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Prehospital Cardiac Arrest Management: A Narrative Review

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Abstract

Out-of-hospital cardiac arrest (OHCA) is a global health issue with high mortality and morbidity. Prehospital management is crucial for improving survival and neurological outcomes. This narrative review examines the epidemiology, global burden, survival rates, and the importance of early prehospital interventions in OHCA. The incidence of EMS-treated OHCA ranges from 30 to 97 per 100,000 population annually, with survival to hospital discharge rates between 8.6% and 9.9%. Age is a significant factor, with the median age of OHCA cases between 65 and 70 years. Survival rates vary widely by region, partly due to differences in EMS systems, bystander CPR rates, and AED availability. Early, effective prehospital interventions, such as high-quality CPR, rapid defibrillation, and appropriate airway management, significantly influence outcomes. The chain of survival concept guides prehospital care, emphasizing early recognition, high-quality CPR, rapid defibrillation, advanced care, and post-resuscitation management. Challenges in prehospital settings include limited resources, environmental factors, and decision-making complexity. Emerging technologies, such as mechanical CPR devices, extracorporeal CPR, and point-of-care ultrasound, show promise in enhancing care. International guidelines from the American Heart Association, European Resuscitation Council, and Asian perspectives provide evidence-based recommendations for prehospital management. However, regional variability in EMS systems and barriers in low-resource settings highlight the need for context-specific strategies. Future directions include optimizing paramedic education, refining termination of resuscitation protocols, and integrating innovative technologies to improve OHCA outcomes globally.

Keywords: Prehospital Cardiac Arrest, paramedicine.

Introduction

Out-of-hospital cardiac arrest (OHCA) is a significant global public health concern characterized by the sudden cessation of cardiac mechanical activity and loss of systemic circulation occurring outside the hospital setting. It represents one of the leading causes of mortality worldwide, with emergency medical service (EMS)-treated OHCA incidence estimates ranging from 30 to 97.1 per 100,000 population, and survival to hospital discharge rates generally between 8.6% and 9.9% (Ho et al., 2022).

The burden of OHCA extends beyond immediate mortality, encompassing long-term survival challenges and substantial disease burden reflected in disability-adjusted life years (DALYs), signifying years of healthy life lost either due to premature death or years lived with disability. This highlights the importance of optimizing not only acute resuscitative efforts but also early interventions that impact long-term quality of life.

Due to its sudden nature and need for rapid response, prehospital management forms the critical link in the chain of survival. Early, effective prehospital interventions such as timely cardiopulmonary resuscitation (CPR), defibrillation, airway management, and appropriate EMS protocols significantly influence survival outcomes and neurological recovery (Girotra et al., 2016).

The aim of this narrative review is to provide a comprehensive overview of the epidemiology and global burden of OHCA, describe survival rates and the disparities observed across different regions, underscore the importance of early prehospital interventions, and discuss evolving strategies and technologies in prehospital cardiac arrest care.

Epidemiology and Global Burden of OHCA

The global incidence of EMS-treated OHCA ranges widely, with reports suggesting between 30 to 97 per 100,000 population annually, and with substantial regional variability influenced by demographic, socioeconomic, and healthcare system factors. For example, in Singapore, an age-adjusted incidence of approximately 50 per 100,000 person-years has been reported (Zheng et al., 2023).

Age plays a significant role, with the median age of OHCA cases typically between 65 and 70 years. The aging global population predicts an increasing incidence rate of OHCA cases in the coming decades, thereby amplifying the demand on emergency and prehospital care systems (Chen et al., 2025).

The disease burden from OHCA extends beyond mortality, with considerable societal and healthcare costs from survivors who may suffer neurological impairment and other disabilities. DALYs associated with OHCA in the US, for instance, are estimated at 4,354,192 annually.

Survival Rates and Outcome Disparities Across Regions

Survival rates from OHCA remain low globally but vary widely by region and population. Overall survival to hospital discharge ranges around 8–20%, with variability partly explained by differences in EMS systems, public awareness, bystander CPR rates, and access to automated external defibrillators (AEDs) (Dwivedi et al., 2025a).

For example, U.S. county-level survival ranges from as low as 3.4% to as high as 22%, with functional recovery rates (good neurological outcome) also varying significantly. Much of this variation is attributed to differences in bystander CPR rates and AED availability rather than patient demographics alone, highlighting the potential impact of public health interventions targeting early response.

Regional studies show that EMS providers' performance, availability of advanced resuscitation techniques, and variability in termination of resuscitation protocols further contribute to outcome disparities.

Importance of Early, Effective Prehospital Interventions

Early prehospital interventions remain the cornerstone in improving OHCA outcomes. Immediate bystander CPR and rapid defibrillation for shockable rhythms are critical to restoring circulation and reducing brain injury. Increasing public education and AED accessibility significantly improve survival levels, as bystander CPR rates strongly correlate with survival variability across communities (Cheng et al., 2021).

Airway management remains a debated topic; basic airway management may be associated with better outcomes than advanced airway techniques in adults, although pediatric populations may benefit from early advanced airway management due to the frequent respiratory etiology of arrest in children.

Emerging prehospital technologies such as mechanical chest compression devices (MCCDs) and extracorporeal membrane oxygenation (ECMO)-facilitated resuscitation are showing promise but require further protocol standardization and training to optimize their utility and minimize interruptions in CPR (Li et al., 2023a).

Research consistently supports administering prolonged on-scene resuscitation efforts rather than premature transport, with protocols evolving to guide EMS decisions on termination of resuscitation, particularly advocating for the presence of shockable rhythms, witnessed arrest, and return of spontaneous circulation (ROSC) before transport is attempted.

Pathophysiology and Determinants of Cardiac Arrest

Sudden cardiac arrest primarily results from electrical disturbances in the heart, leading to the failure of coordinated myocardial contractions responsible for pumping blood. The most frequent arrhythmias seen in sudden cardiac arrest are ventricular fibrillation (VF) and pulseless ventricular tachycardia (VT), which disrupt effective ventricular output and result in hemodynamic collapse. Less common arrhythmias include pulseless electrical activity (PEA), bradyarrhythmias, and asystole (Patel & Hipskind, 2023).

At the cellular level, ischemia from halted circulation leads to rapid depletion of adenosine triphosphate (ATP), causing ion pump failure with subsequent ionic imbalances (potassium efflux, sodium and calcium influx). Elevated intracellular calcium leads to mitochondrial dysfunction, increased free radical production, and activation of destructive enzymes, precipitating cell damage and apoptosis. Brain edema follows due to cytotoxic injury and increased intracranial pressure, contributing to poor neurological outcomes after resuscitation.

Inflammatory mediators released during ischemia-reperfusion injury also exacerbate cellular damage and microvascular thrombosis, further impairing post-arrest organ perfusion.

Common Causes of Cardiac Arrest

Cardiac Causes

- **Ischemic Heart Disease:** Coronary artery disease is the predominant cause, accounting for approximately 70% of cardiac arrests. Acute coronary occlusion triggers fatal arrhythmias.
- **Structural Heart Disease:** Cardiomyopathies (hypertrophic, dilated), valvular diseases, congenital anomalies, and cardiac tamponade can precipitate arrest.
- **Inherited Arrhythmia Syndromes:** Conditions such as Brugada syndrome, Long QT syndrome, and Wolff-Parkinson-White syndrome may cause fatal arrhythmias.
- **Heart Failure and Left Ventricular Hypertrophy:** Contribute to electrical instability.

Respiratory Causes

- Primary respiratory arrests due to airway obstruction, severe asthma, pneumonia, or pulmonary embolism often progress to cardiac arrest if uncorrected.

Traumatic Causes

- Trauma-induced cardiac arrest (TCA) differs in etiology, often related to hypovolemia from hemorrhage, tension pneumothorax, cardiac tamponade, or direct myocardial injury.

Toxicological Causes

- Overdoses of cardiotoxic drugs (e.g., beta-blockers, calcium channel blockers), poisoning, or electrolyte disturbances such as hyperkalemia are important reversible causes.

Factors Influencing Survival in Prehospital Cardiac Arrest

Time to Recognition and Intervention

Early identification of cardiac arrest and prompt initiation of cardiopulmonary resuscitation (CPR) dramatically improve survival chances. The highest survival rates occur with witnessed arrest and immediate bystander CPR. Time intervals of less than 10 minutes from collapse to advanced life support arrival associate with better outcomes (Ke et al., 2024).

Comorbidities

Preexisting conditions such as heart failure, diabetes, and chronic respiratory diseases negatively impact survival as they reduce physiological reserves and complicate resuscitation.

Patient Demographics

Age and sex influence outcomes; younger patients generally have better survival rates. Males have higher incidence but survival is modulated by overall health status and arrest circumstances (Tateishi et al., 2023).

Arrest Characteristics

- **Initial Rhythm:** Shockable rhythms (VF or pulseless VT) are associated with higher survival rates compared to asystole or PEA.
- **Bystander CPR and AED Use:** Early defibrillation using automated external defibrillators (AEDs) and continuous high-quality CPR optimize neurological outcomes.

Chain of Survival in Prehospital Settings

The concept of the Chain of Survival is a critical framework designed to improve outcomes in out-of-hospital cardiac arrest (OHCA). This model outlines a sequence of lifesaving actions that, when executed promptly and effectively, significantly increase the likelihood of survival and favorable neurological outcomes. The adult out-of-hospital Chain of Survival is traditionally composed of six interconnected links: early recognition of cardiac arrest and activation of the emergency response system, early high-quality bystander cardiopulmonary resuscitation (CPR), rapid defibrillation, advanced resuscitation provided by emergency medical services (EMS), post-cardiac arrest care, and recovery including rehabilitation and psychological support (Graham et al., 2015a).

In prehospital settings, each link plays a specific and essential role in reducing the time to reperfusion and limiting ischemic injury. The strength of the chain depends on the seamless integration and performance of these links, with any weak or delayed step compromising patient outcomes.

Concept and Evolution of the Chain of Survival

The Chain of Survival has evolved over decades as a concept that initially focused on early recognition, CPR, and defibrillation, with subsequent emphasis on advanced care and post-resuscitation treatment. Its metaphorical structure highlights the dependence of each step on the previous, emphasizing that survival chances decrease with any delay or failure in the sequence. Over time, the concept expanded to include the entire continuum from bystander actions to hospital care and recovery.

Initially, the chain included four major steps, but now six links encompass comprehensive care—recognition and activation of EMS, early CPR, rapid defibrillation, advanced EMS care, hospital care, and

rehabilitation. This evolution reflects advances in resuscitation science and technology, as well as system-level improvements in emergency response coordination (Thannhauser et al., 2022).

Early Recognition and Activation of EMS

The first crucial link in the chain is the rapid recognition of cardiac arrest and immediate activation of emergency medical services. Prompt identification requires recognizing signs such as unresponsiveness and absence of normal breathing, including agonal gasps. Lay rescuers are advised to call EMS immediately upon suspecting cardiac arrest without delay for pulse checks, which are difficult and delay CPR initiation.

Dispatcher-assisted CPR instructions further help bystanders promptly recognize cardiac arrest and start CPR while EMS is en route, shortening the call-to-CPR interval. Early activation reduces the time to advanced interventions and defibrillation, which are vital for survival.

Importance of High-Quality Bystander CPR

Bystander CPR is among the most impactful interventions for OHCA survival. High-quality chest compressions—deep, fast (100-120 per minute), and with minimal interruptions—maintain blood flow to vital organs until professional help arrives. Studies demonstrate that bystander CPR can triple a victim's chance of survival and enhance neurological outcomes by preserving brain function (Oliveira et al., 2025).

The timing of CPR initiation is critical; commencing within minutes of collapse yields the greatest benefit. Even delayed bystander CPR up to 10 minutes after arrest significantly improves survival chances compared to no bystander intervention. Public training programs, dispatcher coaching, and promoting hands-only CPR are all strategies to increase bystander CPR rates and quality.

Early Defibrillation Before EMS Arrival

Rapid defibrillation of shockable rhythms such as ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT) is the third essential link. The probability of successful defibrillation decreases by about 7-10% with each minute of delay. Studies show survival rates are substantially higher in patients who receive defibrillation within the first few minutes after collapse.

Automated external defibrillators (AEDs) placed in public settings empower lay rescuers to deliver early shocks guided by simple audio-visual prompts. Early defibrillation by bystanders or first responders before EMS arrival significantly improves outcomes and forms a cornerstone of prehospital cardiac arrest management.

Advanced Prehospital Care and Transport Decisions

Upon EMS arrival, advanced life support (ALS) measures including advanced airway management, intravenous or intraosseous access, medication administration, and continuous cardiac monitoring are performed. Paramedics provide tailored interventions to maximize chances of return of spontaneous circulation (ROSC) and prepare patients for safe transport (Graham et al., 2015).

Transport decisions depend on multiple factors including initial cardiac rhythm, response to ALS, EMS protocols, and local resources. Guidelines often recommend resuscitation on scene until ROSC is achieved unless medically justified to transport during ongoing resuscitation. Termination of resuscitation protocols guide decisions to cease efforts when futile (Li et al., 2023b).

Communication between prehospital and hospital teams is essential for a smooth handover and to prepare for post-arrest care such as targeted temperature management and cardiac catheterization.

Prehospital Cardiac Arrest Management Strategies

The chain of survival concept guides prehospital care, comprising early recognition and emergency response activation, high-quality cardiopulmonary resuscitation (CPR), rapid defibrillation, advanced airway and pharmacologic interventions, and post-resuscitation care. EMS protocols vary, but evidence supports continued on-scene resuscitation over premature transport except in select cases (Li et al., 2023c).

Initial Recognition and Call Activation

Identifying Cardiac Arrest in the Field

Rapid identification of cardiac arrest by bystanders or dispatchers is crucial. Dispatchers play a pivotal role by recognizing OHCA over the phone, triggering timely interventions. Delays in recognition are common barriers to initiating early care.

Dispatcher-assisted CPR Instructions (Telephone CPR)

Dispatcher-assisted CPR (DACPR) significantly increases bystander CPR rates and improves outcomes. Studies show that untrained bystanders can perform effective compressions guided by dispatch instructions, though ventilation quality may be lower.

Barriers to Early Recognition in the Community

Barriers include lack of public knowledge of cardiac arrest signs, hesitancy to act due to fear or lack of confidence, and delays in calling EMS. Training and public health initiatives can overcome these obstacles.

Cardiopulmonary Resuscitation (CPR)

Bystander CPR: Training, Quality, and Public Health Initiatives

Widespread CPR training and public awareness programs have increased bystander CPR rates, linked to better survival. Training in schools and free community courses have proven effective in improving willingness and quality of bystander CPR (Tian et al., 2024).

High-Performance CPR in Prehospital Settings

High-performance CPR focuses on optimizing compression depth (5–6 cm), rate (100–120/min), minimizing interruptions, and avoiding excessive ventilation. This approach significantly improves blood flow to vital organs and survival.

Mechanical vs Manual CPR Devices in the Field

Mechanical chest compression devices (MCCDs) provide consistent compressions and may be beneficial where prolonged CPR or limited personnel exist. However, current evidence does not definitively demonstrate superiority over manual CPR regarding survival or neurological outcomes (El-Menyar et al., 2024).

Airway and Ventilation Management

Basic Airway Maneuvers by Bystanders

Bystanders are encouraged to perform chest compressions-only CPR due to challenges with ventilations. Basic maneuvers such as head-tilt-chin-lift facilitate airway patency.

Bag-Valve-Mask Ventilation by First Responders

Bag-valve-mask (BVM) ventilation is effective and commonly used by first responders. Studies indicate BVM-only ventilation is associated with improved outcomes compared to advanced airway interventions in some OHCA cases.

Advanced Airway Interventions by EMS

EMS providers perform advanced airway management via endotracheal intubation or supraglottic airway devices. These techniques secure the airway and facilitate ventilation but require skill and may cause CPR interruptions (Lupton et al., 2020).

Controversy: Advanced Airway vs BVM in OHCA Outcomes

Research shows mixed results; some studies favor BVM ventilation for better survival and neurologic outcomes possibly due to fewer interruptions, while others support advanced airways in select cases. The optimal approach may depend on provider experience and circumstances.

Defibrillation in Prehospital Care

Public Access AED Programs

Automated external defibrillators (AEDs) in public places enable early defibrillation and markedly improve survival rates. Public access defibrillator (PAD) programs integrate AED deployment, training, and maintenance to maximize impact.

Early Defibrillation and Survival

Survival decreases by 7–10% with every minute of delayed defibrillation. Early defibrillation (within 3–5 minutes) can increase survival to 49–75%. Strategic AED placement and bystander use are critical.

Paramedic Role in Manual Defibrillation and Rhythm Analysis

Paramedics perform manual defibrillation and cardiac rhythm assessment to guide resuscitation efforts. Proper timing and minimizing delays during defibrillation are essential to maximize efficacy.

Double-Sequential Defibrillation for Refractory VF

Double-sequential defibrillation (DSD) involves delivering two rapid defibrillations for refractory ventricular fibrillation but remains controversial with limited evidence supporting routine use.

Pharmacological Interventions

Epinephrine Use in Prehospital Cardiac Arrest

Epinephrine administration is a standard advanced life support measure. While it improves return of spontaneous circulation (ROSC) rates, evidence on its impact on long-term survival and neurological outcomes is mixed, with some studies showing no benefit or potential harm especially in traumatic cardiac arrest (Witt et al., 2025).

Amiodarone, Lidocaine, and Other Antiarrhythmics

Amiodarone and lidocaine are used for refractory ventricular arrhythmias during resuscitation and may improve ROSC but have limited evidence for improved survival to discharge (Li et al., 2023).

Vasopressin and Alternative Agents

Vasopressin was historically included in resuscitation guidelines but has largely been replaced by epinephrine based on current recommendations. Ongoing research continues to explore novel agents.

Real-world Controversies and Evidence Gaps

There is ongoing debate regarding optimal timing, dosing, and choice of drugs during cardiac arrest. More high-quality randomized trials are needed for definitive guidance.

Point-of-Care and Adjunctive Technologies

Prehospital ECMO (Extracorporeal CPR)

Extracorporeal membrane oxygenation (ECMO) during cardiac arrest, termed ECPR, is emerging as a rescue strategy for select patients refractory to conventional CPR but remains rare, resource-intensive, and requires specialized protocols.

Capnography as a Tool for Monitoring CPR Effectiveness

End-tidal carbon dioxide (ETCO2) monitoring provides real-time feedback on CPR quality and ROSC likelihood. It helps guide ventilation and compression quality during resuscitation.

Ultrasound in Prehospital Cardiac Arrest Management

Paramedic-led focused ultrasound is increasingly feasible and aids in identifying reversible causes of arrest such as pericardial tamponade or pneumothorax, albeit requiring training and protocol development.

Decision-Making in Prehospital Cardiac Arrest

Effective decision-making in the prehospital setting involves rapid assessment, initiation of cardiopulmonary resuscitation (CPR), airway management, defibrillation, and appropriate transport or termination decisions. EMS providers often face challenges balancing ongoing resuscitation efforts with timely transport to definitive care.

Prehospital advanced airway management techniques, such as endotracheal intubation (ETI) and supraglottic airway (SGA) devices, have been studied extensively. While ETI is associated with improved return of spontaneous circulation (ROSC) and survival compared to SGA and basic airway management in adults, confounding factors such as shockable rhythms and witnessed arrests affect interpretation. Decision-making protocols that integrate patient factors and response to therapy help optimize outcomes.

A 2025 narrative review emphasized basic life support (BLS), rapid EMS activation, high-quality CPR, and defibrillation as cornerstones of prehospital decision-making impacting survival (Fatimah et al., 2025).

Termination of Resuscitation (TOR) Rules and Ethical Considerations

TOR protocols provide guidance on when to cease resuscitative efforts in the field to avoid futile care and optimize resource use, while addressing ethical concerns around patient dignity and family support.

Common TOR criteria include unwitnessed arrest by EMS personnel, absence of shockable rhythm, and no ROSC despite advanced cardiac life support (ACLS). Modified TOR rules, such as the Goto's TOR rule, also consider CPR duration (e.g., >20 minutes). EMS providers may experience conflict in terminating resuscitation, emphasizing the need for clear protocols supported by medical direction to ensure ethical and evidence-based decisions.

In traumatic cardiac arrest, termination decisions incorporate additional factors, including injury type and presence of reversible causes detected by ultrasound. The European Resuscitation Council (ERC) recommends withholding resuscitation if no signs of life are observed within 15 minutes and trauma is incompatible with survival (Weegenaar et al., 2024).

Transport Versus Scene Resuscitation: Evidence and Guidelines

Deciding between continuing resuscitation on scene or rapid transport to hospital influences survival outcomes. Recent evidence supports prioritizing high-quality on-scene resuscitation over early transport during active CPR, as transport may disrupt resuscitative efforts and reduce survival rates.

Adjusting on-scene CPR duration based on expected transport time has been proposed to optimize outcomes, with longer CPR durations favored when transport times are prolonged. Guidelines advocate for flexible EMS protocols incorporating transport times into resuscitation and transport decisions, supported by evidence demonstrating improved survival with continued on-scene CPR (Kim et al., 2025).

Pediatric Cardiac Arrest Considerations

Pediatric OHCA differs significantly from adults in epidemiology, etiology, and outcomes. Pediatric arrests are often asphyxial rather than cardiac in origin, with initial rhythms commonly non-shockable (e.g., asystole). Mortality in pediatric prehospital arrest is high, with neurological causes constituting the majority of deaths.

Bystander CPR rates in pediatric patients remain suboptimal despite simplified resuscitation algorithms designed to lower the threshold for intervention. Recent studies in the Asia-Pacific region indicate that advanced airway management in pediatric OHCA was associated with decreased survival and unfavorable neurological outcomes compared to basic airway management , highlighting the need for tailored pediatric protocols considering airway strategy (Tham et al., 2022).

Traumatic Versus Non-Traumatic Cardiac Arrest Protocols

Traumatic cardiac arrest (TCA) carries a distinct pathophysiology, often involving hemorrhage, tension pneumothorax, cardiac tamponade, or airway obstruction. Traditional views considered TCA resuscitation futile; however, recent paradigm shifts recognize potential for survival, especially in blunt trauma and certain penetrating injuries.

Prehospital protocols emphasize rapid identification and correction of reversible causes using focused ultrasound and clinical assessment. Pulseless electrical activity (PEA) predominates in TCA and is generally a poor prognostic sign unless reversible factors are addressed. ALS interventions such as intravenous fluids and airway management are applied cautiously, as some studies indicate supraglottic airway devices or intubation may be associated with decreased survival compared to bag-mask ventilation in TCA.

Outcomes and Prognostic Factors in Prehospital Cardiac Arrest Management

Prehospital cardiac arrest (CA), often termed out-of-hospital cardiac arrest (OHCA), remains a significant global health challenge with considerable mortality and morbidity. The management of cardiac arrest in the prehospital setting critically influences survival outcomes, neurological recovery, and long-term quality of life. Understanding outcomes and prognostic factors is essential for optimizing care strategies and resource allocation.

Survival to Hospital Discharge

Survival to hospital discharge is a key endpoint for assessing the effectiveness of prehospital cardiac arrest management. Recent large cohort studies report survival rates varying widely based on several factors, including initial rhythm, quality of bystander CPR, timely advanced life support, and system-level interventions. Survival rates to hospital discharge after OHCA currently range between 6% and 34% in different populations, with an observed 22.6% overall survival in a large registry study, and approximately 11.9% survival reported from advanced prehospital critical care settings in the UK (Dwivedi et al., 2025b).

Return of spontaneous circulation (ROSC) before hospital arrival strongly correlates with survival. For example, a Danish helicopter emergency medical service study reported a 23% prehospital ROSC rate with a 4% 30-day survival in traumatic cardiac arrest cases, highlighting the challenge of these injuries but underscoring the value of early advanced interventions like endotracheal intubation and shockable rhythms.

Additional factors positively associated with survival include the initial presence of a shockable rhythm, witnessed arrest, and early defibrillation. Conversely, prolonged resuscitation duration correlates inversely with survival, with probabilities dropping below 1% after approximately 30-40 minutes of resuscitation efforts (Kreutz et al., 2024).

Neurological Outcomes and Long-Term Quality of Life

Survival alone is insufficient without considering neurological outcomes and the quality of life of survivors. Favorable neurological outcomes are often assessed using scales like the Cerebral Performance Category (CPC). Studies indicate that while a substantial fraction of survivors achieve good or moderate neurological recovery, rates vary widely from 4% to approximately 57%, depending on study populations and definitions.

Long-term follow-ups demonstrate sustained neurological function and quality of life in a meaningful subset of patients, especially those with initial shockable rhythms and early ROSC. Improvements in prehospital care protocols, damage control resuscitation, and post-resuscitation care have contributed to these neurological outcome improvements. However, severe neurological disability or vegetative states persist as common adverse sequelae among survivors without early ROSC.

Additional prognostic models incorporate prehospital variables, such as no-flow and low-flow intervals and biochemical markers, to estimate the likelihood of favorable neurological outcomes, which help guide clinical decision-making and family counseling.

Predictors of Favorable Versus Poor Prognosis

Numerous clinical, demographic, and operational factors serve as predictors of outcome following prehospital cardiac arrest:

- **Favorable Prognostic Predictors:**
    - Initial shockable rhythm (ventricular fibrillation or pulseless ventricular tachycardia)
    - Early bystander CPR and witnessed arrest
    - Short no-flow time (time without circulation)
    - Rapid defibrillation and advanced airway management
    - Younger age and absence of comorbidities
    - Presence of ROSC at the scene or during transport
- **Poor Prognostic Predictors:**
    - Non-shockable initial rhythms (asystole or pulseless electrical activity)
    - Longer duration of resuscitation without ROSC
    - Advanced age (>70 years)
    - Absence of bystander CPR
    - Comorbid conditions such as diabetes, hypertension, and peripheral artery disease
    - Presence of traumatic cardiac arrest, particularly with penetrating injuries

A predictive score derived from out-of-hospital cardiac arrest patients includes variables such as age, initial rhythm, aspiration, pupil response, gasping/apnea, and whether bystander CPR was performed. This score

demonstrated high specificity and predictive value for poor prognosis, supporting its clinical utility in prehospital assessment.

Regional Outcome Variations (Urban vs Rural Influence)

Outcomes after prehospital cardiac arrest demonstrate significant variation depending on geographic location, highlighting disparities in emergency response systems and social determinants of health.

- **Urban vs Rural Differences:**
    - Urban areas generally report higher survival rates and better neurological outcomes compared to rural areas.
    - Patients experiencing OHCA in rural regions have lower odds of ROSC on ED arrival and reduced survival to discharge, linked to factors like delayed EMS response, longer transport times, and limited access to advanced interventions.
- **Socioeconomic and Neighborhood Deprivation Effects:**
    - Urban areas with high socioeconomic deprivation have lower survival rates and less favorable discharge destinations, reflecting compounded challenges in healthcare access and quality.
    - Such disparities indicate that improvements in clinical care alone may not fully eliminate geographic inequalities in outcomes, and broader public health and policy interventions are necessary.

Role of Paramedics in Cardiac Arrest Management

Paramedics play a critical frontline role in rapidly recognizing cardiac arrest, providing high-quality CPR, managing airways, delivering defibrillation, and administering medications aimed at resuscitation and stabilization. Their interventions in the field directly influence the likelihood of return of spontaneous circulation (ROSC) and survival to hospital discharge with favorable neurological outcomes.

- **Recognition and Initial Response:** Early identification of cardiac arrest signs and initiation of CPR is paramount. Paramedics are trained to assess unresponsiveness, absence of normal breathing, and pulse assessment to confirm cardiac arrest and activate the emergency response system promptly.
- **High-Quality CPR:** Chest compressions with adequate rate (100-120 compressions per minute) and depth (at least 5 cm in adults) with minimal interruptions are essential. Paramedics deliver CPR while preparing for defibrillation and airway management.
- **Airway Management:** Paramedics utilize airway adjuncts such as oropharyngeal or nasopharyngeal airways, bag-valve-mask ventilation (BVM), and when skilled, advanced airway devices like tracheal intubation or supraglottic devices to ensure effective ventilation during resuscitation.
- **Defibrillation:** Rapid defibrillation for shockable rhythms (ventricular fibrillation or pulseless ventricular tachycardia) by paramedics significantly increases survival chances. Use of automated external defibrillators (AEDs) or manual defibrillators is a core part of paramedic resuscitative care.
- **Medications:** Paramedics administer medications according to protocols, with epinephrine being critical for improving outcomes in cardiac arrest, especially in non-shockable rhythms. Advanced interventions may include antiarrhythmics and other drugs.

Paramedic-Led Advanced Life Support (ALS) Interventions

Paramedics trained in ALS provide interventions beyond basic life support (BLS), including advanced airway management, intravenous access, administration of vasoactive drugs, and coordinated resuscitation efforts guided by established protocols and evolving evidence-based guidelines.

- ALS-trained paramedics play a vital role in prehospital thrombolysis for acute myocardial infarction when indicated, reducing reperfusion delays and potentially improving survival and morbidity.
- Evidence supports structured ALS interventions by paramedics including judicious airway management, timely administration of epinephrine, and adherence to defibrillation timing recommendations to optimize ROSC and survival.
- Continuous education and skill maintenance in advanced procedures and algorithm updates are essential for paramedic efficacy in ALS.

Skills, Training, and Guideline Adherence

The effectiveness of paramedic interventions depends heavily on comprehensive training, competence in technical skills, and adherence to international and national resuscitation guidelines such as those from the American Heart Association (AHA) and European Resuscitation Council (ERC).

- Training programs emphasize high-quality CPR, airway management, defibrillation techniques, pharmacology, and scenario-based simulation to prepare paramedics for diverse cardiac arrest scenarios.
- Consistent guideline adherence has been associated with improved outcomes in prehospital cardiac arrest, underscoring the importance of ongoing professional development and audit.
- Skill decay and challenges in field conditions necessitate continuous refresher training and performance feedback mechanisms.

Challenges in Prehospital Cardiac Arrest Scenarios

Paramedics face multifaceted challenges that complicate cardiac arrest management in the often unpredictable and resource-limited prehospital environment.

- **Limited Resources:** Compared to hospital settings, paramedics work with limited equipment, medications, and personnel, which may hamper optimal resuscitation.
- **Environmental Factors:** Adverse weather, confined or unsafe scenes, poor lighting, and difficult patient access affect intervention quality and timeliness.
- **Bystander Variability:** Paramedics rely on bystanders for early recognition and CPR initiation, but bystander awareness and willingness vary widely, impacting survival.
- **Decision-making Complexity:** EMS clinicians must make rapid critical decisions sometimes with limited information, including when to initiate or terminate resuscitation efforts.

Innovations in Paramedic Practice

Recent advancements and innovations aim to enhance paramedic effectiveness and overall cardiac arrest survival through community engagement, integration with specialized response teams, and deployment of emerging technologies.

- **Community Paramedicine and Cardiac Arrest Awareness:** Community paramedicine programs promote public education, CPR training, and early intervention strategies. Paramedics also serve as community health advocates increasing awareness and readiness for cardiac emergencies.
- **Integration with Rapid Response and Helicopter EMS:** Coordinated response involving ground paramedics, rapid response vehicles, and aeromedical teams improve rapid access to advanced care in rural or difficult terrains.
- **Decision-Support Technology and AI:** Artificial intelligence tools are increasingly researched to assist paramedics in early recognition of cardiac arrest, predicting outcomes, optimizing CPR quality, and guiding real-time resuscitation decisions. AI applications at the dispatch level and in the field may enhance accuracy and efficiency of emergency care.

Integration of EMS with Hospitals and Cardiac Arrest Centers

Effective management of cardiac arrest in the prehospital setting relies on a highly coordinated system of care that spans from community response to in-hospital treatment. Integration of Emergency Medical Services (EMS) with specialized hospitals and cardiac arrest centers ("centers of excellence") is critical to improve patient outcomes after out-of-hospital cardiac arrest (OHCA). This system integration ensures a seamless transition of care from the field to advanced hospital interventions including targeted temperature management, early coronary angiography, and multidisciplinary critical care. Cardiac arrest centers provide standardized post-resuscitation protocols, continuous quality monitoring, and dedicated multidisciplinary teams, factors shown to increase survival with good neurological function.

Hospitals designated as cardiac arrest centers typically feature a cardiac intensive care unit, availability of 24/7 interventional cardiology, neurology, pulmonary, and critical care specialists. Regionalized care models promote directing patients to these centers, which consolidates expertise and resources to optimize post-resuscitation management, similar to models successful in trauma and stroke care.

Dispatcher Training and Community Education Programs

Dispatchers serve as vital first responders by identifying cardiac arrest cases promptly through emergency calls and providing immediate telephone CPR (t-CPR) instructions to bystanders. Specialized training programs for dispatchers have significantly improved the rate and quality of bystander CPR. Studies demonstrate that dispatcher training enhances the ability to recognize cardiac arrest via telephonic cues such as agonal breathing and greatly increases bystander initiation of chest compressions, which correlates with improved neurologically intact survival.

Community education integrates with dispatcher efforts by increasing public CPR knowledge and willingness to act. Programs employing simulation-based and scenario-focused training help overcome barriers like fear or lack of confidence. Dispatcher-assisted CPR programs, like Singapore’s DARE, condense training to one hour and emphasize calling emergency numbers, delivering hands-only CPR, and using Automated External Defibrillators (AEDs).

Public Awareness Campaigns: Hands-Only CPR and AED Access

Public awareness campaigns play a pivotal role in enhancing survival from cardiac arrest by promoting immediate actions such as hands-only CPR and rapid AED application before EMS arrival. Hands-only CPR involves continuous chest compressions without mouth-to-mouth breaths, making it easier for bystanders to perform and increasing the likelihood of early intervention. Campaigns have documented rising public participation and training exposure, with evidence indicating that hands-only CPR can double or triple survival chances from sudden cardiac arrest.

Moreover, increasing public access to AEDs in community settings—airports, schools, shopping centers—and educating the public on their use is essential. AEDs are designed for layperson use with voice prompts guiding the rescuer, and their prompt application can double the survival rate compared to no defibrillation. Awareness campaigns also leverage technology like smartphone apps (e.g., PulsePoint) to notify trained responders nearby, effectively expanding the network of first responders.

Regionalization of Care and Specialized Centers for Post-Resuscitation Management

Regionalization refers to organizing post-cardiac arrest care within defined geographic areas to ensure patients receive treatment at facilities equipped with advanced capabilities. This approach has been demonstrated to improve survival and neurological outcomes, particularly when specialized therapies like targeted temperature management and early percutaneous coronary intervention are employed. In studies, regionalized care with bundled post-resuscitation protocols improved neurological outcomes significantly compared to non-specialized care.

The establishment of cardiac arrest centers has enabled consolidation of resources and expertise, standardized protocols, continuous quality assurance, and multidisciplinary collaboration, ultimately raising the standard of care and outcomes across regions. This model is analogous to regional systems successfully implemented for trauma and stroke.

Prehospital Cardiac Arrest Management: International Guidelines and Comparative Perspectives

Out-of-hospital cardiac arrest (OHCA) remains a critical global health challenge with significant morbidity and mortality despite advances in emergency medical care. Effective prehospital management is crucial to improve survival and neurological outcomes. This narrative review examines current international guidelines, their evidence-based recommendations, and the variability in EMS systems worldwide with a focus on the American Heart Association (AHA), European Resuscitation Council (ERC), and Asian perspectives contextualized within global prehospital resuscitation protocols.

American Heart Association (AHA) Guidelines

The American Heart Association provides comprehensive evidence-based guidelines for the management of cardiac arrest that emphasize the “chain of survival,” a series of critical actions improving outcomes: early recognition and activation of emergency response, immediate high-quality cardiopulmonary resuscitation (CPR), rapid defibrillation, advanced resuscitation, and post-cardiac arrest care.

The 2024 AHA Scientific Statement highlights key priorities including optimizing bystander CPR rates, public access to automated external defibrillators (AEDs), dispatcher-assisted CPR, and the importance of equitable access to resuscitation training and resources. High-quality CPR parameters are specified as a compression depth of at least 2 inches (5 cm) at a rate of 100-120 compressions per minute with full chest recoil and minimal interruptions. Advanced cardiac life support (ACLS) protocols in the field include continuous cardiac monitoring, rhythm analysis, airway management, administration of vasopressors like epinephrine, and addressing reversible causes summarized by the H’s and T’s mnemonic (hypovolemia, hypoxia, hydrogen ion (acidosis), hypo/hyperkalemia, hypothermia, tension pneumothorax, tamponade, toxins, thrombosis).

AHA guidelines encourage rigorous data collection and reporting on cardiac arrest incidence, treatments, and outcomes to facilitate quality improvement and research, with emphasis on improving survival with favorable neurological recovery by 2030.

European Resuscitation Council (ERC) Guidelines

The ERC 2025 guidelines continue the European tradition of evidence-based recommendations for both in-hospital and out-of-hospital cardiac arrest settings, underscoring the importance of regional EMS coordination and tailored care based on resources and setting.

Key topics addressed by the ERC include epidemiology disparities, community response systems, use of video-assisted dispatch, integration of new technologies such as drones for AED delivery, and advanced life support (ALS) techniques like anticipatory defibrillator charging and physiology-guided CPR. The ERC guidelines also focus on ethical considerations in prehospital resuscitation, specialized approaches for pediatric and newborn resuscitation, post-resuscitation care, and management of special circumstances such as drowning or sports-related cardiac arrest.

One notable feature is the emphasis on resuscitation quality metrics and education tailored for different healthcare providers to enhance competence and standardized response, with recommendations for continuous local registry establishment to guide system-level improvements.

Asian Perspectives and Context-Specific Challenges

Asian countries demonstrate considerable variability in prehospital cardiac arrest survival rates attributed to differences in EMS organization, training, dispatch, cultural attitudes, and resource allocation.

Studies from China show that advanced airway management (AAM) and combined treatments increase return of spontaneous circulation (ROSC) but usage rates of advanced airway interventions remain much lower than in developed Western countries. In Japan and Korea, observational studies indicate a controversial relationship between prehospital AAM and survival outcomes, possibly due to regional training and protocol differences.

Asian EMS face unique challenges including limited access to dispatch-assisted CPR, lower bystander CPR rates, less public AED availability, and infrastructural constraints especially in rural or low-resource areas. Varied protocols exist, with some countries emphasizing basic life support and rapid transport, while others incorporate advanced interventions depending on regional EMS capabilities.

Cultural factors also influence decisions to initiate or terminate resuscitation and public willingness to engage in life-saving measures, necessitating context-specific guideline adaptation and capacity building.

EMS System Variability and Prehospital Arrest Protocols Worldwide

Globally, EMS systems differ vastly in structure, resources, and clinical protocols affecting prehospital cardiac arrest management and outcomes.

A cross-sectional international survey of 59 countries revealed heterogeneity in resuscitation initiation, termination criteria, and use of do-not-resuscitate (DNAR) orders. While most countries initiate resuscitation if signs of irreversible death are absent, the decision to terminate resuscitation or withhold it varies by legal, cultural, and protocol frameworks. Approximately 45.8% of countries rely on provider discretion for termination decisions, indicating a lack of standardized global criteria.

Advanced airway management protocols, mechanical CPR devices, adrenaline use, and scene times also differ and influence survival. Some countries emphasize rapid transport to hospitals with minimal on-scene ALS, while others pursue extended on-scene resuscitation efforts. Protocol discrepancies reflect differences in EMS staffing levels, training, equipment availability, and health system integration.

Efforts to standardize protocols under organizations like ILCOR (International Liaison Committee on Resuscitation) drive consensus guidelines but implementation relies on local adaptation. Addressing EMS disparities by strengthening infrastructure, education, technology use, and data registries is essential to improve global cardiac arrest outcomes.

Barriers in Low-Resource and Rural Settings

Prehospital cardiac arrest management in low-resource and rural settings faces unique and significant barriers impacting patient outcomes. Rural areas often have limited healthcare infrastructure, including

fewer EMS units, longer distances to hospitals, and scarce trained medical personnel. These factors contribute to prolonged EMS response times, which significantly reduce chances of survival and favorable neurological outcomes after out-of-hospital cardiac arrest (OHCA). Despite this, some studies paradoxically show rural patients receive bystander CPR at rates comparable or sometimes higher than urban areas, suggesting community willingness is not a limiting factor but access and resources remain critical constraints.

Moreover, disparities in public health education, availability of essential emergency equipment like automated external defibrillators (AEDs), and accessibility to advanced prehospital interventions create further inequities in survival rates. These barriers are compounded by socioeconomic and demographic factors, including education level and racial disparities within communities, which influence outcomes.

Delayed EMS Response and Strategies for Improvement

Timely EMS response is critical in cardiac arrest management because survival dramatically decreases with every minute of delay before initiation of CPR and defibrillation. Average EMS response times are longer in rural and resource-limited areas due to geographic spread and fewer EMS resources. Strategies to improve EMS response include:

- **Strategic ambulance deployment:** Using predictive analytics and historical incident data to position EMS units dynamically in high-demand zones reduces travel time and improves availability.
- **Advanced GPS and routing technology:** Real-time traffic monitoring and integration with city traffic systems aid faster navigation during emergencies.
- **Cross-training first responders:** Coordinating EMS with fire and police departments to ensure rapid and efficient multi-agency response.
- **Public CPR education and apps:** Increasing bystander CPR rates through widespread CPR training and digital alert systems that notify trained civilians nearby cardiac arrests increases early intervention before EMS arrival.
- **Specialized response teams and community engagement:** Establishing dedicated cardiac arrest response teams and educating communities on emergency recognition and response.

These multifaceted approaches are essential to shorten EMS delays, especially in underserved locations.

Technological Advancements

Emerging technologies show great promise to bridge gaps in prehospital cardiac arrest care and improve survival:

- **Drones delivering AEDs:** Unmanned aerial vehicles can rapidly deliver AEDs to remote or inaccessible locations faster than traditional EMS, potentially reducing time to defibrillation. While drone networks have demonstrated time savings in trials, practical challenges remain with bystander drone/AED interaction and environmental factors.
- **Telemedicine:** Real-time remote guidance from medical experts during resuscitation allows paramedics and bystanders to optimize CPR quality and AED use.
- **Real-time CPR feedback systems:** Devices and apps that provide live feedback on compression depth, rate, and interruptions during CPR have been linked to improved chest compression quality and patient outcomes.

- **Physiology-directed CPR:** New technologies allowing non-invasive hemodynamic monitoring during CPR may enable optimization of perfusion tailored to individual physiology, though widespread prehospital use is still limited.

Technology integration into prehospital care holds the potential to enhance overall cardiac arrest survival globally.

Research Gaps

Despite advances, key research gaps persist in prehospital cardiac arrest management:

- **Pharmacology:** There remains limited high-quality evidence on the optimal medication protocols during OHCA, including vasopressors and antiarrhythmics, with a need for randomized controlled trials to establish benefits and protocols.
- **Airway management strategies:** Current evidence does not definitively support the superiority of tracheal intubation versus supraglottic airway devices during cardiac arrest in the prehospital setting. Ongoing clinical trials (such as AIRWAYS-3 and HART) aim to clarify best practices in airway management for both adult and in-hospital cardiac arrest cases.
- **Termination of Resuscitation (TOR) protocols:** There is a need for standardized, evidence-based TOR rules that can be applied reliably in the field to improve resource utilization and patient outcomes, particularly in varied geographic and resource settings.

Addressing these gaps through multi-center clinical trials and large registry analyses is crucial for evidence-based improvements.

Future of Paramedic Education and Scope of Practice

As prehospital care evolves with technological advances and expanded interventions, the education and scope of practice for paramedics must adapt correspondingly:

- **Curriculum enhancement:** Paramedicine education requires ongoing updates to prepare practitioners for complex decision-making, advanced airway management, pharmacology, and integration of new technologies in cardiac arrest care.
- **Expanded scope of practice:** Many EMS systems are revisiting and broadening paramedic roles to include advanced procedures and autonomous decision-making, under appropriate protocols and medical oversight. This can optimize treatment initiation and patient outcomes before hospital arrival.
- **Simulation and continuous training:** Modern training methods emphasizing simulation, tele-education, and scenario-based learning enhance paramedic preparedness for high-stakes resuscitations.
- **Interdisciplinary collaboration:** Increasing cross-training and interaction with other emergency responders and healthcare providers improve coordination and patient care.

Developing paramedic education and scope in tandem with evolving practice demands is a strategic imperative for future cardiac arrest management success.

Conclusion

Out-of-hospital cardiac arrest remains a major global health challenge with persistently high mortality and morbidity despite decades of research and protocol development. Survival is profoundly influenced by early recognition, high-quality bystander CPR, and rapid defibrillation—critical steps that form the backbone of

the chain of survival. Paramedics and other prehospital providers play a pivotal role in bridging community response and advanced hospital care through timely interventions, clinical judgment, and adherence to evidence-based guidelines.

While advances in airway management, pharmacology, mechanical CPR devices, and emerging technologies such as ECMO and telemedicine hold promise, gaps in research and variability in system-level implementation continue to limit uniform progress. Regional disparities, particularly in rural and low-resource settings, highlight the importance of strengthening EMS systems, public education, dispatcher-assisted CPR, and equitable access to defibrillators.

Future efforts should focus on optimizing paramedic training, refining termination of resuscitation protocols, and integrating innovative tools such as AI decision-support and drone-delivered AEDs. Equally essential is the expansion of regionalized cardiac arrest centers to ensure seamless continuity of care from the field to hospital discharge. By reinforcing the links in the chain of survival and addressing existing disparities, prehospital cardiac arrest management can significantly improve survival rates and long-term neurological outcomes worldwide.

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