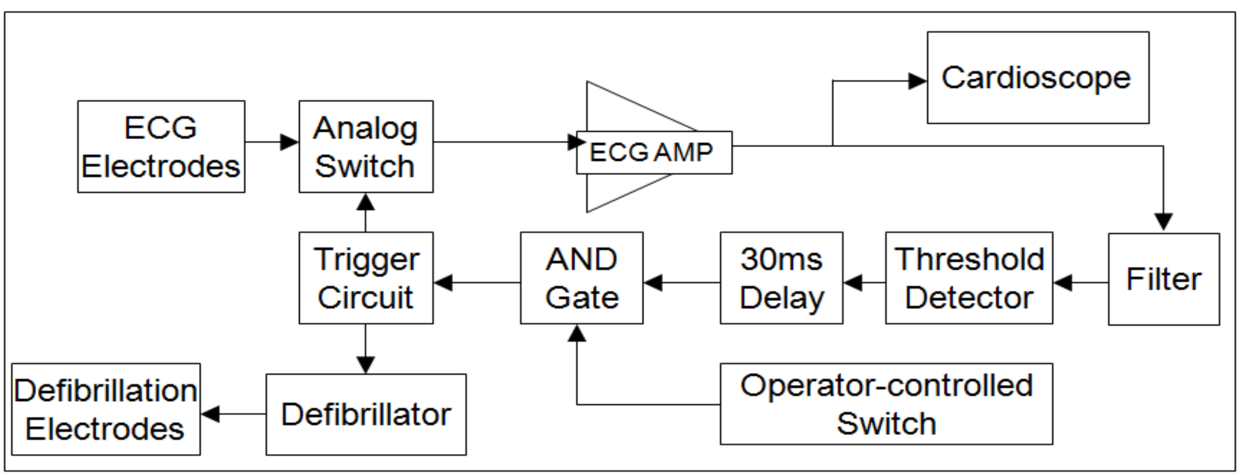
Applied directly on chest wall

Cardioversion:

In certain type of arrhythmia (atrial fibrillation) the patients ventricles maintain their ability to pump blood, evidence by R-wave, these arrhythmias are also corrected by electrical shock to the heart, but it is necessary to avoid delivering this shock during T-wave.

The shock used to correct the problem may actually create much more serious arrhythmia such as ventricular fibrillation.

The shock is timed to occur 30 ms after the R- wave peak to prevent ventricles fibrillation to occur. The machine equipped with synchronizer cct. Is called a cardioverter.



The block diagram of the cardioverter

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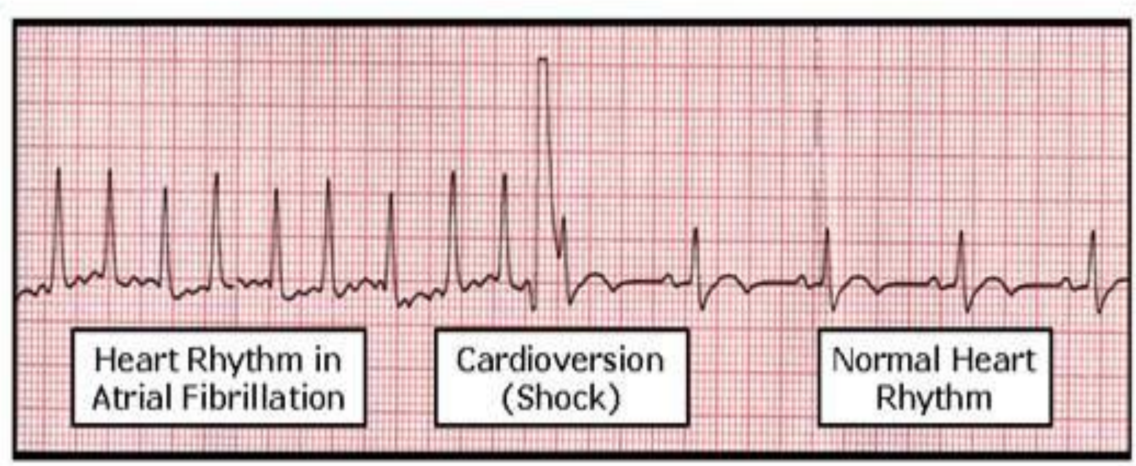

Cardoiversion after defibrillation