

Pacemakers and Defibrillators

Brief History

- **17th and 18th Centuries**
 - The harnessing of electricity, observations of its effects on animal tissues and the discovery of 'animal electricity'.
- **1842**
 - Carlo Matteucci shows that an electric current accompanies each heart beat. He used a preparation known as a 'rheoscopic frog' in which the cut nerve of a frog's leg was used as the electrical sensor and twitching of the muscle was used as the visual sign of electrical activity.
- **1850**
 - Bizarre unregulated actions of the ventricles (later called ventricular fibrillation) is described by Ludwig Hoffa during experiments with strong electrical currents across the hearts of dogs and cats
- **1856**
 - Rudolph von Koelliker and Heinrich Muller confirm that an electrical current accompanies each heart beat

Brief History (Cont.)

- **1872**
 - Guillaume Benjamin Amand Duchenne de Boulogne describes the resuscitation of a drowned girl with electricity. This episode has sometimes been described as the first 'artificial pacemaker'
- **1887**
 - British physiologist Augustus D. Waller publishes the first human electrocardiogram.
- **1889**
 - Dutch physiologist Willem Einthoven sees Waller demonstrate his technique at the First International Congress of Physiologists. Waller often demonstrated by using his dog "Jimmy" who would patiently stand with paws in glass jars of saline.
- **1893**
 - Willem Einthoven introduces the term 'electrocardiogram'
- **1895**
 - Einthoven, using an improved electrometer distinguishes five deflections which he names P, Q, R, S and T

Brief History (Cont.)

- **1899**
 - Karel Frederik Wenckebach describes impairment of AV conduction leading to progressive lengthening and blockage of AV conduction in frogs.
- **1899**
 - Jean-Louis Prevost, and Frederic Batelli discover that large electrical voltages applied across an animal's heart can stop ventricular fibrillation.
- **1905**
 - Einthoven starts transmitting electrocardiograms from the hospital to his laboratory 1.5 km away via telephone cable
- **1924**
 - Willem Einthoven wins the Nobel prize for inventing the electrocardiograph.
- **1926**
 - A doctor from Sydney, (wished to remain anonymous), resuscitates a new-born baby with an electrical device later called a 'pacemaker'

Brief History (Cont.)

- **1931**
 - Dr Albert Hyman patents the first 'artificial cardiac pacemaker' which stimulates the heart using a transthoracic needle
- **1934**
 - By joining the wires from the right arm, left arm and left foot with 5000 Ohm resistors Frank Wilson defines an 'indifferent electrode' later called the 'Wilson Central Terminal'
- **1947**
 - Claude Beck, a cardiovascular surgeon in Cleveland, successfully defibrillates a human heart during cardiac surgery
- **1950**
 - John Hopps, a Canadian electrical engineer shows that a coordinated heart muscle contraction can be stimulated by an electrical impulse delivered to the sino-atrial node. The apparatus, the first cardiac pacemaker, measures 30cm, runs on vacuum tubes and is powered by household 60Hz electrical current.

Brief History (Cont.)

- **1952**
 - Paul Zoll is the first to use an external pacemaker clinically, delivering 100V pulses to chest electrodes.
- **~1950**
 - Lillehei uses internal pacemaker developed by Earl Bakken to treat heart block after repairing septal defects in children.
- **1956**
 - Paul Zoll, a cardiologist, performs closed-chest defibrillation in a human.
- **1958**
 - Greatbatch and Chardack use implantable pacemaker in animals
- **1960**
 - Greatbatch and Chardack use implantable pacemaker in humans (myocardial electrodes)
- **1960s**
 - Fixed rate, zinc-mercury batteries, myocardial electrodes

Brief History (Cont.)

- **Mid 1960**
 - Transvenous electrodes
- **1970's**
 - Lithium batteries
 - complex pulse generators
 - Telemetry
 - Data monitoring
 - Control of function
- **1980's**
 - Cardioversion

Clinical conditions and causes

- **Adams-Stokes Disease**

- transient condition caused by a heart rhythm disorder. It involves fainting, with or without convulsions.

- **Mechanism**

- The normal electrical signal that passes from the heart's upper to lower chambers is interrupted. This causes a "heart block," which usually slows the heart rate considerably. This can cause inadequate blood flow to the brain and fainting.
- Can be hereditary, aging, ischemic attack

Clinical conditions and causes

- **Arrhythmias**

- Irregular heart beats that can originate in the atria or in the ventricles and disturb the normal rhythm of the heart. Disturbance originating in the atria can cause slow or fast heart rate. Disturbance in the ventricle cause premature ventricular contraction

- **Mechanisms**

- Sinus bradycardia
 - But normal AV conduction
- Ventricular tachycardia
 - Can lead to ventricular fibrillation
- Atrial fibrillation
- Others

Clinical conditions and causes

- **Ventricular fibrillation**

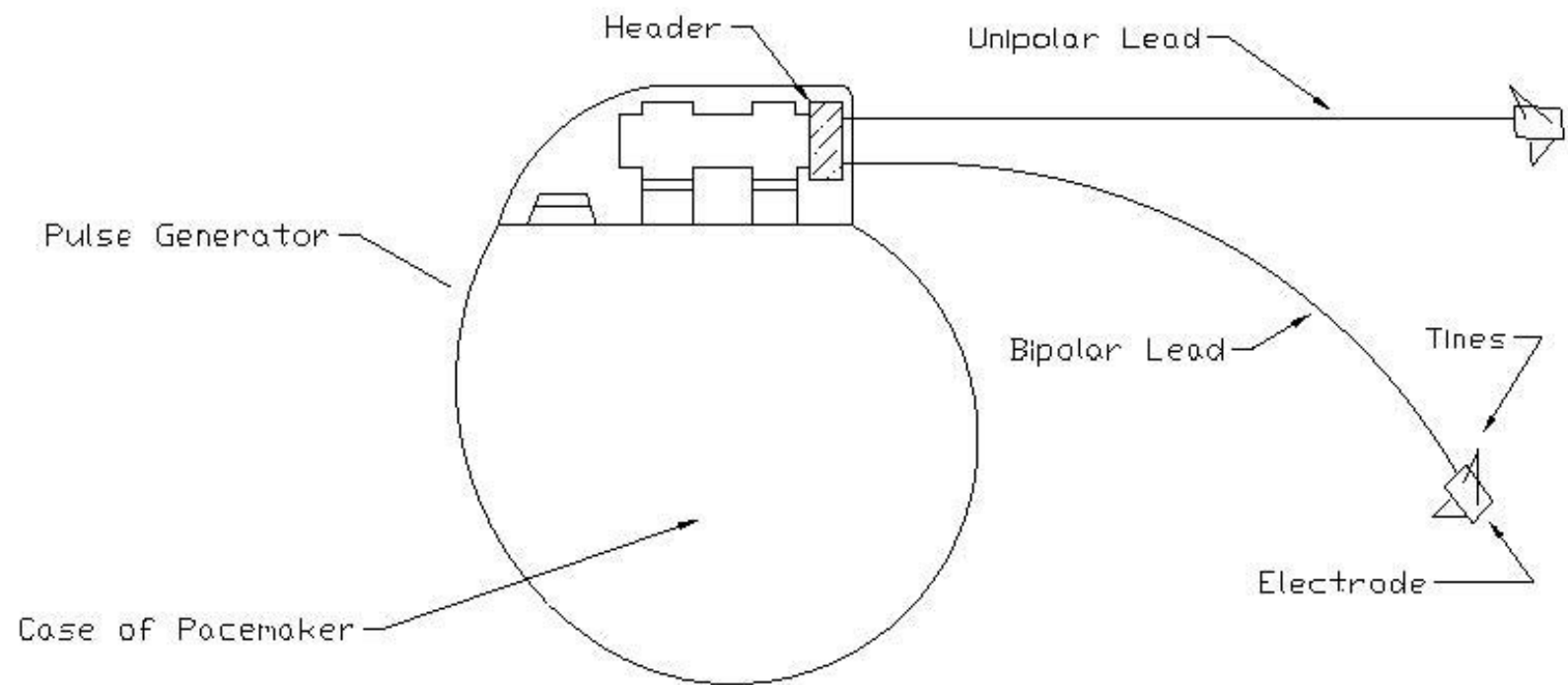
- Sudden loss of responsiveness; No normal breathing; No signs of circulation. No movement or coughing; Collapse and sudden cardiac death follows in minutes unless medical help is provided immediately

- **Mechanisms**

- The heart's electrical activity becomes disordered. The ventricles contract in a rapid, unsynchronized way. The heart pumps little or no blood.

The pacemaker

- **Housing**
 - Protects the pacemaker from body fluids (Titanium)
- **Pulse generator**
 - Provides electrical pulses that depolarize cardiac tissue
- **Power supply (battery)**
 - Long lasting (excess of 5 years)
- **Leads (1 or 2)**
 - Carry the electrical signal to the electrode
 - Carry information from the heart to the generator
- **Electrodes (1 or 2)**
 - Located at tip of lead
 - Attach to the tissue





VIGOR DR

TYPE DDDR MODEL 1230
SN PG 25339-08
CARDIAC PACEMAKERS, INC.
ST. PAUL, MN USA



Main types of pacemakers

- **Fixed rate single chamber (Rarely used)**
- **Demand (sensing and pacing)**
- **Triggered**
- **Programmable using telemetry**

- **Implantable Cardioverter Defibrillator**
 - **Used in patients at risk for recurrent, sustained ventricular tachycardia or fibrillation.**
 - **Leads are positioned inside the heart or on its surface. These leads are used to deliver electrical shocks, sense the cardiac rhythm and sometimes pace the heart, as needed**

Original 3-letter code

| Chamber paced | Chamber sensed | Mode of Response | Description | Old designation |
|---------------|----------------|------------------|--|---|
| V | O | O | Ventricular pacing, no sensing | Asynchronous, fixed rate |
| A | O | O | Atrial pacing, no sensing | Atrial fixed rate, atrial asynchronous |
| D | O | O | Atrioventricular pacing, no sensing | AV sequential fixed rate. asynchronous |
| V | V | I | Ventricular pacing and sensing, inhibited mode | Ventricular inhibited, demand, standby |
| V | V | T | Ventricular pacing and sensing, triggered mode | Ventricular triggered, R synchronous, demand |
| A | A | I | Atrial pacing and sensing, inhibited mode | Atrial inhibited, P suppressed |
| A | A | T | Atrial pacing and sensing, triggered mode | Atrial triggered, P synchronous |
| V | A | T | Ventricular pacing, atrial sensing, triggered mode | Atrial synchronous, AV synchronous |
| D | V | I | Atrioventricular pacing, ventricular sensing, inhibited | Bifocal sequential demand, AV sequential |

NASPE 5-letter codes

| I | II | III | IV | V |
|------------------|-------------------|----------------------------|------------------------|---------------------------|
| Chamber(s) paced | Chamber(s) sensed | Mode(s) of response | Programmable functions | Antitachycardia functions |
| V=Ventricle | V=Ventricle | T=Triggered | R=Rate modulated | O=None |
| A=Atrium | A=Atrium | I=Inhibited | C=Communicating | P=Paced |
| D=Dual (A&V) | D=Dual (A&V) | D=Dual Triggered/Inhibited | M= Multiprogrammable | S=Shocks |
| O=None | O=None | O=None | P=Simple programmable | D=Dual (P&S) |
| | | | O=None | |

Some Programmable Parameters

- **Amplitude (atrial and ventricular) 8-10 mAmp**
- **Duration (atrial and ventricular) 1-1.2 mSec**
- **Refractory period (atrial and ventricular)**
- **Atrial sensitivity (atrial and ventricular)**
- **Pacing rate**
- **AV delay**
- **Pacing mode**

Leads

- **Required properties**
 - **Stable mechanically, flexible**
 - **Must withstand constant flexing (35 million per year)**
 - **Durability**
 - **Inert to body fluids**
 - **Good conductor**
 - **Insulated from body fluids**
 - **Embedded in silicone or polyurethane**

Electrodes

- **Required properties**
 - Inert
 - **Compatible with tissue**
 - **Low inflammation at interface with tissue**
 - **Stable chemically**
 - **Low interface impedance (low polarization losses)**
 - **Effective size requires compromise**
 - **High current density at tissue site for efficient stimulation and low battery drain**
 - **Low current density for low polarization and low losses across interface**
- **Materials used**
 - **Nickel-Cobalt alloy**
 - **Platinum-Iridium alloy**
 - **Titanium alloy**
 - **Silver**

Power Source

- **Originally Zinc-Mercury cells**
 - Projected to last 5 years but lasted less than 2
- **Current: Lithium-Iodide**
 - 10-12 years life
- **Future**
 - Biological batteries