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History of Medicine

History of Cardiopulmonary Resuscitation

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Introduction

In his book titled Life in the Balance: Emergency Medicine and the Quest to Reverse Sudden Death (1997), Author Mickey Eisenberg describes a case of sudden death via drowning that was submitted to the Royal Humane Society in 1778. This was a case of a maid and an infant who were found drowned in a pond. Eisenberg describes the efforts made by physicians during this event. All efforts were administered in the home of the victims and involved removing clothes, warming, applying noxious substances, administration of tobacco smoke into the rectum, mouth-to-mouth and mouth-to-nose respiration, and bleeding of the jugular vein.

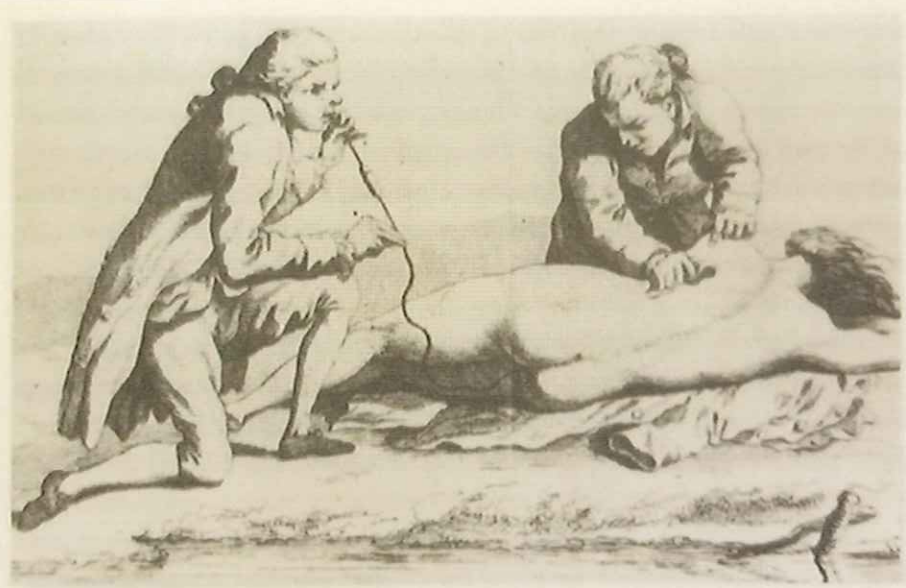


FIGURE 10. *Rectal smoke used to stimulate respiration in a drowing victim. (Courtesy of Wood Library-Museum of Anesthesiology, Park Ridge, Illinois)*

The infant in this case was reanimated with warming and mouth-to-mouth respiration. Unfortunately, the maid did not survive. This brief glimpse into the early days of resuscitative medicine is a stark contrast to the maverick attitudes and heroic technology assisted efforts of resuscitation depicted in today's mainstream media. This example does however, serve as a wonderful representation of the medical traditions of recognizing patterns in disease as well as treatment and promulgating information deducted from these patterns.

On May 1, 1960 the Baltimore Fire Department recorded the first successful administration of prehospital mouth-to-mouth ventilation and chest compression; what is known today as cardiopulmonary resuscitation (CPR). CPR is defined as the administration of artificial circulation through the application of chest compressions along with artificial respiration. Today it is difficult to imagine what the field of medicine would be like without this ubiquitous and ever important life-saving procedure. Yet, this medical breakthrough was over two centuries in the making and relied on several factors. The aim of this essay is to provide a brief history of the seminal events that eventually led to the development of CPR and will begin by describing societal perceptions of death and how shifts in these perceptions paved the way for physicians and scientists to ultimately develop CPR. This will be followed by a retelling of some of the earliest documented examples of mouth-to-mouth resuscitation in cases of drowning after which I will describe demographic shifts in population mortality that led to the development of defibrillators and external chest compression. Lastly, I will describe how over two hundred years of efforts fatefully culminated in Baltimore, MD and resulted in the development of CPR as we know it today.

Societal Concepts of Death

> In our day, in approximately a third of a century, we have witnessed a brutal revolution in traditional ideas and feelings, a revolution so brutal that social observers have not failed to be struck by it. Death, so omnipresent in the past that it was familiar, would be effaced, would disappear. It would become shameful and forbidden. (Aries, 1976).

There is much novelty surrounding the topic of death as it pertains to the practice of medicine. However, as novel as early notions of death and fears of reanimated corpses may be, it is important to discuss them. After all, these fears stemmed from the dead returning to life and the development of CPR is essentially the development of a medical procedure intended to return the very recently deceased back to life.

The concept of death in western civilizations has changed drastically over the past three hundred years or so. Prior to this, religion maintained a stronghold over the human body as well as the death-bed. Under the reign of religion, the church forbade the study of anatomy using human subjects and it maintained a dominance over bedside presence at end-of-life. However, in the late 1700s physicians began to infringe upon the death-bed and the rituals of death; duties once monopolized by religious leaders (Porter, 1998). Concepts of death prior to the late eighteenth century demanded that religious leaders be present at or near the time of death and some concepts of death established a paranormal fear of the dead. On the other hand, the sentiment of the late eighteenth century sought to ensure death before burial, while earlier concepts of death were replete with fear and superstition. Such fearful and superstitious concepts created sentiments where societies were more concerned with burying the dead far from communities and ensuring that the dead remain dead (Eisenberg, 1997). However, the development of morgues supports a major shift in societal ideology in which western societies feared being buried alive more than they feared reanimation of the dead.

Jean Jacques Winslow, On the uncertainty of the signs of death (London, 1746), plate opposite page 7. Courtesy National Library of Medicine, Bethesda, Maryland 20014.

As accounts of accidental live burials grew more common, western societies began to take further measures to ensure that the dead were truly dead. In 1740 French physician and anatomist Jean Jacques Winslow, whom twice during childhood was thought to be dead and placed in a coffin only to wake up in said coffin, began a public debate among medical professionals with the publication titled "The Uncertainty of the Signs of Death and the Danger of Precipitate Internments and Dissections" (Alexander, 1980). This publication was the result of his own fear of being buried alive and pushed forward the idea that putrefaction of a decaying corpse was the only true sign of death. Unfortunately for Winslow, his publication was met with resistance as physicians chimed in on the "art" of medicine and that any skilled expert could appropriately utilize the various signs of death to diagnose death with certainty (Alexander, 1980). Winslow's efforts led to public ridicule and is evident in the cartoon drawn above in which he is made out to be running in fear from the corpse of a misdiagnosed death.

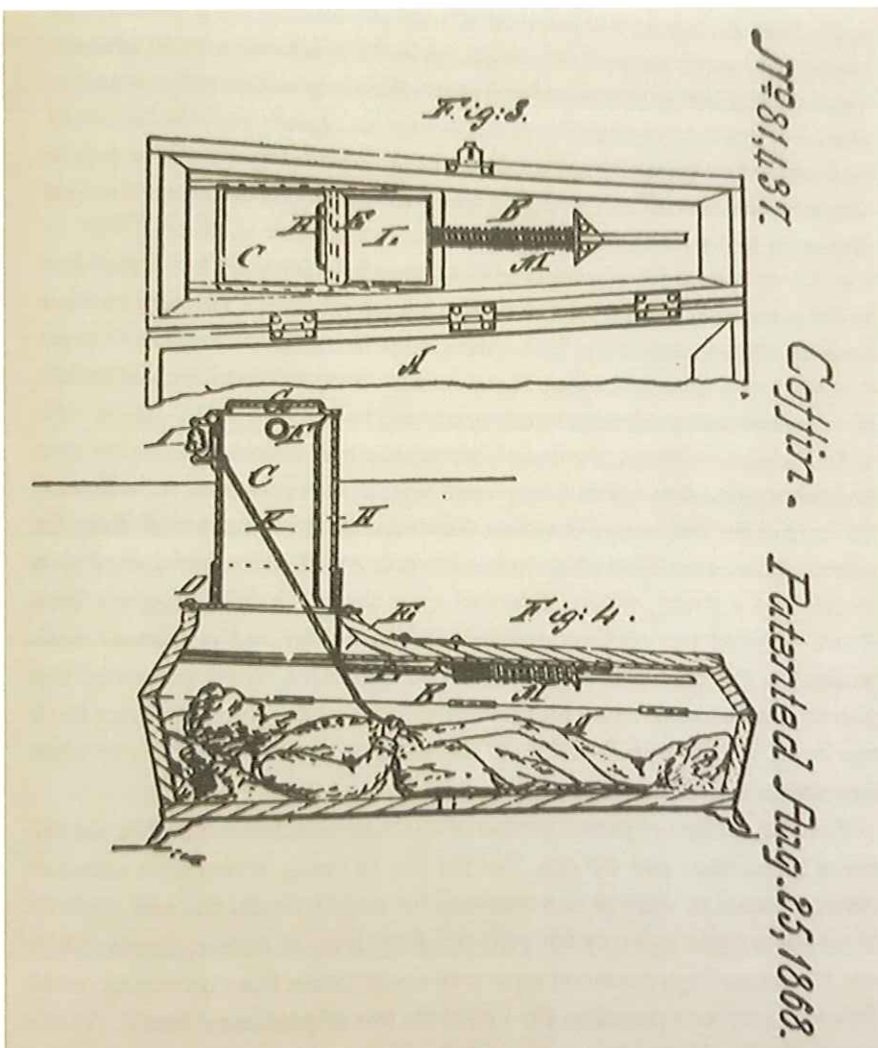
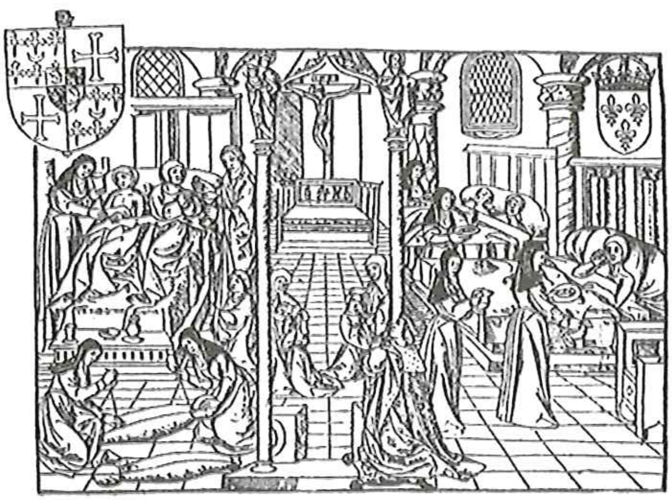


FIGURE 11. *Device to allow a prematurely buried person to pull a rope and signal a bell above ground. (Courtesy of Dover Publications, Inc.)*

Despite the ridicule he endured, history and public perception turned out to be on Winslow's side. Public fear of being buried alive led to the advent of interesting coffin contraptions which would allow a person to alert the outside world if they were inappropriately pronounced dead (as pictured above). Ultimately, it was the very fear of being buried alive that led to the creation of morgues where the deceased could be kept and monitored until the stench of putrefaction, the one definite sign of death, could be ascertained (Eisenberg, 1997).

In the late nineteenth and early twentieth century the development, construction, and shift towards modern hospitals led to further drastic shifts in the concept of death.



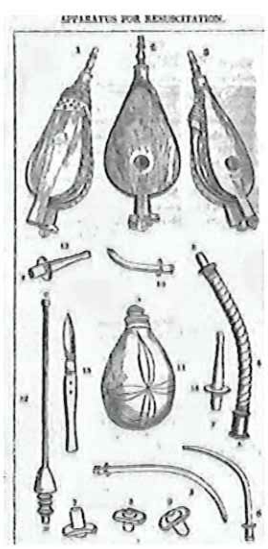
During medieval times, hospitals would be described more like modern day hospices and much less like the life-saving facilities that we know them today. As pictured on the left, these hospitals were typically run by religious orders and their main purpose was to ensure that Christians made confession and received sacraments prior to death (Porter, 1998).

Fast forward to the Nineteenth century and we find that hospitals, despite the centuries of time that separated them, were not much more advanced than their medieval counterparts. During the mid-nineteenth century the wards of American hospitals consisted of large open air rooms with multiple beds where examinations, some surgical procedures, and even death occurred in plain view of the mostly poor patients who occupied the surrounding beds (Rosenberg, 1987). The late nineteenth and early twentieth centuries ushered in an era during which a need to maintain better hospital records, increase overall compartmentalization of hospitals, and a push to cater to the needs of the rich is evident (Rosenberg, 1987; Porter, 2003; Howell, 1989). Furthermore, after the development of the germ theory in the late nineteenth century, hospitals began constructing sterile operating rooms and during the early twentieth century hospitals in the United States began to take on a more familiar form with the addition of sophisticated laboratories and expensive medical technology (Porter, 2003). With the modernization of the hospital new medical capabilities became realized and the site of death in Western society moved rapidly outside of the home and mostly away from the oversight of religious leaders. Ultimately, as will be discussed later, the shift towards modernization of hospitals is important because it paved the way for the development of CPR and the subsequent concept of a "forbidden death" in which death is no longer inevitably brought in the hands of fate. Instead, in this concept of death, death itself is only acceptable when all options to prevent it have been exhausted (Aries, 1976).

Artificial Respiration

According to medical historian Mickey Eisenberg, a Scottish surgeon named William Tossach performed the first successful mouth-to-mouth resuscitation in 1732 (p. 55). This feat was reported in 1745 by a London physician named John Fothergill. During this time it was common to employ the use of a bellow to provide artificial respiration to a drowned individual. Fothergill not only reported Tossach's account but he also recommended the use of mouth-to-mouth, over the use of bellows, in all cases of drowning or suffocation whenever possible. In the report he issued to the Philosophical Society, Fothergill states, "I thought it of so much consequence to the Public, as to deserve to be recommended in this manner to your notice: For tho' it is already published in a Work…it may be overlooked by some, forgot by others, and perhaps , after all the Care that can be taken, it may never come to the Knowledge of a tenth of those who ought not to be ignorant of it" (p. 280-281). Although other methods of artificial respiration had been used beforehand, this is the earliest documented use of mouth-to-mouth I encountered.

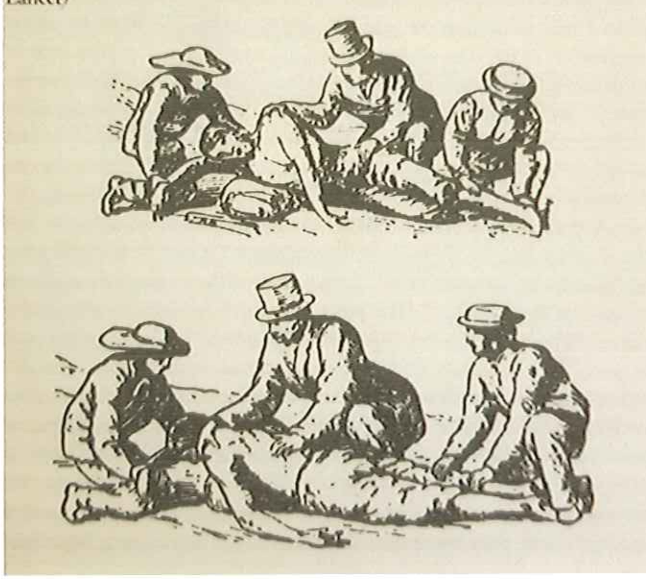
The Royal Humane society, similarly, is one of the earliest organizations to disseminate information regarding resuscitation of drowned persons. The Royal Humane Society was founded in 1774 by Dr. Thomas Cogan, Dr. William Hawes, and Dr. John Fothergill. This society went on to gain considerable influence with regards to resuscitation efforts. During its early years, the primary purpose of the Royal Humane Society was to disseminate cases of attempted resuscitation and to advocate various resuscitative techniques that came to light based on these cases. Initially, the society did not possess or employ any methods to study or to determine the efficacy of any case-based technique. Gradually, the society made it its mission to seek out the most effective means of resuscitation and began keeping statistics on rescues that were reported and investigated (Eisenberg, 1997). Based on their studies and the information they gathered, the society also began to ban the use of methods that its research deemed to be dangerous or out dated.



By 1790, the society established 11 stations that were to used as sites for resuscitation of drowning victims. These sites were located near waterways and were stocked with equipment, like the bellow and tubing shown left, and resuscitation devices that were studied and deemed to be appropriate methods of resuscitation (Eisenberg, 1997). Much like Dr. Fothergill made efforts to promote the use of mouth-to-mouth resuscitation over existing methods after reading Dr. Tossach's account, the Royal Humane Society also promoted new techniques and attempted to do away with ineffective methods.

In 1853 Dr. Marshall Hall, a prominent London physician, published a book titled "Prone and Postural Respiration in Drowning Etc." in which he thoroughly criticized and rejected the resuscitative methods that were being promoted by the Royal Humane Society (1853). Among other things, he denounced the use of receiving stations stating that precious time is lost in transporting a drowned person. On top of that, Hall took issue with all forms of forced inhalation including the use of mouth-to-mouth resuscitation. He states that, in infants "even the human breath, forced on the infant's lips, may tear the delicate tissue of the foetal lungs" (p. 58). In the case of adults, Hall states that "It is important to remember that whatever the mode of artificial respiration adopted… whether the direct application of the mouth, the syringe, the bellows, pressure, &c.—it may and does fail; nay that it frequently does worse—driving fluids present in the fauces fatally into the windpipe" (p. 60). Ultimately, Hall goes on to recommend a new technique for manual respiration in which a drowned person's body is continually shifted from lying flat on their stomach to laying on their side in order draw air into and expel it out of the lungs.

FIGURE 12. *Marshall Hall's technique of artificial respiration, 1856. Top figure shows inspiratory phase and bottom figure depicts expiratory phase. (Courtesy of* The Lancet)



This new method was not met with any of the harsh criticisms that were aimed at previous methods nor did it require any equipment or complicated training. Because of this, Hall's suggested method of manual respiration became the preferred method endorsed by the Royal Humane Society along with other rescue societies. Thus, ushering in a new era of artificial respiration (Eisenberg, 1997). It was an era that would be promoted and defended for almost one hundred years.

By the early 1950s there were a slew of governing bodies that presided over the methods of artificial respiration in the United States. Among them were the American Red Cross, the American Medical Association, the National Research Council, and the National Academy of Sciences along with others.

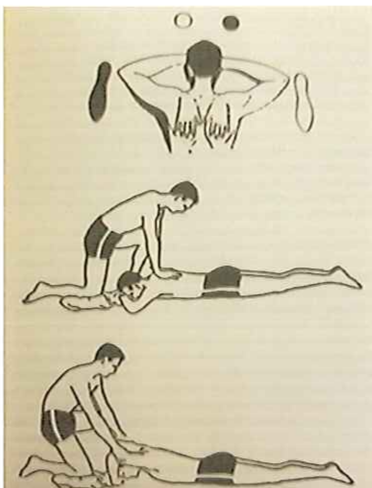


FIGURE 16. *Holger Nielsen's technique of artificial respiration, known as the back-pressure arm-lift method, 1932. The top figure shows hand, feet, and knee placement of rescuer, middle figure depicts expiration; bottom figure shows inspiration. (Courtesy of Danish Red Cross, Copenhagen)*

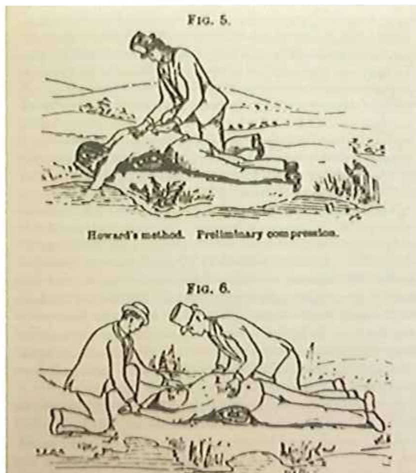


FIGURE 14. *Benjamin Howard's technique of artificial respiration, 1871. (Courtesy of The Lancet)*

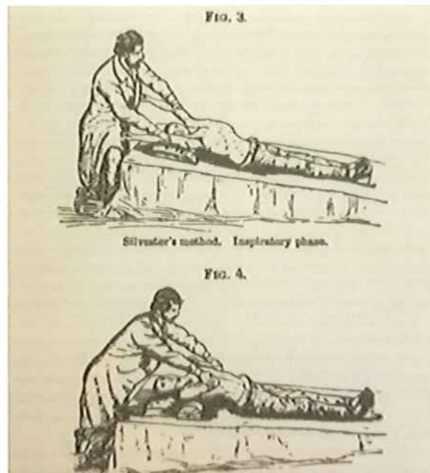


FIGURE 13. *Henry Silvester's technique of artificial respiration, 1858. Top figure shows inspiratory phase and bottom figure depicts expiratory phase. (Courtesy of The Lancet)*

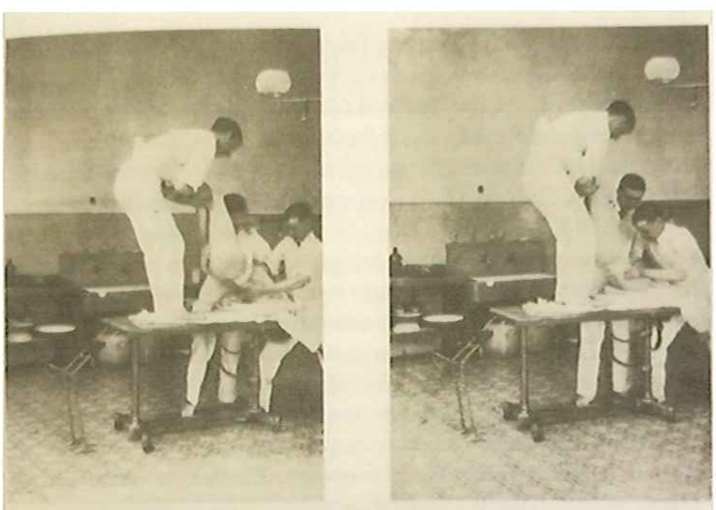


FIGURE 18. *Howard Kelly's technique of inducing artificial respiration using chest compression, 1895. Left photo shows inspiration, right photo expiration. (Courtesy of Johns Hopkins Hospital, Baltimore)*

By this time there were literally hundreds of manual methods of respiration that had been developed most of which were named after the physician who developed it. Similar to the manner in which the Royal Humane society investigated the efficacy of various existing methods, these governing bodies were tasked with digging through the hundreds of methods in order to weed out best one for artificial respiration. As late as 1951 research was being conducted to determine which combination of manual respiration methods were most effective. By this time a physician named James Elam had been successfully administering mouth-to-mouth and mouth-to-nose methods of artificial respiration for half a decade.

Medical historian Mickey Eisenberg details Dr. Elam's path to reintroducing mouth-to-nose and mouth-to-mouth methods of artificial respiration which began when Dr. Elam used the mouth-to-nose method to artificially ventilate a patient suffering from polio. As told by Mickey Eisenberg, Elam had read a chapter on the history of resuscitation during his studies just days prior to this incident. In an interview with Eisenberg, Elam stated, "The chapter detailed 84 manual methods of artificial respiration. Mouth-to-nose and mouth respiration were mentioned as early techniques… The method was dropped as a reliable method of resuscitation largely because 'the medical profession considered it a vulgar act" (p. 89). At the time, transmission of disease was a concern and it was also believed that expired air was not sufficient to adequately supply appropriate oxygenation thus, manual methods of respiration were favored (Eisenberg, 1997). Elam went on to conduct numerous experiments to demonstrate that expired air is sufficient to oxygenate an apneic person and in 1954 his work was published in the New England Journal of Medicine. This publication demonstrated to the medical community that adequate oxygenation can be maintained by the administration of expired air to a non-breathing person (Elam et al., 1954). With these findings, Elam cleared a major obstacle placed in front of him by the advocates of manual methods of respiration. However, without support from governing bodies such as the National Research Council or the Red Cross Dr. Elam faced a difficult time disseminating his methods. He was still tasked with the challenge of proving that mouth-to-nose and mouth-to-mouth methods were more effective than manual methods (Eisenberg, 1997).

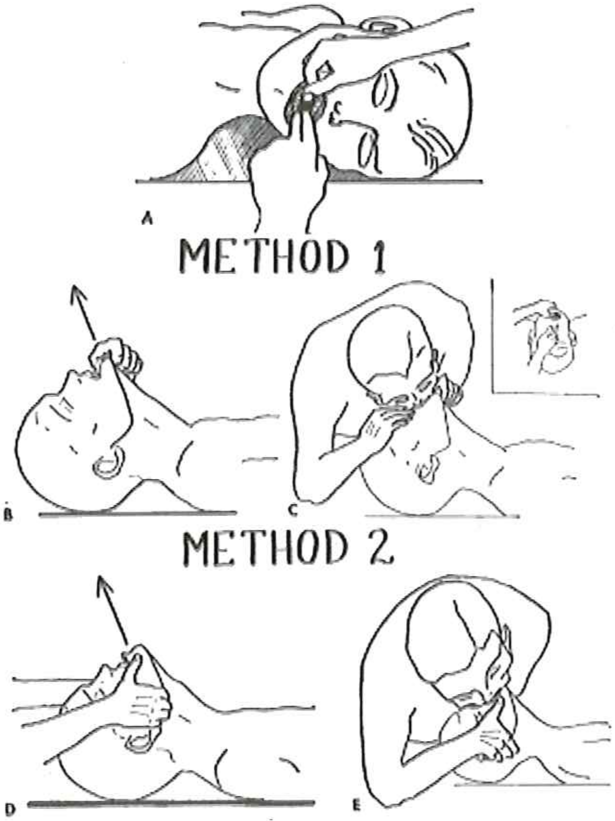


Fig. 1.–When victim is found, place him supine and kneel close to his left ear. *A*, if foreign material is visible at the mouth, turn victim's head to the side and quickly clean mouth and throat with your fingers or a piece of cloth. This should take only a few seconds. If the mouth appears clean, start mouth-to-mouth breathing immediately. Repeat cleaning procedure during mouth-to-mouth breathing whenever necessary. *B*, support of upper airway, method 1. Extend victim's head, insert your left thumb (which may be wrapped for protection) between his teeth, grasp mandible at midline, and hold it forcefully forward (upward), so that lower teeth are leading. *C*, mouth-to-mouth breathing, method 1 (for adults and large children). Maintain support of upper airway as described in *B*. Close victim's nose with your right hand. Take a deep breath, place your mouth firmly over victim's mouth, and blow forcefully in adults and gently in children. Watch victim's chest, and when it rises, take your mouth off victim's mouth and let him exhale passively by the elastic recoil of his lungs and chest. Repeat inflations about 20 times per minute. *D*, support of upper airway, method 2. Extend victim's head, grasp with both hands the ascending rami of mandible just beneath ear lobes, and hold mandible forcefully forward (upward), so that lower teeth are leading. Prevent lip obstruction by retracting victim's lower lip with your thumbs, but never flex victim's head. *E*, mouth-to-mouth breathing, method 2 (for children below 3 years of age and for adults whose mouths cannot be opened). Maintain support of upper airway as described in *D*. Take a deep breath, place your mouth firmly over victim's mouth(in an infant cover both his mouth and nose with your mouth) and blow. Cover nose of an adult victim with your right cheek to prevent air leakage. Blow forcefully in adults, gently in children, and use only puffs from the cheeks in newborn babies. When you see victim's chest rise, take your mouth off victim's mouth and let him exhale passively. Repeat inflations about 20 times per minute.

In 1957, Dr. Peter Safar joined forces with Dr. Elam and the two went on to conduct experimental research that convincingly demonstrated the superiority of mouth-to-mouth ventilation over the various existing methods of manual artificial respiration. In January of that year they recruited medical personnel including physicians, medical students, and nurses to serve as volunteers to be medically sedated and chemically paralyzed. Sedation and paralysis was administered for up to three hours. During this time nonmedical members of the community ranging from children as young as 10 to elderly men and women administered mouth-to-mouth ventilation. In the end, this study showed that this form of artificial ventilation delivered adequate oxygenation via expired air and that the method could be performed easily by a layperson with little training (Safar, 1958; Eisenberg, 1997). This work went on to be published in the Journal of the American Medical Association in 1958.

The work of Dr. Elam and Dr. Safar dismissed the notion that manual methods of ventilation were superior to mouth-to-mouth ventilation. Their work was being closely watched by various interested parties. News of the efficacy of their methods led the Army chemical center to be one of the first major groups to officially adopt the method. Also, after publication of their results in the Journal of the American Medical Association, the American Medical Association officially endorsed mouth-to-mouth ventilation in 1958. Later that same year several other governing bodies such as the American Red Cross, the National Research Council, and the National Academy of Sciences followed suit. As a result of this sequence of events, mouth-to-mouth ventilation became the official method of ventilation during resuscitation efforts (Eisenberg, 1997).

Demographic Shift: Cause of Death

Prior to the twentieth century the leading cause of death in the United States was predominantly due to acute events such as drowning and accidents. By the 1920s chronic conditions such as cardiac disease became the leading cause of all deaths in the United States (*The Center for Disease Control*). At the core of medicine is the desire to treat and/or prevent disease. It is easy to deduce that a change in cause of death has the potential to lead to a shift in the focus of new research towards the development of treatment strategies, medical procedures, and even the medical infrastructure in order to combat the diseases that result in greatest mortality. Cardiac disease such as arrhythmias and coronary artery disease lead to myocardial infarction and cardiac arrest which, over the course of the early twentieth century, gradually became the an increasingly common cause of sudden death (Eisenberg, 1997). While methods such as artificial respiration may have been sufficient to resuscitate a recently drowned patient in previous centuries, deaths caused by cardiac arrest require more sophisticated methods that better restore or mimic the function of the heart; circulation and oxygenation of blood. Defibrillation, which utilizes electric shock to correct a cardiac arrhythmia, is an example of a method which was developed to achieve the aim of reversing sudden death resulting from cardiac arrest. By restoring the heart's rhythm this method has the potential to effectively stop the process of death. However, this method must be administered immediately in order for it to be effective. Administering CPR, as we know it today, can effectively maintain oxygenation of the brain and vital organs for a person in cardiac arrest long enough for that person to be administered defibrillation and other more advanced intervention. By the mid-1900s defibrillation technology existed but the apparatus required to administer it were only available in hospitals (Kouwenhoven et al., 1960). During this time period one of the biggest challenges to preventing sudden death from cardiac disease was maintaining circulation and oxygenation long enough for a patient to make it to the hospital to receive defibrillation.

Origins of external chest compressions

Throughout the mid-1800s, coinciding with the introduction of the use of chloroform during surgery, accounts of sudden cardiac arrest in controlled medical environments began to appear. One of the first researchers to study deaths in the operating room secondary to chloroform administration was Professor R. Boehm. In the 1870s he experimented with chloroform on feline models and discovered that cats could survive the administration of chloroform if circulation was maintained until the anesthesia wore off. He ultimately determined that compression of the cat's thorax was sufficient to accomplish the goal of artificial circulation. Less than twenty years later early reports of successful chest compression in humans begin to surface. The first of these reports occurred in Germany and was written in 1891 (Eisenberg, 1997). In 1904 the first case of closed-chest cardiac massage was reported in the United States (*The American Heart Association*). However, during the late nineteenth and early twentieth century artificial circulation was most commonly performed in the operating room as a result of anesthesia complications. These scenarios allowed surgeons the ideal environment to develop surgical methods of artificial circulation, namely open-chest cardiac massage. This procedure required the surgeon to open the patient's chest and to directly compress the heart with his hands (Eisenberg, 1997).

By the 1950s open cardiac massage was a fairly common practice in the operating room and surgery/cardiac residents were often tasked with repairing the incisions from such procedures. During the late 1950s a research team consisting of one such surgical resident named James Jude as well as electrical engineering graduate student Guy Knickerbocker and an electrical engineer named William Kouwenhoven accidently stumbled upon the (re)discovery of artificial circulation via chest compression while working to improve the design and function of existing defibrillators (Kouwenhoven et al., 1960; Eisenberg, 1997). The story of this remarkable yet accidental discovery is as follows. One day while performing defibrillation experiments on canines, Dr. Kouwenhoven was holding defibrillation pads while preparing to defibrillate a dog. Unfortunately,

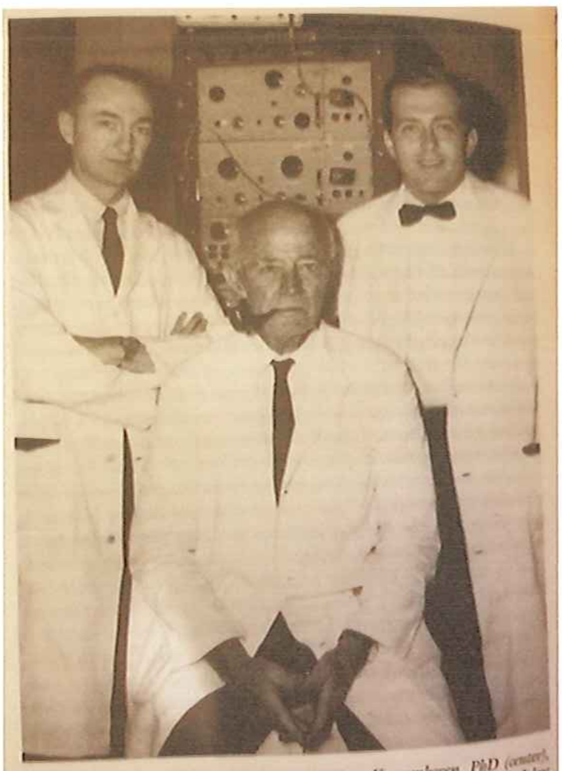


FIGURE 19. *James R. Jude, MD (left), William Kouwenhoven, PhD (center), and G. Guy Knickerbocker, PhD (right), in Kouwenhoven's laboratory at Johns Hopkins Hospital, 1961. (Courtesy of Peter Safar)*

a research assistant accidently charged and fired the defibrillator prematurely and Dr. Kouwenhoven took the full charge of the defibrillator to his own chest. This led him to implement safety features on the paddles. Kouwenhoven figured that by requiring 15 pounds of pressure to be applied to the paddles prior to delivering a shock healthcare providers and future researchers would avoid receiving an accidental shock. After implementing this safety feature Kouwenhoven and his team made an interesting observation. They noticed that the blood pressure of the dogs they were defibrillating increased momentarily just before the shock was delivered. Ultimately, they realized that applying pressure to the chest wall could be sufficient to provide artificial circulation in cases of cardiac arrest. This led to the development of external chest compression as we know it today.

Fig 2.–Position of hands during massage of adult.

A Fateful Culmination of Minds in Baltimore, MD

> Cardiac resuscitation after cardiac arrest or ventricular fibrillation has been limited by the need for open thoracotomy and direct cardiac massage. As a result of exhaustive animal experimentation a method of external transthoracic cardiac massage has been developed. Immediate resuscitative measures can now be initiated to give not only mouth-to-nose artificial respiration but also adequate cardiac massage without thoracotomy. The use of this technique on 20 patients has given an over-all permanent survival rate of 70%. Anyone, anywhere, can now initiate cardiac resuscitative procedures. All that is needed is two hands (Kouwenhoven et al., 1960).

During the late 1950s research on artificial respiration and artificial circulation were simultaneously being conducted in the city of Baltimore, MD. However, these two teams of researchers were unaware of each other, the other's research goals, or the importance that their eventual collaboration would produce. Luckily, for them and for us, the captain of the Baltimore Fire Department served as a human bridge between these two research teams.

Captain Martin McMahon was the Fire Chief that ran the Baltimore Fire Department's ambulance service during the late 1950s. He was contacted by Dr. Safar in 1956 and subsequently spent the following year recruiting first responders such as ambulance personnel and firefighters from across Maryland. These first responders would then participate in experiments led by Dr. Safar during which they were taught mouth-to-mouth ventilation. In 1958 Fire Chief McMahon was contacted and an invitation was extended to him to visit Dr. Kouwenhoven's lab where artificial circulation was being performed via external chest compression. While discussing his observations with medical historian Mickey Eisenberg, Captain McMahon described his initial response as follows, "They had a tube down the throat of the animal, but nobody was blowing. There was no air exchange being made. I told them, you've got to supply air at the time you're compressing the chest" (p. 127). Similar to his role with Dr. Safar's study, McMahon spent the following year recruiting first responders such as ambulance personnel and firefighters from across Maryland to learn artificial circulation via chest compression.

On July 9, 1960 the Journal of the American Medical Association published the research conducted by Kouwenhoven, et al. Three months later Kouwenhoven and Safar attended a meeting at the Maryland Medical Society where they described their individual research and introduced their combined product; artificial respiration and circulation through the use of external mouth-to-mouth ventilation and external chest compression (Eisenberg, 1997). Known today as CPR. Although this major breakthrough in prehospital care was presented in 1960, it took a few years before this new method would be appropriately classified and endorsed by major governing bodies.

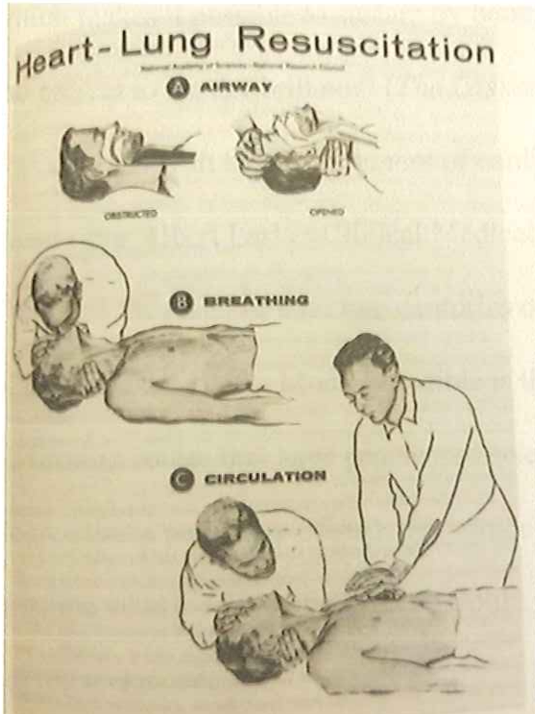


FIGURE 20. *Heart-lung resuscitation (today known as cardiopulmonary resuscitation) showing the ABC steps of Airway, Breathing, and Circulation, from the 1966 issue of the* Journal of the American Medical Association. *(Courtesy of the* Journal of the American Medical Association, *October 24, 1966;198:372–379. Copyright 1966, American Medical Association, Chicago)*

This new procedure now needed to be appropriately classified in order to be implemented in everyday practice across the country. Classification and appraisal is the responsibility of governing bodies. In this case, the American Heart Association (AHA) took the responsibility over designation of this new procedure. In November of 1961, the AHA made a firm decision that the implementation of CPR education and training would be postponed until the new procedure was adequately classified and until the qualifications for administration of the procedure were appropriately determined. In 1963, after over a year of intense debate, this new method was classified as a first aid technique and gained formal endorsement from the AHA (*The American Heart Association).* Having the backing of a reputable governing body such as the AHA legitimized CPR and allowed for rapid and wide spread of the method. Finally, in 1967, the Red Cross began offering education and training in CPR (Eisenberg, 1997).

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