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Comprehensive Analysis of Cardiovascular Emergencies though Interventions, Technologies, and Methodologies in Cardiopulmonary Resuscitation out of Hospital

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Abstract

Cardiovascular diseases (CVD) are a leading global health concern, contributing significantly to mortality worldwide. With an estimated 17.9 million deaths annually, CVD includes conditions like coronary artery disease and cerebrovascular disease. The high incidence of sudden cardiac death (SCD) and myocardial infarction underscores the need for effective emergency interventions. Immediate medical response, including cardiopulmonary resuscitation (CPR) and the use of automated external defibrillators (AEDs), is crucial for improving survival rates. This study systematically evaluates various CPR strategies and technologies, focusing on advancements such as real-time feedback devices, community training programs, and the LUCAS automated chest compression device. By adhering to PRISMA guidelines and using rigorous methodology, the research identifies effective interventions and highlights gaps in current practices. Key findings suggest that community training, rapid response systems, hands-only CPR, and advanced technologies significantly enhance the efficacy of out-of-hospital cardiac arrest management. The study also introduces the DARCP device, which improves airway management and CPR quality. Overall, this research emphasizes the need for ongoing technological and methodological advancements to optimize emergency cardiac care and improve patient outcomes.

Keywords: Cardiovascular Diseases; Cardiopulmonary Resuscitation; Automated External Defibrillators; Sudden Cardiac Death (SCD); Real-Time Feedback Devices; Emergency Medical Response; Out-of-Hospital Cardiac Arrest

Abbreviations

AEDs: Automated External Defibrillators.
CVD: Cardiovascular diseases.
CPR: Cardiopulmonary resuscitation.

Introduction

Cardiovascular diseases (CVD) are highly prevalent globally and continue to be one of the leading causes of death, being the primary cause of death worldwide. It is estimated that 17.9 million people die each year due to CVD. CVD encompasses a variety of disorders affecting the heart and blood vessels, including coronary artery disease, cerebrovascular disease, rheumatic heart disease, and other conditions. More than 80% of deaths from CVD are due to heart attacks and strokes, and one-third of these deaths occur prematurely in people under 70 years old [1]. Additionally, in Spain, a high proportion of deaths occur suddenly and outside of hospitals, affecting individuals with no known prior disease, as revealed by the studies of Moretín and Auricana [2], and more recently, Rosell Ortiz et al. (2015) with an incidence of Sudden Cardiac Death (SCD) of 16.6 events per 100,000 inhabitants, where ultimately, only 10.2% of individuals are discharged with good neurological status [3]. In other words, both myocardial infarction and SCD are of great importance due to their significant impact on global mortality and morbidity.

Both myocardial infarction and SCD occur suddenly and require an immediate and effective medical response to improve the chances of survival and quality of life, which is known as a cardiac emergency. In this context, the speed of medical attention, the availability of advanced resuscitation techniques such as cardiopulmonary resuscitation (CPR), and the use of automated defibrillators are crucial for stabilizing the patient and restoring proper cardiovascular function.

Cardiopulmonary resuscitation (CPR) is a procedure that combines chest compressions and rescue breaths to maintain the circulation of oxygenated blood in a person who has suffered cardiac arrest. The process begins with assessing the scene to ensure safety, followed by checking the patient's responsiveness. If there is no response, emergency services are called, and CPR is initiated. The maneuver starts with chest compressions, which are performed by placing the hands in the center of the person's chest, compressing to a depth of at least 5 cm at a rate of 100 to 120 compressions per minute. If the responder is trained, rescue breaths can be performed by opening the patient's airway and inflating their lungs with air.

However, due to the difficulty involved in achieving proper airway opening, effective mouth-to-mouth sealing, and correct inflation without excessive pressure or volume, the American Heart Association [4] and the European Resuscitation Council [5] generally recommend that untrained laypersons should not perform rescue breaths and should instead carry out continuous compressions at a rate of 100 to 120 compressions per minute and a depth of 5 to 6 cm.

The automated external defibrillator (AED) is often a critical element in CPR. However, the use of AED requires proper professional training and knowledge. It must be turned on and its instructions followed precisely. This device can restore a normal heart rhythm and is essential to increase the patient's chances of survival. However, it is not always possible to administer an electric shock with an AED, which may be due to various reasons, such as the absence of an AED at the scene, adverse environmental conditions that prevent its use, or simply if the personnel are not adequately trained to operate it safely and effectively. Moreover, in many interventions, it is common for the first responders at the scene to be an emergency team qualified to perform chest compressions but not to use an AED.

In such cases, the focus is on high-quality chest compressions and adequate ventilation to maintain the circulation of oxygenated blood until advanced medical help arrives. In these situations, other devices such as the bag-valve-mask (BVM), colloquially known as an "Ambu," are commonly used in CPR. If used by properly trained and experienced personnel, this device provides effective ventilation for patients in cardiac arrest, maintaining oxygenation in emergencies until the advanced medical team arrives. In the CPR procedure, the safety of the environment must first be ensured, and the patient's responsiveness checked, calling emergency services before starting CPR. Second, if advanced equipment is available, the AED is turned on, and the pads are placed on the patient's chest.

Subsequently, the patient's airway is opened by tilting the head back and lifting the chin. A properly sized mask is selected and placed over the patient's nose and mouth, using a "C-E" hold technique to create a good seal between the mask and the patient's face.

To ventilate, the mask is held with one hand and pressed slightly against the face, compressing the Ambu bag slowly with one hand, ensuring the patient's chest rises. The bag must fully re-expand before administering the next breath. Ventilations are performed at a rate of one breath every six seconds (about ten breaths per minute) if continuous chest compressions are being performed. If the 30:2 sequence is followed, 30 compressions are performed, followed by a pause and two breaths with the Ambu [6].

In summary, the BVM allows for manual ventilation of the patient, ensuring they receive sufficient oxygen. It is compatible with various accessories and advanced ventilators, making it versatile for use at different levels of medical care. In cases where rapid intubation is not achieved, these devices provide effective and safe ventilation, being essential in managing cardiac emergencies.

CPR can be a very effective medical intervention in preventing premature death, but it can also be harmful by prolonging the dying process, increasing patient suffering, family distress, and the unnecessary use of significant economic resources for society [7-9]. In this context, it is understood that CPR should be performed in the absence of a do-not-resuscitate order, considering it an expected intervention in all respects, for which it is crucial that the rescuer is trained in the proper technique to ensure a tight seal and avoid inflating air into the stomach, which can cause additional complications.

Technological advancements and best medical practices continue to refine emergency methods, seeking to improve survival outcomes and post-event quality of life. In addition to conventional cardiopulmonary resuscitation (CPR) and automated external defibrillators (AED), other emerging devices and technologies complement the management of cardiac emergencies. One such device is the LUCAS (Lund University Cardiopulmonary Assist System) automated chest compression device. LUCAS provides consistent, high-quality chest compressions automatically, which is crucial for maintaining blood circulation in cardiac arrest patients without the fatigue associated with manual compressions.

Additionally, other devices like the CardioHelp System, a ventricular assist system, can provide temporary circulatory support until normal cardiac function can be restored or more advanced intervention can be performed. These technological advancements aim to improve survival rates and post-event quality of life in patients with severe cardiac emergencies.

As technology continues to evolve, it is crucial to evaluate and compare these alternatives to determine which is most suitable in different clinical contexts and emergency situations.

Materials and Methods

This papers aims to systematically analyze and evaluate various strategies, technologies, and methodologies in cardiopulmonary resuscitation (CPR) and cardiovascular emergency management, with the goal of identifying effective interventions that improve survival rates and patient outcomes in out-of-hospital cardiac arrest scenarios.

For the analysis of the selected studies, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were followed, a recognized standard for the transparent and comprehensive presentation of systematic reviews and meta-analyses in the scientific literature.

The protocol for this scoping review was conducted in accordance with the principles established in the "Cochrane Handbook for Systematic Reviews of Interventions" [10]. This handbook provides detailed guidelines to ensure that the review process is rigorous and transparent, including precise planning, exhaustive literature search, and critical assessment of the quality of the studies.

By following these guidelines, the review is ensured to be consistent and based on solid methodologies, allowing for the effective identification of gaps in the existing literature and the formulation of future research questions. This contributes to the validity of the findings and the advancement of knowledge in the field of the evaluated interventions.

Searches were conducted in the following bibliographic databases: Scopus, ProQUEST Central, DOAJ, PubMED, Health & Medical Collection, ROAD, MEDLINE, OVID Journals, IngentaConnect Journals, Nursing & Allied Health Database, ScienceDirect (Elsevier), Web of Science, ABI/Inform Collection, Springer Databases, Wiley Online, Public Health Database, and Single Journals. The search strategy used was as follows:

- *Search Extension*: "CPR Support Devices" OR "Mechanical CPR" OR "Cardiac Arrest Devices" OR "Advanced CPR Technologies" OR "Portable CPR Systems" OR "Chest Compression Devices" OR "Ventilation in Cardiac Emergencies."
- *Inclusion Criteria*: Articles published in the last 5 years, from 2019 to the present, addressing topics related to improvements in CPR, both in terms of automated devices and conventional methods and innovative strategies, were included.
- *Search Timing*: The search was conducted between July 12 and 19, 2024.

Results and Discussion

The initial research in the DAMA database of the Miguel Hernández University (UMH) resulted in the identification of 6,880 relevant publications. This initial set of publications was then subjected to a rigorous filtering process. First, publications that were not directly related to the specified topics of interest were eliminated, such as: "mortality," "male," "female," "hospitals," "pediatrics," "surgery," "anesthesiology," "anesthesia," "cardiac surgery," "malalties del cor" (heart diseases), "health diseases in pregnancy," "anesthesia methods," and "veterinary analgesia." After this first exclusion phase, 2,148 publications were discarded for not meeting these thematic criteria, leaving a total of 4,732 publications considered eligible for further detailed review.

In a second filtering phase, a comprehensive evaluation was carried out to identify publication types that did not correspond to original studies. At this stage, review articles, reports, and undergraduate theses were excluded, as they did not meet the requirements for originality in research. As a result, an additional 450 publications were eliminated, reducing the number of eligible studies to 4,282.

These 4,282 original studies were then subjected to a detailed review process to assess their relevance and quality in relation to the research topic. The review of these articles followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, which is a widely accepted standard to ensure transparency and comprehensiveness in systematic reviews. The application of the PRISMA strategy, which includes a series of phases of identification, screening, eligibility, and inclusion, is visualized in Figure 2 of the document, where the steps followed and the article selection flow throughout the process are illustrated.

The analysis is divided into several sections: community CPR training, rapid response system, hands-only CPR, use of feedback devices, public access defibrillators, mobile alert applications, and continuity of care. Table 2 provides a summary of the main results obtained, including a total of 537 articles analyzed.

The results presented highlight various effective strategies to improve the efficacy of out-of-hospital cardiopulmonary resuscitation (CPR), with the goal of increasing survival rates in cases of out-of-hospital cardiac arrest. Among the most notable strategies is community CPR training, which has been shown to increase bystander confidence and willingness to intervene in emergency situations [11].

Additionally, the implementation of rapid response systems, which optimize emergency dispatch centers and train operators to provide CPR instructions over the phone, has proven crucial in improving response times [12]. Other strategies include the promotion of hands-only CPR, which has shown results comparable to traditional CPR [13], and the use of real-time feedback devices, which enhance the quality of compressions [14].

Moreover, the installation of automated external defibrillators (AEDs) in public places has proven effective in increasing survival rates, provided that the public is trained in their use [15]. Finally, the development of mobile applications that notify nearby rescuers has been shown to promote more continuous care [16, 17], which, combined with recent innovations in the continuity of care from pre-hospital to hospital care, could substantially improve emergency care [18].

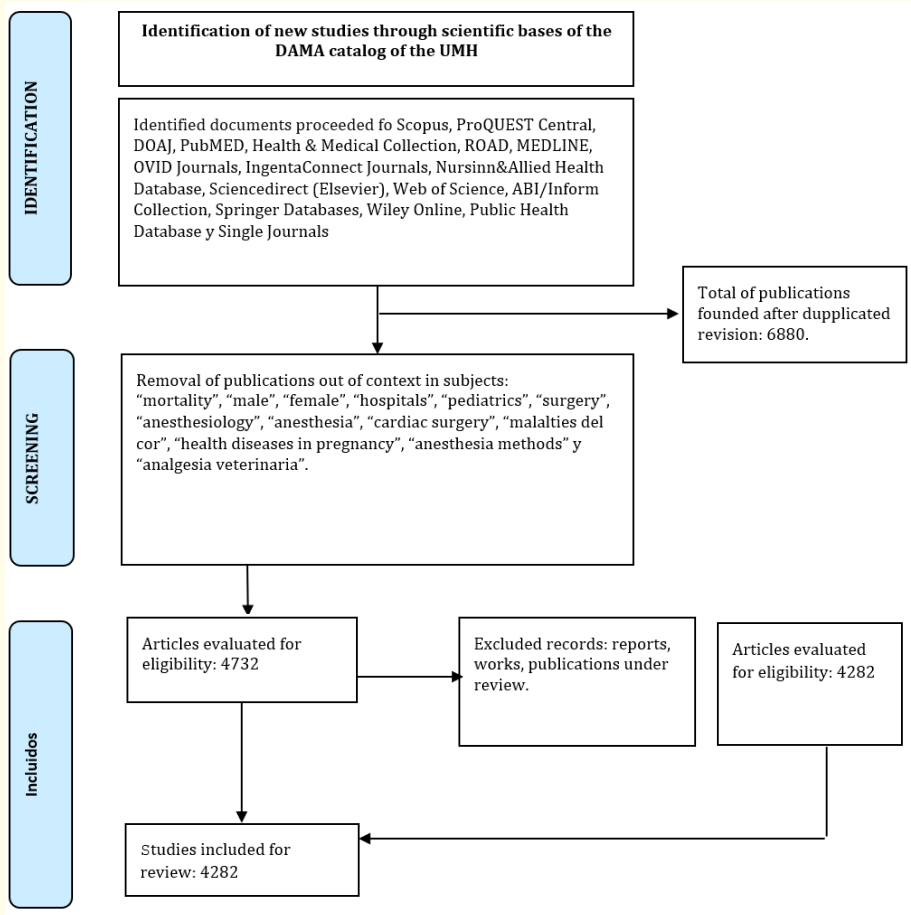

Figure 1: PRISMA process selection diagram.

Sections	***Brief description***	***Number of articles***	***Example article title***	***Full reference***
Community CPR training	CPR training programs for the general population	87	Associations between cardiopulmonary resuscitation (CPR) knowledge, self-efficacy, training history and willingness to perform CPR and CPR psychomotor skills: A systematic review	M Riggs, R Franklin and L Saylany. "Associations between cardiopulmonary resuscitation (CPR) knowledge, self-efficacy, training history and willingness to perform CPR and CPR psychomotor skills: A systematic review". Resuscitation 138 (2019): 259-272.
Rapid response systems	Optimization of emergency services and response times	73	Telecommunicator Cardiopulmonary Resuscitation: A Policy Statement from the American Heart Association	MC Kurz., et al. "Telecommunicator Cardiopulmonary Resuscitation: A Policy Statement from the American Heart Association". Circulation 141.12 (2020): E686-E700.

Chest compression-only CPR	Effectiveness of simplified CPR without ventilations	92	Do cardiopulmonary resuscitation real-time audiovisual feedback devices improve patient outcomes? A systematic review and meta-analysis	N Sood., et al. "Do cardiopulmonary resuscitation real-time audiovisual feedback devices improve patient outcomes? A systematic review and meta-analysis". World J Cardiol 15.10 (2023): 531-541.
Feedback device usage	Implementation of technology to improve CPR quality	68	Effects of real-time feedback on cardiopulmonary resuscitation quality on outcomes in adult patients with cardiac arrest: A systematic review and meta-analysis	SA Wang., et al. "Effects of real-time feedback on cardiopulmonary resuscitation quality on outcomes in adult patients with cardiac arrest: A systematic review and meta-analysis". Resuscitation 155 (2020): 82-90.
Public access defibrillators	Impact of AEDs in public places	81	Lay People Training in CPR and in the Use of an Automated External Defibrillator, and Its Social Impact: A Community Health Study	F Villalobos., et al. "Lay People Training in CPR and in the Use of an Automated External Defibrillator, and Its Social Impact: A Community Health Study". Int J Environ Res Public Health 16.16 (2019): 2870.
Alert mobile applications	Use of apps to notify nearby rescuers	65	Enhancing citizens response to out-of-hospital cardiac arrest: A systematic review of mobile-phone systems to alert citizens as first responders	T Scquizzato., et al. "Enhancing citizens response to out-of-hospital cardiac arrest: A systematic review of mobile-phone systems to alert citizens as first responders". Resuscitation 152 (2020): 16-25.
Continuity of care	Improvement in the transition from prehospital to hospital care	71	The global survival rate among adult out-of-hospital cardiac arrest patients who received cardiopulmonary resuscitation: a systematic review and meta-analysis	S Yan., et al. "The global survival rate among adult out-of-hospital cardiac arrest patients who received cardiopulmonary resuscitation: a systematic review and meta-analysis". Crit Care 24.1 (2020): 61.

Table 1: Detail of the main results by sections, brief description, number of relevant articles, example of article and bibliographic reference.

Community CPR Training

Widespread training of the population in basic CPR techniques has been demonstrated as one of the most effective strategies for improving survival in cases of out-of-hospital cardiac arrest. Training programs in schools, workplaces, and communities have shown significant results in increasing bystanders' confidence and willingness to perform CPR. These programs not only teach the correct techniques but also help overcome the psychological barriers that might prevent people from intervening in emergency situations. Implementing periodic recertification programs may be viable to keep the skills and knowledge of those performing CPR up to date.

Rapid Response Systems

The implementation of systems that enable rapid activation of emergency services has proven fundamental in improving response times and, consequently, survival rates. These systems include the optimization of emergency dispatch centers, the use of geolocation technologies, and efficient coordination between bystanders, dispatchers, and emergency teams. Training emergency operators to provide CPR instructions over the phone has also proven to be an effective strategy for initiating CPR more quickly and effectively.

Hands-Only CPR

The promotion of hands-only CPR for untrained bystanders has gained considerable attention in recent years. This simplified technique not only increases bystanders' willingness to perform CPR but has also shown results comparable to or even superior to traditional CPR in some studies. Eliminating mouth-to-mouth ventilation reduces the complexity of the procedure and the interruption time of chest compressions, which may result in better perfusion of vital organs. However, it is important to note that conventional CPR remains preferable in cases of non-cardiac origin cardiac arrest, especially in children.

Use of Feedback Devices

The implementation of devices that provide real-time feedback on the quality of compressions has been shown to significantly improve CPR efficacy. These devices help maintain the correct depth and frequency of compressions, critical factors for the effectiveness of resuscitation. Some advanced devices can even provide guidance on hand positioning and full chest recoil. By incorporating these devices into training and daily practice for emergency professionals, as well as in public access AEDs, can contribute to improving the overall quality of CPR performed by both professionals and bystanders.

Conclusion

The findings of this study underscore the critical importance of rapid and effective intervention in out-of-hospital cardiac arrest scenarios. Community training in CPR, the implementation of rapid response systems, and the use of hands-only CPR are shown to be highly effective in increasing survival rates. The integration of advanced technologies, such as real-time feedback devices and automated external defibrillators (AEDs), further enhances the quality of resuscitation efforts. Additionally, the development of mobile alert applications and the continuity of care from the pre-hospital to hospital phases play a significant role in improving patient outcomes.

Moreover, innovative devices like DARCP represent a significant advancement in the field of emergency medical response. DARCP consists of three main components: a board, a wedge, and a robust, portable base that provides a stable surface for the patient's head; a tilting headrest that allows controlled airway opening with adjustable angles; and a central piece with ear supports that ensures correct and firm positioning of the patient's head. The device allows for quick assembly and adaptation to different conditions and patient sizes, ensuring effective support during CPR without the need to move the patient from the ground. The versatility, stability, controlled airway management, and ease of adjustment offered by DARCP enhance emergency interventions by ensuring that even a single rescuer can effectively manage CPR, including ventilation, which is a groundbreaking capability not found in existing technologies. The classification of DARCP as a Class I medical device also facilitates its broader adoption and use by first responders and medical personnel.

Collectively, these strategies and innovations highlight the need for a multidisciplinary approach to optimize emergency response and ultimately save more lives. Continued research and development in this field are essential to refine and expand these practices, ensuring they are accessible and effective across different populations and settings.

Conflict of interest

This study was partially funded by Design and Production of CPR Systems (DARCP), for which the lead author prepared a prior report related to the topics discussed in the article. Additionally, the co-author Mr. Adolfo Ferrero is the director of this company, establishing a direct relationship with the mentioned entity. Finally, the device described in this article, DARCP may represent a commercial interest. The authors have declared these potential conflicts of interest in accordance with the journal's transparency policies.

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