DEFIBRILLATORS

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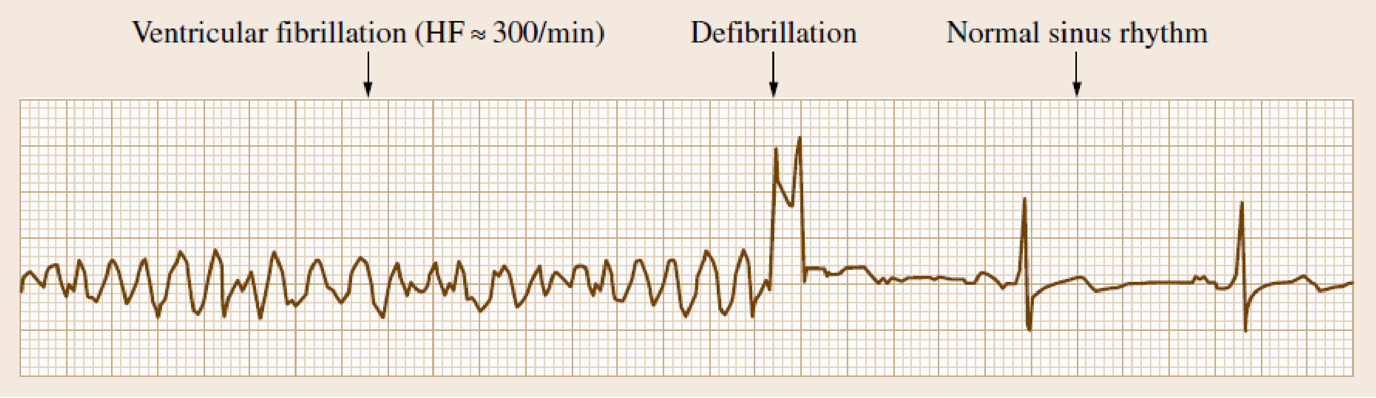
Basics

- Defibrillation is definitive treatment for life-threatening cardiac arrhythmias such as ventricular fibrillation
- Defibrillation consists of delivering therapeutic dose of electrical energy to affected heart with device called defibrillator, which can be external, trans-venous, or implanted
- Automated External Defibrillators (AEDs): automatic diagnosis of treatable rhythms and application of treatment energy
  - Lay responders or bystanders are able to use AEDs successfully with little or no training at all except safety precautions
- Implantable Cardioverter-Defibrillator (ICD) is small, battery-powered implanted electrical impulse generator programmed to detect cardiac arrhythmia and correct it by delivering jolt of electricity
  - Implanted in patients at risk of sudden cardiac death due to ventricular fibrillation and ventricular tachycardia

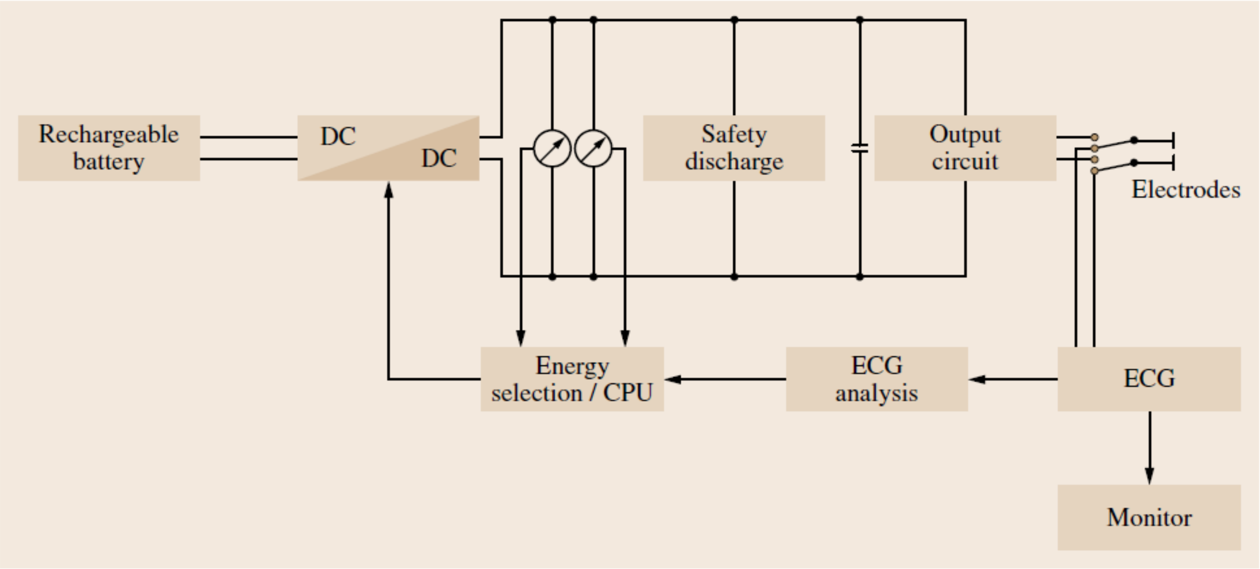
Defibrillator Theory of Operation

- Defibrillators are electrotherapeutic high-voltage devices which are used within course of resuscitation and to terminate tachycardic ventricular and supraventricular arrhythmias
- Defibrillation is defined as applying brief, phasic pulse of energy intended to cause simultaneous depolarization of all myocardial fibers
  - After approximately 5 s of administering electrical pulse, no ventricular fibrillation or ventricular tachycardia are detected any longer in ECG
  - Objective: to terminate tachycardic ventricular and supraventricular arrhythmias so that following refractory period which generally lasts 200-500 ms, SA-node once more resume primary pacemaker function



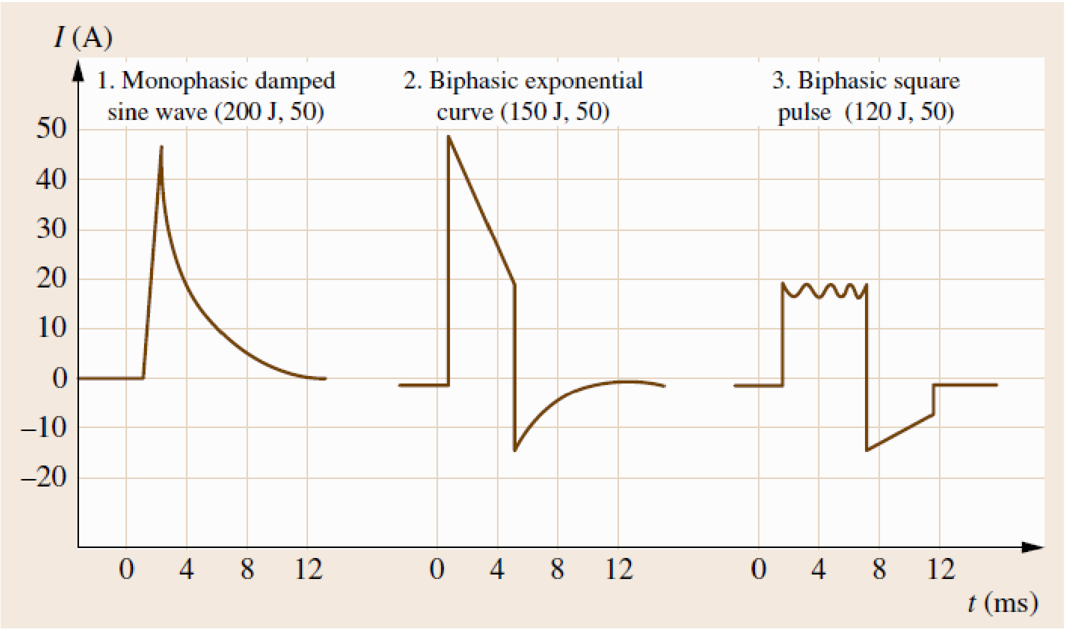
DC Defibrillator Components

- Portable defibrillator is DC voltage system, usually not dependent on mains electricity, essentially composed of:
  - Energy supply via mains connection or rechargeable batteries
  - Capacitor as energy store ($E = \frac{1}{2} C V^2$)
  - Charging circuit for capacitor
  - Discharge circuit to deliver current pulse at different, preselectable energy levels
    - Pulse range: 3-8 ms at current of 10–27A (internal) and 22–60A (external)



Waveform of Energy Shock

- Shape of wave dictates how much energy is supplied to patient and over what period this energy is administered
- Optimum amount of energy for defibrillator pulse is amount of energy which causes least myocardial damage
- Distinction is made between mono-, bi-, and triphasic pulses



Waveform of Energy Shock

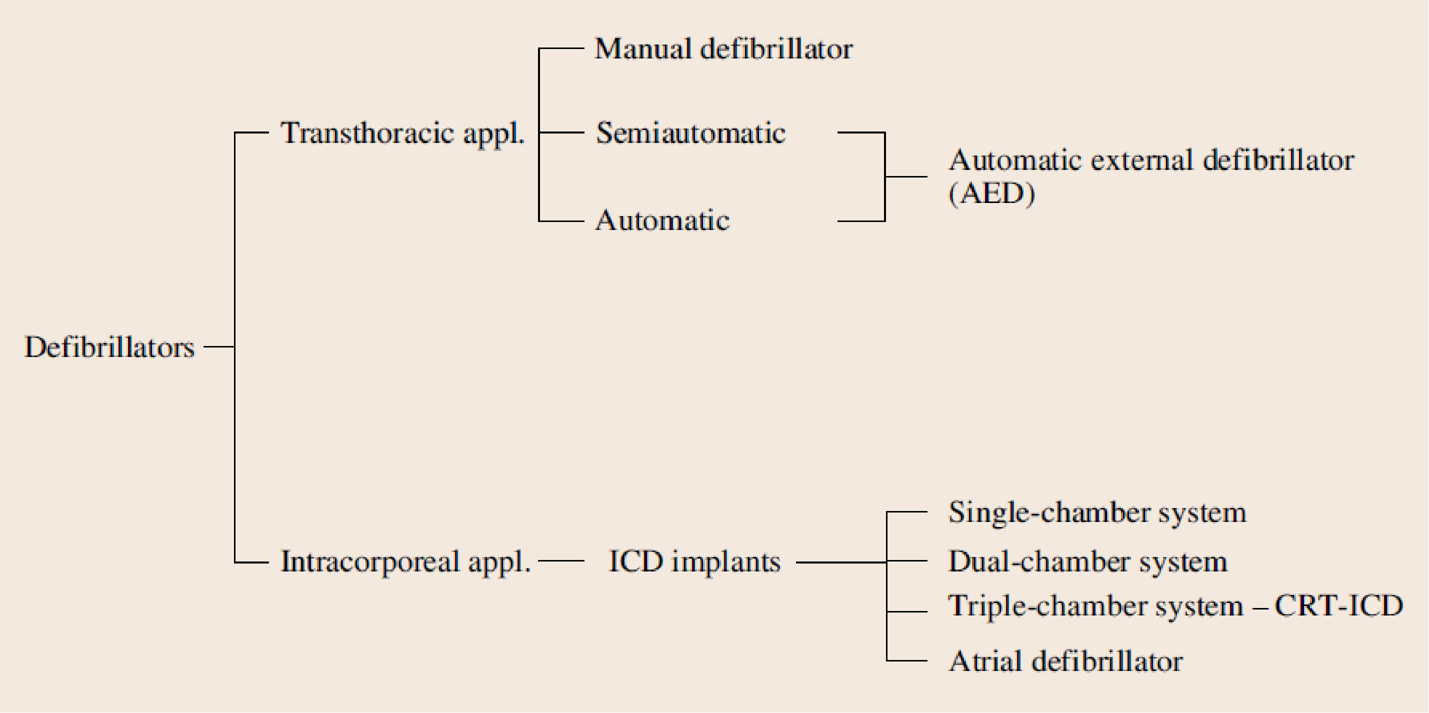
- Biphasic waveforms are preferably used
  - More effective on first shock and gentler on heart with less dysfunction
  - Differ with varied adaptation to thoracic impedance of patient (e.g., peak-to-peak voltage and pulse duration)
  - Defibrillation success achieved with lower energy and voltage
    - Device-dependent amount of energy is 150–200 J for first defibrillation and 200–360 J for all others, whereas it is always 360 J with monophasic wave
  - Biphasic pulse forms allow devices to be further miniaturized
  - Whereas optimum energy flow in monophasic defibrillation is in range 30-40 A, with biphasic shock it is in range 15-20 A
- Operating modes: synchronous and asynchronous operation
  - Synchronous: heart's own pulses are taken into account (QRS triggering)
  - Asynchronous: reserved for strictly emergency defibrillations

Thoracic Impedance

- Definition: resistance in body which opposes energy pulse from defibrillator
- Ranges between 15 and 150 Ω; usually it is 70–80 Ω
- Must be taken into consideration when necessary energy is administered, as patient's thoracic impedance is crucial to amount of energy required
- Because impedance varies to large degree in humans, dynamic adaptation of energy pulse waveform is important feature
  - Modern devices automatically measure thoracic impedance and take into account before defibrillation to deliver energy more accurately

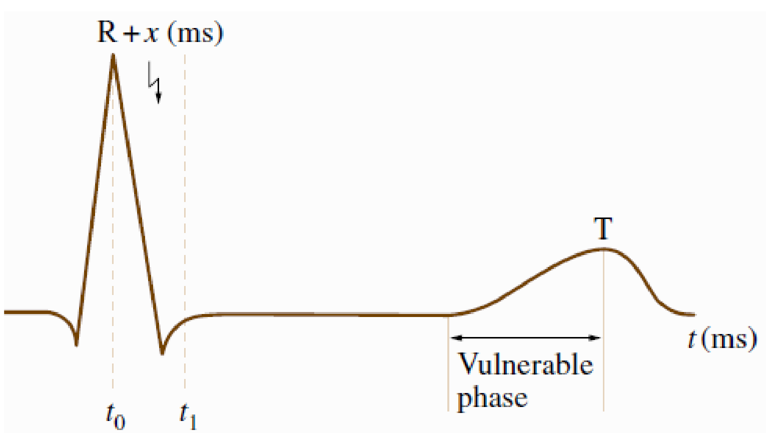
Defibrillator Types

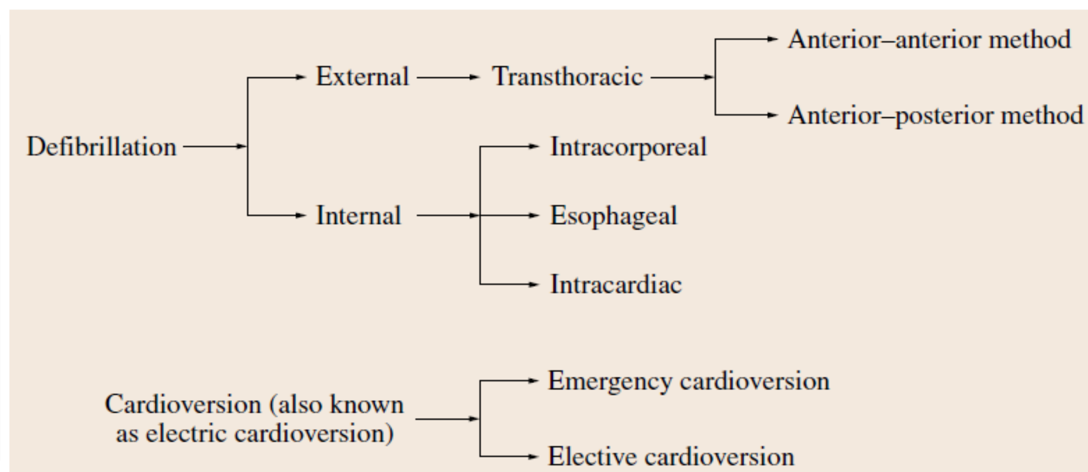
- Divided into manual, semiautomated, and fully automated external defibrillators, in addition to defibrillator implants
  - Semiautomated: user is shown defibrillation recommendation but administration of pulse is triggered by user
  - Fully automated: everything is done by device



Cardioversion

- Synchronized defibrillation is referred to as cardioversion
  - Pulse of energy is triggered by R wave in the ECG
  - Synchronization is carried out to prevent pulse being delivered in vulnerable phase (T wave) and to prevent risk of ventricular fibrillation being triggered
- Different possible methods of application





Methodological Notes

- All commercially available defibrillators are operated same
- As a rule, visual and/or audible signal generated when defibrillator is operational (i.e., when capacitor is charged)
- Electrodes (with gel) placed firmly on thorax and pressed on and preselected energy dose is triggered from handles
- Practice of performing defibrillation 3 times within a minute using mono- and biphasic defibrillators is obsolete
  - Replaced by delivery of single shock at full energy (one-shock strategy)
  - Monophasic: 360 J, Biphasic: at least 150–200 J advised
- Following shock, cardiopulmonary resuscitation performed for 2 min before administering next shock if necessary
  - Monophasic defibrillators: energy level is kept at 360 J
  - Biphasic defibrillators: energy level is successively increased

Electrodes and Contact Agents

- Adhesive electrodes (pads) preferred
  - Quicker to administer the first pulse of energy
  - Possible to defibrillate from safe distance and without leaning over patient
  - Gel pads: contact gel included – avoid risk of arcing and short circuit
- Normal plate electrodes (paddles)
  - Contact gel needed between skin surface and metal plate to reduce skin impedance and better electrical contact and to prevent burns
- AAMI standard recommends minimum area of 150 cm^2
  - Diameter of common electrodes is 8–12 cm for adults and children with body weight > 10 kg and 4.5 cm for children with body weight < 10 kg

Complications

- Induced ventricular fibrillation, e.g., as a result of incorrect triggering, which can ultimately lead to asystole (cardiac arrest) (currents > 10mA flowing through the heart can cause fibrillation in the ventricles)
- Post-defibrillation arrhythmias such as ventricular and supraventricular extra-systoles and ventricular flutter
- Arterial embolisms
- Burns and irritation of the skin, for example, due to an insufficient amount of electrode contact paste being used on the electrode surface

Technical Safety Aspects: Use

- Avoid direct contact with electrodes (life-threatening), conductive contact with patients or people (safe distance)
- There should be no moisture on patient's skin (electrical bridge), and patient should also be positioned to be electrically isolated
- Only perform cardioversion if ECG is free from artifacts and if reliable ECG monitoring is possible
  - When too much electrode contact paste is used on paddles there is chance of electrical bridge forming (risk of short circuit)
- All other devices connected to patient must be defibrillation-proof
  - Otherwise, they must be disconnected from patient during defibrillation
- Caution should be exercised with patients with energized implants
  - Functioning of implant may be restricted or suspended
  - Implant itself may be damaged or even become unusable.

Technical Safety Aspects: Device

- Defibrillators must only be used in explosion-proof atmosphere
- Disconnect devices which are not defibrillator proof from patient
  - Equipment labeled according to DIN-IEC 601 as defibrillator proof
- Maximum energy 360 J
- Trigger buttons only on both paddles (connected in series)
- Protective circuits: ensure reduced power setting when defibrillator is switched off and ensure energy recovery no later than 1 min after defibrillator charging
- Because of their unforeseeable and frequently changing use, defibrillators should always be connected to mains electricity at their device base locations so they are operational and ready for use

Reading Assignment

- Read Chapter 28 of *Springer Handbook of Medical Technology*