Review of Contemporary Philosophy
ISSN: 1841-5261, e-ISSN: 2471-089X
Vol 22 (1), 2023
Pp 4550 - 4556

The Role of Paramedics in Prehospital Management of Cardiac Arrest: Innovations in Cardiopulmonary Resuscitation and Defibrillation Techniques

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Abstract

Background: Out-of-hospital cardiac arrests (OHCAs) remain a critical challenge for emergency medical services (EMS), with global survival rates stagnating between 5% and 10%. Despite advancements in training and technology, these rates highlight the urgent need for improved prehospital interventions. This systematic review evaluates the impact of high-performance cardiopulmonary resuscitation (HP CPR) and multi-tiered response (MTR) strategies on OHCA outcomes.

Methods: A comprehensive literature search was conducted across multiple databases, yielding 208 relevant publications from 2000 to 2023. The analysis reveals that HP CPR, which emphasizes team dynamics and defined roles, correlates with improved return of spontaneous circulation (ROSC) and survival to discharge.

Results: Key findings indicate that early defibrillation significantly enhances outcomes, particularly when facilitated by MTR systems. Notably, the ratio of emergency medical technicians (EMTs) to paramedics plays a crucial role; higher paramedic involvement correlates with better survival rates. Conversely, reliance on mechanical CPR devices has shown limited benefits, suggesting a paradigm shift towards minimizing interruptions in manual chest compressions.

Conclusions: The findings underscore the necessity for tailored EMS protocols that prioritize team proficiency and resource allocation. This review highlights the potential of HP CPR and MTR strategies to enhance patient outcomes in OHCA cases, advocating for further research to standardize best practices in prehospital cardiac arrest management.

Keywords: Out-of-Hospital Cardiac Arrest, High-Performance CPR, Emergency Medical Services, Defibrillation Techniques, Survival Rates

Received: 13 October 2023 **Revised**: 27 November 2023 **Accepted**: 11 December 2023

1. Introduction

Among the many prehospital issues faced by emergency medical services (EMS) systems globally, out-of-hospital cardiac arrests (OHCAs) persist as a significant issue. Notwithstanding systematic enhancements in training and the advancement of equipment and skill sets, survival rates persistently stay unsatisfactorily low [1-3]. Recent research assessed the worldwide survival rate for out-of-hospital cardiac arrest (OHCA) to be between 5% and 10%, showing only marginal increases over the years, along with suboptimal neurological and functional outcomes among survivors [4].

Disruptions to chest compressions consistently represent a significant factor in the elevated death rates linked to out-of-hospital cardiac arrests (OHCAs) [5,6]. The effectiveness of prehospital interventions is significantly affected by time sensitivity, as emphasized in the chain of survival. This chain delineates the sequence of events that govern the treatment of out-of-hospital cardiac arrests (OHCAs), namely early access, early cardiopulmonary resuscitation (CPR), early defibrillation, early advanced life support, and early post-resuscitative care [7,8]. There is a significant focus on prompt discovery, rapid community reaction, and the immediate implementation of life support measures to enhance survival rates [9].

The persistent COVID-19 pandemic has considerably obstructed every aspect of the survival chain, prompting further investigation and innovation in out-of-hospital cardiac arrest (OHCA). During the COVID-19 pandemic, worldwide EMS systems have documented a rise in the occurrence of out-of-hospital cardiac arrests (OHCAs) and worse outcomes. A comprehensive evaluation of ten studies across five countries indicated a "greater than twofold" rise in the incidence of out-of-hospital cardiac arrest during the pandemic [7]. Singaporean research also revealed an increase in the prevalence of OHCA and worse outcomes, consistent with findings from EMS systems in Europe, New York City, and Victoria [8]. The results during the present epidemic emphasize the urgent need to assess existing and novel solutions to enhance prehospital treatment systems for OHCA.

Recent years have seen an increasing interest in the benefits and execution of high-quality prehospital resuscitative measures for out-of-hospital cardiac arrest (OHCA). Diverse methodologies have been used to delineate excellent quality [10,11]. This encompasses high-performance CPR (HP CPR), multi-tiered response (MTR), and minimally interrupted cardiac resuscitation (MICR) [12-16]. The methodologies detailed in this research converge on a shared objective of delivering high-quality resuscitation by emphasizing responder competencies and intra-professional role coordination.

Nevertheless, these studies together have failed to provide a definitive response regarding the best structure of EMS teams or to establish that high-quality resuscitative efforts, hereafter referred to as HP CPR, may yield superior results for OHCAs. The use of HP CPR in some EMS systems has shown negligible changes in prehospital restoration of spontaneous circulation (ROSC) in certain cases [16]. There is no universally accepted definition of HP CPR; nonetheless, it is often understood that HP CPR is a coordinated, team-based resuscitation effort, with each person designated a defined role. It is essential to evaluate the existing data on HP CPR adoption to validate its effect on OHCA outcomes and guide further initiatives by EMS systems to establish it as a standard of treatment.

2. Methods

A preliminary search utilizing the keywords “high-performance CPR OR HP CPR OR HPCPR OR HP-CPR OR team CPR” across the PubMed, OVID Medline, Embase, ScienceDirect, Clinicaltrials.gov, Web of Science, and Google Scholar databases resulted in 208 English-language publications from 2000 to 2023. To optimize sensitivity, the search techniques used a combination of topic headers and keyword (free text)

methodologies. Efforts were undertaken to explore the gray literature using Google searches and manual examination.

3. High-quality resuscitative measures to enhance outcomes of out-of-hospital cardiac arrest

The investigations endorse the execution of high-quality resuscitative measures to enhance outcomes of out-of-hospital cardiac arrest, specifically for prehospital return of spontaneous circulation, survival to discharge, and neurological recovery of survivors. Nevertheless, the studies exhibited varying operational circumstances and EMS setups. The majority were carried out in urban environments rather than rural areas and included a paramedic team of a minimum of four EMTs. Given that EMS organizations are limited by personnel and other scarce resources, it is essential to evaluate the makeup of the HP CPR team [17-21].

There is increasing study on high-performance cardiopulmonary resuscitation (HP CPR), which is administered via a team-based approach where each participant is designated a particular role. North American research [22] indicated that the advantages of implementing a Mobile Treatment Response (MTR) were more pronounced in out-of-hospital cardiac arrest (OHCA) patients with an initial shockable rhythm; hence, the authors concluded that early defibrillation facilitated by a MTR is essential for enhancing outcomes.

South Korean research on MTRs [20] indicated that an early MTR (defined as 0–18 minutes from the first call to the second EMS arrival) significantly improved neurological outcomes and survival-to-discharge rates compared to both the single-tiered response group and the late MTR group (19 minutes or more from the call to the second EMS arrival). A delayed MTR exhibited marginally superior prehospital ROSC rates compared to the single-tiered response system, although had worse survival and neurological outcomes. This is likely anticipated since prior research has validated the time-sensitive characteristics of OHCAs [23,24]. The arrival of advanced life support (ALS) within 10 minutes of the call, deemed the best threshold, correlates with enhanced outcomes in out-of-hospital cardiac arrest (OHCA) patients [24]. Additionally, an increased number of EMS responders arriving within 15 minutes of the call is linked to better survival rates [22].

Alongside numerical data, the proficiency of the EMS team is a crucial factor to evaluate. Research from Taiwan indicates that the EMT–paramedic ratio, rather than the quantity of EMTs, correlates favorably with survival rates. Recent Taiwanese research [13] confirmed this conclusion; the training duration necessary for EMT paramedic accreditation in Taiwan is 1280 hours, exceeding four times that needed for EMT intermediate accreditation. Furthermore, the EMT paramedic is equipped to execute more sophisticated operations, such as endotracheal intubation, manual defibrillation, intravascular therapy, and transcutaneous pacing, which the EMT intermediate is unable to undertake. In a two-year examination of the nationwide MTR implementation in Korea [14], the authors observed a notable enhancement in prehospital ROSC outcomes as the MTR progressed, attributing this improvement to the augmented administration of intravenous medications and sophisticated airway care by paramedics. The timing of the first defibrillation and the administration of the first intravenous epinephrine are critical treatments that must be prioritized, and team members must possess the requisite abilities to execute these procedures.

An additional facet of HP CPR implementation merits consideration. Co-interventions like mechanical CPR, formerly considered a crucial element of the resuscitation algorithm, may not be as important as previously thought. Recent research in Victoria indicated that the local EMS system has dissuaded the use of mechanical CPR during the critical first phases of resuscitation [16]. The reduced use of mechanical CPR lessened interruptions to chest compressions during high-performance CPR. The diminished focus on mechanical CPR is corroborated by a recent systematic evaluation of both controlled and uncontrolled studies, which indicated no significant improvement in survival outcomes with the use of mechanical CPR [25]. A further Australian investigation demonstrated a heightened occurrence of airway hemorrhage in non-traumatic out-of-hospital cardiac arrest patients, which would negatively affect survival rates [26]. This indicates that the Victorian approach, which emphasizes minimizing interruptions by maximizing hands-on-chest duration without mechanical CPR, might enhance optimal high-performance CPR designs.

This research has several strengths. This is the first systematic review and meta-analysis examining the effects of HP CPR and associated therapies on ROSC and survival rates. Consequently, our findings may facilitate worldwide comparisons of EMS systems and stimulate additional discourse on the topic. This research demonstrates that (1) high-performance cardiopulmonary resuscitation (HP CPR) may enhance rates of return of spontaneous circulation (ROSC) and survival to discharge, and (2) the makeup of the HP CPR team is significant. This may need modifications in paramedic training and procedure formulation to enhance patient outcomes.

The possible constraints of this research must be recognized. The review procedure was not registered prospectively. Secondly, due to the varying operational settings and team structures of the EMS systems examined in this research, we remain uncertain about the optimal design for high-performance cardiopulmonary resuscitation (HP CPR). This is contingent upon the local environment and topography. Thirdly, substantial heterogeneity was seen in the meta-analysis, as shown by the forest plots and indicated by the elevated I2 statistic (>50%). This may be ascribed to variations in EMS arrangements, the study population, the training standards of providers, and the resultant quality of CPR. The study designs among the included papers were heterogeneous, since various EMS systems had differing numbers of team members and compositions. Fourthly, just three investigations indicated the secondary result of neurological state. Ultimately, as the majority of the studies used an observational design, it was challenging to account for possible confounding variables, including event-related characteristics and patient demographics. The studies exhibited a moderate to significant risk of bias, necessitating careful interpretation of the results in consideration of these limitations. Table 1 represents the summary of innovations in prehospital cardiac arrest management and their outcomes.

Table 1. Innovations in Prehospital Cardiac Arrest Management and Their Outcomes

Innovation	Description	Impact on Outcomes	Key Studies
High-Performance CPR (HP CPR)	Team-based approach emphasizing coordinated, uninterrupted chest compressions and defined roles.	Improved return of spontaneous circulation (ROSC) and survival-to-discharge rates.	Bobrow et al. [12], Nehme et al. [16]
Multi-Tiered Response (MTR)	Deployment of multiple EMS units to ensure timely advanced life support (ALS).	Significant improvement in survival and neurological outcomes in shockable rhythms.	Lee et al. [14], Park et al. [20]
Minimally Interrupted CPR	Focus on reducing pauses in chest compressions during resuscitation.	Enhanced hands-on-chest time, contributing to better survival rates.	Bobrow et al. [12], Lim et al. [7,8]
Mechanical CPR Devices	Automated devices providing consistent chest compressions.	Limited benefits over manual CPR; potential for airway hemorrhage in specific cases.	Liu et al. [25], Asha et al. [26]
Advanced Paramedic Training	Increased paramedic competencies, including intubation, IV therapy, and advanced airway care.	Improved prehospital ROSC and survival outcomes.	Fang et al. [13], Sun et al. [21]

4. Conclusions

Current research indicates that high-performance cardiopulmonary resuscitation (HP CPR), mechanical chest compression (MTR), and analogous therapies markedly enhance prehospital return of spontaneous circulation (ROSC), survival to discharge, and neurological recovery in out-of-hospital cardiac

arrest (OHCA) patients. The operational environment is significant, and the ideal EMS team design has yet to be determined. The proficiency level and the EMT-to-paramedic ratio are other contributing factors. A greater number of paramedics, equipped with an expanded arsenal of medications and expertise, may have a more significant impact than the enhanced hands-on-chest time provided by teams with fewer EMS personnel. In practical terms, HP CPR and the MTR may demand more resources than a single-tiered response system and might be challenging to sustain as EMS use escalates. Therefore, it is essential to promptly triage and detect OHCA instances. Subsequent research should additionally assess and regulate community, patient, and hospital attributes. A randomized, controlled study design might provide more insight into the subject as well.

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دور المسعفين في إدارة السكتة القلبية خارج المستشفى: الابتكارات في تقنيات الإنعاش القلبي الرئوي والتعطيل

الملخص

الخلفية :تظل السكتات القلبية خارج المستشفى (OHCAs) تحديًا كبيرًا لخدمات الطوارئ الطبية(EMS) ، حيث تتراوح معدلات البقاء على قيد الحياة عالميًا بين 5% و10%. على الرغم من التقدم في التدريب والتكنولوجيا، فإن هذه المعدلات تسلط الضوء على الحاجة الملحة لتحسين التدخلات قبل الوصول إلى المستشفى. تقوم هذه المراجعة المنهجية بتقييم تأثير الإنعاش القلبي الرئوي عالي الأداء (HP CPR) واستراتيجيات الاستجابة متعددة المستويات (MTR) على نتائج حالات السكتة القلبية خارج المستشفى.

الطرق :تم إجراء بحث شامل في الأدبيات عبر قواعد بيانات متعددة، مما أسفر عن 208 منشورات ذات صلة من عام 2000 إلى 2023. تكشف التحليلات أنHP CPR ، الذي يركز على ديناميات الفريق والأدوار المحددة، يرتبط بتحسين معدل العودة للدورة الدموية الذاتية (ROSC) والبقاء حتى الخروج من المستشفى.

النتائج :تشير النتائج الرئيسية إلى أن التعطيل المبكر يعزز النتائج بشكل كبير، خاصة عندما يتم تسهيله بواسطة أنظمة .MTR من اللافت أن نسبة فنيي الطوارئ الطبية (EMT) إلى المسعفين تلعب دورًا حاسمًا؛ فالتورط العالي للمسعفين يرتبط بمعدلات بقاء أفضل. على الجانب الآخر، أثبت الاعتماد على الأجهزة الميكانيكية للإنعاش القلبي الرئوي فوائد محدودة، مما يشير إلى ضرورة التحول نحو تقليل الانقطاعات في الضغطات اليدوية على الصدر.

الاستنتاجات :تؤكد النتائج على ضرورة وضع بروتوكولات مخصصة لخدمات الطوارئ الطبية التي تعطي الأولوية لمهارات الفريق وتخصيص الموارد. تبرز هذه المراجعة إمكانيات HP CPR واستراتيجيات MTR في تحسين نتائج المرضى في حالات السكتة القلبية خارج المستشفى، وتدعو إلى مزيد من الأبحاث لتوحيد أفضل الممارسات في إدارة السكتة القلبية قبل الوصول إلى المستشفى.

الكلمات المفتاحية :السكتة القلبية خارج المستشفى، الإنعاش القلبي الرئوي عالي الأداء، خدمات الطوارئ الطبية، تقنيات التعطيل، معدلات البقاء على قيد الحياة.