Physics of Medical Devices

Eleven lecture

Cardiac Defibrillators

Msc. Eman Ahmed

Third Stage

Department of medical physics

Al-Mustaqbal University-College

2021- 2022

Introduction

A defibrillator is a device that sends electrical energy, or shock, to the heart. The aim of using a defibrillator is to treat cardiac arrest. The need for this generally arises when the patient has ventricular fibrillation or ventricular tachycardia, which are life-threatening arrhythmias that occur when contraction of the ventricles become abnormal. Defibrillators have electrocardiogram (ECG) leads and adhesive patches (or paddles). The adhesive electrodes are the patches placed on the patient's chest that deliver the electric shock.

History

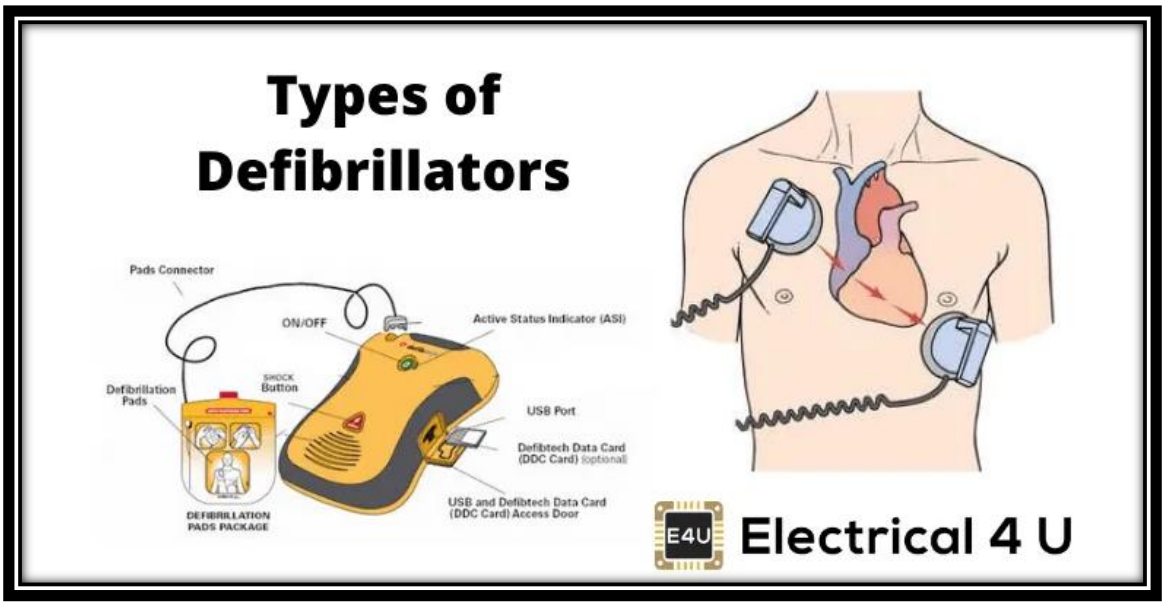
- First Demonstration; 1899, Prevost and First Demonstration; 1899, Prevost and Batelli Batelli, Physiologists from , Physiologists from
- Switzerland. Switzerland.
- *f* Small charges cause ventricular fibrillation Small charges cause ventricular fibrillation
- *f* Large charges reverse the syndrome. Large charges reverse the syndrome.

- ƒ Claude Beck, 1947, Western Reserve University Claude Beck, 1947, Western Reserve University
- 'Heart too good to die Heart too good to die"
- ƒ 14 Year Old Boy saved from 14 Year Old Boy saved from congenital heart disease by congenital heart disease by
- defibrillation with procaine amide heart medicine. defibrillation with procaine amide heart medicine.
- ƒ AC Current 110 AC Current 110-240 V →300-1000 V; Damage to Cells; Bulky ; Damage to Cells; Bulky
- Transformers Transformers
- ƒ Dr V. Eskin and A. Klimov in Frunze , USSR 1950 in Frunze , USSR 1950's; Closed Chest s; Closed Chest
- Method; AC >1000V

Types of Defibrillators (AC and DC Defibrillators)

Two **types of defibrillators** are showing below.

1. AC defibrillators
2. DC defibrillators

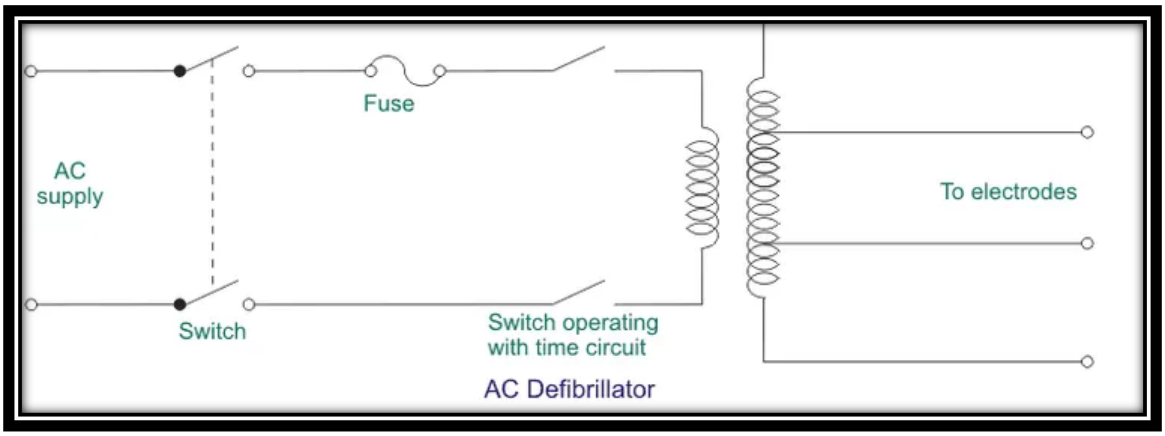


AC Defibrillators

An **AC defibrillator** is the oldest and simplest type. The construction of AC defibrillator is such that appropriate values are available for internal and external defibrillation. In AC defibrillation, a shock of 50 Hz a.c frequency is applied to the chest for a time of 0.25 to 1 second through electrodes. The procedure of applying electric shock to resynchronize heart is known as Counter shock.

Defibrillation continues until patient responds to the treatment. An AC defibrillator consists of a step-up transformer with primary and secondary winding, and two switches. A.C supply is given through switches and fuse to primary winding of the transformer. The timing circuit is connected with switch, which is used to preset the time for the defibrillator to deliver shock to the patient.

For safety reasons, secondary coil should be isolated from earth to avoid shock. For internal fibrillation voltage values between 60 V to 250 V is applied. To produce uniform and simultaneous contraction of heart muscles large currents are used for external defibrillation. However, this results in skin burn under electrodes and violent contraction of heart muscles. It also results in atrium fibrillation and stops ventricular fibrillation.



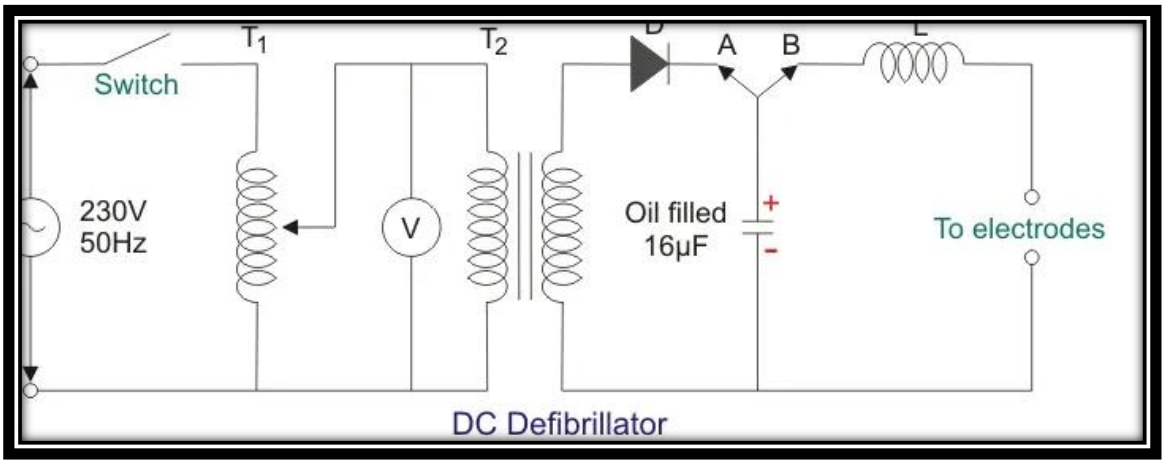
DC Defibrillators

DC defibrillator does not produce side effects and produces normal heartbeat. Ventricular fibrillation is avoided when high-energy shock is passed through discharging capacitor that is exposed to heart or chest of the patient. DC defibrillator consists of auto transformer T_1 that acts as primary of the high voltage transformer T_2.

A diode rectifier rectifies the output voltage from T_2. It is connected to vacuum type-high voltage over switch. At position A, switch is connected

to one end of the capacitor. When connected in this position capacitor charges to a voltage. A foot switch present on the handle of the electrode is used to deliver shock to the patient.

Now the high voltage switch changes it position to B that makes the capacitor to discharge to the heart through electrodes. To slow down the discharge from the capacitor an inductor L is placed in one of the electrode lead. This L induces a counter voltage that reduces the capacitor discharge value.



Waveform change

Until the mid 90s, external defibrillators delivered a Lown type waveform (see Bernard Lown) which was a heavily damped sinusoidal impulse having a mainly uniphasic characteristic. Biphasic defibrillation alternates the direction of the pulses, completing one cycle in approximately 12 milliseconds. Biphasic defibrillation was originally developed and used for implantable cardioverter-defibrillators. When applied to external

defibrillators, biphasic defibrillation significantly decreases the energy level necessary for successful defibrillation, decreasing the risk of burns and myocardial damage.

Ventricular fibrillation (VF) could be returned to normal sinus rhythm in 60% of cardiac arrest patients treated with a single shock from a monophasic defibrillator. Most biphasic defibrillators have a first shock success rate of greater than 90%.

Implantable devices

A further development in defibrillation came with the invention of the implantable device, known as an implantable cardioverter-defibrillator (or ICD). This was pioneered at Sinai Hospital in Baltimore by a team that included Stephen Heilman, Alois Langer, Jack Lattuca, Morton Mower, Michel Mirowski, and Mir Imran, with the help of industrial collaborator Intec Systems of Pittsburgh.[39] Mirowski teamed up with Mower and Staewen, and together they commenced their research in 1969. However, it was 11 years before they treated their first patient. Similar developmental work was carried out by Schuder and colleagues at the University of Missouri.

The work was commenced, despite doubts amongst leading experts in the field of arrhythmias and sudden death. There was doubt that their ideas

would ever become a clinical reality. In 1962 Bernard Lown introduced the external DC defibrillator. This device applied a direct current from a discharging capacitor through the chest wall into the heart to stop heart fibrillation.[40] In 1972, Lown stated in the journal *Circulation* — "The very rare patient who has frequent bouts of ventricular fibrillation is best treated in a coronary care unit and is better served by an effective antiarrhythmic program or surgical correction of inadequate coronary blood flow or ventricular malfunction. In fact, the implanted defibrillator system represents an imperfect solution in search of a plausible and practical application."[41]

The problems to be overcome were the design of a system which would allow detection of ventricular fibrillation or ventricular tachycardia. Despite the lack of financial backing and grants, they persisted and the first device was implanted in February 1980 at Johns Hopkins Hospital by Dr. Levi Watkins Jr. assisted by Vivien Thomas. Modern ICDs do not require a thoracotomy and possess pacing, cardioversion, and defibrillation capabilities.

The invention of implantable units is invaluable to some regular sufferers of heart problems, although they are generally only given to those people who have already had a cardiac episode.

People can live long normal lives with the devices. Many patients have multiple implants. A patient in Houston, Texas had an implant at the age of 18 in 1994 by the recent Dr. Antonio Pacifico. He was awarded "Youngest Patient with Defibrillator" in 1996. Today these devices are implanted into small babies shortly after birth.