Optimization of the Prehospital Chain of Survival for Cardiac Arrest: Progress from High-Quality Cardiopulmonary Resuscitation to Early Defibrillation

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Abstract: Out-of-hospital cardiac arrest remains a major cause of sudden death, and survival largely depends on the effectiveness of the prehospital chain of survival. This review aims to summarize current progress in optimizing early recognition, bystander cardiopulmonary resuscitation, high-quality chest compressions, automated external defibrillator access, and coordinated emergency response. Evidence from recent guidelines, registry studies, systematic reviews, and implementation research was analyzed to identify key strategies that shorten treatment delay and improve early resuscitation quality. The results show that survival improvement depends not on a single intervention, but on the integration of rapid arrest recognition, dispatcher-assisted guidance, immediate CPR, timely defibrillation, public-access AED systems, trained citizen responders, digital dispatch tools, and emerging AED delivery models. In conclusion, optimizing the prehospital response system through coordinated, time-sensitive, and community-supported strategies is essential for improving outcomes after out-of-hospital cardiac arrest.

***Keywords*:** out-of-hospital cardiac arrest, cardiopulmonary resuscitation, automated external defibrillator, early defibrillation, prehospital emergency care

1. Introduction

OHCA is one of the most time-critical emergencies in medicine. Survival remains highly variable despite advances in resuscitation science and EMS organization [1,2]. After arrest, interrupted blood flow rapidly causes cerebral ischemia and myocardial injury, so treatment must begin immediately [3,4]. Modern resuscitation is therefore a linked pathway of recognition, emergency activation, CPR, defibrillation, and transfer to advanced care [5].

2. Epidemiology of Out-of-Hospital Cardiac Arrest

Registry data continue to show marked international variation in OHCA incidence and outcomes [6]. Survival gains remain uneven even where care systems improve [7]. Initial rhythm strongly predicts prognosis, and shockable rhythms have better outcomes when treated early [3,4]. Early CPR by first responders and population-level support for bystander CPR are associated with improved survival [8,9]. OHCA is therefore both a clinical emergency and a systems problem.

3. The Prehospital Chain of Survival

The chain of survival depends on speed and coordination. Recognition is often delayed by agonal breathing, panic, or uncertainty. Dispatcher-assisted pathways are therefore essential. Recent studies show that dispatcher-assisted CPR shortens time to first compressions, while better telephone instructions and telecommunicator recognition remain key targets for system improvement [10,11,12].

4. High-Quality Cardiopulmonary Resuscitation

Once arrest is recognized, high-quality CPR is the main bridge before rhythm control. Guidelines emphasize adequate compression depth and rate, full recoil, minimal interruptions, and high compression fraction [3,4]. Interruptions reduce coronary perfusion pressure and may lower the chance of successful defibrillation. Feedback devices may improve performance, but their benefit depends on integration with training and quality improvement rather than technology alone

[13].

5. Early Defibrillation and AED Deployment

For ventricular fibrillation or pulseless ventricular tachycardia, early defibrillation remains the intervention most directly linked to rhythm conversion and survival [2,3]. Public-access defibrillation depends not only on AED availability but also on whether devices can be found and delivered in time. Dispatcher-supported AED retrieval is increasingly important [14]. Dispatching trained citizens and smartphone-activated volunteers can strengthen early response and increase bystander defibrillation [15,16]. Updated reviews also support organized public first-responder networks as part of AED strategy [17].

6. Integrated Optimization Strategies of the Prehospital Chain of Survival

Recent work has focused on shortening the interval between collapse and AED arrival. Drone-delivered AEDs reached suspected OHCA scenes faster than ambulances in selected Swedish settings [18]. Community-based interventions likewise support coordinated public response [19]. Machine learning may improve dispatcher recognition of OHCA [20], and combining first-responder activation with drone delivery may increase the chance of very early AED deployment [21]. Interest in drone-based AED systems remains strong, although implementation barriers persist [22]. Current AHA guidance emphasizes integration across recognition, dispatch, CPR, defibrillation, and organized response rather than isolated technical advances [23].

7. Conclusion and Future Perspectives

Improving OHCA survival requires a coordinated prehospital system in which each early step strengthens the next. Recognition must be rapid, dispatcher guidance actionable, CPR early and effective, and defibrillation delivered with minimal delay [5,23]. Public AED programs, volunteer responder systems, digital dispatch tools, and drone-supported delivery are valuable when they shorten real-world treatment delay.

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