Resuscitation Science: From the Beginning to the Present Day

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1.1 Introduction

Cardiovascular disease remains the leading cause of death in the Western world, with 350,000 Americans and 700,000 Europeans sustaining cardiac arrest each year [1]. Indeed, cardiopulmonary resuscitation (CPR) is an emergency procedure to be performed as soon as possible after collapse in the attempt to restore spontaneous circulation and respiration. Resuscitation is a relatively modern science, although its roots extend back in the centuries. The earliest report of a resuscitation attempt, in fact, has been described in the Bible, in the Old Testament, where "the life of a boy was restored by placing a mouth in the boy mouth" [2]. However, until the nineteenth century, routine resuscitation from death was not viewed as feasible. Yet, as early as the nineteenth century, resuscitation by delivery of an electrical shock was demonstrated. Indeed, modern CPR emerged only during the latter half of the twentieth century. A sequence of interventions was established in the 1960s under the acronym ABCD [3], namely airway, breathing, chest compression, and defibrillation. Although to some extent now modified to take into account priorities of chest compression over the airway, breathing, and defibrillation, the ABCD acronym continues to have a determinant role and practical utility.

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1.2 History

Indeed, it was in 1874 when the pathophysiology of the direct cardiac compression was explained by Dr. Moritz Schiff. He noted the presence of carotid pulsations closely corresponding to the ejection of blood produced by directly squeezing the canine heart in an open-chest dog model. This led to the term "open chest cardiac massage." Friedrich Maass is credited with the first successful human closed-chest cardiac massage that was performed in 1891 [4]. However, all these initial trials remained anecdotal. Consequently, during the first half of the twentieth century, cardiac resuscitation was restricted to the operating room or closely proximal in-hospital settings. In 1958, however, Dr. Kouwenhoven and his coworkers, Drs. Jude and Knickerbocker [5], reawakened the potential value of chest massage when they observed that coincidental with the positioning of paddles on the anterior chest for delivery of an electrical shock, an arterial pulse was produced. External compression could therefore be performed without surgical expertise or equipment and now became widely taught and used, and open-chest cardiac massage became obsolescent except for intraoperative or post traumatic resuscitation. A combination of closed-chest compression and mechanical ventilation thereupon formed the platform after the 1960s and remains as the present-day CPR.

The modern resuscitation achieved its consistency in the 1950s, thanks to the experiments of doctors James Elam, Peter Safar, and Archer S. Gordon. Dr. Elam was the father of *rescue breathing* [6]. His experiments were soon joined by Dr. Safar who proved the efficacy of exhaled air ventilation without adjuncts and airway patency by backward tilt of the head with jaw thrust. The S-shaped oropharyngeal airway, which continues to be used in the present, was utilized by Safar, together with the now routine positions of the forehead and mandible with which a patient airway is secured in unconscious victims [7]. Correct patency of the airway was described by Dr. Safar who observed in anesthetized, breathing patients, the return of inflated gas into a bag which was connected to the endotracheal tube. In 1954, the mouth-to-mask ventilation for resuscitation was proposed by Elam which achieved arterial oxygen saturations of more than 90 % [8]. Safar, instead, reproposed mouth-to-mouth ventilation as an effective ventilation method during resuscitation because it required no instrumentation [9]. Subsequently, the self-refilling bag introduced by Ruben [10] in 1958 followed by the addition of the oxygen gas-powered pneumatic demand valve resuscitator in 1964 added importantly to support breathing in emergency settings. Concurrently, the valve mask bag became the primary manual emergency ventilation device for resuscitation and it continues to be in active use to the present day [11]. Mouth-to-mouth ventilation was then further improved by Dr. Gordon's clinical observation on children population. As for mechanical ventilation, the Drinker respirator or "iron lung" paved the way for prolonged mechanical ventilation, especially for patients afflicted with neuromuscular failure of breathing, including cervical spinal cord injury and, most of all, paralytic poliomyelitis. Intermittent positive pressure ventilation, instead, first evolved in Europe when cuffed tracheotomy tubes became available. In 1952, Bjørn Ibsen [12] utilized manual positive pressure ventilation during the Danish polio epidemics with the participation of hundreds of medical students breathing for victims who had a tracheostomy tube attached to a vented rubber bag for delivery of air or oxygen.

The first demonstration that ventricular fibrillation could be terminated by an electrical current was in 1899, when Prevost and Battelli [13] observed that directly delivered low voltage AC currents induced ventricular fibrillation in dogs and higher voltage currents terminated ventricular fibrillation. Dr. Paul Zoll subsequently recorded the first successful closed-chest human defibrillation in 1955 in a man with recurrent syncope which terminated in ventricular fibrillation [14]. In 1979, the first portable external defibrillator was developed, the precursor to automatic external defibrillators.

1.3 Introduction of CPR Guidelines

Under the auspices of the National Academy of Science National Research Council, James Elam, Archer Gordon, James Jude, and Peter Safar formed a working committee. This committee developed the first national guidelines for what to teach to whom and how, which was published in 1966 [15]. The first CPR guidelines were established. Guidelines were also developed under the auspices of the World Federation of Societies of Anesthesiologists, which expanded guidelines for advanced life support (ALS), including cerebral resuscitation. In the decade that followed, the first National Conference on Standards for CPR and Emergency Cardiac Care (ECC) was organized under the auspices of the American Heart Association (AHA), which thereafter assumed increasing responsibility for professional leadership in the field both nationally and later internationally. In 1973, the second National Conference on CPR was held under the auspices of the AHA [16]. At the end of the 1970s Advanced Cardiovascular Life Support (ACLS) was developed. Ten years later the AHA introduced the first pediatric basic life support (BLS) and ALS and neonatal resuscitation guidelines. In the 1990s, Public Access Defibrillation (PAD) programs were developed and the International Committee on Resuscitation (ILCOR) was founded. The importance of early cardiac arrest recognition and activation of emergency system, early CPR, early defibrillation, and early ALS was addressed by Cummins and colleagues, who first introduced the concept of the "Chain of Survival" [17, 18]. Today a new link has been added to the chain, the so-called "post-resuscitation care" [19]. The implementation of the fifth link provided significant and important improvements in favorable neurological outcome and survival and became more and more emphasized in the 2010 guidelines [20]. The 2005 and, even more, 2010 guidelines stressed also the importance of high-quality CPR in order to achieve better outcome of cardiac arrest [21].

1.4 Utstein Style

Despite the large amount of literature focusing on out-of-hospital cardiac arrest outcome, a comparison of data among different emergency medical service systems was almost impossible until two decades ago, due to the lack of consensus and uniformity in data recordings and reporting. Thus, in order to establish uniform terms and recommendations for the evaluation and reporting of data from cardiac arrest, in 1991 a task force developed the **Utstein style** [22]. Member representatives of different organizations, i.e., AHA, European Resuscitation Council, European Society of Cardiology, European Academy of Anesthesiology, and European Society for Intensive Care Medicine, attended an international resuscitation meeting hosted at the Utstein Abbey, in Norway. It represented a starting point for a more effective registration of data and information from a cardiac arrest event and a better understanding of the elements of resuscitation practice. Thereafter, the term "Utstein style" was adopted to indicate the uniform reporting of data from prehospital cardiac arrests [23]. Moreover, the international meeting addressed the importance and the potential value of bystander CPR which demonstrated to reduce the mortality of cardiac arrest. The need for easy accessibility to training and CPR education was another topic of interest. Many other Utstein style international consensus statements have been published over the past 20 years, including the uniform reporting of pediatric ALS, laboratory CPR research, in-hospital resuscitation, neonatal life support, CPR registries, and trauma data. The standardized definitions established by the Utstein scientific statements enabled comparative analysis between resuscitation studies and healthcare systems. Nevertheless, there is still confusion in the scientific literature due to a persisting lack of uniformity in reporting some specific data. For example, differences in terms referring to defibrillation success or in the different survival outcomes chosen to report the effect of a specific treatment/intervention [24–27]. Moreover, the likelihood of survival from cardiac arrest patients may depend also on sociodemographic factors as well as biological and clinical characteristics. There are, for example, some areas with higher cardiac arrest risk population and consequently higher risk of poor outcome; thus the estimation of cardiac arrest and outcome may be subject to potential external bias [24]. Other factors to be taken into consideration are the local emergency response organization and post-resuscitation care after hospital admission [24, 26]. Thus, knowledge of regional variations in outcome after cardiac arrest could guide identification of effective interventions to be undertaken, such as appropriate public health initiatives, community support, high-quality pre and posthospital emergency care, and good education in CPR skills.

1.5 Translational Research

The translation of basic science into the clinical practice may be difficult and remains a major issue in contemporary medicine. For this purpose, a new discipline has been created, the *translational research*, which tries to assess the discrepancies between research and clinical needs. Translational research is a continuum loop in which basic science discovering is integrated into clinical application and clinical observations are used to generate scientific topics to be studied by basic science [28]. This integration is extremely important for medicine improvement. Translation science deals with health policy, health economy, and it should have a holistic approach. However, about three-quarters of the basic science promises have not been tested yet in randomized clinical trials and only few of the basic science promises have had a major impact on current medical practice [29]. This result may represent a failure of translational medicine to match basic science advances. Many explanations might account for this “failure,” such as lack of sufficient fundings, high cost and slow results, inadequate samples, conflict of interest, fragmented infrastructures, shortage of qualified investigators, shortage of willing participants, incompatible databases, and lack of congressional and public supports [29–32]. Health systems should consider translational science as a cornerstone of modern health which can have a strong impact on the well-being of society and on clinical practice. Only educational interventions may implement translational science for improving collaboration among scientists, clinicians, researchers, and healthcare systems.

1.6 Resuscitation Science

Advances in resuscitation science have improved survival rate of cardiac arrest. Resuscitation science was first defined by the Post-resuscitative and initial Utility in Life Saving Efforts (PULSE) Conference, an initiative taken by leaders of the international scientific community to improve clinical outcomes after CPR [33]. This conference defined *resuscitation science* as the study of pathophysiology, mechanisms, and management of sudden states of illness, in particular of the states of whole body oxygen deprivation. Resuscitation science includes five principal domains which are: basic science, pharmacology, translational studies, bioengineering, and clinical evaluative research. All of the above domains focus their attention on scientific research which might ameliorate resuscitation care. For example, different studies have shown that therapeutic hypothermia is an effective treatment for comatose adults resuscitated from cardiac arrest [34–37]. It requires a multidisciplinary team approach and comprehensive targeted temperature protocols, which include shivering assessment and seizure management. However, despite the strong evidence of efficacy and apparent simplicity of intervention, recent surveys show that therapeutic hypothermia is delivered inconsistently, incompletely, and often with delay. This is a case of difficulty in translation research into clinical practice. Different reasons might be listed, such as lack of awareness of recommended practice, of standard protocols for applying hypothermia, and staff shortages. To overcome these, standardized protocols, educational sessions, reminders, audit feedbacks, and education of clinicians are mandatory.

1.7 Education

The quality of education, training programs, and frequency of retraining are critical factors in improving the effectiveness of resuscitation. Resuscitation programs should systematically monitor cardiac arrests, the quality of resuscitation care provided, and the outcome. These informations are necessary to optimize resuscitation care and improve the resuscitation performance [38]. Survival rates after cardiac arrest depend, in fact, not only on the validity and reliability of guidelines and a well-functioning Chain of Survival, but also on the quality of education. These factors interact with each other. Unfortunately, less than 15 % of adult out-of-hospital cardiac arrest victims survive to hospital discharge despite the progress on resuscitation care [1].

Training courses on resuscitation are now well-established worldwide. Many courses provide combined training in BLS and ACLS skills. Training organized in small groups is advantageous and more interactive. Scenario-based teaching allows for useful repetition of sequence and items and should be a central part of the course. Teaching strategies should be evaluated and compared on the basis of how well attendees achieve predefined teaching goals [38]. Patient simulation could be an ideal tool for teaching and lets attendees to be actively engaged in their learning process. By definition, in fact, simulation places trainers in a similar realistic scenario created with a simulator that replicates the real environment. Unfortunately, there is not a single method suitable for all circumstances. Thus, audit for evaluation of training methods, instructors' skills, acquired knowledge, and effectiveness of courses should be mandatory. Mass education and television campaigns are other examples of educational tools in CPR training [39]. Another example of a potential good teaching method might be the "virtual technology" which includes computer games and videogames. This method has been efficiently experimented in schools [40]; it is feasible, reliable, and it could represent an alternative starting point for teaching CPR to young laypersons.

1.8 A Tribute to Dr. Weil

Finally, we cannot conclude this chapter without a tribute to the "father of the critical care" and pioneer of resuscitation science, Dr. Max Harry Weil [41]. He, in fact, first introduced the term critical care medicine in the late 1950s at the University of Southern California Medical Center. In 1961, Dr Weil cofounded, together with Dr. Shubin "The Institute of Critical Care Medicine," a nonprofit public foundation at the University of Southern California, recognized as a comprehensive international center for medical and biomedical engineering research in critical care and resuscitation medicine. Indeed, together with Dr. Safar, he signed a progress in understanding the pathophysiology of sudden death and in recognizing the importance of early cardiopulmonary and cerebral resuscitation maneuvers. These concepts were considered a real challenge to achieve by continuous refining of guidelines and their popularization, including widespread programs of training. In 1967, Safar, Shoemaker, and Weil had an impromptu meeting on the Boardwalk of Atlantic City in conjunction with an annual meeting of the American Physiological Society. They subsequently corresponded regularly, and Dr. Weil then invited 28 medical leaders from different specialties representing internal medicine, cardiology, surgery, anesthesiology, and pediatrics to propose a multidisciplinary organization to implement and guide the field which evolved into the "Society of Critical Care Medicine." Dr. Weil's effort contributed to a long list of insights that led to the dramatic improvement in survival of people suffering "circulatory failure" due to sepsis, septic shock, heart failure, cardiac arrest, and trauma. He realized that in the absence of real-time measurements of vital signs and alarms, professional providers were either not aware of immediate life threats or they could not define with sufficient precision the immediate events that led to the fatal outcome. The assumption was that immediately life-endangered patients, the critically ill and injured, may have substantially better chances of survival if provided with professionally advanced minute-to-minute objective measurements. Thus, Dr. Weil was prompted to implement continuous monitoring of the electrocardiogram, blood pressure, pulse, breathing, and other vital signs complemented by arterial and central venous pressures, urine output, central, and peripheral temperatures, and by intermittent measurements of blood gases from vascular sites. That concept was pioneered in a four-bed unit called the "Shock Ward" that became the prototype of the early intensive care unit (ICU) [42]. Thereafter, progress in the management of the acutely life-threatened patient has been accelerated by rapid advances in both monitoring and measurement technologies and the interventions today routinely used worldwide in modern ICUs.

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