Chapter

History of the Development of Automated External Defibrillators

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Abstract

This chapter is structured as a historical overview of the history of the development of defibrillators and the most prominent personalities who contributed to the development of the modern concept of resuscitation. Defibrillators in medical practice can be external or implanted. The devices, known as automated external defibrillators, automate the diagnosis of a patient's rhythm and the process of stopping arrhythmias, meaning they can be used successfully by nonspecialists. In Europe, 350,000–700,000 people suffer from sudden cardiac arrest every year. On average, it is 55–113 per 100,000 people. Most of these people are usually at home, but about 10–20% of victims are in a public place at the time. Defibrillation within 3–5 minutes of cardiac arrest can increase survival by 50–70%. For every minute that defibrillation is delayed, the chance of survival decreases by 10–12%. A significant contribution to the development of the defibrillation concept was made by Peter Kristians Abildgård, Albert Salisbury Hyman, William Bennett Couwenhoven, Paul Morris Zoll, James Francis Pantridge, and many others. Clinical studies confirm that public access defibrillators (PADs), when available and used correctly during out-of-hospital cardiac arrest, were associated with a 40% median survival rate.

Keywords: history of defibrillators, sudden cardiac death, resuscitation, automated external defibrillators, public access defibrillation

1. Introduction

To us, people living in the twenty-first century, many things seem self-evident. Both various household electronics, transcontinental flights, space exploration, and much more. We take medical advances, including rapid advances in resuscitation options and automated external defibrillators available in public places, as a matter of course. Whether it is an airport or a railway station, a gym or a large store, the existence of such a device and its easy identification seems completely normal. You see the classic sign of an Automated external defibrillator (AED), and it triggers no emotions – this is the norm as it should be. However, at such moments, interest arises – how long did science need to develop, so that these great devices, which have saved thousands of lives, have become a self-explanatory part of your everyday life? Who are the people who took the first steps in their invention, research and did so much to

make the concepts of "defibrillation," "cardioversion," "resuscitation" not something unknown and exotic anymore but completely normal? Historical aspects have always been fascinating, both in architecture, linguistics, and culture. The same can be said about medical science. Medical development has been focused on preserving human life and health for many thousands of years. Unfortunately, clinical medicine often encounters acute and urgent situations where every second counts, and a person's life depends on quick and professional action. What has this path been like? What personalities have contributed to AED being a classic every day? About that and a few other things in this chapter.

The authors chose to structure this chapter as a historical excursion, in which we invite you to walk with us through the history of defibrillation and the creation of defibrillators, to dwell on the personalities, and to look at the first clinical studies and further development of AED.

2. The concepts of "defibrillation" and "synchronized cardioversion"

What do we mean by the terms "defibrillation" and "synchronized cardioversion"? What is the basis of the defibrillation process? What changes are caused by defibrillation? About it in this subsection.

2.1 Defibrillation

Defibrillation is a treatment for life-threatening heart rhythm disorders, especially ventricular fibrillation (VF) and ventricular tachycardia (VT). A defibrillator delivers a dose of electrical current (often called a defibrillator) to the heart. Although not fully understood, this process depolarizes the heart muscle cells, stopping an existing arrhythmia. After the depolarization, the body's natural pacemaker – the rhythm generation cells of the conduction system in the heart's sinoatrial node are able to restore normal sinus rhythm. A heart in asystole (isoelectric line on the ECG) cannot be restarted with a defibrillator but can only be treated with cardiopulmonary resuscitation (CPR) and intravenous vasopressors such as epinephrine (adrenaline).

Defibrillators in medical practice can be external, transvenous, or implanted (implantable cardioverter-defibrillator), depending on the type of device used or required. Some external devices, known as automated external defibrillators (AEDs), automate the diagnosis of the patient's rhythms, which means that they can be used successfully by nonspecialists either after a short training course (security personnel, sports complex instructors, flight crews, police officers, etc.) or without that provided by the algorithms built into these machines for fully automatic operation.

2.2 Synchronized electrical cardioversion

Unlike defibrillation, synchronized electrical cardioversion is an electrical shock that is delivered by synchronizing the shock with the heart's cycle. Although the person may still be in a critical condition, the goal of cardioversion is usually to stop cardiac arrhythmias that result in significant impairment of circulation and perfusion, such as ventricular tachycardia or atrial flutter, or atrial fibrillation.

The defibrillator system generates a rapid discharge of electric current, depolarizing most of the heart muscle quickly (practically instantly). One could even

say that the simultaneous depolarization puts the action potential in the 0 state in most myocardial cells. The effect of this energy discharge, which is often referred to as a "shock," interrupts the electrical activity of chaotic cells, and stops the inefficient operation of the heart. The term used to describe this inefficient and chaotic cellular activity is "fibrillation," successively stopping this process is called "defibrillation." After complete depolarization, there is a period in which the electrical activity of the heart is at zero level, but after this pause, cells of the sinus node start to work as the highest centers of rhythm generation of the cardiac conduction system, or in some cases, the cells of the rhythm generation system of the secondary level or substitute levels are activated. Consequently, the normal physiological sequence and synchronicity of the heart rhythm is restored.

After defibrillation is performed, in the optimal version, it returns to normal sinus rhythm, where it begins to provide physiological circulation in the body, ensuring that oxygen-rich blood reaches cells throughout the body. Skin color may return to normal, oxygenation improves, and in some cases, the person will also spontaneously recover other life-sustaining functions as physiological circulation is restored.

Defibrillation stops the heart's electrical activity and allows the action potential of its pacemaker cells to fire. The effectiveness of the procedure depends on the metabolic state of the myocardium (due to the cause and time of heart failure) and the correct realization of the defibrillation protocol.

2.3 What is the defibrillation mechanism?

Extracellular electric current shocks are widely used to treat ventricular tachyarrhythmias. Extracellular current flow induced by defibrillation shocks is thought to produce changes in membrane potential (ΔVm); these changes then interrupt reentrant circuits, prolonging ventricular refractoriness, and/or generating new waves of excitation. The defibrillation shock causes depolarization or hyperpolarization, which takes place in the ventricular myocardium and which is located at a relatively large distance from the surface electrodes used in the defibrillation process. Several mechanisms are known that most likely explain such limited ΔVm formation. When performing myocardial mapping with the application of continuous linear leads, the parameters of ΔVm are limited to the area located in the immediate vicinity of the discharge electrodes. Such a region, whose dimensions exceed ≈3 length constants, is defined as the "close-field" or "polarity region." The resulting ΔVm, labeled "primary source." When analyzing secondary sources, i.e., those located within ΔVm (>2 to 3 mm) of the electrical discharge electrodes, such a situation may arise if the current flowing during the shock is forced to divide locally between the extracellular and intracellular environments. Such a distribution can be caused by a number of factors such as systemic electrical changes in electrical connections between myocardial cells, changes in cell order or myocardial fiber geometry, heterogeneity of the extracellular space and associated resistance changes, as well as anisotropy-induced changes in the resistance ratio of intracellular and extracellular systems, also denoted as "bidomain effect."

2.4 Why is this topic so relevant?

In Europe, 350,000–700,000 persons suffer sudden cardiac arrest every year. On average, it is 55–113 per 100,000 people. In Latvia, on average, around 1500 people have a sudden cardiac arrest during the year. Most of these people are usually at home,

but it also happens in public places – about 10–20% of the victims are currently in a public place – an airport, a supermarket, a public institution, or a sports center.

When you are with a person who has suffered a sudden cardiac arrest, it is important to make a decision in the first few seconds and provide help in the first few minutes. Although the first aid provider himself does not realize it at all, the health and even life of the patient depends on his correct actions.

The most important thing in sudden cardiac arrest is to provide continuous chest compressions. Chest compressions achieve continuous blood supply to the entire body. However, chest compressions are not always enough.

About 20–50% of all sudden cardiac arrests are those that can be treated with electrophysiological therapy, or defibrillation. The importance of defibrillation has been particularly emphasized in recent years – it has been scientifically proven that every minute in which defibrillation is not performed decreases the patient's survival by 7–10%.

3. Briefly about AED

3.1 Automated external defibrillator (AED)

AEDs are portable devices that automatically analyze the heart rhythm of patients in cardiac arrest and deliver a shock, or defibrillation, if ventricular fibrillation or ventricular tachycardia is detected. Rhythm diagnosis is not part of the competence of peer assistance. The only difference between a shockable and a nonshockable rhythm is the AED's audible message, which will say "shock advised," indicating that the device has detected either VF or VT.

As previously mentioned, defibrillation within 3–5 minutes of loss of consciousness can increase survival by 50–70%. For every minute that defibrillation is delayed, the probability of survival decreases by 10–12%. Early defibrillation can be achieved by first responder use of publicly available automated external defibrillators. This type of approach should be implemented in public places with high population density, such as airports, railway stations, bus stations, sports arenas, shopping malls, or in places where there has been one case of cardiac arrest in 5 years. A record of previous such events (cardiac arrests) in a given area, as well as neighborhood characteristics, can help determine the most appropriate AED placement.

Both audio instructions and graphic instructions on the device are used to operate and operate the AED. The devices are safe and effective and designed for use by both trained and untrained people. AEDs allow rapid defibrillation for several minutes before receiving professional help. The helper should focus on following the voice instructions and continue to act according to the instructions. Standard AEDs are suitable for use on victims who have reached the age of 8 years.

AED designs may vary by manufacturer, but the basic components are the same for these devices. The user is instructed to turn on the device and expose the victim's chest. The paddles of the device must be opened and removed from the protective base, then placed on the victim's chest according to the AED graphic so that the heart rhythm can be detected and a discharge can be performed if necessary. Background motion can affect the accuracy of the result, so providers are instructed to stop CPR during rhythm analysis. International standards require AED sensitivity to detect VF >90% (VF at least 0.2 mV amplitude) and overall specificity >95%.

Most AEDs deliver 120–350 J of power. The choice of power depends on several factors, including the number of previous defibrillations and the resistance of the chest wall. AEDs typically provide audio instructions that prompt responders to stand away from the victim during rhythm analysis and press a button to deliver the shock. The AED is programmed to perform a rhythm analysis every 2 minutes and also instructs the rescuer to continue CPR.

Another important aspect that can affect survival in cardiac arrest is the registration of AEDs for public access and the availability of information to call dispatchers so that responders can be directed to the nearest AED {Ringh, 2018, The challenges and possibilities of public access defibrillation} if necessary [1].

ILCOR has developed an AED identification mark/marking that is recognized worldwide (see **Figure 1**).

ILCOR (*The International Liaison Committee on Resuscitation*) is an international cooperation committee whose goal is to promote the creation of common protocols for collaborative resuscitation and emergency medical care. The internationally accepted abbreviations CPR (Cardiopulmonary Resuscitation) and ECC (Emergency Cardiovascular Care) are used to denote the protocols. The organization was established in 1992. ILCOR includes professional associations and organizations such as the American Heart Association (AHA), the European Resuscitation Council (ERC), the Heart and Stroke Foundation of Canada (HSFC), the Australian and New Zealand Committee on Resuscitation (ANZCOR), the Resuscitation Council of South Africa (RCSA), the Asian Resuscitation Council (RCA), Inter American Heart Foundation (IAHF). Interestingly, the name of the organization is formed from the compound "ill cor," which means a sick heart; in Latin "cor" means heart.

A significant practical obstacle to using an AED is that, in this case, at least two helpers are needed – one to perform CPR and the other to obtain the AED.

One of the strategies for more effective attraction of fellow citizens provides that, while the emergency medical service (EMS) is being called, the instructions for

Figure 1.
International AED designation [2].

providing help are additionally given over the phone, and during this time, the dispatchers can warn other members of the public about such a case with the help of messaging or a special phone application. This approach allows for the notification of people who have volunteered for such digital transmission of information in the event of a cardiac arrest, thereby obtaining information about the event, its location, and, in some cases, the nearest publicly available AED. Although this is a new strategy, early studies have shown an increase in the rate of early initiation of CPR and the associated survival rate. Such a strategy is officially supported by the AHA.

Finally, a dispatcher may be able to send an AED to the scene by drone. This approach is still being researched, but early modeling of the system indicates that an AED can be delivered to the scene significantly faster by drone than by standard EMS transport, reducing time to the scene by 6 minutes in urban settings and 19 minutes outside of urban settings.

The potential lifesaving benefits of AEDs in public settings have been extensively studied. A review of several studies of public access defibrillation noted that the average number of patients who survived hospital discharge was 53% when defibrillated by bystanders compared with 28.6% of patients who survived when defibrillated by EMS personnel.

A 2018 study compared bystander defibrillation with an AED and defibrillation by an EMS specialist. The study examined nearly 50,000 cardiac arrests in 9 United States regions. According to the study, 66.5% of patients who were defibrillated by a bystander, compared to 43% of patients who were defibrillated by EMS personnel, survived to hospital discharge. In addition, it was found that at the time of discharge, a better neurological outcome was more often observed in patients who were defibrillated by peers (57.1 and 32.7%, respectively). Among all reported out-of-hospital cardiac arrests, an AED was used in 15.9% of cases. The benefit of bystander defibrillation with an AED increased with increasing time to EMS arrival [3].

Although AEDs offer many advantages and are essential in providing assistance, there are several challenges to their availability. For example, many AEDs are located in public places such as schools, business offices, and sports centers that are not accessible to the public at night or on weekends. One example is Toronto, where the total number of registered AEDs is 737, of which 707 were available during the middle of the day, and 228 or 30.9% were available at night [4].

3.2 Why is this topic so relevant?

Sudden cardiac arrest is one of the leading causes of death in Europe and worldwide. For a large number of people, cardiac arrest occurs outside the hospital, when first aid can be provided by fellow citizens. The number of people who survive OHCA (Out-of-Hospital Cardiac Arrest) varies around 10% in Europe [2]. The most important thing is the ability to recognize this condition and to initiate a set of assistance in time. In order to improve the survival abilities of these people, fellow citizens must act immediately – it is necessary to call emergency medical help and start cardiopulmonary resuscitation measures, which include chest compressions and breathing.

In recent years, the topic of the use of AEDs in such cases has been brought up, and various studies have been conducted to clarify their effectiveness and the involvement of fellow human beings in the use of these devices. An AED is a device that performs a defibrillation function and can be used by nonmedical personnel. It has been shown that early defibrillation in cases of cardiac arrest, when it is needed, reduces the victim's probability of survival until discharge from the hospital by 10–12%. The

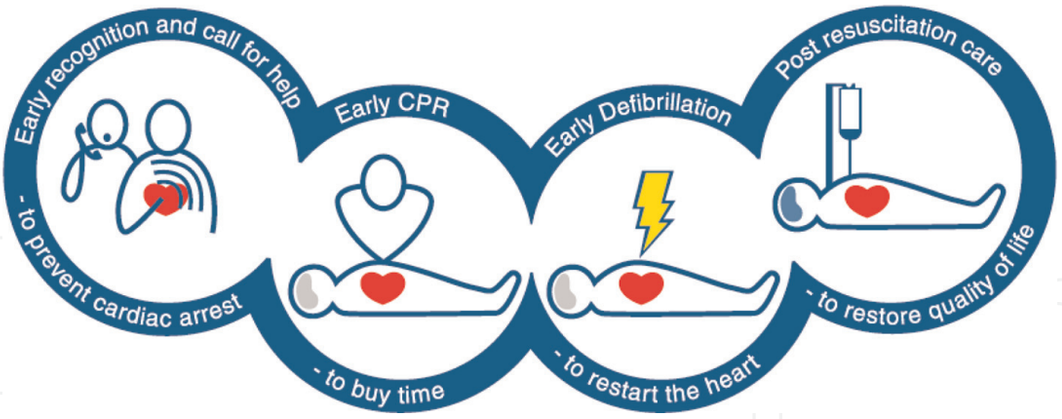

Figure 2.
The chain of survival [2].

combination of both measures (early CPR and defibrillation) has a synergistic positive effect on outcome.

Different organizations around the world offer slightly different representations of the most important set of steps during resuscitation, known as "The Chain of Survival." Such sets of images have been created and are used to facilitate the perception of information and the necessary actions that should be taken by the first responder (early recognition, calling for help, bystander CPR, early defibrillation, emergency care by medical personnel, and postresuscitation care).

As soon as the AED is brought, the defibrillator should be turned on, and the electrode pads should be attached, placing them on the victim's chest (without clothes). If there is more than one rescuer, cardiopulmonary resuscitation is not interrupted during electrode placement. Next, follow the AED's spoken/visual instructions. Ensure no one touches the victim while the AED analyzes the heart rhythm. If defibrillation is indicated, ensure no one has touched the victim, press the discharge button as directed, and resume cardiopulmonary resuscitation immediately after repeated instructions. If defibrillation is not indicated, resume CPR immediately after heart rhythm analysis. Follow up on AED instructions.

If an AED is not available, continue CPR. Resuscitation measures are not stopped until a medical worker tells them to stop it, the victim confidently starts to wake up, moves and breathes normally, or the rescuer loses all strength.

The European Resuscitation Council and other organizations offer '"The Chain of Survival," which is a metaphorical representation of a series of critical actions that rescuers should take to improve the chances of survival after cardiac arrest (**Figure 2**).

Several studies conducted on cardiac arrest resuscitations have confirmed that the most important steps in the "chain of survival" are the early stages of the chain – timely recognition of cardiac arrest and initiation of CPR. Both of these are more often performed by nonmedical peers, so these people play an important role in further development. Knowing and understanding these links in the chain can reduce the mortality rate.

4. History and personalities

Personalities have influenced our ability to help people in critical situations involving spontaneous circulatory arrest related to ventricular fibrillation.

Peter Christian Abildgaard.

In 1775, the Danish veterinarian and doctor Peter Christian Abildgaard conducted experiments with electric countershock on animals. He managed to first kill the birds with an electric shock and then revive them with a countershock applied to the chest. Ventricular fibrillation and defibrillation were unknown and undocumented at this early date, but his report suggests that he made these changes long before other physiologists described them. Dr. Abildgar's long and varied career included many important contributions to veterinary and human medicine, biology, zoology, botany, physics, chemistry, and mineralogy.

Abildgaard founded the Christian Veterinary School in 1773, which is one of the oldest schools in Europe and whose first library contained Abildgaard's own collection. In 1858, the school was moved to Frederiksberg to become the Royal Veterinary and Agricultural University, and today it forms the Faculty of Natural Sciences of the University of Copenhagen.

Birth December 22, 1740 Copenhagen.

Death 21 January 1801 (aged 60) Copenhagen (**Figure 3**).

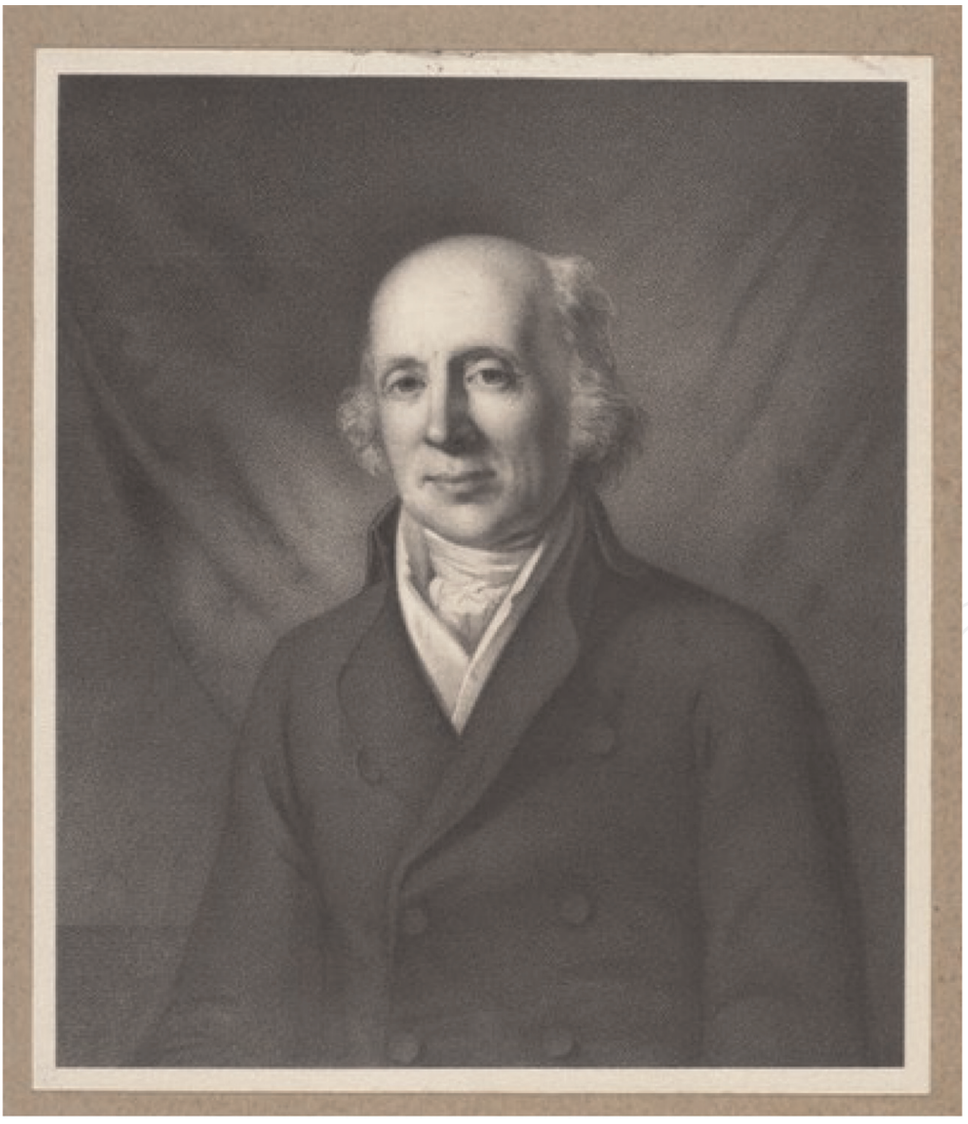

Figure 3.
Peter Christian Abildgaard *[5].*

John Alexander McWilliam.

Professor John Alexander McWilliam of the University of Aberdeen was outstanding in the development and understanding of sudden death and the mechanisms of ventricular fibrillation. McWilliams studied the mechanisms of ventricular fibrillation and was the first scientist to link ventricular fibrillation to sudden death. He has a very important role in the research of arrhythmia mechanisms, McWilliams' works discussed the possibility of stopping ventricular fibrillation with an electric shock and also recommended transthoracic electrostimulation as a nontaxing treatment method in case of asystole. John McWilliams became a professor at the University of Aberdeen at the age of 29.

Born on July 31, 1857.

Died on January 13, 1937.

McWilliams' research on the physiology of ventricular fibrillation and sudden death, as well as the defined basic concepts, have remained relevant throughout the centuries and significantly influenced later scientific research and practice in clinical cardiology and electrophysiology, as well as served as a basis for the development of the basic principles of cardiopulmonary resuscitation. It was McWilliams who was the first scientist to develop the concept of ventricular fibrillation as a cause of sudden death. His methods are the basis of many modern clinical studies. The study of the role of the autonomic nervous system in modulating the electrical and mechanical properties of the heart began directly with the works of this scientist (**Figure 4**).

Figure 4.
John Alexander McWilliam *[6].*

Albert Salisbury Hyman.

Cardiologist Albert Salisbury Hyman in the USA between 1930 and 1932, in cooperation with his brother Charles, created an interesting and, at that time, unseen electromechanical device, which was able to cause myocardial contractions with the help of electrical impulses. This Hyman invention can be called one of the first artificial pacemakers. One example of Hyman's heart "electric machine" is on display at the Heart Rhythm Society's museum. There are also reports in the literature about the use of this equipment in practice with experimental animals and there are data that the equipment was used to help at least one patient.

Born in 1893.

Died in 1972 (**Figures 5** and **6**).

In 1933, Popular Mechanics published an article about a new device developed by Dr. Albert Hyman and his brother Charles, an electrical research engineer. The device is described as a "Dead Man's Heart Self-Starting Device." The device can be compared to a car's automatic starter, because when the car's engine stops, the starter

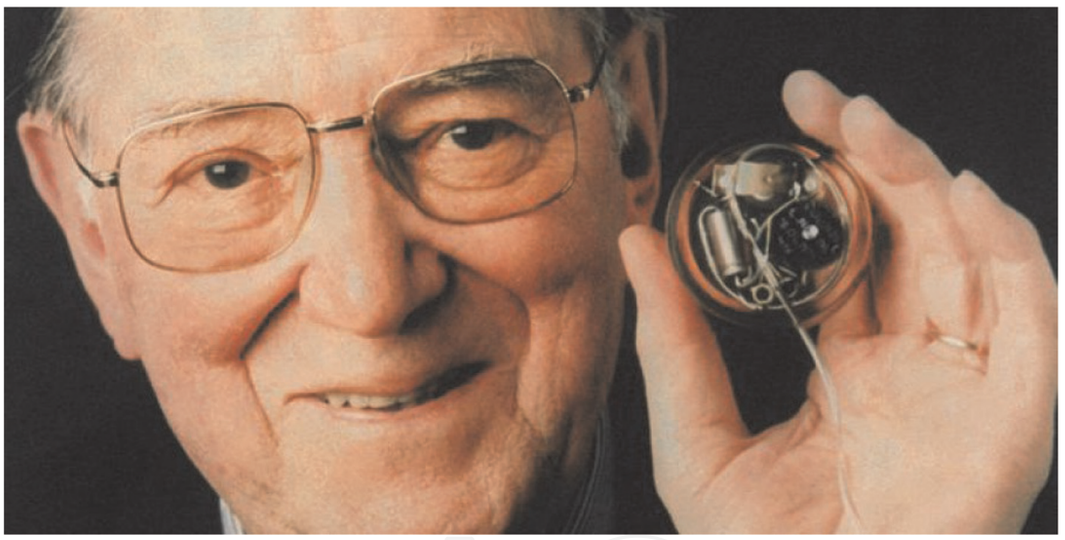

Figure 5.
***Albert Salisbury Hyman** [7].*

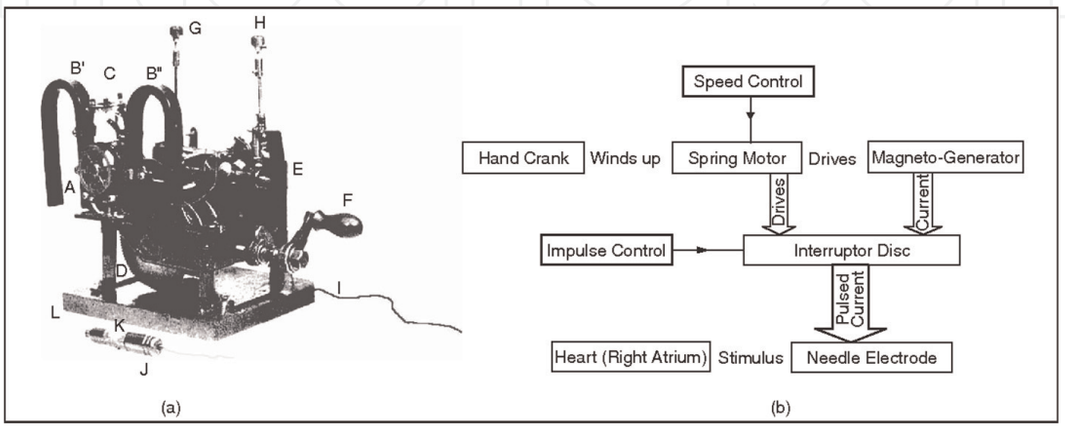

Figure 6.
Diagram and principle of operation of the first Hyman artificial pacemaker [8].

motor turns it over again until the cylinders start working again. In a similar way, the new device is able to give an electrical signal to the heart to start working again. In Albert Hyman's description, this was done by inserting one needle between the ribs and the other into the auricle of the right atrium of the heart, then starting the generator and turning it to the correct frequency. The article concludes that the medical establishment predicts widespread utility for the device, called the "Hyman Otor."

Mark C Lidwell.

Australian anesthesiologist Mark C. Lidwell first used the artificial heart pacemaker (the principle of this method and the equipment at his disposal) in clinical practice in a Sydney hospital as early as 1926, but in history, it is Hyman's name that is associated with the concept of "artificial pacemaker," which the medical and nonmedical community still used today. It is debatable who really deserves the laurels of the first discoverer, but Lidwell did not patent his device and chose to remain anonymous for many years. It is true, however, that in the medical circles of that time, the opinion against Hyman's version was quite contradictory, and it was not accepted in the professional environment for a long time (**Figure** 7).

Figure 7.
Mark C Lidwell *(in some published and available sources mark C Lidwill) [9].*

Federico Battelli.

Federico Battelli (Italian Federico Battelli) or Frederic Battelli (Fr. Frédéric Battelli; April 6, 1867, Macerata Feltre; September 5, 1941, Geneva) was an Italian-Swiss physiologist and biochemist. Brother of Angelo Battelli.

He studied medicine in Urbino and Turin. In 1885, he began teaching at the Faculty of Medicine of the University of Turin, but then left Italy for political reasons and settled in Switzerland, taking a position as an assistant in the Physiology Department of the University of Geneva under Jean. -Louis Prevost, and in 1913 he succeeded his mentor as Professor of Physiology and held it until the end of his life.

Together with Prevost at the turn of the century, he studied death by electrocution and the effects of electricity on the heart muscle; these works anticipated later discoveries in the field of cardiac resuscitation. In 1909, together with L. S. Stern, he synthesized alcohol dehydrogenase for the first time.

Swiss physiologists Jean-Louis Prevost and Frédéric Batelli confirmed in 1899 that electric shocks can cause ventricular fibrillation in dogs, but even stronger shocks can stop the ventricular fibrillation and restore a normal physiological rhythm (**Figure 8**).

Figure 8.
Federico Battelli *[10].*

William Bennett Kouwenhoven.

William Bennett Kouwenhoven is often called the father of cardiopulmonary resuscitation in the professional environment, and this is not a mistake. Interestingly, Kouwenhoven began his professional and scientific career with a doctorate in engineering at the Technical University of Karlsruhe, Germany, and later moved to Baltimore, USA, to Johns Hopkins University, where he worked both as a scientist and as a dean, in cooperation with the Edison Electrical Institute and the support of the same J. Hopkins University School of Medicine, he and his colleagues managed to develop a real-life defibrillator that can be applied to a closed chest. This scientist has outstanding merits in introducing the closed chest compression method into resuscitation practice. Kovenhoven has received many major awards, including the Albert Lasker Award for Research in Clinical Medicine and an honorary doctorate from Johns Hopkins University.

Born on January 13, 1886.

Died on November 10, 1975 (**Figure 9**).

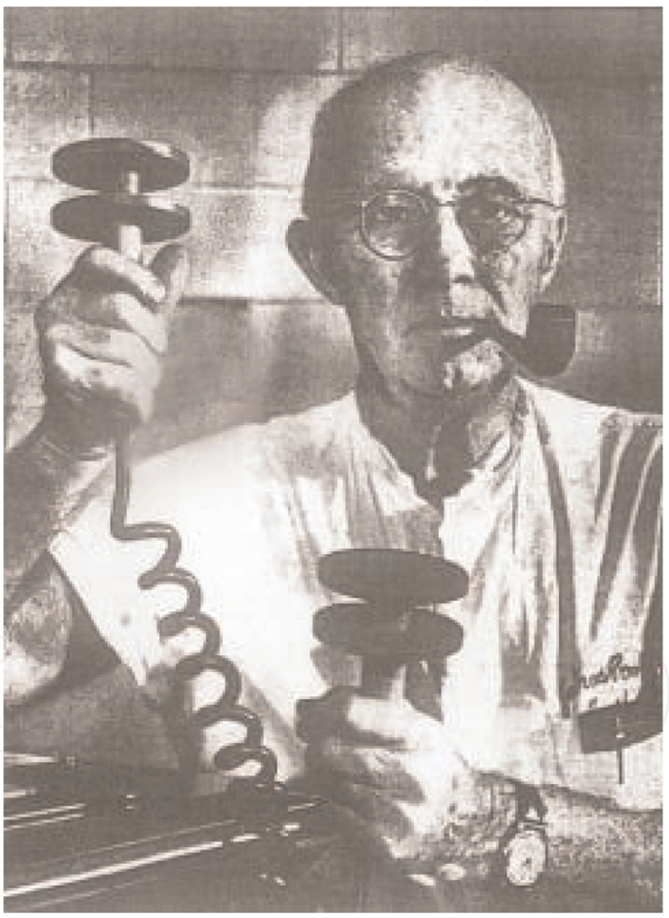

Figure 9.
William Bennett Kouwenhoven *[11].*

Claude Schaeffer Beck.

Claude Schaefer Beck has left many records for himself in history. He was also a candidate for the Nobel Prize in Medicine in 1952. Throughout his career, Beck has always been an advocate and supporter of highly innovative methods. Beck's operations are still methodologically recognized, cardiopericardiopexy (Beck's operation I)

in 1935 and the creation of a shunt between the aorta and coronary sinus (Beck's operation II) in 1940 can be found in any medical textbooks and are still appreciated by the specialist community. The pectoral muscle implantation technique in the

Figure 10.
Claude Schaeffer Beck [10, 12].

Figure 11.
Claude Schaeffer Beck [10, 12].

pericardium, which was performed by Beck back in 1930, which was a very innovative method for those times, has lost its relevance today, but at that time was very well received in the professional environment.

In terms of resuscitation, Beck's name is associated with the successful defibrillation during surgery of a 14-year-old boy with congenital heart defects who went into cardiac arrest after surgery. After 45 minutes of ineffective direct (manual) heart massage after repeated chest opening, Beck applied a defibrillator built by Rand Development Corp. and designed by Beck himself. A normal heartbeat was restored, and the boy made a full recovery.

Beck's name in clinical medicine is also associated with the analysis of the physiological basis of the signs of cardiac tamponade, and clinicians call these signs Beck's triad. The signs are low arterial blood pressure (hypotension), distended neck veins, and distant, muffled heart sounds.

Please do not confuse with Aaron Beck's triad, which is associated with depression.

Born on November 8, 1894.

Died on October 14, 1971 (**Figures 10** and **11**).

Paul Morris Zoll.

Paul Morris Zoll (July 15, 1911 to January 5, 1999) was a Jewish-American cardiologist and one of the pioneers of the artificial pacemaker and cardiac defibrillator. He graduated from Boston Latin School in 1928.

During his long professional career, Paul Zoll managed to divide his time equally between clinical work and scientific research. The results of his research led to a paradigm shift in the practice of cardiology. For example, the pacing of a stopped heart from the surface of the chest in 1952; monitoring of clinically significant cardiac

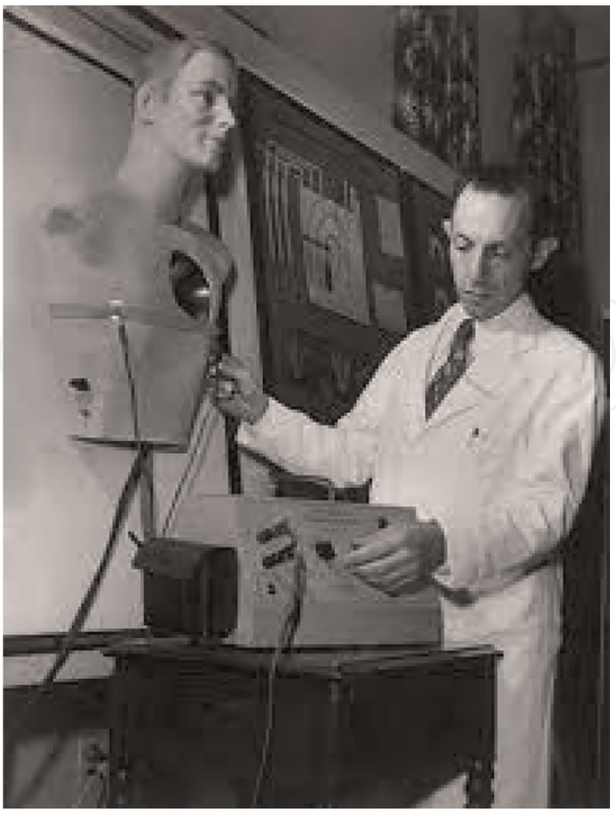

Figure 12.
Paul Morris Zoll [13].

Figure 13.
Paul Morris Zoll [13].

arrhythmias in 1953; performing defibrillation from the chest surface to stop life-threatening ventricular fibrillation in 1956; Installation of a Zoll-Belgard-Electrodyne self-contained long-term pacemaker in a child in 1960; and the introduction of a new concept that allowed for "painless" electrostimulation of the chest surface in 1982. The new device led to the formation of a small company that later became known as Zoll Medical Corporation.

In collaboration with Alan Belgard, chief electrical engineer and co-owner of Electrodyne, effective chest surface pacemakers were developed to meet Paul Zoll's needs. This collaboration became long-lasting as they jointly developed a series of chest surface pacemakers (transthoracic), monitors for clinically significant heart rhythm disturbances, external defibrillators, cardiac monitors – automatic pacemakers, and long-term implantable pacemakers (**Figures 12** and **13**).

Bernard Lown.

Bernard Lown has many merits in the development of both electrophysiology and cardiosurgery, as well as in intensive care pharmacotherapy. Precisely in 1961, in an experimental way, Lown's group with his colleagues were able to prove that a special direct current waveform can stop the fibrillation process without causing damage to the skeletal muscles and myocardium. This, in the words of the authors, "low waveform," did not cause electrical injury to the muscle tissue and did not traumatically affect the conduction system of the heart. This discovery was a big step toward the development of defibrillators and their introduction around the world.

Lown's work significantly improved the survival of patients with coronary heart disease, both in acute situations, and also had a significant impact on outcomes during cardiosurgical operations using artificial blood circulation techniques. According to

Figure 14.
Bernard Lown [14].

literature sources, in 1962, Donald B. Effler was the first cardiosurgeon, who performed the first coronary artery bypass surgery both in his own operations and later in the same hospital, René Favloro, in 1967, and purposefully used a defibrillator to restore a physiological heartbeat.

Lown's research also touched on the use of electrical discharges to terminate arrhythmias that were not directly life-threatening to patients. Since then, the term "electrical cardioversion" has been introduced into clinical practice.

In the field of pharmacotherapy, Lown's influence changed the attitude toward cardiac glycoside digitoxin, which until the 50s of the last century, was widely used for the treatment of congestive heart failure and often encountered the toxic effects of the drug. By replacing the long-acting digitoxin with the shorter-acting digoxin and additionally intensively controlling the potassium concentration, the patient's survival improved significantly. Lown studied the relationship between the concentration of potassium and the intensity of the use of diuretics and the correlations of the results and also introduced the drug lidocaine into the cardiology practice, which was previously only used as an anesthetic in the stomatology practice.

It is interesting that Bernards Lown was born in Utena, on the territory of Lithuania, in a family of Jews living in Lithuania, in 1935 he moved to the USA, New England state, Maine, where he started studying zoology at the University of Maine. He further developed his professional career in the USA in connection with the John Hopkins University School of Medicine, Yale University, New Haven, Connecticut, and the Peter Bent Brigham Hospital, now Brigham and Women's Hospital, in Boston. Lown was the founder of the Lown Cardiovascular Center and the Lown Cardiovascular Research Foundation.

Born on June 7, 1921.

Died on February 16, 2021 (**Figure 14**).

James Francis Pantridge.

James Francis Pantridge, CBE MC OStJ was a Northern Irish physician, cardiologist, and professor who transformed emergency medical and paramedic services with the invention of the portable defibrillator.

By 1957 Pantridge and his colleague Dr. John Geddes had introduced a modern cardiopulmonary resuscitation (CPR) system for the early treatment of cardiac arrest. Further research led Frank Pantridge to realize that many of the deaths were due to ventricular fibrillation, which should have been treated before the patient was admitted to the hospital. Analyzing and evaluating these facts, he created a system called Mobile Coronary Care (MCCU), an ambulance equipped with special equipment and appropriately trained personnel to provide specialized prehospital medical care.

Paintridge's outstanding contribution was the development of a portable defibrillator which was installed in a Belfast Ambulance Service vehicle. The first version of this device did not stand out with special portability and the ability to easily move it (weight around 70 kg and operated from a car battery), but in a short time until 1968, an excellent portable device was developed, which weighed 3 kg and which worked thanks to the miniature capacitor made by the National Aeronautics and Space Administration (NASA). When mentioning Paintridge, it would not be correct not to mention the engineer John Anderson, head of biomedical services at the Royal Victoria Hospital in Belfast, who later became a co-founder of Heartsine.

In 1967, an article was published in the Lancet magazine about these defibrillators and their role in saving people's lives. The Belfast system of treatment and management of emergency critical, life-threatening situations was

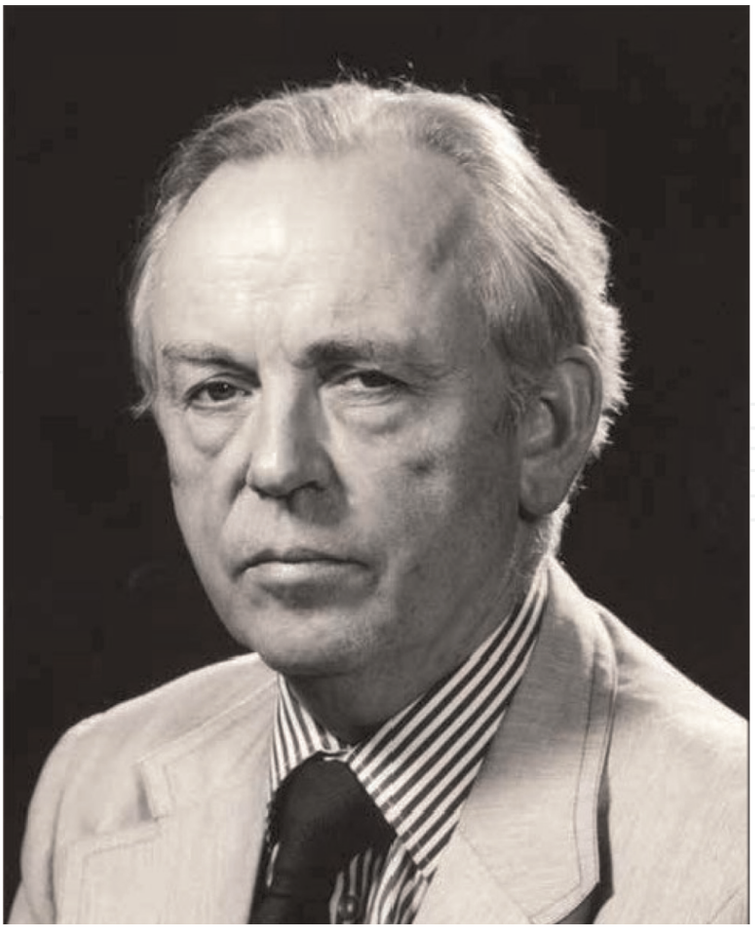

Figure 15.
James Francis Pantridge [15].

accepted by emergency services around the world, often referred to professionally as the Paintridge Plan. The portable or portable defibrillator was recognized as the main means of first aid in life-critical situations, and the developed automated external defibrillator allowed it to be safely recommended for use even by nonspecialists in emergency situations.

As strange as it may seem, James Francis Pantridge, who is known worldwide as the "father of emergency medicine," was little known in his country for a long time. It was not until after 1990 that all ambulances in the UK were equipped with portable defibrillators.

Born on October 3, 1916.

Died on December 26, 2004 (**Figure 15**).

Barouh Vojtec Berkovits.

Barouh Vojtec Berkovits (May 7, 1926 to October 23, 2012 [16]) was one of the pioneers of bioengineering, especially the cardiac defibrillator and artificial cardiac pacemaker. In particular, Berkowitz invented the "demand pacemaker" and the direct current defibrillator.

Berkovits was born in Czechoslovakia. He immigrated to the United States in the 1950s and worked for the pacemaker company Medtronic from 1975 until his retirement. In 1982, Berkovits received the Heart Rhythm Society's "Outstanding Scientist Award." Graduated from New York University's Tandon School of Engineering in 1956. He was also a faculty member at NYU Tandon (**Figure 16**).

Figure 16.
Barouh Vojtec Berkovits [10].

Carl John Wiggers.

Carl John Wiggers (May 28, 1883 to April 28, 1963) was a physician and medical researcher famous for his research on the heart and blood pressure.

Wiggers' main merits are associated with the discovery and implementation of a new method to be able to record the activity of the heart together with the blood pressure of different stages, as well as the effect of low oxygenation on the activity of the heart. Wiggers has outstanding merits in the study of the impact of shock effects, in the study of the impact of heart valve defects on heart function. Two excellent medical experts, scientists – Carl John Wiggers and Claude Beck together created the excellent Wiggers diagram, which is still used in the teaching process of students and doctors when we talk about the physiology of the cardiovascular system.

Carl John Wiegers is the first editor of the renowned medical journal Circulation Research, has written seven books, and is the author of more than 300 scientific articles. In 1952, he received the Golden Heart Award from the American Heart Association. In 1951, he was elected to the National Academy of Sciences. Wigers was awarded the highly prestigious Modern Medicine Award in 1954 and the Albert Lasker Award in 1955 for outstanding achievements in cardiovascular research.

From 1918 to 1953, Carl John Wiegers was Professor and Chairman of the Department of Physiology at Western Reserve University School of Medicine, which became known as Case Western Reserve University School of Medicine (**Figures 17** and **18**).

In 1940, together with Dr. René Wegria (Dr. René Wegria, College of Physicians and Surgeons, Columbia University) discovered that ventricular fibrillation can be induced during a precise period called the "vulnerable period." From these studies, the science of the cardiac pacemaker of the future was concluded [19].

4.1 Defibrillators

The development of defibrillators used in practical everyday medicine began in the twentieth century and is already in the 20s. As the availability of technical

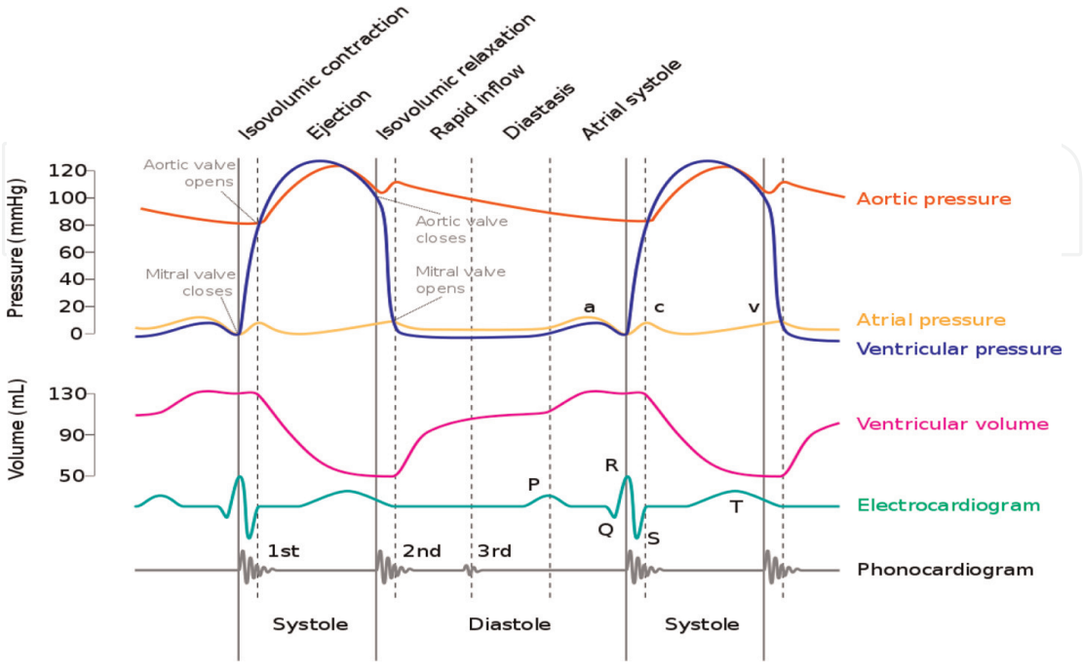

Figure 17.
Wiggers diagram [17].

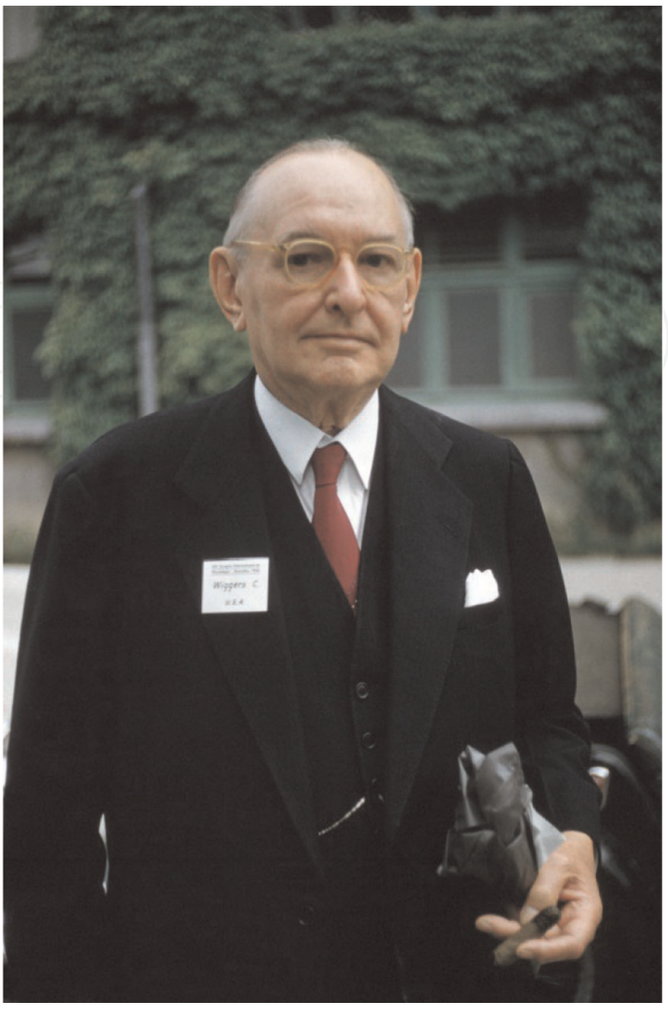

Figure 18.
Carl John Wiggers [18].

achievements increased and, first of all, the use of electricity in everyday life, the number of electrocutions began to increase. People's lifestyles and standards have also changed their views on the possibilities of providing emergency care on an ever-widening scale. Substantial support for these programs was provided by Consolidated Edison of New York by establishing a cooperative project and supporting research with funding. We have already mentioned Beck's defibrillation during surgery, in which this methodology was used to revive a 14-year-old boy. Zoll, in 1956, reported the first successful application of the defibrillation method using external defibrillation. Technical parameters included 15 amperes of alternating current, which generated 710 volts, which were acquired in a transthoracic approach in 0.15 seconds (150 milliseconds). Alexander, Kleiger, and Lown first published in the literature the use of alternating current with the intention of terminating ventricular tachycardia (VT). In the publications of the beginning of the 60s, in the already mentioned publications of Alexander, Kleiger, and Lown, the superiority of direct current over alternating current was confirmed from the point of view of safety.

In the previous chapters, it was already mentioned that the first successful out-of-hospital defibrillation was performed in Belfast by the doctors of the emergency medical service of this city [20] Defibrillation was performed for the first time in Portland,

Oregon, USA for 1969, without the presence of doctors, when the procedure was performed by paramedics (paramedics) during an emergency. It was reported in 1972.

4.2 The beginnings of automatic defibrillators

At the beginning of the 70s in the state of Portland, doctors Arch Diak, W. Stanley Welborn and Robert Rulmen began to focus in depth on the development of AED prototypes [21]. Their work led to the creation of the Cardiac Resuscitator Corporation.

The work with the Heart Aid system in Brighton, UK, is usually cited as the first nonhospital trial in this context. The work started in 1980. Early prototypes weighed 28 pounds. Two electrodes were used to ensure their operation: an anterior thoracic electrode located on the chest to record ECG leads and sequentially record heart activity, as well as a second electrode located orally, or more precisely, orally/epigastrically, and deliver electric shocks as needed. This device was also able to stimulate the heart if necessary (known as transcutaneous or transthoracic electrical stimulation). In 1982, the US Food and Drug Administration (FDA) approved clinical trials of EMT defibrillation (EMT-D). The first US initiatives for this application of emergency medical techniques and defibrillation were in Washington, Iowa, Minnesota, and Tennessee.

In the early 1990s, successful training and use of AEDs by police officers and other first responders was reported. The FDA approved the lay use of AEDs in the 1990s, and Good Samaritan legislation soon followed. It could be said that the road to AED seemed to be clear and with green lights; however, several problems appeared over time. Some are quite serious and essential.

4.3 The nuances of operation of automatic external defibrillators

In the first AED models, in order to achieve the desired effect and obtain information about the heart's activity, relatively complex manipulations had to be performed when the AED was started. In situations where time is limited and every second is worth its weight in gold, this behavior prolonged the performance of adequate resuscitation. To achieve the required result, the oral/epigastric electrode had to be inserted first and the other electrode placed on the front of the patient's chest. AEDs in use today require the defibrillator electrodes to be placed on the right side of the chest and in the projection of the apex of the heart or on the front and back of the torso (this procedure applies to infants and young children). Electrodes serve both for heart rate monitoring and defibrillation. An AED can also notify the user when there is insufficient electrode contact, signal when the device is preparing for defibrillation, record and notify the responders when the patient's pulse should be checked, allow for recording when a nonshockable rhythm is present or when any spontaneous movement is detected.

4.4 Algorithms and possibilities of rhythm analysis

Early AED diagnostic algorithms were designed to respond primarily to a heart rate (usually ventricular rate) greater than 150 electrical complexes per minute (essentially electrical complexes) and an electrocardiographic QRS complex amplitude greater than 0.15 mm. Modern AED machines use a combined sum of several criteria to analyze the ECG rhythm. In addition to the previously applied frequency

and QRS amplitude criteria, QRS data are analyzed in relation to its slope, complex morphology, power spectral density, and the time the complex is away from predefined isoelectric line levels, which in turn are defined as pathological. The device performs these checks at intervals of 2 to 4 seconds. The standard algorithm provides that if three consecutive parameter checks detect abnormal complexes with an intensity of occurrence at least twice as frequent as the QRS generated by any other site, the AED will be signaled to perform defibrillation.

Short-wave ventricular fibrillation (VF) is significantly more problematic than long-wave VF. Modern AEDs have special programs that allow you to make correlations and diagnostic compromises between setting the amplitude criterion with a sufficiently low sensitivity threshold. This shriek is low enough to recognize microwave ventricular fibrillation but maintains a sufficient threshold to not respond to asystole or artifacts. There are data in the literature that confirm that the sensitivity of VF detection of modern AED systems is 76–96%, but at the same time the specificity (correct detection of nonfibrillator rhythms) is close to 100%. In any case, considering the importance of AED and the real application environment as well as users, these features are extremely important.

4.5 Application of two-phase versus single-phase discharge

Monophasic defibrillation delivers electrical shock in one direction only. Biphasic defibrillation provides an electrical discharge in one direction for half of the discharge time and an electrical discharge in the opposite direction for the second half of the discharge.

Studies in dogs have shown less cardiac conduction disturbances and fewer ST-segment changes after biphasic electrical discharge than monophasic discharge. In clinical studies, it has been confirmed that monophasic electrical discharge is equivalent to biphasic discharge in cases of ventricular fibrillation induced by electrophysiological examinations. There are also similar data on the use of defibrillation techniques in the prehospital stage in patients with ventricular fibrillation and ventricular tachycardia. Research data shows that a biphasic waveform of 115 J is equivalent to a monophasic discharge waveform of approximately 200 J. Due to reduced discharge energy, virtually all implantable cardioverter-defibrillators (ICDs) use biphasic waveforms. Most AED manufacturers are switching to biphasic discharge technology, as the lower amount of energy used can result in both longer battery life and a shorter time to full charge.

Although the use of biphasic defibrillation may have theoretical clinical advantages, most patient studies, and reports have shown equivalence rather than the superiority of one form at equivalent doses (biphasic doses are lower).

4.6 Some important nuances need to be known when dealing with an AED

Most manufacturers recommend testing the AED at specified time intervals. Some devices need to be turned on to perform a self-test; other models have a built-in self-test system with a visible indicator that indicates the state of the battery and possible operation.

All manufacturers label their AED's pads with an expiration date, and it is important to ensure that AED defibrillation pads are within the appropriate expiration date. AED pads have a typical life expectancy of 18 to 30 months. Usually, these data are visible and on the outer side of the package. For many modern AED models, this date

is visible through a "window" embedded in the body of the device, which, of course, facilitates their control and possible regular maintenance or replacement of equipment accessories. For some devices, however, you have to open the device case to make sure of the expiration dates. Logically, AEDs that are less complicated and simpler to maintain and control are preferred.

It is very important to make sure that the batteries in the AED device have not expired. The AED manufacturer will specify how often the batteries should be changed. Each AED has a different recommended maintenance schedule outlined in the user manual. Each AED has a specific checklist that includes a monthly battery capacity check, including checking the green indicator light when it is on, the condition and cleanliness of all cables and the device, and checking that there is enough power to perform the defibrillation procedure in sufficient time in number.

When the AED is turned on, or the case (box) of the device is opened, it will automatically prompt the user to attach the electrodes (pads) to the patient (the latest models are provided with a voice command system, which may be adapted to different countries with different basic languages). When the defibrillation pads are attached, everyone should avoid touching the patient to avoid false device readings. The pads allow the AED to check the electrical signals from the heart and determine if the patient is in a shockable rhythm (ventricular fibrillation or ventricular tachycardia). If the device detects that an appropriate situation exists and a defibrillation shock is necessary, it will use the battery to charge its internal capacitor in preparation for delivering an electric shock. The system of the device is safe enough – charging and preparation for defibrillation are done only when necessary.

Once the device has charged its system, it tells the user (usually with a loud beep) that no one touches the patient and then tells them to press a button to deliver the electrical discharge; The standard requires human intervention to deliver a defibrillation shock (by pressing a button) to avoid accidental shock injury to another person (which may occur in response to the patient or a bystander touching the patient at the time of the shock), as AEDs are expected to be used in public areas, often in a limited space, and the public response in such extreme situations is not always predictable. Many modern models will automatically analyze the patient's heartbeat according to the built-in algorithm after an electric shock and will either order CPR or prepare for the next shock.

Many AEDs have a special feature called "event memory" that stores the patient's ECG, as well as all the information obtained regarding the time the device was activated, the number of shocks delivered, and the strength of those shocks. A voice recording option exists for several equipment groups [22] in order to be able to analyze the actions taken by the medical staff and to be able to analyze whether these actions have an impact on the performance results, respectively, on survival. The material recorded in the device system can be used both in the recording of computer systems and also made available in another format (printed, graphically) so that the assisting organization, professional association, or government bodies can analyze the effect of CPR and defibrillation on survival. Some AEDs are able to collect data on the resuscitation process and to assess the quality of chest compressions.

Unlike conventional defibrillators, using an automated external defibrillator (AED) requires only minimal basic training, or some AED versions allow you to do it without any skills at all. This possibility is provided by a special sound information system, or so-called "electronic voice" that tells the helper every next step of the operation.

Such AEDs are approved for use in the United States and many other countries. Given that the responder may be hearing impaired or unable to fully understand the language in which the AED provides information, most modern AEDs also have special visual instructions with special pictograms. The placement of AEDs in public and freely accessible places, as well as the ease of their use, has created the concept of public access defibrillation (PAD). It should be noted that most often the first persons who start resuscitation are not specially trained people or professional doctors.

One of the most important functions of an AED is the ability to record and automatically detect a heart rhythm and, guided by the recorded data, automatically determine whether a shock should be delivered. In practice, fully automatic models are used, which are able to carry out an electric discharge even without the helper's command. Semi-automatic models will tell the user that a shock is needed, but the user must tell the machine, usually by pressing a button. In most cases, the user cannot ignore the AED's "no shock" warning. Some AEDs can be used on children who weigh less than 55 pounds (25 kg) or who are younger than 8 years old. If a specific AED model is approved for pediatric use, only more suitable pads should be used.

4.7 Benefits of AEDs

Clinical studies confirm that public access defibrillators (PADs), when available and used correctly during out-of-hospital cardiac arrest, were associated with a 40% median survival rate. Even in situations where they are handled by nonspecialists without training, sudden death victims have a much higher chance of survival. It should be noted that in many publicly accessible AED locations, the device's location block is linked to the emergency medical system or rescue services dispatch office. An alarm signal is immediately received, and professionals immediately rush to the rescue.

5. Classic AED studies

5.1 Location

Classic AED studies have examined the effectiveness of AEDs in urban, suburban, and rural settings.

Seattle.

In 1987, Cummins et al. reported a controlled trial comparing the effectiveness of AEDs with manual defibrillators used by EMTs to treat 147 patients with ventricular fibrillation (VF) in suburban Seattle, Washington. No statistically significant differences were observed in admission rates (54% AED; 50% manual) or survival to discharge (30% AED; 23% manual [23].

In 1988, Weaver et al. reported the results of AED practice by non-EMT first responders (event response time 3.3 minutes) compared to baseline CPR by first responders (event response time 3.4 minutes). This was followed by the involvement of paramedics with the application of an AED (response time to the event was 5.1 minutes). It is important to note that the AED model used was modified during the study. Overall results for the group of patients with ventricular fibrillation detected (504 patients) showed no significant difference in clinical parameters when assessing hospitalization (59% first responders, laypersons with AEDs; 53% professional

paramedics with AEDs) but significantly higher patient survival and consecutive discharge from the hospital was observed in the first group of patients, those who had CPR with an AED administered by first responders (30% vs. 19%). Admission rate and discharge rate are not the same thing. [24]

Iowa.

In 1986, Stults et al. reported a study in a rural setting comparing AEDs with manual defibrillators used by EMTs. Results for 88 VF patients showed no significant difference in admission rates (29% AED; 32% manual) or survival to discharge (17% AED; 13% manual) [25].

Minnesota.

Bachmann et al. failed to confirm results from Iowa and Seattle in rural northeastern Minnesota [22]. They reported a survival-to-discharge rate of 11% for paramedics, 5% for EMTs with manual defibrillators, and 2.5% for cardiac arrests performed by EMTs performing CPR. A separate analysis of VF was not performed. They found no survivors of witness arrest, as had been the case in previous studies, and the results led them to question the use of AEDs in rural areas.

In contrast, Vukow studied EMT defibrillation in rural southeastern Minnesota in 1988 [26]. In a report of 63 patients, patients treated by EMTs with AEDs had significantly higher admission rates (30 vs. 12%) and survival to discharge (17 vs. 4%) than patients treated with EMT without AED.

Detroit, Chicago, and New York.

Reflections and also discussions were caused by the data presented by Detroit colleagues on the affectivity of revitalization. A total of 595 patients with circulatory arrest (cardiac arrest) of various causes underwent basic EMTs with AED application. The first finding confirmed that only 20% of these patients recorded VF. About 5% were hospitalized in a clinical condition defined as "alive," but none of these 5% were discharged alive. Analyzing such unpleasant results, it was concluded that the EMS response time exceeded 10 minutes, as well as the time from the event to the activation of the EMS system. It should be kept in mind that time is both the viability of the myocardium and the brain, as well as potential electrical activity in the myocardium. Unfortunately, this data was not published.

Similar studies reported a 4% survival rate from VF in Chicago and a 5% survival rate in New York. The average response time was more than 10–12 minutes.

Defibrillation "time to shock" analysis.

In the initial research conducted in Seattle, another interesting nuance was found: a significant time difference was recorded in the period until the defibrillation discharge was performed. AED defibrillation time was 1.1 minutes compared to 2 minutes for manual defibrillators. Bock and colleagues found that EMTs who used fully automated defibrillators on the job were, on average, 30 seconds faster in delivering shocks than their colleagues who used semi-automated devices [27].

AED Selection Factors Population density: Stapczynski et al. concluded that areas with population densities of less than 100 persons per square mile have minimal benefit from AEDs [28]. A study in Washington identified 172 sites with a much higher density of individuals (out of 71,000 sites). Similar local assessments, in conjunction with data analysis of emergency medical systems, can assist in the effective location of public AEDs. Increasingly, the placement of AEDs is more and more often directly related to places where there is an intense movement of people in intensive traffic nodes with a corresponding density of people in their location, which is more precisely depicted in the concept of public access defibrillation. Such places are

airports, stadiums, large shopping malls, concert halls, and other places of mass events. The first airline to equip its transcontinental aircraft with AEDs (with an emphasis on transoceanic flights) was American Airlines in 1997. Subsequently, subsequent FAA regulations very quickly established the level of strict regulation that commercial passenger aircraft must be equipped with an AED and that aircraft personnel on board in their professional duties must be trained in the use of an AED (Aviation Medical Assistance Act of 1998, Section 121. part amendment). The reaction time was also regulated: the average reaction time to the AED application should be less than 4–6 minutes because only under this condition can a real positive effect from the AED be expected. Delta Airways, the Brazilian airline VARIG (also known as the VARIG study), and others were involved in the further implementation of AED in aviation. Currently, AEDs are the norm on any commercial flight. Levels of response systems: Multi-level response systems must be compatible equipment. If an AED is to be used by a first responder, the defibrillators or their electrode lead system must be compatible with the transport units listed below. Monitoring function: If the unit is also used by paramedics to monitor the patient's condition and not just by the AED technician in case of cardiac arrest, a monitor screen is required. Print options are also desirable.

Public access defibrillation.

Public access defibrillation (PAD) has been shown to be an important part of a successful chain of survival program [1]. AED placement has been most cost-effective in certain locations, including casinos, airports, stadiums, health clubs, universities, and senior centers [29–31].

A systematic review of AED availability and survival rates for out-of-hospital cardiac arrest, which included 16 studies with 55,537 participants, found that the one-month survival rate in schools, sports venues, and airports was 39.3% compared with 23.5% elsewhere. The 1-month survival rate was 39.3% in schools, sports venues, and airports, compared to 23.5% in other locations. Longer time between cardiac arrest and AED arrival and greater distance between AED location and cardiac arrest location were negatively correlated with one-month survival rates, but the correlations were not statistically significant [32].

5.2 Experiences and conclusions of some countries

Poland.

Zuratynski P. et al. performed an analysis of the use of AEDs, evaluating the frequency of their operation by calendar days, months of the year, seasonality, as well as time of day. It is interesting that AEDs were most often used in April and least often in November, and compared to the days of the week, AEDs were most often used on Fridays but less often on Sundays. More frequent out-of-hospital cardiac arrest (OHCA) events were noted between 12:00 and 16:00 during the day. If the day is divided into two stages: daytime 8:00–20:00 and nighttime 20:00–8:00, then the ratio of daytime and nighttime is 70–30%. [33]

Denmark.

According to the Register of Danish colleagues in the Danish capital, Copenhagen, the vast majority of AEDs were freely available during the day on all days of the week, but another very significant problem was their availability within 24 hours. 50 AEDs (9.1%) of all AEDs recorded in the public access system were available 24 hours a day, 7 days a week [34]. At the same time, we cannot fail to mention Lin Zhang et al., the

Figure 19.
Automatic external defibrillator [37].

very important sentence indicated in the publication about 40% of AEDs registered in three districts of Shanghai, which are located in school buildings or government institutions, and their availability restrictions are related to security concerns [35]. Full public availability of AEDs has also been noted as a problem in Toronto, Canada, and many other cities. Some AEDs are located in large office buildings, institutions, supermarkets, universities, and schools, which are closed in the evening hours, and some of them are also on holidays; sequentially, AEDs are theoretically available, but practically there is no possibility to use them in practice. Similar problems with AED availability within 24 hours and throughout the week were demonstrated by Agerskova et al. In the OHCA analysis in Copenhagen [36].

Thirty-day survival in people after OHCA almost doubled in cases where the event was in a location where the nearest AED was within 200 m of the scene. This concept is also used in planning the placement of AEDs in grandstands of large stadiums, shopping malls, concert halls, and similar mass gathering places.

Mortality after OHCA is significantly influenced by time: both the time in which CPR is started and, even more, the time how quickly an AED can be used to save the patient's life. Public access to defibrillators and their location information – key solutions to improve survival (**Figure 19**).

6. Instead of an afterword

This chapter is only a small part of the interesting world that opens up when you start to delve into the nuances of resuscitation and the problems associated with it, as well as the history of this medical field. Not infrequently, the pioneers of the field have had to overcome a wall of profound opposition and misunderstanding, but in the end, science has won, and all of us, the medical profession, the people associated with it, and those whom this knowledge and discoveries have helped to return to this side of the River Styx, are grateful, to the great minds who contributed to the progress of medicine.

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Automated external defibrillators are an excellent example of collaboration between medicine, biology, and engineering. The authors of this chapter each have their own experience and resuscitated patients, one in intensive care cardiology, another in the emergency medicine system, and another also during veteran basketball competitions. How great it is if you have this great and seemingly invisible helper nearby or even next to you – an AED. And how many lives he has helped save and how many more he will help, together with our professional knowledge and skill.

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