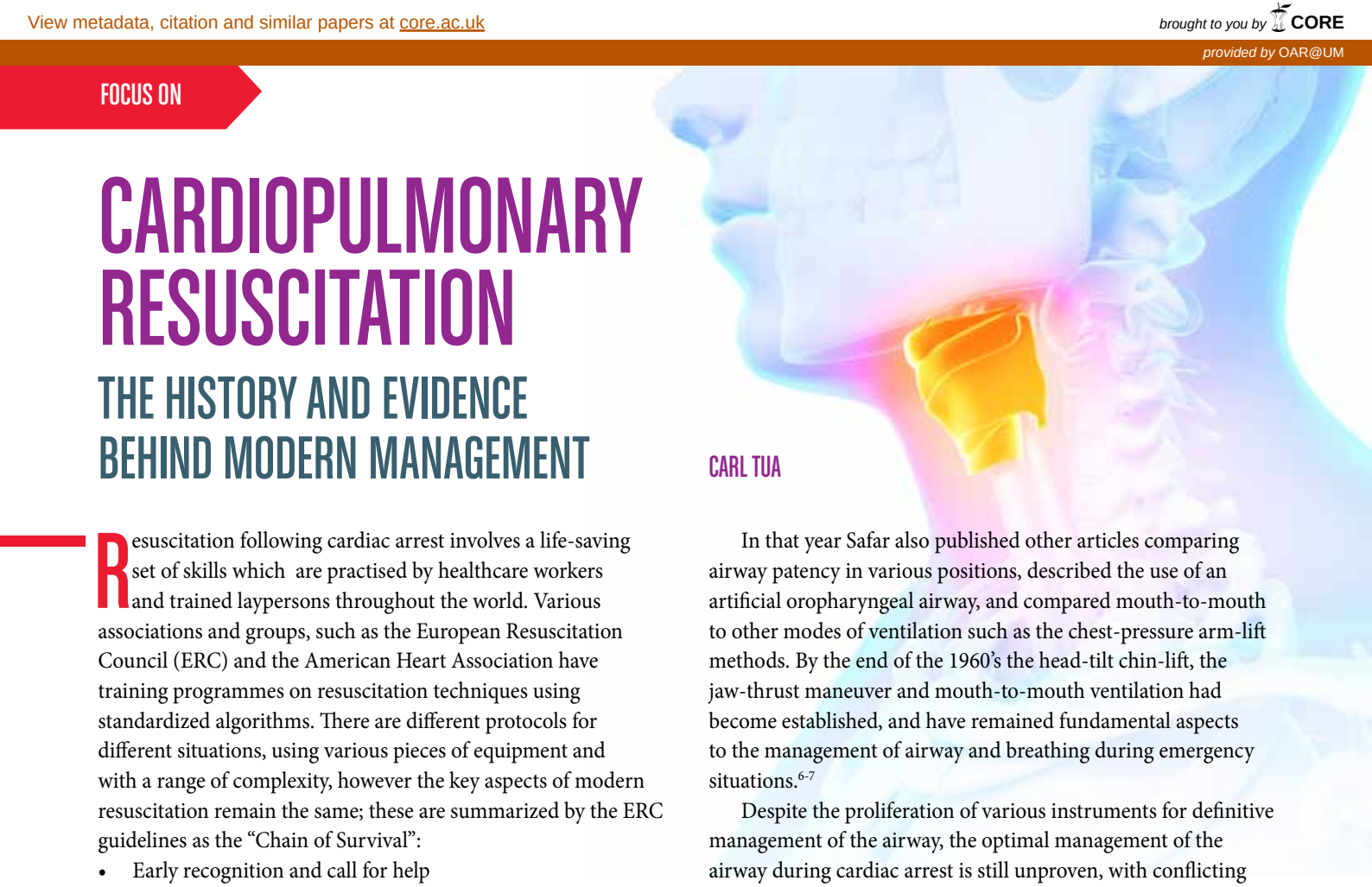
CARDIOPULMONARY RESUSCITATION

THE HISTORY AND EVIDENCE BEHIND MODERN MANAGEMENT



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Resuscitation following cardiac arrest involves a life-saving set of skills which are practised by healthcare workers and trained laypersons throughout the world. Various associations and groups, such as the European Resuscitation Council (ERC) and the American Heart Association have training programmes on resuscitation techniques using standardized algorithms. There are different protocols for different situations, using various pieces of equipment and with a range of complexity, however the key aspects of modern resuscitation remain the same; these are summarized by the ERC guidelines as the "Chain of Survival":

- Early recognition and call for help
- Early Cardiopulmonary resuscitation (CPR)
- Early defibrillation
- Post-resuscitation care

This article focuses on the history and development of the evidence behind some of the key aspects of modern resuscitation: airway maintenance and breathing, circulation and chest compressions, and defibrillation.[1]

AIRWAY AND BREATHING

In the Book of 2 Kings, in the Old Testament the prophet Elisha restores life to a boy using a technique including placing his mouth in the mouth of the boy.[2] There are other historical references to mouth-to-mouth including one by Napoleon's battle surgeon[3] and William Tossach, a British surgeon who successfully used mouth-to-mouth ventilation on a coal miner in 1744.[4] However it was only in 1958 that Safar and McMahon provided the first evidence for the efficacy of mouth-to-mouth and mouth-to-airway ventilation by experimenting on anaesthetized and curarized adults. Their description of how to maintain an airway and provide mouth-to-mouth is similar to what one would find in a modern resuscitation textbook:

> *"The mouth-to-airway method, as well as the mouth-to-mouth method, permits a breath-to-breath evaluation and control of the efficacy of ventilation, since the rescuer can observe the patient's chest at all times and can listen to the expiratory gas flow while at the same time he has both hands free for extending the head and supporting the jaw, thus maintaining a patent upper airway."*[5]

In that year Safar also published other articles comparing airway patency in various positions, described the use of an artificial oropharyngeal airway, and compared mouth-to-mouth to other modes of ventilation such as the chest-pressure arm-lift methods. By the end of the 1960's the head-tilt chin-lift, the jaw-thrust maneuver and mouth-to-mouth ventilation had become established, and have remained fundamental aspects to the management of airway and breathing during emergency situations.[6-7]

Despite the proliferation of various instruments for definitive management of the airway, the optimal management of the airway during cardiac arrest is still unproven, with conflicting evidence for the use of tracheal intubation, supraglottic devices and bag-mask ventilation.[8] One of the reasons that definitive airways have not always resulted in better outcomes in observational studies may be because placement of a definitive airway during CPR requires considerable experience, and may result in interrupted chest compressions and misplacement. Observational studies indicate that patients tend to be over-ventilated since this results in decreased circulation due to decreased venous return; in fact, animal experiments show that hyperventilation greatly reduced absolute survival.[9-10] In Seattle a randomized study comparing CPR by chest compressions alone with CPR by chest compressions plus mouth-to-mouth ventilation found no statistically significant difference in outcomes. This is probably due to interruptions to chest compressions from over-emphasis on ventilation.[11] In another study, in Ontario, adding a program of advanced life support including endotracheal intubation and intravenous drugs did not improve the survival rate.[12] These studies seem to indicate that, while ventilation is important, uninterrupted chest compressions are fundamental to CPR outcome.

CIRCULATION AND CHEST COMPRESSIONS

Friedrich Maass in 1891 was the first person to successfully use external cardiac massage to revive a 9-year-old boy who, during an operation for cleft palate, required extra applications of chloroform which resulted in him becoming cyanotic and pulseless. At this point Maass applied direct compressions in the region of the heart, and after 30 minutes of compressions the cyanosis disappeared and a pulse was felt.[13] Unfortunately his discovery lay dormant, and open-chest cardiac massage,

first performed successfully in 1901 for anesthetic induced arrest, remained the dominant technique, possibly only in theatre conditions and requiring technical expertise. It was 60 years later that closed-chest cardiac massage was rediscovered when researchers experimenting with defibrillation in animals noted by chance that forceful placement of electrodes over the chest resulted in an increase in blood pressure. Following further research, they published their findings, excitedly writing about the use of closed-chest cardiac massage:

> *"Immediate resuscitative measures can now be initiated to give not only mouth-to-nose artificial respiration but also adequate cardiac massage without thoracotomy ... Anyone, anywhere, can now initiate cardiac resuscitative procedures. All that is needed are two hands."*[14]

There is clear evidence that good quality chest compressions are essential for resuscitation. As discussed earlier, trials have shown that compression-only CPR did not result in worse outcomes when compared to compression and ventilation CPR. In 2006, a study showed that longer pre-shock pauses and shallow chest compressions are associated with defibrillation failure.[15] Yet despite this, several large studies of in and out-of-hospital cardiac arrests have shown that chest compressions are not being adequately delivered. One study showed that chest compressions were not given 48% of the time without spontaneous circulation.[16-17] This significant amount of inadequately applied manual chest compressions has led to the suggestion that mechanically applied CPR using automated machines may be superior. However a systematic review in 2012 showed that there is no evidence to show that they improve survival[18] and a recent randomized control trial comparing mechanical CPR with defibrillation during ongoing compressions with manual CPR and standard defibrillation among adults with out-of-hospital cardiac arrest showed no significant difference in 4-hour survival.[19] In a review of the history and future directions of CPR, Cooper et al. suggest that if, despite optimizing closed chest compressions overall survival does not improve, then open cardiac massage should be reexamined as technique, particularly when closed chest CPR fails to resuscitate patients within a short time-frame.[20]

DEFIBRILLATION

The experiments of the Danish veterinarian P. C. Abildgaard who described killing chickens with a shock to the head, and then reviving them with a second shock to the chest are often described as the first scientific description of defibrillation; however it is likely that given the Leyden jars used at the time to generate the shock, the current generated would have been too small to result in defibrillation.[21] There are several reports that may be considered to be the first descriptions of successful defibrillation in humans. In 1787 the Royal Humane Society published the case of Sophia Greenhill, a three-year-old girl who was pronounced dead after a fall, but was revived by the application of electrical shocks administered by her neighbor. However many years would have to pass for the scientific basis of defibrillation to be understood.[22]

In the late 1880s the British physiologist John McWilliam wrote the classic description of ventricular fibrillation, and suggested its importance in humans:

> *"Instead of a coordinated contraction leading to a definite narrowing of the ventricular cavity, there occurs an irregular and complicated arrhythmic oscillation of the ventricular walls."*[23]

The next breakthrough was by Prevost and Battelli who described inducing fibrillation in the hearts of dogs using electrodes placed in the mouth and small intestine of the dog, but more significantly, they described how a second shock delivered to a fibrillating heart, may defibrillate the ventricles.[24] This work was largely forgotten until 20 years later when these experiments were independently replicated. Nonetheless defibrillation was still considered only for the theatre environment with the chest wall open, as transthoracic defibrillation was considered too dangerous due to the voltage and current required. It was research done by the USSR Academy of Medical Sciences, in particular Naum Gurvich that allowed defibrillation to be carried out using significantly less energy, by using a DC shock and biphasic waveform; features that quickly became adopted around the world.[25] Using this technology Paul Zoll described the first successful closed-chest human defibrillation in 1955.[26]

With increased usage of defibrillation it quickly became clear that time is of essence. Data suggests that each passing minute of untreated ventricular fibrillation reduces the likelihood of survival by 7-10%, and the introduction of Automatic External Defibrillators (AED) with rapid response times have been shown to significantly improve outcome,[27-28] with one study reporting an incredible 74% hospital discharge rate if a shock was delivered within 3 minutes.[29] Despite this, performing chest compressions for 1.5 to 3 minutes before defibrillation actually results in improved survival.[30]

CONCLUSION

From the earliest origins of CPR thousands of years ago, to modern-day CPR carried out by bystanders using AEDs in our hospital situations, CPR has undergone countless advancements and reinventions. Yet despite its important role in modern medicine, the ethical and logistical difficulties in carrying out scientific trials means that high level evidence is not always available, and guidelines often rely on observational data and expert consensus. The future of CPR will depend on furthering novel techniques, but perhaps more importantly it will depend on becoming a widespread set of skills practised by the general public and not just healthcare workers, which together with increased availability of public AEDs has shown to improve outcomes. As W.B. Knouwenhoven et al. wrote in the landmark article in 1960:

> *"Anyone, anywhere, can now initiate cardiac resuscitative procedures. All that is needed are two hands."*[14]

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