TESTING DEFIBRILLATORS PER INTERNATIONAL STANDARDS

FUNCTION TESTS FOR DEFIBRILLATORS,
POWER MEASUREMENT AND SYNCHRONIZATION CHECKING

DEFIBRILLATION

Due to advances in medical science at the turn of the 19th to the 20th century resulting in longer life expectancies, heart diseases became a serious health problem and the leading cause of death. Previously, people usually died of infectious diseases before they reached an age at which heart problems posed a real health threat. Around this time, Swiss researchers Jean-Louis Prévost and Frédéric Batelli made the paradoxical discovery that electric current could cause fibrillation of the ventricles and, more importantly, defibrillation when they experimented with a dog's heart.

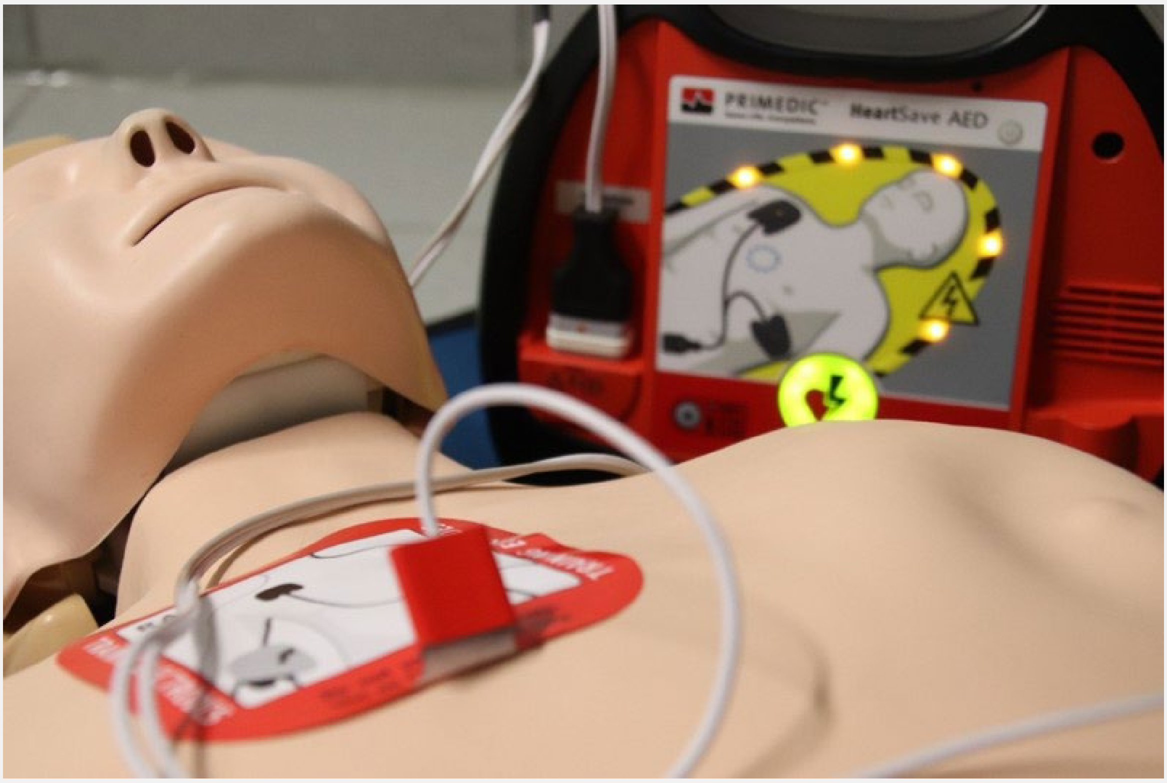

Figure 1: Defibrillator Training with a Manikin

A defibrillator is a medical device used for defibrillation and, under some circumstances, cardioversion. It's capable of stopping cardiac arrhythmias such as ventricular fibrillation and ventricular flutter, as well as ventricular tachycardia, atrial fibrillation and atrial flutter by applying targeted electric shocks (cardioversion). Defibrillators are kept available in intensive care units, operating rooms, emergency rooms and ambulances. To an ever greater extent since the 1990s, automated external defibrillators have been made available in buildings open to the public such as train stations, airports, and other locations for use by laypersons.

A defibrillator improves the chances of successful cardiopulmonary resuscitation, but can't replace it.

Today's modern external defibrillators are rugged, portable and comprehensive medical devices used by emergency medical service personnel, which provide a complete life-saving solution. Defibrillator technologies provide essential emergency care for adults, children and infants. Higher-end, top-of-the-line defibrillators are available on the market with AED (automated external defibrillation), manual defibrillation, non-invasive transcutaneous stimulation and synchronized electrical cardioversion. Other optional enhancements include functions for monitoring vital signs.

THE HISTORY OF DEFIBRILLATION

Resuscitation with the help of electricity was already documented in 1825: "... but the most expedient method is blowing in pure vital air (dephlogisticated air, oxygen gas). However, this blowing in must be performed with moderation and ... with appropriate electrical or galvanic cardiac shock."[1] After the principle had already been recognized in the 1930s in experiments at Johns Hopkins University conducted by electrical engineer William B. Kouwenhoven in collaboration with physicians and was first used in surgery by surgeon Claude Beck (Case Western Reserve University) in 1947, development of a defibrillator for use with closed chest was initiated by Kouwenhoven at Johns Hopkins University in 1950, again in close collaboration with physicians. The device was used successfully in an operation in 1957, and in 1960 for the first time on a patient in the emergency admissions unit. British-Irish cardiologist Frank Pantridge invented the first portable defibrillator in 1965.[2, 3, 4] Levi Watkins and Vivien Thomas were the first to successfully implant an automatic defibrillator in a human patient at Johns Hopkins University on the 4th of February, 1980.[5] In the late 20th century, public access defibrillation (PAD) was recommended by the American Heart Association for early defibrillation with a semiautomatic device (see also automated external defibrillator).[6]

Figure 2: Dr. Beck's Defibrillator from James H. Rand III in 1947

In 1938/39, Naum L. Gurvich began work on a less dangerous monophasic direct current device for transthoracic defibrillation. Gurvich discharged between 2 and 6 kV from a capacitor over the chests of animals in order to restore cardiac function. Bulky generators are required for AC defibrillation, and severe chest contractions caused by this technique may result in broken ribs. DC discharging is less liable to cause fibrillation, and the heart is more likely to resume functioning spontaneously without artificial intervention.

Much progress was made in the development of defibrillators in the 1950s and 60s. Research conducted at this time contributed to the development of the portable, safe, external transthoracic defibrillator as we know it today.

From the 1960s to the 1980s, further technological advances paved the way for sophisticated defibrillators and pacemakers which can interact within the human body to maintain cardiac rhythm. The two branches of defibrillation – cardioversion and pacemaking – merged, resulting in the development of ICDs.

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[1] Handbook of police law: with special reference to applicable police laws in the Kingdom of Saxony, Leipzig, 1825, books.google.de

[2] Defibrillator inventor honored, BBC, 11 June 2009, retrieved 9 August 2017

[3] Obituary, Frank Pantridge, from: Guardian, 6 January 2005, retrieved on 9 August 2017

[4] Geschichte der Innovationen: HeartSine: Ein lebensrettendes Vermächtnis kardialer Defibrillatoren und mobiler Defibrillator-Technologie de.heartsine.com, retrieved on 9 August 2017

[5] Dr. Levi Watkins Jr. dies at 70; cardiac surgery innovator, activist, 21 April 2015, retrieved on 4 April 2021

[6] Walied Abdulla: Interdisziplinäre Intensivmedizin, Urban & Fischer, Munich 1999, ISBN 3-437-41410-0, pp. 4–22 (Kardiopulmonale Reanimation)

THE HEART

The heart is located in the thoracic cavity. It pumps blood, generates blood pressure and circulates oxygen, nutrients, and other assimilated substances throughout our bodies. The heart has four chambers:
the right and left atria and the right and left ventricles. The chambers are made of cardiac muscle also known as myocardium. The electrical activity of the myocardium controls the mechanical sequence of events referred to as the cardiac cycle.

The human heart is about the size of a fist and weighs roughly 300 grams for men and 250 grams for women. However, the size of the heart can vary greatly. In the case of athletes or pathological enlargement, it can be larger and heavier. From an anatomical standpoint, the heart consists of a left and a right hemicardia (lateral half of the heart). The two halves are separated by the cardiac septum. This is very important because oxygen-poor blood flows in the right hemicardia and oxygen-rich blood flows in the left hemicardia. Each hemicardia consists of a ventricle (main chamber) and an atrium.

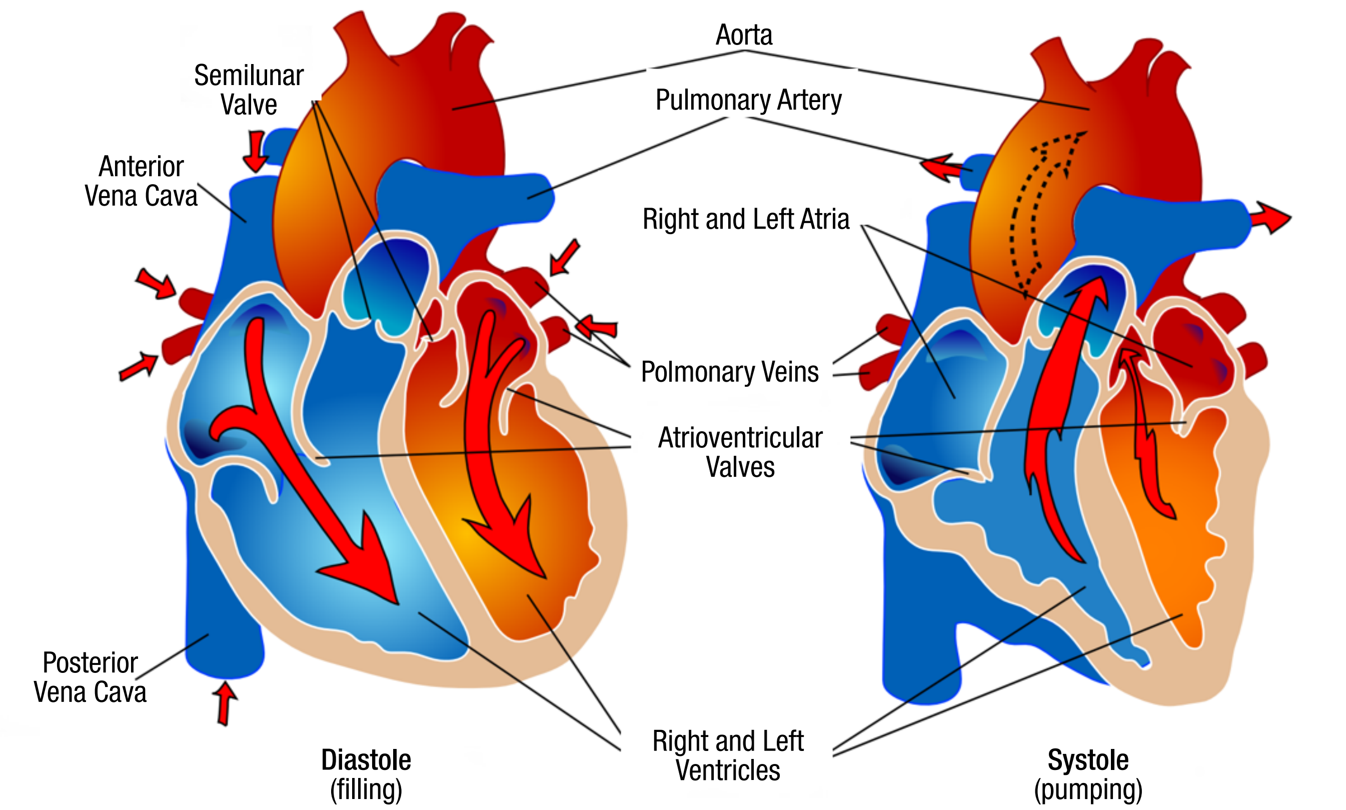

Figure 3: The Human Heart

In order to ensure that the blood flows in the right direction on its way through the heart, the cardiac valves are located between the atria and their respective ventricles, as well as between the ventricles and the draining arteries. They function as check valves and allow blood to flow in only one direction. They open pliantly and thus avoid becoming an obstacle for the flow of blood, and close tightly in order to prevent backflow. We distinguish between two basic forms: the leaflet valves (antrioventricular valves) separate the atria from their respective ventricles, while the pocket valves perform their function at the heart's outlets. The valves between the atria and the ventricles are called the mitral valve (left) and the tricuspid valve (right). The semilunar valves are designated pulmonary valve (right) and aortic valve (left).[7]

[7] Deutsche Herzstiftung, Das menschliche Herz – Anatomie und Aufbau

THE HEART'S ELECTRICAL ACTIVITY

The myocardial cells can contract spontaneously without any nerve impulses. The heart produces its own rhythm, and its natural pacemaker is the sinoatrial (SA) node – a cluster of highly conductive cells in the right atrium. The SA node initiates the heartbeat with a rapid depolarization. Impulses from the SA node travel along a conductive path to the atrioventricular (AV) node and to the atrial myocardium; this transmission causes contraction of the atrium.

ELECTROCARDIOGRAM

The sequence of electrical events produced by the myocardium can be visualized by means of an electrocardiogram (ECG) by applying electrodes to the skin of the chest, arms, and legs.

A typical ECG (see figure 4) consists of the **P wave** which represents depolarization of the SA node in the atria, the **QRS complex** which represents depolarization of the ventricles as impulses propagate through the myocardial tissue, and the **T wave** which represents repolarization of the ventricles. Atrial repolarization is obscured by the QRS complex, which is why it doesn't have its own wave.[8, 9]

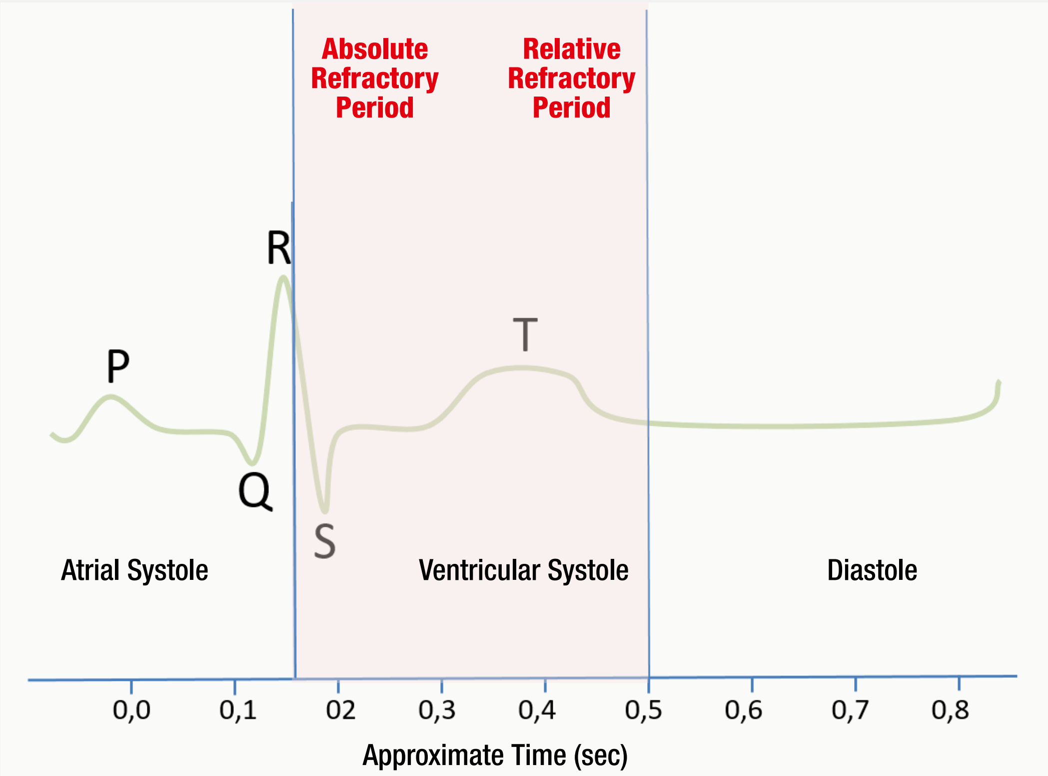

Figure 4: Cardiac Cycle

The myocardial cells are dormant during certain phases of the cardiac cycle, which are referred to as refractory (see figure 4). The cells are unable to respond to stimuli at these times because they're charging up for the next heartbeat. The absolute refractory period (ARP) is the period of ventricular depolarization from the onset of the QRS complex to the repolarization phase near the peak of the T wave. The myocardial cells are unable to respond to strong stimuli during this period. The relative refractory period (RRP) is the duration of ventricular repolarization from the peak to the end of the T wave. The cells respond to strong stimuli.[15, 16]

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[8] V. C. Scanlon and T. Sauders, Essentials of Anatomy and Physiology, 5th ed., Philadelphia, PA: F. A. Davis Company, 2007
[9] National Institute of Health, "Electrocardiogram", 2016
[15] P. Nevins, "Events That Occur in the Resting Phase of a Cardiac Cycle", 2017
[16] J. W. Jones, "Refractory periods", 2016

DEFIBRILLATOR DESIGN

Fundamentally, a defibrillator consists of a rechargeable battery, a DC/DC converter, a capacitor, an output stage and a control unit. Due to the fact that the DC voltage from the rechargeable battery is too small for an electric shock, a larger voltage is generated with the help of the DC/DC converter, which is used to charge the capacitor. The capacitor's fixed capacitance ensures that it stores a specified amount of energy.
At the push of a button, the capacitor discharges its stored energy – roughly 200 to 360 J – to the electrodes via the output stage. High voltage at the capacitor amounts to as much as 4 kV and is applied to the patient for a duration of 3 to 40 ms. With typical body resistances within a range of 50 to 100 Ω, current reaches a value of up to about 50 A for a short period of time. For the capacitor, this results in capacitance within a range of 45 to 500 µF.[10]

Energy from the capacitor is released via electrodes with large surface areas, which are either pressed onto the patient's chest with the hands (so-called paddles) or adhered to the chest (so-called adhesive electrodes or fast patches). Above all where public access defibrillators (PADs) are involved, adhesive electrodes are used almost exclusively in order to simplify operation and reduce the risk of electric shock to the user. Device variants are available for use with open thorax (during surgery) that are equipped with spoon-like electrodes which are applied directly to the myocardium.

The output stage generates specific pulse shapes. The control unit regulates the capacitor charging process and, as a protective function, also ensures that the capacitor, which is charged with high voltage, is discharged via a device-internal resistor if the stored energy is not released.

Modern defibrillators are based on biphasic operation. This means that not only a current pulse with a single polarity is delivered from the output stage – the direction of the current is also reversed by changing polarity at the electrodes. In this way, biphasic devices make it possible to achieve the same degree of effectiveness with lower energy output and less damage to the myocardium.[11]

Technically advanced biphasic defibrillators also measure the patient's complex body resistance (impedance) by means of adhesive electrodes prior to energy discharge, and adjust current and voltage accordingly. As a result, for example, less current is applied to thin, small patients with low impedance than to large, overweight patients. In the meantime there's also evidence indicating that if more than one treatment is required, the use of rising (escalating) levels of energy is more effective than delivering constant levels of energy to the patient.

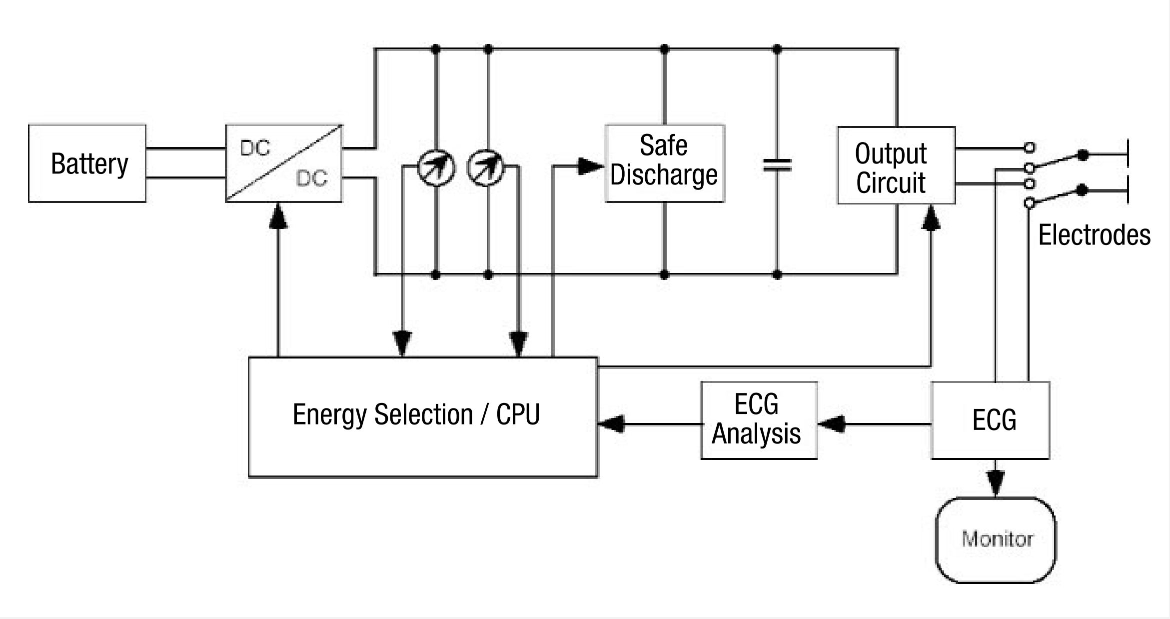

Figure 5: Defibrillator Block Diagram (Docplayer.org)

[10] Promotionsschrift Martin Schönegg, iq-biphasic.com
[11] Defibrillator, from: Pschyrembel Klinisches Wörterbuch, 261st edition, de Gruyter, Berlin 2007, ISBN 978-3-11-019126-4

CARDIAC ARRHYTHMIA

Arrhythmia, or irregular heartbeat, is caused by damage to the cardiac conduction system, in which case the pulses may be too slow, too fast or irregular. As a result, the heart is no longer capable of pumping blood effectively through the body, thus causing damage.

Typical arrhythmias include:

Atrial fibrillation (AF) – rapid, irregular contraction of the atria
Atrial flutter (AFL) – similar to atrial fibrillation but not irregular
Bradycardia – slow heart rate at rest, i.e. < 60 bpm
Ventricular tachycardia (VT) – fast heart rate at rest, i.e. > 100 bpm
Ventricular fibrillation (VF) – rapid tremor of the ventricles [12, 13]

Fibrillation is a regular but very fast heartbeat which can cause 300 contractions per minute. Atrial flutter is not imminently life-threatening because the pumping action of the atria is not critical. Ventricular flutter is usually a short transitional phase between VT and VF. Fibrillation involves very rapid, uncoordinated contractions which cause a sudden reduction in cardiac output (the amount of blood pumped by the ventricles per minute). In this case, the ventricles no longer pump the necessary amount of blood through the arteries to the rest of the body – this is referred to as cardiac arrest.

A heart attack – myocardial infarction (MI) – is the sudden interruption of the supply of blood to the body and can cause VF. In the event of ventricular fibrillation, intervention is required in order to prevent death.[13, 14]

DEFIBRILLATION

Defibrillation is a corrective measure which terminates VF or, in simple terms, converts the arrhythmia into an NSR. A defibrillator can deliver a powerful electric shock to the heart, which depolarizes the heart cells thus causing them to contract. At the same time, the cells then repolarize themselves to a relaxed state.

Energy from the capacitor is released via electrodes with large surface areas, which are either pressed onto the patient’s chest with the hands (so-called paddles) or adhered to the chest (so-called adhesive electrodes or fast patches). Above all where public access defibrillators (PADs) are involved, adhesive electrodes are used almost exclusively in order to simplify operation and reduce the risk of electric shock to the user. Device variants are available for use with open thorax (during surgery) that are equipped with spoon-like electrodes which are applied directly to the myocardium.

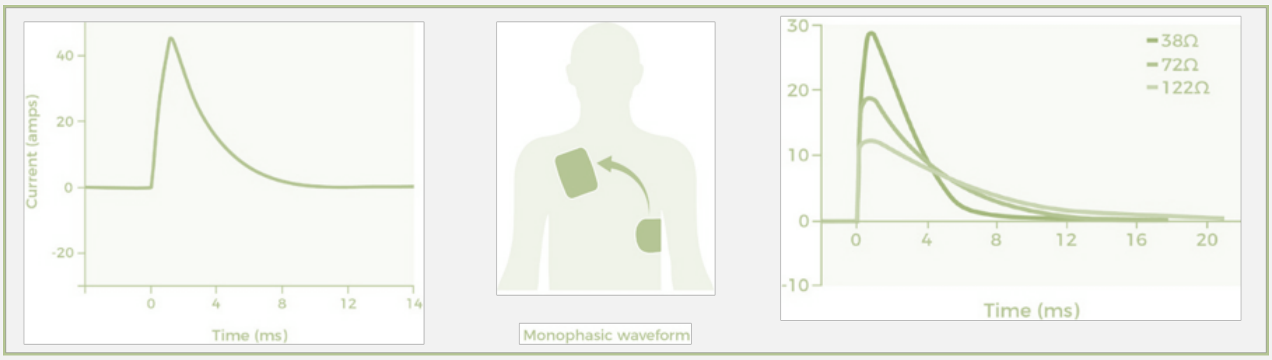

Figure 6: Monophasic Waveform, Current Flow, Graph Showing Impedances of 38 Ω, 72 Ω and 122 Ω

[12] C. Scanlon and T. Sauders, Essentials of Anatomy and Physiology, 5th ed., Philadelphia, PA: F. A. Davis Company, 2007
[13] The American Heart Association, “About Arrhythmia”, 2016
[14] British Heart Foundation, “Cardiac arrest”

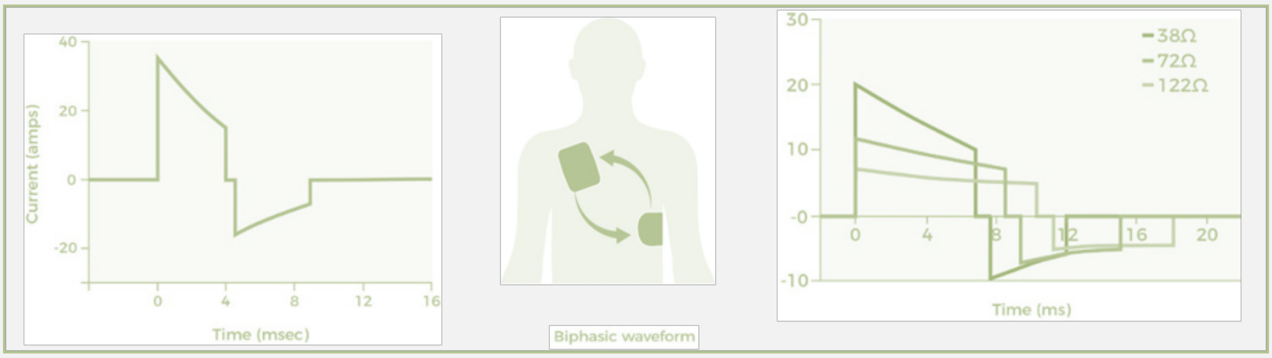

Figure 7: Biphasic Waveform, Current Flow, Graph Showing Impedances of 38 Ω, 72 Ω and 122 Ω

Energy applied to the patient must be great enough to influence the heart cells. In general, shocks of short duration necessitate greater amperages, whereas smaller values are adequate for shocks of longer duration. In actual practice, shock energy levels delivered by the electrodes of a defibrillator to a patient's thorax range from 1 to 360 joules (J) with current in the tens of amperes range and several thousand volts over a duration of 3 to 10 ms.
Typical impedance values for a patient's thoracic cavity lie within a range of 25 to 180 **Ω**. Factors which affect impedance values include body/tissue mass, age, health and skin resistance. Only a fraction of the current conducted into the thoracic cavity actually reaches the heart. [15, 16, 17, 18]

The first commercially available defibrillators were biphasic. However, monophasic defibrillators were used in the Western world for 30 years up through the mid-1990s, at which time the fact was recognized that biphasic technology increases defibrillation success.

Monophasic defibrillation (see figure 6) involves a damped sine wave with high peak current – current flows in one direction through the heart.Current drops as body impedance increases – if impedance is high, the heart may not receive enough current for defibrillation.

Biphasic current flow (see figure 7) is bidirectional. The current waveforms adjust themselves in order to maintain the delivered amount of energy, regardless of the patient's impedance. And thus regardless of his impedance, the patient always has the same chance of survival.

Biphasic waveforms are not uniform from one defibrillator to another. Manufacturers have their own, patented biphasic technologies. There are three patented technologies: biphasic truncated exponential waveform (BTE), rectilinear biphasic waveform (RBW) and pulsed biphasic waveform (PBW).

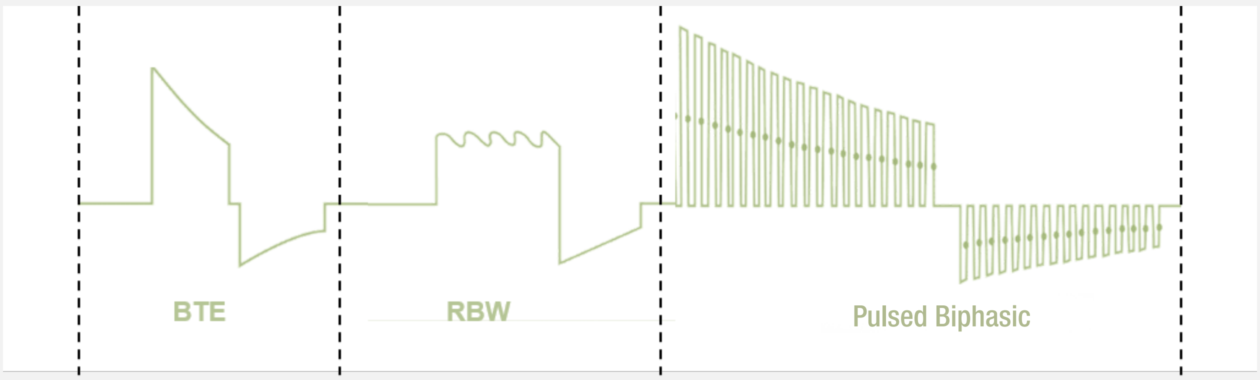

Figure 8: Biphasic Waveforms: BTE, RBW, Biphasic Pulsed

Biphasic defibrillators have advantages over monophasic devices. The lower energy levels delivered by biphasic devices can be just as effective as the higher energy levels delivered by monophasic devices.

[15] Anaesthesia UK, "Biphasic defibrillators", 2005
[16] V. C. Scanlon and T. Sauders, Essentials of Anatomy and Physiology, 5th ed.
[17] W. A. Tacker, "External Defibrillators", in The Biomedical Engineering HandBook
[18] B. J. Roth, "Defibrillators", in Encyclopedia of Medical Devices and Instrumentation

TYPES OF DEFIBRILLATORS

Automated External Defibrillators

Figure 9: AED

AEDs use algorithms in order to accurately assess cardiac rhythms and deliver the appropriate countershock in the event of an arrhythmia. AEDs distinguish between shockable and nonshockable rhythms and discharge energy only to patients who exhibit signs of VF or VT (pulseless) with specific peak-to-peak ECG amplitudes in accordance with American Heart Association (AHA) guidelines. Some AEDs are semi-automatic, in which case the operator is required to press the shock button in order to deliver a shock. With fully automated AEDs, there's no need for the operator to intervene when a shock is required. Modern AEDs evaluate ECG signal quality and contact integrity, and measure patient impedance. As a rule, AEDs deliver biphasic energy with fixed values ranging from 120 to 200 J for adults, and 50 J for children. However, some manufacturers offer units that cover the entire energy range from 20 to 360 J. [19, 20]

Implantable Cardioverter Defibrillators

ICDs are invasive devices placed under the patient's collarbone which play an important role in arrhythmia treatment. ICDs monitor the heart's electrical activity with electrodes attached directly to the myocardium for the purpose of:

- Defibrillation – electric shock for the restoration of an NSR
- Cardioversion – delivery of one or more small shocks for restoration of an NSR (normal sinus rhythm)
- Transvenous stimulation – rapid, low-voltage pulses for the correction of a slow cardiac rhythm
- Transcutaneous stimulation – stimulation with electric pulses in order to induce depolarization of the heart

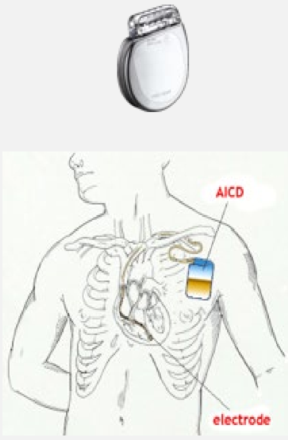

Figure 10: Implantable Defibrillator

Gejordan https://commons.wikimedia.org/w/index.php?curid=5231160

Defibrillator Vest

If patients need to be safeguarded against any temporarily increased risk of life-threatening, rapid cardiac arrhythmias, for example before implantation of an ICD or a CRT-D, they can be protected by a defibrillator vest (wearable cardioverter/defibrillator, WCD). On detecting a malignant arrhythmia, the device is automatically switched to the treatment mode. This is indicated visually, acoustically and by means of a vibration alarm to the patient and other nearby persons.

Figure 11: Defibrillator Vest

Photo: Zoll Medical Corporation

Manual Defibrillators

Conventional (manual) defibrillators also include ECG functions and are used, for example, by emergency medical service personnel. Some of these devices can also be used as external pacemakers, as well as for oxygen saturation and blood pressure measurements, or as capnometers, and often have an integrated option for semiautomatic defibrillation for use by non-medical EMS personnel. [21]

Figure 12: Manual Defibrillators

Photo: Schiller Medical Corporation

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[19] R. E. Kerber, L. B. Becker, J. D. Bourland, "Automatic External Defibrillators for Public Access"
[20] J. A. Zijlstra, "Automated external defibrillator and operator performance in out-of-hospital cardiac arrest"
[21] Wikipedia 2022, Defibrilatorarten

DEFIBRILLATOR USAGE

Energy is conducted via the heart and current flows between the atria and the ventricles. The paddles of an external defibrillator are positioned from the sternum to the apex. The paddles can be arranged from front to front or from front to back. Defibrillator paddles are unequivocally identified as apex (+) and sternum (-) for ease of placement.

Synchronization, or synchronized electrical cardioversion, is utilized by defibrillators in order to detect the QRS complex. This is intended to prevent inadvertent shock during the ECG's T wave – the so-called vulnerable period (see figure 9). Shocks during the ECG's T-wave may result in VF.
The defibrillator measures the timing of the R wave and synchronizes itself to the patient's heart rate, so that energy is delivered close to the R wave period.

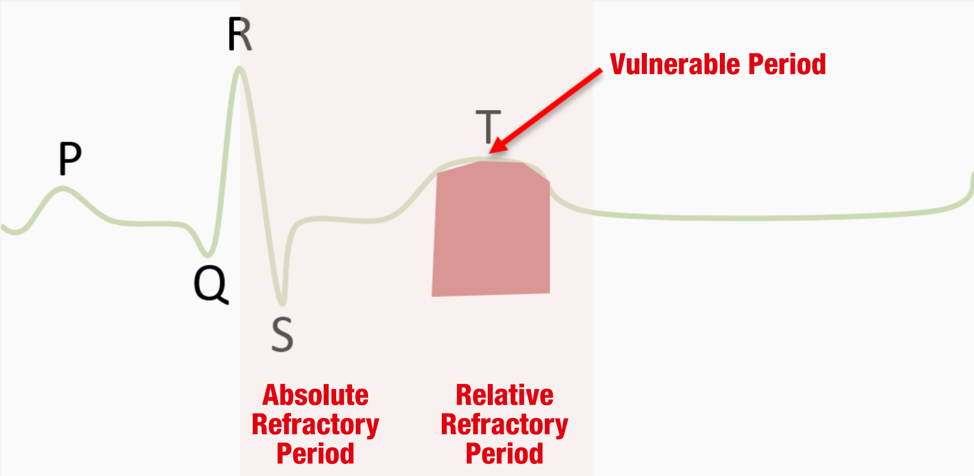

Figure 13: Cardiac Cycle with Vulnerable Range

Shockable arrhythmias include VF, VT, AFL, and AF. Shockable rhythms can be divided into two categories:

Non-cardio-synchronized defibrillation
VF and VT (pulseless)

Cardio-synchronized defibrillation
AF, AFL and VT (with pulse)

Synchronization, or synchronized electrical cardioversion, is utilized by defibrillators in order to detect the QRS complex. This is intended to prevent inadvertent shock during the ECG's T wave – the so-called **vulnerable period** (see figure 13). Shocks during the ECG's T-wave may result in VF.
The defibrillator measures the timing of the R wave and synchronizes itself to the patient's heart rate, so that energy is delivered close to the R wave period. [22, 17]

Arrythmia	Biphasic	Monophasic
Adult VF, VT (without pulse)	120 to 200 J	360 J
Adult AF	120 to 200 J	Up to 200 J
Adult SVT, AFL	50 J stepwise increases	Up to 100 J
Adult VT (with pulse)	100 J stepwise increases	Up to 200 J
Pediatric VF, VT (without pulse)	2 J per kg – 4 to 10 J per kg	Biphasic equivalent
Pediatric tachycardia	2 J per kg – 4 to 10 J per kg	Biphasic equivalent

Figure 14: Recommended Absorbed Dose According to AHA

[22] ACLS, "Shockable Rhythms", 2018
[17] W. A. Tacker, "External Defibrillators", in The Biomedical Engineering HandBook

TESTING DEFIBRILLATORS

As a rule, testing a defibrillator always includes several steps. On the one hand, electrical safety in accordance with nationally and internationally applicable regulations must be ensured and, on the other hand, all of the device's functions must be tested in order to rule out any risk to the user and the patient. In any case, the operator is responsible for technically correct, proper testing and standards-compliant documentation.

As a basic prerequisite for every defibrillator test, the inspector must understand the mode of operation of the device under test. Energy discharged from defibrillators is extremely dangerous, for which reason precautions must be implemented in order to protect the inspector. Furthermore, tests may only be performed by a competent, appropriately trained person.

Recommended Defibrillator Test Procedure

Visual Inspection
Housing, connection cables (mains cable, ECG cables), electrodes, switches, paddle box (if included), paddle adapter, fuse

Electrical Safety
Leakage current, insulation

Battery Power

Alarms
Verification of all alarm functions by means of simulation

ECG Performance
Amplitude gain, BPM rate check (simulation), frequency response

Vital Signs Check
SPO_2, NIBP, CO_2

Auto-Function (if included)
Synchronization/cardioversion, arrythmia detection, recording synchronization delay

Energy Output
Energy linearity, delivery after a specified period of time (typically 1 minute at maximum power), charge time at maximum power (typically < 10 s), test with various output power levels, test with various output impedances (if required by manufacturer), paddle impedance test

Pacemaker Output
Current linearity, synchronization, pulse width, refractory times

TESTING DEFIBRILLATORS

Defibrillators play an important role in implementing the measures necessary for successful CPR (cardiopulmonary resuscitation). Thanks to technological advances, emergency responders are now able to provide solutions which reduce the number of potentially fatal cases. AEDs also improve recovery results for out-of-hospital cardiac arrest (OHCA), and can be found in many public places all over the world for use by laypersons.

High performance GOSSEN METRAWATT defibrillator test sets can accurately analyze energy levels ranging from 0 to 360 J for all monophasic, biphasic, standard and pulsating waveforms via a non-inductive, fixed 50 Ω load and can accommodate external variable loads if required.

E (energy in J), Vp (peak voltage in V), Ip (peak current in I), and t (pulse duration in ms) can all be indicated at the displays. No oscilloscope is required to view the captured waveforms.

Defibrillator cardiac synchronization timing can be measured in ms with the analyzers.
The defibrillator synchronizes itself to the ECG's R wave. Heart rate can be varied; timing of the synchronized R wave and the delivered energy pulse is measured.

Battery recovery recording is required by IEC 60601-2-4. The **SECULIFE DF PRO** is equipped with a stopwatch function for the determination of charging time duration, which is typically set to maximum charging. Charging time is measured from triggering of the charging cycle at the defibrillator through discharging of the energy via the analyzer's load.

The instruments are capable of simulating cardiac arrhythmias via the test loads, thus making it possible for an AED to analyze and distinguish a shockable ECG from a nonshockable ECG; the AED discharges its energy accordingly via the test load.

Figure 15: SECULIFE DF BASE, SECULIFE DF PRO

ECG Simulation

The analyzers feature a categorized range of ECG simulations.

Sinus rhythms, ventricular arrhythmias, atrial conduction and arrhythmias, pacemaker curves and power curves can be easily simulated. The analyzers display each ECG curve at the screen, so there's no need to refer to instruction manuals in order to determine the shape of the curves. Adjustable parameters are available for verifying the defibrillator's patient monitoring capabilities.

The following parameters are included:

- Amplitude
- Frequency
- Heart rate
- Noise

Transcutaneous Pacemaker Measurement

The pulse shapes used by pacemaker manufacturers vary from brand to brand. SECULIFE defibrillator analyzers cover the algorithms of many manufacturers in order to correctly measure current delivered by pacemakers. In the pacemaker pulse mode, rate (heart rate in ppm), PW (pulse width in ms), Ip (peak current in mA) and E (energy in mJ) can be displayed at the screen. A graphic representation of the pulse can be displayed as well.

Stimulation can be delivered to a fixed, non-inductive 50 Ω load (defibrillation input) or to a variable load (pacemaker input).

Refractory Period

The pacemaker refractory period (PRP) is the amount of time the pacing pulse is delayed by the pacemaker due to an incoming QRS signal.

Sensitivity Test

The sensitivity test increases the amplitude of R wave simulation until the pacemaker under test detects the simulation and blocks the output. Pacemakers in demand mode don't deliver pulses when a heart rate above the selected pacing rate is detected.

Defibrillators are dangerous medical devices which surely involve a certain amount of risk. Defibrillator performance and safety testing conducted on a regular basis improves patient safety by ensuring that the devices meet the manufacturer's specifications, that they're accurate and that they fulfill their intended purpose.

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