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 tachycardias is called cardioversion.

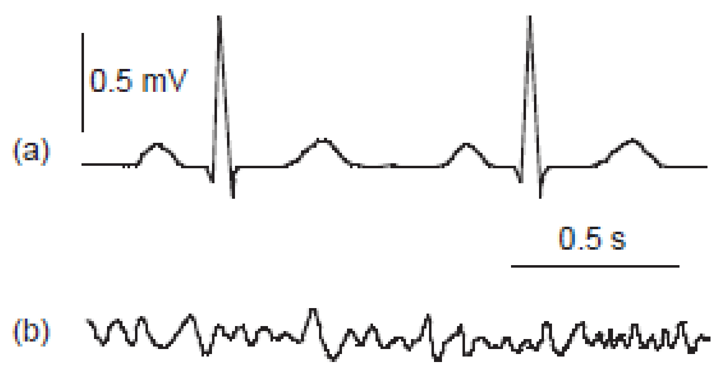

Figure 1. (a) A normal electrocardiogram (ECG). (b) The ECG during fibrillation.

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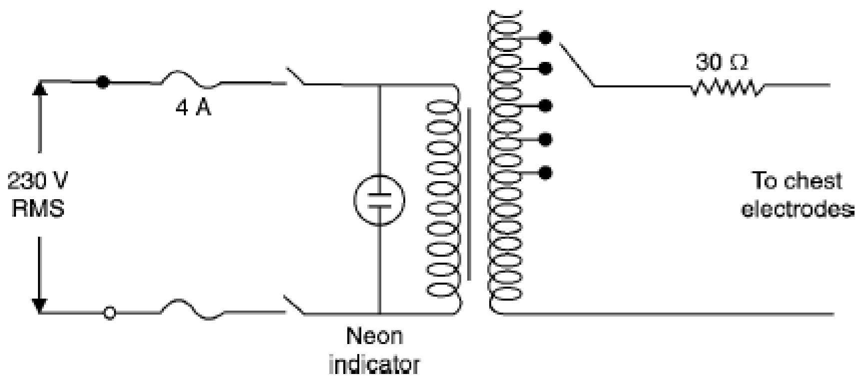
AC Defibrillator:

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

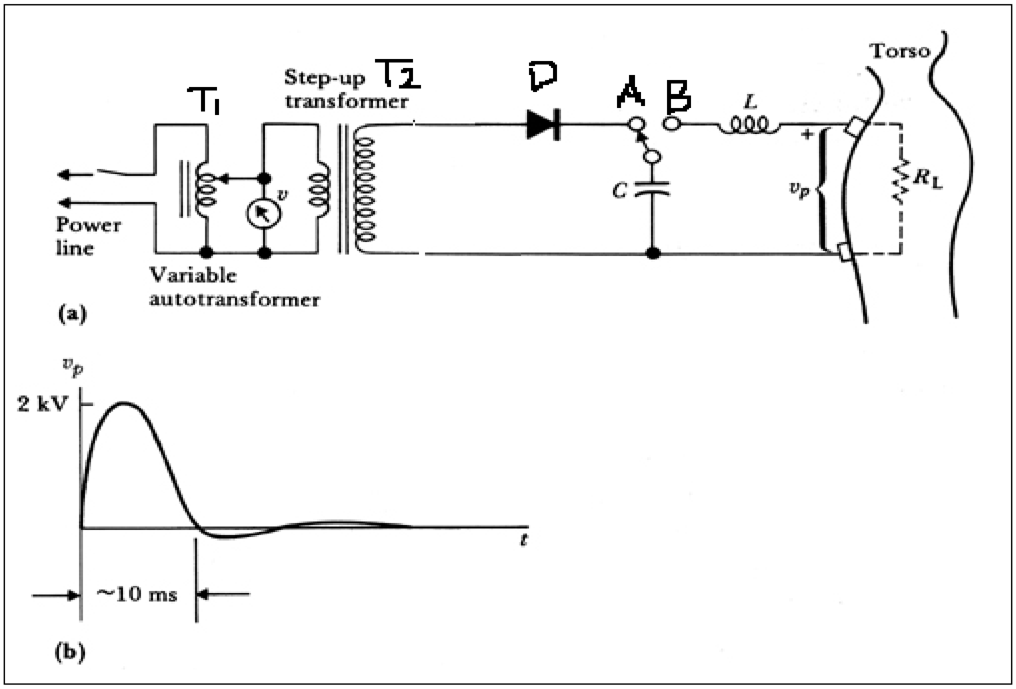
DC Defibrillator:

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 rectified by a diode rectifier and is connected to a vacuum type high voltage change-over switch. 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

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.

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