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CARDIOPULMONARY RESUSCITATION: A HISTORICAL PERSPECTIVE LEADING UP TO THE END OF THE 19th CENTURY

KARDIOPULMONALNO OŽIVLJAVANJE: POVIJESNI PREGLED OD POČETKA DO KRAJA XIX. STOLJEĆA

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Summary

Social laws and religious beliefs throughout history underscore the leaps and bounds that the science of resuscitation has achieved from ancient times until today. The effort to resuscitate victims goes back to ancient history, where death was considered a special form of sleep or an act of God. Biblical accounts of resuscitation attempts are numerous. Resuscitation in the Middle Ages was forbidden, but later during Renaissance, any prohibition against performing cardiopulmonary resuscitation (CPR) was challenged, which finally led to the Enlightenment, where scholars attempted to scientifically solve the problem of sudden death. It was then that the various components of CPR (ventilation, circulation, electricity, and organization of emergency medical services) began to take shape. The 19th century gave way to hallmarks both in the ventilatory support (intubation innovations and the artificial respirator) and the open- and closed chest circulatory support. Meanwhile, novel defibrillation techniques had been employed and ventricular fibrillation described. The groundbreaking discoveries of the 20th century finally led to the scientific framework of CPR. In 1960, mouth-to-mouth resuscitation was eventually combined with chest compression and defibrillation to become CPR as we now know it. This review presents the scientific milestones behind one of medicine's most widely used fields.

Key words: *cardiopulmonary resuscitation; cardiac arrest; history; ventilation; circulation; defibrillation*

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Introduction

Resuscitation was forbidden through most of the recorded history, with few accounts of successful reversal of death. Although resuscitation evolved to a modern science with the major discoveries of the 20th century, an awareness of the history of cardiopulmonary resuscitation (CPR) will underscore an understanding of the scientific milestones behind one of medicine's most widely used fields. Table 1 summarises some of these breakthroughs through the ages, which will be discussed in detail below.

Antiquity

In antiquity, life and death were governed by the Gods or their agents, and any attempt to resuscitate was forbidden [1]. Although according to Egyptian mythology Isis resurrected Osiris, [2] the first reference of resuscitation dates to 1500 B.C., where a patient was hung by his feet and began to breath after his chest was compressed and released alternately [3]. At the battle of Kadesh (1237 B.C.), the King almost drowned in the river, and soldiers attempted to save him by lifting him by his feet [4]. In Ancient China, forced respiration was applied by laying the victim across the back of an ox, with arms on one side and legs on the other [4].

Greek philosophers postulated the *pneuma* theory in the seventh century B.C., where immortality was achieved when the *pneuma* left the body with the last breath. For this reason, a noble death was achieved by sword or poison. Both Hippocrates (460-377 B.C.) and the Greek physician Soranus (2nd century A.D.), described intubation as means to support ventilation by "blowing" the *pneuma* back into the body [4-6]. Galen of Pergamum (second century A.D.) believed that life and its innate heat were produced in the furnace of the heart. When a man is born, the heat is turned on, and when he dies, it is extinguished and can never be 'lit' again. Galen used bellows to inflate the lungs of a dead animal, noting the usefulness of artificial respiration [7].

Biblical history

The Bible is full of accounts of attempts at resuscitation, described as 'crouching over', 'mouth-to-mouth', 'breathing into', and 'pressing upon' [8]. In the Old Testament the prophet Elijah restored the life of a boy by placing his mouth, eyes, and hands on the mouth, eyes, and hands of the child [9]. In the *Book of Exodus*, the Hebrew midwife Puah 'breaths into the baby's mouth to cause the baby to cry' [10]. The Babylonian Talmud

records that a lamb with a neck injury was saved by a hole into the trachea, supported by a hollow reed [11].

The Middle Ages

The Middle Ages temporarily halted medical progress. Not only were attempts at reviving forbidden, but also the value of human life was generally underestimated. Even in shipwrecks, the ship's cargo was more important than its crew. According to maritime law, the drowned victim was not to be handled until representatives decided on the cause of death [4]. References to resuscitation are scarce. Jacob Ben Asher referred to human victims resuscitated by intubation, while in 1472, Paolo Bagellardis advised midwives to blow into the mouths of newborn babies showing no signs of respiration [12,13]. The Middle Ages developed methods to warm bodies with hot water or warm ashes (*heat method*). Even methods such as whipping or the *barrel method* were used [14,15]. During Europe's scientific oblivion, the rise of Islam resulted in an unprecedented Arabic flourish in medicine and pharmacy. Avicenna (981-1037) described the use of a silver or gold cannula for intubation of the trachea [16].

Renaissance

Origins of ventilation

Medieval values were rejected and an interest in exploring the human body was restored during the Renaissance. Mary of Burgundy (1457-1482) ruled that a body can be pulled out of the water if it did not appear dead, and the coroner had to examine the body to decide if the body was dead or nearly dead [17].

Scientists established the connection between life and warmth. Methods of re-warming included warm water immersion and placing the victim near a fire or even burying it into warm sand. Fire bellows were widely used in resuscitation efforts [18]. Through them, air or tobacco smoke was introduced through the mouth. Burning of elixirs and dried excreta over the victim along with incantations were also used to resuscitate the dead [19,20].

Andreas Vesalius (1514-1564) described his artificial respiration technique for maintaining an experimental animal alive to examine its thoracic contents. A tube of reed or cane was placed (through an opening) in the trunk of the trachea, into which one had to blow, so that the lung could

rise and the animal take in air [21]. Other prominent scientists also used some kind of artificial respiration, including Leonardo da Vinci [7], and Realdo Colombo, an Italian anatomist (1544-1559) [22]. William Harvey and Nathaniel Highmore were the first to refer to artificial respiration [23,24]. Harvey was the first to describe the possibility of resuscitating an arrested heart; in 1628, he reported using his fingers while restoring the heartbeat in doves [15]. In 1664, W. Croune demonstrated to the Royal Society of London how to revive strangled chickens using artificial respiration [25]. In 1667, Robert Hooke revived an open-chest dog, showing that the movements of the heart and lungs were independent. When the bellows were removed, the dog's lungs became flaccid, but on restarting the motion of the bellows, the heart of the dog recovered [26]. Robert Lower, in 1669, reported his own artificial respiration experiments on dogs proving that blood changed colour in the lungs and that this change depended on respiration [27]. In 1670, a Swiss priest Sebastian Albinus, published a how-to booklet describing techniques to rescue drowned victims [4].

Enlightenment

During the Enlightenment, scholars sought to understand the science behind life so as to reverse death [15]. King Louis XV recognised the importance of promoting resuscitation, which was no longer punishable by law. In 1740, a publication circulated to present the techniques of how to save a drowned victim [4]. In the 1700s, North American Indians and American colonists introduced to the Europeans the procedure of blowing tobacco smoke into the victim's rectum [14]. This practice continued for 100 years, until Benjamin Brodie demonstrated that tobacco, when injected into the rectum of dogs and cats, led to their death due to nicotine poisoning [4,28].

As the current concepts of resuscitation, including ventilation, circulation, electricity, and emergency medical services emerged [8], a debate regarding the preferred method of ventilation (bellows or mouth-to-mouth) began [4]. In 1740, René Antoine Ferchault de Réaumur reported a successful use of mouth-to-mouth resuscitation [29], and the French Academy of Sciences issued an expert opinion advocating mouth-to-mouth resuscitation as the optimal method for drowned victims [16]. The Scottish surgeon, William Tossach, who used mouth-to-mouth resuscitation to successfully resuscitate a coal miner, published the first article regarding mouth-to-mouth ventilation in 1744 [30]. John Fothergill stressed the advantages of mouth-to-mouth over bellows, in that 1) bel-

lows may not be at hand, 2) the strength of the breath of the rescuer can be tolerated by the victim in contrast to that of the bellows, and 3) the warmth and moisture of the breath is more likely to promote the circulation than the chilling air forced out of bellows [7,31]. Dominique Jean Larrey (1776-1842), Napoleon's chief battlefield surgeon, also described mouth-to-mouth resuscitation [20].

However, mouth-to-mouth respiration soon became discredited as grotesque and scientists believed that expired air did not contain enough oxygen to sustain life [1]. The chemist Carl Wilhelm Scheele (1742-1786) discovered oxygen, or *fire air*, and Joseph Priestley reported on the different composition of expired versus inspired air, rendering the former 'unfit to enter the lungs again' [32,33]. Priestley's experiments consisted of using a 'burning lens' so as to focus sunlight on a sample of mercuric oxide in an inverted glass container placed in a pool of mercury. When the emitted gas was tested on mice, the entrapped animals were kept alive for quite a while. Priestley reported that the newly discovered gas was 'five or six times as good as common air'. His experiments, replicated by Antoine Lavoisier, showed that respiration was a slow combustion of organic material using inhaled oxygen [34].

In 1776, John Hunter introduced the use of bellows only into one nostril, while at the same time the other nostril and the mouth were occluded, generating both positive and negative pressure. Hunter was the first to describe that applying pressure on the larynx against the oesophagus and spine could prevent overdistension of the stomach [7]. Relying on available data and opinions claiming that mouth-to-mouth respiration was 'vulgar', the Royal Humane Society commented on the superiority of bellows respiration in 1782 [18].

Intubation

Despite their extensive use, bellows were neither efficient nor tolerable by everyone. Alternative methods like intubation were explored, and the Vesalius technique of tracheal intubation became fashionable again. In 1714, Georg Detharding claimed that tracheotomy might assist breathing [35]. Tracheotomy, however, presented the additional difficulty of air leakage; a problem that was eventually solved in the 19th century by wedging the tube in the larynx. In 1752, William Smellie intubated newborn babies with a straight endotracheal tube so as to resuscitate them [5]. In 1754, Benjamin Pugh, a man-midwife, published his own experiences with an endotracheal tube in resuscitating infants [3]. William Hunter, in 1776,

intubated and artificially ventilated animals, by opening up the trachea [3]. Some physicians occasionally advised bronchotomy for intubation [7,35].

In 1787, Charles Kite also recommended endotracheal intubation and suggested that cricoid pressure should be applied. Kite, who reported on the connection between time and appropriate intervention for resuscitation success, also provided epidemiological data regarding successful resuscitation of hundreds of people [36]. He designed a pocket resuscitation kit and reported on the correct way to use these instruments.

Humane societies and registries

As drowning became a major issue, several societies were founded so as to promote recovery of drowned people during the eighteenth century [1,7]. Casualties were hung by their feet, which both drained the water from the lungs and freed the airway from the weight of the head. Many lifeguard stations kept portable frames to hang casualties. In 1766, Abraham Calcoen suggested warming the drowned victim with a large fire and rubbing them with a woollen cloth or brush. He also suggested rubbing the victim's head with alcohol and using bellows or tobacco pipe rectally [17]. A year later, Cornelis van Engelen and Jacob de Clerq proposed that rescuers should be rewarded financially and that the medical expenses of the victim must be paid [17]. Based on this, the "Society for the Recovery of Drowned Persons" in Amsterdam was founded in 1767. Its purpose was to reduce prejudice about not touching a drowned victim, to enhance scientific research, and to promote education [4]. Within four years, the Society claimed saving 150 people [1]. Soon, similar foundations followed in many European cities. The Society recommended blowing tobacco smoke into the anus of the victim as quickly and as forcefully as possible, as well as mouth-to-mouth respiration with simultaneous closure of the nostrils with cloth. Other recommendations included warming the victim, removing swallowed or aspirated water by positioning the victim's head lower than his feet, applying manual pressure to the abdomen and chest during the expiratory phase of respiration, and tickling the victim's throat. Six or more hours were considered a reasonable duration for any resuscitative effort [4]. In London, the Institution for Affording Immediate Relief to Persons Apparently Dead from Drowning was founded in 1774, which later became the Royal Humane Society, also advocating mouth-to-mouth resuscitation [1]. *Resuscitation sets* were placed at selected sites along the Thames for immediate use in cases of drowning [15]. In 1796, Carl Gottlob Rafn and John Daniel Herholdt reported epidemiological data and outcomes of resuscitation attempts [37].

Origins of defibrillation

Electricity was discovered in the mid-1700s [38]. In 1743, professor of Medicine Johann Gottlob Krüger performed experiments on the effects of electricity on life, although electricity was not yet correlated with muscle contraction and cardiac rhythm restoration. Based on Krüger's use of electricity to treat paralysed limbs, Christian Gottlieb Kratzenstein reported on 'a woman who lost the paralysis in her small finger within one quarter of an hour by electrification' [38].

In 1775, Danish physician *Peter Christian Abildgaard* reported using electric shock to kill and then revive a chicken. Although the concept of using electricity for the heart was not yet appreciated, scientists used it to stimulate unconscious victims [39]. The archives of the Humane Royal Society described the first use of a electrical jolt for successful resuscitation; a child was stimulated, with several shocks, back to life as 'upon transmitting a few shocks though the thorax, he perceived a small pulsation; in a few minutes the child begun to breath with great difficulty' [4,38]. In 1776, John Hunter perceived electricity 'as probably the only method … of immediately stimulating the heart' [38]. In 1788, Charles Kite invented the first portable defibrillator, using rods attached to a Layden jar capacitor. Kite used two cables to connect the capacitor to the two poles, which were placed across the chest of the victim using wooden handles [4]. In 1792, James Curry also reported on successful cases of external defibrillation using two electrodes, one above the clavicle and the other over the lower left chest [40]. Marie François Xavier Bichat conducted electrical experiments on decapitated bodies. Bichat used electricity to stimulate cardiac and skeletal muscles, stating that the heart could be excited reliably only through galvanism. The Academy of Turin concluded that the heart would lose its ability to contract in response to electricity 40 min after death [41].

The ability of electricity to cause muscle tissue to contract was appreciated by Luigi Alyisio Galvani. In 1791, Galvani published his theory of *animal electricity* (as a force generated by an electrical fluid that activates muscles) [42], which helped physicians to understand that they could jumpstart the still cardiac muscle with electricity. A few years later, in 1799, Alessandro Giuseppe Antonio Anastasio Volta was credited with the invention of the battery (the Voltaic pile) when using two different metals (zinc and copper) to generate electricity, expanding thus the use of capacitors [38].

Nineteenth century

Development of ventilation

Resuscitation methods used to support ventilation included the *Trotting Horse*, where the victim lays across the horse's back, face down. The chest is compressed by the horse's back, forcing out the air, and then expands letting air in, when the body bounces up during the trot. In the 19th century, physicians *suggested a* bandage that could be tightened and then loosened or a bandage for side-to-side chest compression [7]. Also, suction cups were attached to the chest and methods have been described for lifting the rib cage by pushing the fingers beneath the thoracic margin [7].

Marshall Hall (1790-1857) advocated the use of mechanical expansion and compression of the chest wall. Because the supine position forced the victim's tongue and larynx to fall back and block the airway, he promoted the 'rolling method' that involves repeatedly shifting the victim's position from prone (expiratory) to side (inspiratory) 15 times a minute [7]. In 1861, Henry Sylvester described the chest-pressure arm-lift method, which was adopted by several societies in London. While supine, the victim's arms are raised above the head to expand the upper rib cage and then placed on the chest to apply pressure for exhalation [43].

The *direct method* introduced by Benjamin Howard in 1871 entails that the victim lies prone while the rescuer holds the tip of the tongue. The rescuer would grab the victim's hips and shove them into the upper abdomen about 15 times per minute, which would compress the ribs and exert pressure on the victim's back. Other techniques included vigorous pulling of the tongue of an asphyxiated person (the *Laborde method*) and various 'acrobatic' movements performed by the rescuer on the victim (the *Schulze method*). The *J. B. Francis method* involved raising the victim by hyperextension of the body so as to induce expiration and lowering it to the ground to induce inspiration. The *Prochownick method* involved inversion of the dead newborn, so that gravity could induce expiration. Because so many techniques were introduced, the Royal Humane Society appointed a study group to review them, which resulted in several being adopted by various societies [4].

In 1868, John Hill described chest compression at a rate of 12 per minute in three patients who were apparently dead. The surgeon's left hand was placed firmly across the front of the chest with the fingers resting over the 5th-7th costal cartilages on the right side, and the right hand crossed over the left. The chest was then forced, followed by the sudden

removal of the hands.[44] This method remarkably resembles those described almost a century later, although the rationale behind it was to assist respiration [45]. By the early nineteenth century, doubts were raised concerning the safety of positive pressure respiration with bellows, and both expired air ventilation and mechanical ventilation were abandoned in favour of external chest compression [19]. Jean Jacques Joseph Leroy *d' Etiolles* blamed bellows for emphysema and pneumothorax in drowned animals in 1828 [4]. Sixty years later, Arnold Paltauf, demonstrated pulmonary emphysema resulting from drowning *per se* [7]. In 1887, Sir Francis Henry Champneys reported that the lungs of dead infants could withstand 20 to 80 mm Hg pressure before rupturing [35].

Intubation innovations

Despite criticism, animal experiments using bellows and tracheotomy with artificial respiration continued well in the 19th century. In 1887, George Fell, constructed an apparatus for artificial respiration of patients poisoned by opium. After having failed to save the life of an opiate-poisoned patient using the method described by Sylvester, Fell turned to his animal experiments where he used bellows and tracheotomy as part of an artificial ventilation system and adopted the apparatus for human use. In 1891, Joseph O'Dwyer extended the application of Fell's system, introducing a longer orolaryngeal tube (the *Fell-O'Dwyer apparatus*) [46]. In 1880, Sir William Macewen described a technique of orotracheal intubation [47]. In 1895, Alfred Kirstein invented the laryngoscope to aid visualisation of the trachea [48]. Sir Henry Head introduced the cuffed endotracheal tube in 1889 [49].

The artificial ventilator and iron lung

John Dalziel was the first to describe an artificial ventilator in 1838; a tank-type negative pressure device that applied subatmospheric pressure on the thorax, allowing positive atmospheric pressure to induce respiration. It consisted of an airtight box in which the patient was seated with the head protruding through a neck seal [50]. In 1880, Louis Waldenburg introduced the first cuirass respirator that covered only the thorax and did not enclose the body. At the Obstetrical Society of Boston in 1889, O.W. Doe announced an infant resuscitator box, designed by Egon Braun. This early form of artificial respirator obtained a pressure seal by having the child's mouth pressed against a rubber diaphragm opening, with the rest of the body being entirely enclosed within a wooden box. The operator had to blow into a pipe twenty to thirty times per minute to force the chest

to compress, forcing air out of the pipe and creating a suction that would expand the chest. Doe reported that Braun had used the device successfully in fifty patients [7]. *Alexander Graham Bell* was responsible for the *vacuum jacket* in the 1880s, a device that used a hand-operated bellows. All of these attempts eventually gave rise to the iron lung, a device used during the polio epidemic in the century that followed [51].

Origins of circulatory support

Moritz Schiff performed the first cardiac compression in an animal's open thorax in 1874. Noting that cardiac arrest precedes respiratory arrest, Schiff advocated against using chest compressions, ventilation, or electricity. By performing 'cardiac massage', he claimed that he could restore heart beat in an open chest [15]. Schiff's finding directed medical science towards the notion that restoration of heart activity depended on increased supply of oxygenated blood to the myocardium.

Rudolph Boehm was credited with the first method of closed-chest circulatory support in cats in 1878. His technique was to grasp the feline's chest with both hands and apply rhythmic pressure; 'as soon as the compression decreases, the heart refills itself from the main veins, so that again and again fresh blood is forced out of the heart' [52]. A few years later, Professor Franz Koenig recommended using sternal compression for artificial ventilation and resuscitated six patients after anaesthesia with chloroform [7,38]. However, it was his assistant, Friedrich Maass, who was credited with the first successful closed-chest cardiac massage in 1892. Maass performed compressions in two patients to counter chloroform-induced cardiac arrest, modifying Koenig's technique by increasing the rate of compressions to 120 per minute [53].

Coastal rescue societies and lifeboats

In 1824, the British Society for Preservation of Life from Shipwreck promoted the use of lifeboats that were lighter and self-righting as opposed to earlier types. Steam rescue boats were gradually replaced by motorised rescue boats in the beginning of the twentieth century. 'Lifesaving harnesses' were also introduced. Until then, night guards were equipped with lanterns and ropes alone, with drags near bridges and locks [54]. In 1866, the Society for the Recovery of Drowned Persons in Amsterdam created a first aid box with resuscitation instruments and a shelter for drowning victims [4].

Defibrillation techniques

In 1804, Giovanni Aldini suggested that artificial respiration should be accompanied by the external application of electricity to the diaphragm and the heart [38]. In 1809, Allan Burns recommended universal use of electricity for reversing sudden cardiac death, suggesting that after the lungs inflate, electric shocks should be administered to the chest. In 1820, Richard Reece reported on his reanimation chair, where a battery was attached to the proximal end of a metallic tube inserted into the oesophagus of the individual to be revived. His device also consisted of bellows inserted in the mouth with the nostrils shut to ventilate the lungs. Pressure was exerted on the chest after every use of the bellows, to cause expiration. The second battery wire was attached to the heart, diaphragm, and stomach. There is no record regarding the effectiveness of the reanimation chair [38].

The mid 1850s were marked by the discovery that electricity did not provoke cardiac standstill, but rather irregular 'fibrillar' motion of the ventricles. M. Hoffa and Carl Ludwig described ventricular fibrillation, when a strong current was directly applied to the ventricles of a canine heart; however, this lethal arrhythmia was a medical curiosity with no relevance for humans [55]. In his 1889 report, Professor John McWilliam, described ventricular fibrillation as 'unexpected, and irretrievable cardiac failure.…in the form of an abrupt onset of fibrillar contraction... The cardiac pump is thrown out of gear, and the last of its vital energy is dissipated in a violent and prolonged turmoil of fruitless activity in the ventricular walls' [56]. McWilliam proposed that 'degenerative fatty or fibroid changes' as well as 'diseased conditions of the coronary arteries' could predispose to ventricular fibrillation [38].

In 1899, Jean Louis Prévost and Frederic Batelli experimented on electrically induced fibrillation that was reversed by a 240-volt alternating-current shock applied to the heart within fifteen seconds. If more than 15 seconds elapsed between cardiac arrest and current application, cardiac massage was necessary to provide myocardial oxygenation [57]. While successful internal and external defibrillation in man was not achieved until half a century later [15], the optimal route of electricity (chest, neck, or total body stimulation) remained a matter of debate among physicians [38]. Moreover, the relationship between heart disease, ventricular fibrillation, and sudden death was not appreciated until well into the twentieth century. As a result, the role of chest compression to support artificial circulation was largely ignored until 1960.

Table 1 - Important milestones regarding CPR

Scientist(s)	Year/Century	Discovery or Research	Comments
Hippocrates of Cos	5th and 4th century B.C.	Description of intubation as a means to support ventilation [4].	Breathing is linked to the philosophical *pneuma* theory.
Galen of Pergamum	2nd century B.C.	Experiments on small animals [7].	Use of bellows to inflate the lungs.
Andreas Vesalius	1514-1564/16th century A.D.	Description of a technique for keeping an experimental animal alive to examine its thoracic contents [21].	A tube of reed or cane is placed (through an opening) in the trunk of the trachea, into which one must blow, so that the lung can rise again and the animal take in air.
William Harvey	1578-1657/17th century A.D.	First description of the possibility of resuscitating the arrested heart of a dove [15].	Harvey wets his finger with spittle and keeps it for some time on the heart which, after a while, begins to contract.
René Antoine Ferchault de Réaumur	1683-1757	Reports a successful use of mouth-to-mouth resuscitation in humans [29].	The debate for the preferred method of ventilation rages on (bellows vs. mouth-to-mouth).
Joseph Priestley	1733-1804/17th century A.D.	Experiments on gases and reports the 'dephlogisticated air' (oxygen) [33]	According to his theory, the combustion or oxidation of a substance corresponds to the release of a material substance, the so called *phlogiston*.
Antoine Lavoisier	1743-1794/18th century	Demonstration of the role of oxygen in the rusting of metal as well as in animal and plant respiration [34].	Disproves the *phlogiston* theory
François Chaussier	1746-1828/18th and 19th century A.D.	Bellows and pistons are used for respiration. The later include, in some cases, a withdrawal phase as well to assist expiration [7].	Mouth-to-mouth respiration is outmoded by positive pressure ventilation.
Charles Kite	18th century	Design of a portable resuscitation kit [36].	Delivery of the charge in a way exactly analogous to the DC capacitative countershock of the modern cardiac defibrillator.
Gottlob Rafn and John Daniel Herholdt	1769-1808 and 1764-1836/18th and 19th century	Description of an amphibious craft used to move quickly over rough ice to reach drowning victims [1].	The boat is manufactured in such a way that if, for some reason, the ice breaks and gives way, the rescuer will not be in any danger.
Luigi Alyisio Galvani	1737 - 1798/18th cdntury	Dissection of animals [42].	Description of a force that activates the muscles. This activation is thought to be generated by an electrical fluid that is carried to the muscles by the nerves.
Rudolph Boehm	19th century	First method of closed-chest circulatory support in cats [52].	External compression of the heart provides adequate circulation.

Discussion

Social laws and religious beliefs throughout history underscore the leaps and bounds that the science of resuscitation science has achieved from ancient times until today. The effort to resuscitate victims goes back as far as the ancient Mayan and Inca civilisations in South and Central America, where death was considered a special form of sleep or an act of God. Resuscitation in the Middle Ages was forbidden, but later during Renaissance, any prohibition against performing CPR was challenged, which finally led to the Enlightenment, where scholars attempted to scientifically solve the problem of sudden death. It was then that the various components of CPR (ventilation, circulation, electricity, and organization of emergency medical services) began to take shape. Numerous methods for resuscitating drowned victims were suggested and animal experiments helped in the understanding of the physiology of life.

Artificial respiration began in the 16th century with Vesalius's work on living animals and progressed with the rise and fall of mouth-to-mouth, manual, and positive pressure ventilation methods of the 18th and 19th centuries. Cardiac massage was reported in the end of the 19th century, while electrical defibrillation began in the late 1800s, but was not proven successful in animals until the 19th century. The 18th century also marked the founding of societies that promoted the science of resuscitation, marking the first attempt to deal with the problems of sudden death in a coordinated manner. Until then, artificial ventilation techniques relied on direct pressure on the back, abdomen or chest, as physicians believed that passive entrapment of air into the lungs was sufficient to maintain adequate ventilation. In the early 1900s, the Mayo brothers (Charles Horace and William James) contributed greatly to resuscitation efforts by establishing a multidisciplinary approach [58]. In 1949, Archer S. Gordon commented on the superiority of mouth-to-mouth and mouth-to-nose artificial respiration [1]. In the 1950s, James Elam was the first to prove that expired air was sufficient to maintain adequate oxygenation when using mouth-to-nose breathing in patients with acute poliomyelitis [59].

In 1956, physicians Peter Safar and James Elam advocated mouth-to-mouth resuscitation as sufficient artificial ventilation. In addition, Safar proved that tilting a person's head backward would usually open the airway and that most existing manual ventilation techniques (except mouth-to-mouth) provided little air [20]. Research led to the discovery that cardiac massage created artificial circulation, maintaining a limited oxy-

gen supply to the brain. Even though closed-chest massage was described in 1904 along with the first use of epinephrine for cardiac arrest [18], it was not until 1960 that chest compressions prior to defibrillation were reported to increase defibrillation success rates by William Kouwenhoven, Guy Knickerbocker, and James Jude [60]. The first successful case of internal defibrillation was reported in 1947 by cardiac surgeon Claude Beck, after experimenting with defibrillation to restart arrested hearts [61]. In 1960, mouth-to-mouth resuscitation was eventually combined with chest compression and defibrillation to become CPR as we now know it.

Conclusion

The science behind CPR has greatly evolved through time. Starting from religious beliefs and philosophical 'truths', scientists, scholars, and physicians constantly pursued answers to the problem of resuscitating the dead. Efforts to improve resuscitation throughout the ages coincide with social circumstances, laws, and beliefs that governed human societies and encouraged scientists to experiment and clinically test their findings . Although the resuscitation science has greatly evolved through the discoveries of the 20th century, the historical perspective helps to identify the roots of resuscitation. This is of particular importance for future research and young doctors.

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Sažetak

Društveni zakoni i religijska vjerovanja tijekom povijesti ogledalo su skokovitog razvoja znanosti oživljavanja od starine do danas. Pokušaji oživljavanja idu daleko u povijest, kada se smrt smatrala posebnim oblikom sna, odnosno Božjom voljom. Brojni su biblijski primjeri pokušaja oživljavanja. U srednjem je vijeku, međutim, oživljavanje bilo zabranjeno da bi posloje u renesansi takve zabrane kardiopulmonalnog oživljavanja bile stavljene pod pitanje te da bi konačno u doba prosvjetiteljstva znanstvenici pokušali riješiti problem nagle smrti. Upravo su se u to doba prvi put osvijestili različiti dijelovi kardiopulmonalnog oživljavanja poput ventilacije, cirkulacije, struje i organizacije hitnih službi. U XIX. se stoljeću naglo razvila ventilacijska potpora (inovacijama u intubaciji i umjetnim plućima) te potpora za otvorenu i zatvorenu cirkulaciju u prsnom košu.

U međuvremenu su se razvile nove tehnike defibrilacije te je opisana ventrikulska fibrilacija. Dvadeseto stoljeće pak donosi važna otkrića koja su napokon dala znanstveni okvir kardiopulmonalnom oživljavanju. Godine 1960. sjedinjeni su disanje usta na usta s kompresijom prsnog koša i defibrilacijom, tj. onim što danas smatramo kardiopulmonalnim oživljavanjem. Ovaj se pregled osvrće na najvažnija mjesta u povijesti razvoja jednoga od najviše korištenih polja medicine.

Ključne riječi: *kardiopulmonalno oživljavanje, srčani zastoj, povijest, ventilacija, cirkulacija, defibrilacija*