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Community Approaches to Improve Resuscitation After Out-of-Hospital Sudden Cardiac Arrest

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Sudden cardiac arrest (SCA) is a major cause of mortality in North America and other westernized societies, accounting for ≈10% of all deaths and up to 50% of heart disease–related death.[1,2] The condition is characterized by an unexpected cardiovascular collapse due to an underlying cardiac cause.[3] This definition, although useful as an intellectual foundation, is challenged by operational translation. The challenge of deriving a working case definition for SCA is important because different approaches for ascertainment and classification can influence efforts aimed at estimating incidence, improving prevention strategies, or directing resuscitation care.

For example, various strategies may be used to determine incidence. Death certificates, emergency medical services (EMS) records, witness interviews, medical records, and medical examiner reports can be used singly or in combination to ascertain and classify SCA. Each approach has strengths and limitations. Death certificate ascertainment and classification, for example, are efficient and can be defined by specific objective coding criteria but often overestimate incidence because the approach includes people who do not die suddenly or do not truly die from cardiac causes.[4] Conversely, death certificates exclude people who were successfully resuscitated. Thus, the "best" strategy for SCA ascertainment and classification depends in large part on the intent of the effort and available resources.

The present clinical summary discusses approaches to improve resuscitation of out-of-hospital SCA and therefore focuses on SCA treated by EMS. From an epidemiological perspective, EMS-treated, out-of-hospital SCA constitutes a subset of all heart disease death events. As such, it excludes in-hospital events and out-of-hospital events that either do not have an emergency response or receive a response but no EMS treatment. The latter circumstance arises typically when there are signs of prolonged, irreversible death or when there is a "do not resuscitate" request and documentation.[5] Although community-specific heterogeneity exists with regard to EMS participation in SCA, investigation indicates that EMS attempts to resuscitate people with SCA in 20% of all heart disease death events, 33% of all out-of-hospital heart disease death events, and 50% of death events to which they respond.[6,7] In North America and Europe, contemporary estimates reveal an incidence of >55/100 000 person-years for EMS-treated all-rhythm SCA and 15/100 000 person-years for EMS-treated ventricular fibrillation SCA.[8,9]

Importantly, there has been a decline in SCA incidence, and in particular ventricular fibrillation SCA, in the course of the past generation in many westernized societies that mirrors the decline in overall heart disease mortality.[2,10,11] The reduction is likely multifactorial in origin and is generally attributed to improvements in primary and secondary prevention of heart disease as opposed to improvements in resuscitation outcomes.[12] Thus, any community strategy to reduce the burden of SCA should continue to place substantial emphasis on prevention.

A second paradigm of SCA prevention is early access to medical care after the onset of warning symptoms. Evidence indicates that up to three quarters of people who have SCA experience prodromal symptoms, most commonly chest discomfort or dyspnea, for a median of 60 minutes.[13] Individuals delay activating or seeking medical care for a variety of reasons that include their understanding of the symptoms and the severity of the symptoms, with a consequence that some experience SCA. Thus, initiatives that inform and empower laypeople to access the medical system when warning symptoms occur constitute another effective prevention strategy that can decrease mortality due to SCA.[14]

Despite effective efforts aimed at prevention, SCA continues to occur in substantial numbers. In many instances, the EMS system is activated, and the victim receives attempted resuscitation. On the basis of estimates, nearly 200 000 people receive attempted EMS resuscitation each year in the United States and Canada. On average, only ≈8% who receive EMS treatment are resuscitated and subsequently discharged alive from the hospital.[6] This singular average of SCA survival, however, is a poor gauge of resuscitation care for many communities because there is a remarkable variation in community-specific survival. Survival varies from 0% to 20% for all rhythm EMS-treated arrests and 0% to 45% (median 18%) for ventricular fibrillation arrest.[6,8,9]

The large numbers of treated SCA and the wide range of survival have potential implications for public health. In the United States and Canada, for example, an additional 7500 lives would be saved if average survival could be increased to 12%, the midway point between the current average and the community-best, all-rhythm survival estimates.[6] Efforts

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aimed at improving short-term survival are buoyed by investigations demonstrating meaningful and temporally improving long-term survival after hospital discharge.[15,16] Most people discharged alive from the hospital after resuscitation from SCA enjoy at least a satisfactory quality of life and experience a life expectancy that approaches age- and gender-matched adults who have not experienced SCA.[16,17] Taken together, these circumstances underscore the opportunity and the importance of improving resuscitation.

Community-Based Program of Resuscitation

The subsequent text details core clinical features of effective community-based resuscitation and discuss the challenges of implementation and ongoing improvement. A singular proscriptive approach is not practical and not likely to be successful given the heterogeneous nature of community resources; however, an appreciation of the essential tenets can assist communities as they work to improve resuscitation.

Links in the Chain of Survival

The metaphor "links in the chain of survival" was used to describe the time-sensitive health services tenets that influence the likelihood of successful SCA resuscitation.[18] These stepwise links were composed of early activation, early cardiopulmonary resuscitation (CPR), early defibrillation, and timely advanced care. Subsequently, postresuscitation care has been recognized as an additional integral link in the chain.[19]

The links in the chain of survival concept continues to serve as a useful paradigm for resuscitation care. The likelihood of resuscitation depends on each link such that often the effectiveness of subsequent links relies on the effectiveness of the preceding link or links. Given this interdependence, successful resuscitation requires a unique and challenging coordination of care that typically begins with the layperson and subsequently involves emergency medical dispatchers, first responders, EMS professionals, and multidisciplinary hospital personnel. This broad participation underscores the need for a community-based approach in which optimal resuscitation is achieved only when the spectrum of stakeholders is engaged and committed to success.

Early Access

Early activation of emergency response by bystanders through use of a common and dedicated telephone exchange (9–1-1 in the United States and Canada) is a critical link for successful resuscitation. Increasing evidence indicates that SCA progresses through a time-sensitive pathophysiology that consists of arrhythmia, consequent ischemia, and subsequent metabolic cell death, with each progressive phase more refractory to resuscitation.[20] As a result, delays to care after out-of-hospital SCA have dire consequences, making immediate medical activation imperative for optimal resuscitation. As a surrogate for early activation, a "witnessed" arrest, in which the collapse is heard or seen, occurs in approximately half of EMS-treated arrests and is strongly associated with the presence of ventricular fibrillation (versus asystole or pulseless electric activity). Survival would undoubtedly improve by increasing the proportion of arrests that are functionally witnessed, although no ready strategy or technology is available for the general population.

Early CPR

CPR consists of a combination of chest compressions/decompressions typically interspaced with ventilations. Formally described in 1960 after a series of human experiments, CPR has been the subject of thousands of research publications.[21] Despite this, our understanding of the precise mechanisms of benefit is incomplete. CPR appears to improve cardiac hemodynamics by increasing coronary artery perfusion, assisting left ventricular filling, and preventing right ventricular distension while sustaining some measure of systemic and cerebral perfusion and potentially affecting cellular mechanisms of ischemic conditioning.[22] Regardless of the exact mechanism, early CPR, usually provided by a layperson before professional rescuer arrival, can improve the likelihood of resuscitation.[23,24] This appreciation has produced immense efforts by professional organizations to train laypeople in CPR skills. These training efforts have undoubtedly saved thousands of lives, and yet in many communities less than one quarter of people experiencing SCA receive layperson CPR.

Traditional CPR training, either voluntary or mandated as part of employment or school, will continue to be an important means to achieve early CPR, but additional approaches are needed to increase the delivery of early CPR. In a departure from the conventional compressions-plus-ventilations approach for bystander CPR, the American Heart Association recommended "hands-only" CPR for rescuers who are either untrained or not confident in their ability to provide rescue breaths.[25] Although this technique remains somewhat controversial, the goal is to improve both the likelihood and quality of bystander CPR. Abbreviated courses such as CPR Anytime reduce didactic content while enhancing hands-on practice of CPR skills.[26] Such courses may offer real advantages because they require substantially less time than traditional courses and provide the potential for newly trained individuals to propagate the training to others. In addition, the training emphasizes hands-on practice and repetition. Advances in communication technology also encourage CPR skills. Open-access, multilingual Web sites provide straightforward explanations and demonstrations of CPR (http://www.learncpr.org). Likewise, free applications for telephone technology also provide easy-access CPR skills presentation.

Even with substantial efforts in which traditional and novel training approaches are used, many people who witness SCA will not be trained in CPR. Moreover, people previously trained may be reticent to attempt CPR. As an illustration of the interdependence of the links, early access via the emergency medical dispatcher provides an opportunity for just-in-time CPR training, whereby dispatchers instruct bystanders in CPR on the telephone when SCA is suspected. First developed 25 years ago, dispatcher-assisted CPR constitutes a straightforward opportunity to increase layperson CPR and potentially improve survival in many communities.[27]

Two brief questions from the dispatcher can identify a group at high risk for SCA (Table 1). If the patient is not conscious and not breathing normally, the dispatcher engages the caller in an effort to initiate CPR if CPR is not already ongoing. Several details deserve comment. Open opportuni-

Table 1. Identification and Initiation of Dispatcher-Assisted CPR

1. Is the patient (he/she) conscious? (If "no"...)
2. Is the patient (he/she) breathing normally? (If "no"...)
3. We need to start CPR. Does anyone there know CPR? (Trained bystanders may still need instruction. If CPR is not ongoing ...)
4. Get the telephone next to the person if you can.
5. Listen carefully. I will tell you what to do.

Get them flat on their back on the floor.

Bare their chest.

Kneel by their side.

ties to decline participation are not provided by the dispatcher in an effort to engage the caller (Table 1). The term *normally* used to describe the victim's breathing is important because one third or more of SCA victims may manifest agonal respirations.[28] These "snoring" or "gasping" respirations indicate recent collapse, but paradoxically the respirations can confuse the bystander or the dispatcher regarding the patient's true SCA status. In up to half of instances, the questions will identify patients with acute conditions (eg, seizure, hypoglycemia) who are not experiencing SCA and therefore who do not require CPR. Dispatchers or bystanders may delay or refrain from CPR because of the potential risk of injury in such groups; however, this risk of injury is exceedingly low, and therefore this should not deter dispatcher or rescuer efforts.[29] In summary, optimizing bystander CPR requires a multifaceted community-based approach, supported by civic and health leaders, which tailors the training to the rescuer and the circumstance.[30]

CPR for the Professional Responder

Increasing evidence indicates that CPR is much more than a simple "yes/no" therapy.[31,32] Instead, CPR possesses a composite of characteristics that include the depth and force of compression, the extent and rate of chest recoil (decompression), the rate of compression, the frequency and volume of ventilation, and the extent and timing of CPR interruptions (Table 2).[33] Although research is ongoing, each component has the potential to influence outcome. To this end, improvements in survival have been observed when EMS professionals use a chest compression–only CPR strategy as well as strategies that maintain EMS ventilations.[34,35] Importantly, CPR even by EMS professionals sometimes does not achieve consensus standards.[32] Consequently, strategies have been developed and incorporated into field care to help improve EMS CPR. Some of these strategies emanate from the defibrillator itself and include metronome-style prompts for respective CPR components (chest compression rate and ventilations) or real-time audiovisual feedback to improve CPR performance (compression rate, compression depth, chest wall decompression, ventilation rate).[36,37] Other strategies automate chest compression and/or decompression so that a device instead of human effort delivers this care.[38–40] Finally, other technologies augment intrathoracic pressures to affect circulation during CPR.[41] These technologies have inherent appeal, yet compelling evidence of survival benefits has not been demonstrated and awaits results of randomized trials.

Table 2. CPR Components

Component	Guideline for Adults	Common Challenges	Take-Home Message
Chest compression depth	1.5–2 inches (38–53 mm)	Chest compressions too shallow	"Push hard"
Chest compression rate	100/min	Chest compressions too slow	"Push fast"
Chest recoil	Complete recoil after each compression	Failure to allow full recoil because of leaning on the chest	"Allow complete chest recoil"
Hands-off time	Minimize all CPR interruptions	Prolonged periods with no CPR due to • AED prompts and analysis • Pulse checks • Intubation	"Minimize interruptions to chest compressions"
Ventilation rate	8–10/min	Rate too fast	"Do not overventilate"
Ventilation volume	500 mL/breath	Volume too large	
Ventilation cycle	1–2 s	Cycle too long	

Adapted from Reference 33.

Early Defibrillation

The interval from collapse to defibrillation is an exceptionally strong predictor of SCA survival.[42] This appreciation has extended the purview of defibrillation from hospital-based emergency physician, to field physician, to paramedic, to emergency medical technician, to first responder, and even to the layperson in an effort to more quickly deliver defibrillation. This extension has been facilitated by the automated external defibrillator (AED), a device that can correctly assess the SCA rhythm and, when indicated, deliver a potentially lifesaving shock.[43]

Innovative approaches that achieve earlier defibrillation continue to be a promising priority to improve survival, although important lessons have been gleaned from experiences aimed at achieving earlier defibrillation.[44] For EMS providers, some of the benefit of earlier defibrillation attained with the AED was attenuated by AED-associated interruptions or delays in the other links in the chain, most specifically CPR.[45] Subsequent efforts to decrease AED-associated delays and consequently to increase CPR appear to have produced important survival gains.[34,35,46] For nontraditional first responders (eg, police, security officers), success appears to be determined in part by operational implementation.[47] These personnel favorably affect survival by delivering defibrillation before EMS, although anticipated earlier defibrillation by police is sometimes not realized for a variety of reasons that may include responder reluctance.[48] Considerations are distinct with regard to layperson defibrillation achieved with public access defibrillation (PAD). PAD programs require an investment to purchase AEDs and maintain layperson responder proficiency. Consequently, stakeholders must balance the potential benefit of PAD use and resuscitation versus the required fiscal and personnel investment. To assist strategic allocation, rigorous investigation has identified high-risk sites that can benefit from a PAD program, and observational and interventional studies have supported this approach.[49–51] These findings are informative but not definitive, as evidenced by school-based PAD. In most instances, school-based PAD does not appear to be cost-effective by traditional terms.[52,53] However, the decision may incorporate legal, emotional, and personal considerations that support a school-based or other type of PAD program.[54] Early defibrillation can provide profound survival benefit and should remain at the forefront of community efforts even as the field of resuscitation improves its understanding and refines its approach to other links.

Advanced Life Support

Advanced life support consists of a set of interventions (ie, endotracheal intubation, intravenous access) and medication treatments (administration of vasopressors and antiarrhythmics) designed to aid the "airway, breathing, and circulation" of resuscitation. Individual components and collective implementation of advanced life support lack the most rigorous, highest-level evidence of benefit in large part because such studies have not been conducted.[24] However, these treatments are supported by considerable clinical experience and substantial preliminary animal and human study.[55] To this end, communities with the most proactive and experienced field providers of advanced life support have consistently experienced some of the best SCA survival.[8,9] One interpretation is that effective advanced life support requires proficient critical skills and substantial clinical experience so that advanced care can be expertly interfaced with CPR and defibrillation. Thus, effective advanced life support not only entails proficient interventional skills and timely medication treatment but also requires field leadership to direct and coordinate the resuscitation effort.

Postresuscitation Care

Among SCA patients who are resuscitated and admitted to the hospital, a substantial variability occurs in survival, ranging from as low as 10% to >50%.[56] In accordance with the paradigm of interdependence of the links in the chain, some of this variability is assuredly due to differences in patient characteristics and prehospital care. There is, however, increasing evidence that hospital-based care can significantly improve functional survival, suggesting that some of this variability is due to hospital-based, postresuscitation care.[57]

Postresuscitation care is guided by the understanding of the postarrest syndrome. This syndrome is composed of 4 components: (1) postarrest brain dysfunction, (2) postarrest myocardial dysfunction, (3) systemic ischemia/reperfusion response, and (4) persistent precipitating pathology.[19] Thus, care must be tailored to appropriately address the pathology profile of each patient (Table 3). The majority of patients who die after hospital admission succumb to global anoxic brain injury. Evidence from randomized trials indicates that induction and maintenance of hypothermia between 32°C and 34°C for 12 to 24 hours can improve neurologically intact survival in comatose patients admitted with a pulse after resuscitation from witnessed ventricular fibrillation SCA due to heart disease.[58,59] Subsequent studies in the community-based setting support the safety and lifesaving potential of hospital-based therapeutic hypothermia achieved through a variety of methods.[60] Evidence for other acute postarrest treatments is derived from observational or nonrandomized experiences or is adopted from other disease conditions. Nonetheless, there is increasing evidence supporting comprehensive intensive care typically incorporating "early goal-directed therapy," which can improve each of the components of the postarrest syndrome (Table 3).[19]

Table 3. Components of Postarrest Care

Hypothermia to maintain core temperature 32–34°C for 24–48 h	
Emergent coronary angiography and revascularization in patient with high suspicion of acute coronary syndrome	
Comprehensive intensive care management to include	
• Ventilation and oxygenation	• Control of blood sugar
• Optimizing hemodynamics	• Prevention of thromboembolic disease
• Control of seizures	• Prevention of infection
Treatment of persistent triggering condition(s)	
Rehabilitation	
Implantable cardioverter-defibrillator placement	

One challenge to postresuscitation care has been the implementation of the multifaceted "package" that typically necessitates multidisciplinary cooperation and collaboration.[61,62] Institutional, fiscal, personnel, and expertise barriers may play a role. Importantly, there are open-access, practical informational resources to assist implementation (http://www.med.upenn.edu/resuscitation/hypothermia). Nonetheless, a critical mass of expertise, willpower, and facilities is required to achieve optimal outcomes. Approaches to organizing prehospital triage continue to evolve, although intuitively patients resuscitated from SCA should be directed to hospitals that routinely provide therapeutic hypothermia, comprehensive intensive care, and emergency revascularization. The growing appreciation of the influential survival role of hospital-based, postarrest care ideally should strengthen the partnership between prehospital and hospital.

Understanding Survival Variability: Developing Stronger Links

Many of the core aspects of the links in the chain of survival can be captured in their basic form by measurement of the Utstein data elements that describe patient, circumstance, treatment, and outcome characteristics.[63] Although these elements are a fundamental requirement for evaluation of community-based care, analytical evaluation indicates that in their basic form the Utstein elements collectively account for approximately one quarter of the outcome variability observed for ventricular fibrillation SCA across communities.[64] This finding suggests that incompletely measured or novel factors may influence outcome. Individual-level differences such as the patient's underlying chronic health conditions or distinct genetic profile may contribute to patient-specific outcome heterogeneity and account for within-community survival variability. Many of these patient characteristics are likely to be generally similar from one community to another. Thus, these types of patient-specific factors are not likely to explain a large portion of survival differences between communities.

Given this appreciation, we need to more closely examine the present links to explain community variability. The differences likely lie in the details of care. Indeed, we now can measure and appreciate that the composition of core components of CPR contributes to outcome heterogeneity.[65] Similarly, the dynamic interface between Utstein elements of CPR and defibrillation can also influence survival.[66] Other factors related to the "quality" of the links, however, are more difficult to assess, in part because they often characterize an EMS system or community approach rather than an individual SCA event, so that discerning these system factors eludes ready analysis.

What are these essential system factors that contribute so importantly to a community's SCA survival? First and foremost is the willingness and effort to systematically assess care and outcome with the use of the Utstein template as the foundation. This measurement should be coordinated to include dispatch, EMS, and hospital information. Such measurement includes system performance and individual case performance. Ascertainment of survival status through hospitalization is intrinsic to the usefulness of the activity. Given reasonable assurances from EMS organizations, hospitals should feel compelled to provide outcome information on behalf of patient welfare. Measurement is only useful if the results are thoughtfully interpreted, communicated, reported, and integrated. The collective process is often called "quality assurance" or "quality improvement" and provides the basis to maintain the status quo or make changes. In this regard, SCA research is a formalized evaluation that possesses some of the characteristics of quality assurance yet comes with special requirements and on occasion some criticism. However, communities that consistently conduct SCA research must be intrinsically committed to the processes inherent to quality assurance and improvement and therefore often have some of the highest community SCA survival.[10,47]

Effective quality assurance (or research) requires leadership and partnership. Although leadership may come from different sources, physician involvement can be pivotal because physician leadership can bridge the prehospital stakeholders (including the public) and hospital stakeholders to foster a productive partnership. Moreover, physician involvement reinforces the important role of prehospital care in a functioning system of allopathic emergency health care that focuses most importantly on clinical rather than operational outcomes. With this type of approach, several communities have demonstrated important improvements in resuscitation.[34,67] Such survival improvements will only be sustained if quality assurance efforts and leadership are steadfast and consistent.

System design and system experience also likely influence outcome. Most events that call for EMS do not require advanced care, with SCA being a notable exception. However, in many communities, advanced-level providers respond to most or all medical dispatches. With this EMS response strategy, communities employ substantial numbers of paramedics who often respond to circumstances that require only basic care. Other systems are tiered so that paramedics are reserved for more severe illness on the basis of triage guidelines. With this strategy, paramedics may respond to approximately one quarter of all medical dispatches, with the majority handled solely by basic life support providers. As a consequence, far fewer paramedics are needed to support the system. For example, the 2-tiered EMS system in Seattle and King County is composed of ≈200 field paramedics (advanced providers) who work in pairs to serve a total population of 1.8 million people. With the use of this strategy, associated with an intense training requirement, each paramedic on average cares for ≈8 to 10 SCA events each year. The volume of field resuscitation provides for accrual of substantial and routine experience of critical skill interventions and SCA management, which likely influences the proficiency of resuscitation. Greater proficiency produces greater expectations and, in turn, a cultural and community expectation of excellence.[68]

Putting It All Together

There is increasing awareness of the community-based disparity in SCA outcome.[69] Such an appreciation should activate community stakeholders to make a positive difference. The "difference" should build on the foundation of the links in the chain of survival and be supported by quality assurance, leadership, training, and experience and a consequent

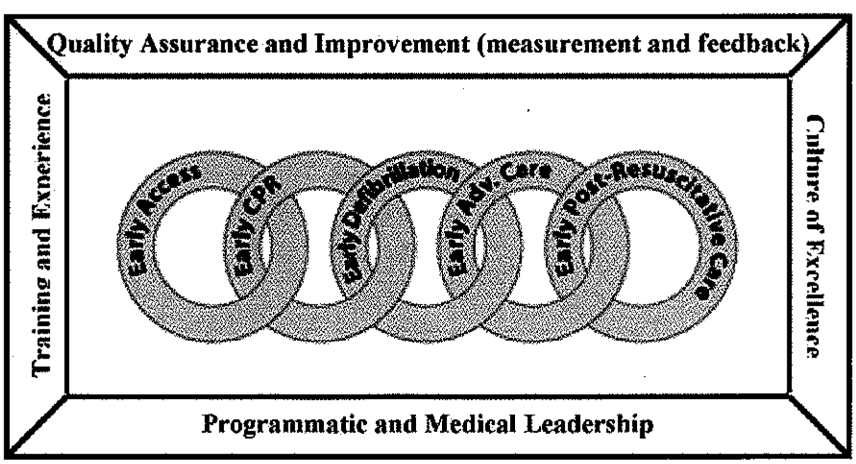

Figure. Framework for optimal community resuscitation. Adv. indicates advanced.

culture and expectation of excellence (Figure). We must be sensible and pragmatic: The challenge of optimal and integrated community resuscitation is formidable, iterative, and perhaps never ending. Each community must assess its individual strengths and limitations and generate an action plan for improvement. Stakeholders must ask questions and improve on the answers. The consequence of a well-integrated and well-delivered community-based strategy of resuscitation can be measured directly in lives saved and, just as important, can be experienced and celebrated by the individuals who live in the community.

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KEY WORDS: cardiopulmonary resuscitation ■ defibrillation ■ emergency medical services ■ heart arrest ■ resuscitation