Strategies to Improve Survival from Sudden Cardiac Arrest: An Evidence-Based Analysis
Executive Summary

This document, written by faculty of the Resuscitation Academy and staff of King County Emergency Medical Services, provides 35 strategies to improve survival from sudden cardiac arrest. We classify the individual strategies under 6 categories of CPR, defibrillation, advanced life support, post-resuscitative care, EMS system, and future approaches. Admittedly our selection of the 35 strategies is somewhat arbitrary but we have tried to be comprehensive. Our approach is focused on the pre-hospital management of sudden cardiac arrest and specifically ventricular fibrillation associated cardiac arrest. Though many of these strategies apply to cardiac arrests in hospitals we have chosen to stick to the world we know best.

In the Resuscitation Academy we categorize strategies into low hanging and high hanging fruit. We think of all the 35 strategies listed in this document, the lowest-hanging fruits (meaning relatively easy to implement and having the highest likelihood to improve cardiac arrest survival) are high-performance CPR and telecommunicator-CPR. These two strategies will not be effective without ongoing quality improvement programs and QI programs are not possible without a cardiac arrest registry. Our emphasis on the low hanging fruit should not discount the other strategies - many of which will have positive impacts. Perhaps the most important strategy may be the most difficult to achieve - creating a culture of excellence. Though hard to quantify, its impact is immense. Leadership, determination, uncompromising standards - the stuff of excellence - is a strategy that subsumes all the others.

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Introduction
Much has been written about how to improve the generally low survival rates from sudden cardiac arrest (SCA) with many strategies offered. This document provides a comprehensive listing of the strategies as well as an evidence-based analysis of each strategy.

The focus is primarily on out-of-hospital ventricular fibrillation since it is the most “resuscitatable” type of cardiac arrest. 35 strategies are considered. Though we do not specifically discuss in-hospital cardiac arrest, many of the strategies are equally applicable in the hospital setting.

Surviving SCA requires an optimal confluence of patient, event, system, and therapy factors. For example the patient factor of co-morbidity is a strongly associated with survival. Similarly the event factors of witnessed collapse and the rhythm associated with the event are critical. Key therapy interventions and the time to provide them (such as the intervals from collapse to the start of CPR and provision of defibrillation) as well as system factors are extremely important as well. This analysis pays little attention to factors of fate (patient and event factors) and instead focuses almost exclusively on therapy and system factors.
A Profile of Out-of-Hospital Cardiac Arrest

Sudden cardiac arrest (SCA) is the leading cause of death among adults in the United States. Though the causes of SCA are many, the leading cause is underlying coronary artery disease. The cardiac rhythms associated with SCA are asystole (flat line), pulseless electrical activity (PEA) and ventricular fibrillation (VF). Of these rhythms VF is the most treatable with a reasonable chance of survival. Among patients with witnessed collapse (meaning the collapse of the person was seen or heard) VF is present 40% of the time. In a few communities, survival (discharged alive from the hospital) from witnessed VF exceeds 50%. Regrettably in most communities survival rates from VF arrest are in the single digits or teens.

The following profile presents data on EMS-treated cardiac arrests in King County, Washington, population 1.4 million (excluding the city of Seattle). The purpose of the profile is to highlight the key patient, incident and system factors that should be considered when discussing sudden cardiac arrest. While the data presented are specific to King County, similar results have been reported elsewhere.

Who is Affected by Sudden Cardiac Arrest?

The incidence of EMS-treated sudden cardiac arrest has been estimated to be approximately 55 per 100,000 population, with survival to hospital discharge approximately 8%. The incidence of arrest with ventricular fibrillation as the initial rhythm is estimated to be between 13 and 21 per 100,000 population, with survival of approximately 20%. In children and young adults, the incidence of cardiac arrest due to cardiac causes is approximately 2 per 100,000 population, with overall survival close to 25%.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Sex</th>
<th>Number (%) with SCA</th>
<th>Mean Age</th>
<th>p-value for difference in age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults 18 and older</td>
<td>Male</td>
<td>4226 (64%)</td>
<td>63.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>2414 (36%)</td>
<td>66.6</td>
<td></td>
</tr>
<tr>
<td>Children less than 18</td>
<td>Male</td>
<td>142 (56%)</td>
<td>5.2</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>114 (44%)</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Number of patients with SCA and mean age by age group in King County, WA, 2005-2012.
In adults, sudden cardiac arrest occurs mostly in men who are, on average, younger than women who suffer a SCA. Several studies have shown that symptoms and presenting characteristics, such as initial rhythm, are different in women compared to men. In children, the trend in age is reversed. For example, Table 1 on the previous page shows that in patients 18 and older, 64% of arrests are in men, who are approximately 3.5 years younger than women. In children and adolescents, 56% of arrests are in boys, who are, on average, 1 year older than girls. This is most likely due to the higher rate of sports-related arrests in boys in their teens.

By definition, SCA excludes traumatic etiologies (although it is sometimes difficult to distinguish whether trauma was the outcome of the cardiac arrest or its cause). There are many causes of SCA, which may vary based on the age of the patient (see Figure 1). Causes (also referred to as etiology) are often classified as cardiac (coronary artery disease, dysrhythmias, structural and electrical problems with the heart) or non-cardiac (respiratory causes, complications of non-cardiac comorbidities, trauma, overdose). Causes are often determined based on EMS provider impressions, but may also be classified based on review of hospital and death records. In the absence of an obvious noncardiac cause, a cardiac arrest is usually presumed to be of a cardiac etiology. Most reports are limited to subjects with a cardiac etiology, as this is considered the most homogeneous subject population.

Figure 1: Percent of sudden cardiac arrest patients with cardiac or non-cardiac causes (excluding trauma) by age group, King County, WA, 2005-2012 (N=6451)
Factors That Influence the Chance of Survival

Most instances of sudden cardiac arrest occur in the home. Patients who arrest in a public location have a better chance of surviving to hospital discharge because, in most cases, someone is more likely to see a person collapse in public and initiate a quick response. EMS-treated arrests may also occur in medical clinics or care facilities such as nursing homes, adult family homes or assisted living facilities. These patients tend to survive at lower rates because they often have multiple serious medical conditions that reduce the chances of a successful resuscitation. See Figure 2 for an example from King County data.

Figure 2: Number of EMS-Treated Cardiac Arrests and Percent Surviving to Hospital Discharge for Each Location Type, King County, WA, 2005-2012 (N=6864). Percentages represent the proportion of patients having a cardiac arrest in each location who survived to hospital discharge.
The likelihood of survival decreases with each minute that a patient goes without CPR or defibrillation. Therefore, the time it takes for EMS personnel to arrive and treat the patient is an important factor that influences the chance of survival. Ideally, this time interval would be measured from the time of collapse. But this time is very difficult to measure, so a common substitute is the time that the EMS response was activated (usually by a call to the emergency response number). A more clinically relevant time interval is the time from EMS activation to the initiation of CPR (whether by a bystander or by EMS personnel) and the time to first defibrillation, if applicable. However, EMS incident reports may not provide accurate CPR and defibrillation times. Emergency dispatch center audio recordings and/or defibrillator data may be queried to obtain these data, which may lead to more accurate times. But collecting data from these sources is difficult and may lead to a high rate of missing times. See Table 2 below.

<table>
<thead>
<tr>
<th>Time from Emergency call to:</th>
<th>Median (25%, 75%)</th>
<th>Percent Missing</th>
<th>Source of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>First EMS unit arrival</td>
<td>5:23 (4:24, 6:46)</td>
<td>1%</td>
<td>Computer aided dispatch report</td>
</tr>
<tr>
<td>CPR by a bystander</td>
<td>2:29 (1:50, 3:26)</td>
<td>47%</td>
<td>Emergency call audio recording</td>
</tr>
<tr>
<td>CPR by EMS when bystander CPR not given (includes EMS-witnessed arrests)</td>
<td>8:24 (6:38, 10:58)</td>
<td>49%</td>
<td>EMS defibrillator data</td>
</tr>
<tr>
<td>First shock</td>
<td>11:36 (7:57, 20:01)</td>
<td>21%</td>
<td>EMS or public access defibrillator data</td>
</tr>
</tbody>
</table>

Table 2 Time from Emergency Call to Key Endpoints, King County, WA Sept. 1, 2012 - Sept. 31, 2013.
When a SCA is seen or heard, the chances of survival increase. If an arrest is witnessed, it is likely that the patient receives treatment relatively quickly, so witnessed status becomes an indicator of the “freshness” of the event.

The initially measured heart rhythm is another important factor. Patients with ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT) can be shocked into a normal rhythm with a defibrillator (these are often referred to as “shockable” rhythms). A defibrillator shock cannot restore a normal rhythm for patients with pulseless electrical activity (PEA) or asystole (these are often referred to as “unshockable” rhythms). However, these rhythms can sometimes resolve to a normal rhythm with high quality CPR and administration of drugs. The graph above depicts the survival from witnessed and unwitnessed cardiac arrest by the presenting arrhythmia. Witnessed VF has the highest likelihood of survival though even unwitnessed VF has a decent chance of survival. PEA has a worse chance of survival and the worst chance of survival is found for asystole.

When the patient population is limited to subjects with a suspected cardiac cause of arrest, the proportion of cases with VF as an initial rhythm is declining (see Figure 4). This is likely due to improved primary and secondary prevention.
efforts targeting coronary artery disease. It does suggest, however, that successful therapies focusing on patients with an initially unshockable cardiac rhythm must be developed in order for improvement in overall survival to continue.

How is Sudden Cardiac Arrest Treated?
The two most critical interventions for ventricular fibrillation cardiac arrest are rapid cardiopulmonary resuscitation (CPR) and rapid provision of defibrillation. When the heart stops pumping blood during a SCA, effective CPR will circulate oxygenated blood to the body and brain. If someone gives CPR before EMS arrives (referred to as bystander CPR), this reduces the time that the patient is without circulation. Community CPR training programs may increase the rate of bystander CPR. Telecommunicator-CPR programs, in which emergency dispatcher provide...
CPR instructions, have been shown to increase bystander CPR rates and survival. It is widely reported that bystander CPR doubles or triples the odds of survival compared to no bystander CPR. Recent data in the past 5 years shows that the quality of CPR also improves the chance of survival. The term widely used for high quality CPR is high-performance CPR (HP-CPR). For ventricular fibrillation cardiac arrest public access defibrillators offer the possibility of achieving rapid defibrillation prior to EMS arrival.

There is an interaction between CPR and defibrillation. When both are provided quickly there is an excellent chance of survival. The two interventions interact and work in parallel. Both are required quickly but if CPR can be started quickly there can be a small delay in providing defibrillation and still achieve decent survival rates. A simplified way to express this interaction is that survival from witnessed VF arrest declines by about 7% - 10% for every minute that CPR and defibrillation are delayed. When CPR is begun quickly (particularly if it is HP-CPR) the rate in the fall of survival with delay to defibrillation is lessened. In other words CPR “slows the dying process” and gives extra time for a defibrillatory shock to be delivered and still be successful.

Other aspects of care include medications and airway control. Paramedics often protect the airway and administer drugs. Hospitals continue patient care and may initiate hypothermia or provide percutaneous coronary intervention (PCI) when appropriate. In some communities paramedics begin hypothermia therapy prior to hospital arrival.

**How are Patient Outcomes Measured?**

Most studies report survival to hospital discharge. If resources allow, neurologic status at hospital discharge (as measured by CPC or modified Rankin Score) should also be reported. Additional patient outcomes that may be reported include: a return of spontaneous circulation (ROSC), survival to hospital arrival, 30-day mortality and 1-year (or greater) mortality.

Most communities in the US have poor survival rates. (See Figure 5, page 12) For VF the rates range from zero to 50% and recent data from Seattle and King County report a survival rate
of 57%. The CARES registry (representing approximately 25% of the US population) reports witnessed VF survival of almost 30%.

Summary facts:
- Of the three rhythms causing cardiac arrest VF has a reasonable chance of resuscitation
- Unwitnessed collapse fares much worse compared to witnessed collapse
- There are variable survival rates throughout the country
- Likelihood of survival falls 7-10% for every minute of delay in CPR and defibrillation
- CPR doubles - triples the likelihood of survival
How are Cardiac Arrest Data Reported?
The Utstein guidelines provide recommendations on the reporting of cardiac arrest data. These guidelines highlight the patient, treatment and system factors that should be reported and, if used correctly, allow comparison between different systems.

The indicator most often used is survival to hospital discharge for witnessed arrests of cardiac etiology with VF or pulseless VT as an initial rhythm. There are two reasons for this: 1) These are the patients with the greatest possibility of survival, and 2) this defines a patient population that is similar from one study to the next and allows comparison over time or between systems.

The following paragraph refers to the “Utstein Survival Report” found in the Appendix. “Resuscitations Attempted” should include all incidents treated by EMS that have a confirmed loss of pulse and blood pressure, that receive CPR by EMS personnel or that receive a defibrillatory shock (either by a by EMS or by a public access defibrillator). The denominator for reporting survival is found in the “Initial Rhythm VF/VT” box (3434) and represents the number of bystander witnessed incidents of cardiac etiology with an initial rhythm of VF or pulseless VT. Following the arrows directly down from this box to the “Discharged Alive” box gives the number of patients discharged alive from the hospital (1087/3434 = 31.7%). The “Neurological Status” box shows that 952/1087 patients (87.6%) had a favorable neurological status at hospital discharge. CARES also provides similar reports focusing on unwitnessed events and events witnessed by EMS providers.

Approach
The treatment of cardiac arrest is complicated and challenging. The multiple strategies are divided into 6 categories. The categories are distinct but not precisely demarcated. For example, teaching CPR to the general public also entails teaching about automated external defibrillators (AEDs). The first four categories (CPR, defibrillation, advanced life support, and post-resuscitative care) follow the sequence in treating a cardiac arrest. The 5th category deals with the EMS system as a whole and the 6th category features future approaches. Each strategy has a brief description followed by a summary of the scientific evidence in support of the strategy (as well as relevant articles) and an overall assessment. In addition there is an appraisal of the strategy’s impact (its potential to improve survival) and its ease or difficulty of implementation.

The categories and the strategies
Following are the 6 categories (CPR, Defibrillation, Advance life support, Post-resuscitative care, EMS system, and Future approaches) and the 35 specific strategies:
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1. CPR

Strategies in this category relate to providing CPR as quickly as possible and performing high quality CPR.

1. Train the general population in CPR/AED

Description:
The technique of closed chest CPR was first reported in 1960 and the skill spread outward from the hospital to involve the general public. In 1973 Dr. Leonard Cobb began a program in Seattle, WA to train the general public in CPR. The goal was to train 100,000 people in a three hour course. Today approximately 75% of the Seattle/King County population has been trained in CPR. Numerous studies demonstrate benefit with bystander CPR with doubling and even tripling of survival. National organizations such as the American Heart Association (AHA) and the American Red Cross (ARC) promote CPR training of the general public and offer courses of varying lengths geared to health care professionals and the general public. Over the past three decades the courses have generally become shorter as a result of attempts to make CPR easier to perform. For example the current AHA HeartSaver course for laypersons is approximately 3-4 hours in length. Starting in 2006 the AHA course eliminated mouth-to-mouth ventilation for its layperson HeartSaver course and emphasizes the importance of initial chest compression only by nonprofessional providers for adult cardiac arrest. As evidence of CPR is required for many employment situations the AHA and ARC have issued certification or completion cards following training. Recent versions of the course also teach about AEDs and how to use them for cardiac arrest events. Traditionally CPR has been taught in classroom setting with instructional movies/videos, demonstrations and practice on training manikins. In the past 10 years some mass training demonstrations (and occasionally practice sessions) have been held at stadium sporting events during half time.

There is widespread belief that training the general public how to do CPR is beneficial.

Assessment:
Bystander CPR improves the probability of surviving cardiac with reported odds ratios of 2.0 to 3.0. The challenge is getting enough of the population trained so that any given cardiac arrest will likely have a trained bystander present. Reaching the demographic most likely to witness a cardiac arrest, namely elderly adults, has proved difficult.

Impact:
This has a potentially huge impact.
Implementation:
It is difficult to train enough people, especially those who are likely to witness a cardiac arrest at home, to have a major impact on cardiac arrest survival. This strategy is not without success, however, as many communities report bystander CPR rates of 25%. In some communities, such as Seattle/King County, the rate of bystander CPR is over 50%.

Science:
The evidence for the benefit of bystander CPR is observational and published studies use retrospective cohort research design. There are no randomized clinical trials of bystander CPR. (such a proposal has been raised (Bardy, NEJM) but is regarded by many as unethical). It is not possible to measure the quality of the bystander CPR and one must assume the quality is variable. Nevertheless virtually all studies of CPR comparing the presence or absence of bystander CPR before EMS-initiated CPR consistently shows benefit when someone initiates CPR prior to EMS arrival.

Evidence for the benefit of chest compression only comes from prospective randomized trials in emergency dispatch centers comparing standard chest compression and mouth-to-mouth ventilation instructions to chest compression only telephone instructions at the time of cardiac arrest calls. (see reference 11 below).


In King County 79% of survey respondents reported ever attending a CPR training class.

2. American Heart Association. Heartsaver® CPR AED – Classroom [Internet]. Dallas, TX; American Heart Association; [updated 2013 Apr 29; cited 2014 Jan 27]. Available from: http://www.heart.org/HEARTORG/CPRAndECC/CorporateTraining/HeartsaverCourses/Heartsaver-CPR-AED---Classroom_UCM_303776_Article.jsp.

Website providing information on Heartsaver® course.


"Overall survival from OHCA has been stable for almost 30 years, as have the strong associations between key predictors and survival. Because most OHCA events are witnessed, efforts to improve survival should focus on prompt delivery of interventions of known effectiveness by those who witness the event.” – from abstract

"When bystander CPR was administered to cardiac arrest victims, 22.9% of the victims survived until they were admitted to the hospital and 11.9% were discharged alive. In comparison, the statistics for cardiac arrest victims who did not receive bystander CPR were 14.6% and 4.7%, respectively (p less than 0.001).” – from abstract


"In this registry-based study, BCPR significantly improved the survival of OHCA with good cerebral outcome.” – from abstract


"Recent developments in bystander CPR have simplified arrest recognition and improved CPR training, while retaining CPR effectiveness. The goal of these developments is to increase and improve bystander CPR and in turn improve resuscitation.” – from abstract


"Our data revealed improved survival rates when bystander CPR was initiated on victims of witnessed cardiac arrest in an EMS system with short response times.” – from abstract


"Increased use of bystander CPR training and simplified CPR techniques” listed as key areas for improving cardiac arrest survival.


The above two prospective studies of T-CPR showed no difference in survival among the chest compression only group compared to the standard CPR group but all categories showed improved survival with chest compression only. The authors concluded that chest compression only was easier to perform and should be the standard method of T-CPR.


A prospective trial showed better long term survival among the group that received chest compression only CPR by telecommunicators.


"The quality of chest compressions was significantly improved following the 2010 AHA guidelines, however, it’s more difficult for the rescuer to meet the guidelines due to the increased fatigue of rescuer." - from abstract


"Annual rates of US CPR training are low and vary widely across communities.... These data contribute to known geographic disparities in survival of cardiac arrest...”- from abstract


An observational study showed improved survival among the patients receiving chest compression only CPR.
2. Use the web and apps to teach CPR

Description:
There are many web and smartphone based apps that show how to perform CPR as well as how to operate an AED. The first to offer free instruction was learncpr.org. This site included one minute videos showing how to do adult, child, and infant CPR as well as how to deal with choking emergencies. LearnCPR.org has been viewed by millions of people. The American Heart Association also provides free online CPR instruction and the Medtronic Foundation offers an interactive training scenario. Many phone apps exist and some are free. Resuscitate! is a free iOS app with one-minute teaching videos on CPR, Choking, and AED along with a free Android version.

Assessment:
The web and apps and new media can help inform the public about cardiac arrest, CPR and AEDs.

Impact:
The impact is probably large.

Implementation:
Relative easy to accomplish and inexpensive relative to the number of viewers. The challenge is getting the public to view and use the sites. There is so much competition for viewers “eyeballs” and so many entertaining sites and apps that the serious message of CPR is easily lost in an avalanche of attention grabbing alternatives.

Science:
The number of potential viewers is immense (LearnCPR.org has had over 3 million views and the Resuscitate! app has been downloaded 100,000 times). What is not known is whether the viewers and users actually learn the skills and whether CPR has been performed solely as a result of viewing the sites and apps. There are many images of CPR in the media and it is not possible to measure the separate impacts of print, TV, movies, apps, web, and other media. It is likely that web and app CPR instructions help inform the public about cardiac arrest and provide a general sense of how to perform CPR (and use an AED). Beyond this it is not possible to quantify the impact. It is as yet unclear whether video based instruction (without manikin practice) is comparable to teaching using a manikin. An exploratory study proposed use of Twitter to identify CPR training needs.

Articles:
Laypersons who received initial CPR training on the web did worse than students in a traditional or case-based class when follow-up CPR performance was measured. This is not surprising given the psychomotor skills required for CPR in which actual performance on a manikin would likely help learn the skill.


Lay subjects randomized to receive a refresher mobile phone video plus reminder Short Message Service (SMS) messages performed better CPR and expressed greater willingness to perform bystander CPR compared to controls.


CPR refresher courses offered online, by email or by text message did not improve CPR training outcomes in laypersons compared to a mailed brochure, but compliance was low for the electronic interventions.


Doctors receiving a smartphone refresher course scored higher than controls on an advanced life support performance test.


A television media campaign led to increases in self-reported willingness to perform CPR and use an AED among the public in Denmark.


A study of depictions of CPR on three popular US television shows concludes that survival rates and affected populations are not accurately represented.

"Continuous chest compression cardiopulmonary resuscitation education resulted in a statistically significant increase in secondary training. This work suggests that implementation of video self-instruction training programs using continuous chest compression cardiopulmonary resuscitation may confer broader dissemination of life-saving skills and may promote rescuer comfort with newly acquired cardiopulmonary resuscitation knowledge.” - from abstract


"...Twitter can be filtered to identify public knowledge and information seeking and sharing about cardiac arrest. To better engage via social media, health care providers can distill tweets by user, content, temporal trends, and message dissemination. Further understanding of information shared by the public in this forum could suggest new approaches for improving resuscitation related education.” - from abstract

3. Telecommunicator CPR
Emergency telecommunicators provide CPR instruction on the telephone - other terms are Dispatcher CPR, Dispatcher-Assisted CPR, and Telephone CPR.

Description:
Telecommunicator CPR (T-CPR) began in King County in 1981. An optimal set of instructions was developed using simulated cardiac arrests. The program led to a dramatic increase in the rate of bystander CPR. The concept was slow to catch on nationally but by 2000 the awareness of the potential of T-CPR generally appreciated and the AHA endorsed the intervention in its 2006 standards for emergency cardiac care (Reference 5). In 2012 the AHA issued a scientific paper with specific recommendation on how to implement T-CPR including performance goals.

Assessment:
T-CPR works and achieves benefit comparable to that of CPR started by previously trained bystanders. All studies of T-CPR have used either before and after study design or retrospective cohort methodologies. As with the benefit of CPR
training in general there has been no randomized study of T-CPR compared to no T-CPR. It is clear that some communities have T-CPR programs in place but are unable to provide rapid instructions (reference 9). It may be that some proprietary computerized assisted dispatch programs (used in emergency dispatch center) are not nimble enough to allow the rapid recognition of cardiac arrest and delivery of the instructions.

Impact:
T-CPR offers a potentially huge impact.

Implementation:
For T-CPR to reach its potential there must be performance standards and a QI (Quality Improvement) program in place to monitor all cardiac arrest calls and provide feedback in order to achieve the standards. The metrics published in King County should serve as national standards for quality T-CPR programs. It would probably require a strong mandate from a respected telecommunicator organization (such as NENA) to create positive momentum.

Science:
The development of the program was described in a series of articles from King County including an analysis of times to deliver the instructions as well as impediments to rapid delivery. The survival benefit of T-CPR was demonstrated in a 2005 paper by Tom Rea. In this paper the witnessed VF cardiac arrest survival was reported for EMS initiated CPR, T-CPR initiated bystander CPR, and bystander CPR (with no T-CPR). Survival rates were highest with the bystander CPR but almost as good as with T-CPR. The most recent paper from King County published metrics of percentage of cardiac arrests recognized, the time to recognition of cardiac arrest, the percentage of cardiac arrests that received chest compression, and the time to first compression. A recent report from Korea demonstrated increased bystander CPR and improved survival following a program of T-CPR (reference 8).

Articles:

   This the first study to demonstrate the value of T-CPR.


   A description of how the T-CPR was developed and validated.

_Demonstration of survival benefit of bystander CPR and T-CPR (called dispatcher-assisted CPR in the paper)._ 


_Agonal respirations are present in 55% of witnessed cardiac arrests (yes, 55%!)._


_A scientific statement from the AHA endorsing T-CPR._


_Recommendations on performance standards based upon actual cardiac arrest calls._


_T-CPR is safe._


_T-CPR was associated with a significant increase in bystander CPR and improved survival and neurological recovery._

This study shows that it can take 4 minutes to begin chest compressions in some communities.

4. Improve the quality of CPR provided by EMS personnel through high-performance CPR (HP-CPR)

Description:
In 2005 the AHA issued new standards for health professional CPR. The standards stressed high quality CPR with minimal interruptions in chest compression, proper rate of compressions and depth of compressions, and full recoil of the chest. In addition the new standards called for periods of two minutes of CPR interspersed with rhythm assessments. CPR should resume immediately after a defibrillatory shock with no pause to reassess the rhythm. If a shock is not indicated the presence of a pulse should ascertained. To minimize interruptions of chest compression the paramedics are trained to provide endotracheal intubation and place an intravenous line with ongoing chest compressions.

<table>
<thead>
<tr>
<th>Characteristics of HP-CPR</th>
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<tbody>
<tr>
<td>Correct hand position</td>
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<tr>
<td>Compression rare of 100-120 per minute</td>
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<tr>
<td>Depth of compression of at least 2 inches</td>
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<tr>
<td>Full recoil on the upstroke</td>
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<tr>
<td>50:50 duty cycle</td>
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<tr>
<td>Ventilation of one second each</td>
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<tr>
<td>Minimal interruptions of CPR (no pause to exceed 10 seconds)</td>
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Assessment:
HP-CPR appears to improve the likelihood of successful resuscitation. From a functional point of view HP-CPR suspends the dying process and allows other interventions (such as proper oxygenation, fluids, medications) to “kick in” and allow the next defibrillatory shock to be successful. Though totally anecdotal, we have reports of numerous communities training all EMS personnel in HP-CPR and achieving a dramatic increase survival from VF. For example, Thurston County in Washington, saw their witnessed VF survival rate increase for 24% to 42% solely as a result
of instituting HP-CPR. Eventually monitoring of hemodynamics may prove to be a useful guide to quality CPR.

**Impact:**
HP-CPR has the potential for huge impact.

**Implementation:**
Since EMS personnel receive annual retraining in CPR it is fairly easy to train in the new technique of HP-CPR. There are now good training videos showing the new technique. We have found that the secret to maintaining this skill, in addition to periodic retraining, is an ongoing QI program. A successful QI program shares the performance metrics with the EMS personnel who participated in the resuscitation. Their performance is compared to the county standard. QI is always used for improvement and never as a disciplinary tool.

**Science:**
The major study, which provided support for the AHA changes, came from King County. This study analyzed high quality CPR compared to the prior AHA guidelines. Patients who received high quality CPR had significantly higher survival rates compared to the “older” CPR. (survival increased to 46% from 33%). The term used in Seattle and King County for this high-quality form of CPR is high-performance CPR (HP-CPR). Other parts of the country use alternate terms such as: choreographed CPR, high-quality CPR, pit-crew CPR, high-quality CPR, dance of CPR, and CPR ballet.

There are physiologic reasons that HP-CPR outperforms the older version of CPR. HP-CPR with its attention on rate and depth and full recoil lead to higher coronary perfusion pressure and perfusion to vital organs. The minimization of interruptions keeps the time of no perfusion pressure to a minimum.

**Articles:**

   *Survival from OOHCA improved with the implementation of 2005 AHA guidelines for CPR and ECC. These changes were associated with improvements in the quality of CPR in one large city.*


"Deeper chest compressions were associated with improved survival and functional outcome following OHCA. Our results suggest that adhering to the 2010 AHA Guideline-recommended depth of at least 51mm could improve outcomes for victims of OHCA." - from abstract


"Survival to hospital discharge was significantly greater during the intervention period compared with the control period (46% [61/134] versus 33% [122/374], P=0.008) and corresponded to a decrease in the interval from shock to start of chest compressions (28 versus 7 seconds)." - from abstract


"Outcomes from OHCA resulting from nonshockable rhythms, although poor by comparison with shockable rhythm presentations, improved significantly after implementation of resuscitation guideline changes, suggesting their potential to benefit all presentations of OHCA."


"There are 5 critical components of high-quality CPR: minimize interruptions in chest compressions, provide compressions of adequate rate and depth, avoid leaning between compressions, and avoid excessive ventilation." - from abstract

“In the context of a community-wide focus on resuscitation, the sequential implementation of 2005 American Heart Association guidelines for compressions, ventilations, and induced hypothermia significantly improved survival after cardiac arrest. Further study is required to clarify the relative contribution of each intervention to improved survival outcomes.” - from abstract


“Chest compression rate was not significantly associated with survival to hospital discharge in multivariable categorical or cubic spline models,” but rates over 125 were associated with lower rates of return of spontaneous circulation. - from abstract


Hemodynamic monitoring may prove to be an even better guide to good CPR compared to achieving adequate compression depth.


The proper rate and depth of chest compressions are significantly associated with improved cardiac arrest survival

5. Mandate CPR/AED training in schools

Description:
King County EMS has facilitated CPR training in high school for many years and recently Washington State passed a law mandating CPR and AED education in all high schools. In addition to Washington State, 14 other states require CPR training in high school. In some European countries CPR training is mandatory (Norway
for example) and others (Great Britain) are considering it.

Assessment:
The rational for mandatory training is straightforward. High school students comprise a captive audience and the hope is that once trained the students will remember the skill for life. In addition the students may inform their parents of the training and maybe achieve a spillover effect. The argument against mandatory training is the time and effort in the school curriculum to provide the training. School officials claim that they are approached all the time with “do good” proposals. Every good proposal added to the curriculum has an opportunity cost with some other content being eliminated. Then there is the issue of cost. In Washington State, the requirement for mandatory training is an unfunded mandate.

Impact:
The impact is likely high though it will take years (decades) to be realized.

Implementation:
The cost involves training the teachers to be the trainers or hiring trainers. Purchasing the training manikins is an initial large cost.

Science:
There are no data about whether mandatory training increases bystander CPR.

Articles:

“This statement recommends that training in CPR and familiarization with automated external defibrillators (AEDs) should be required elements of secondary school curricula and provides the rationale for implementation of CPR training, as well as guidance in overcoming barriers to implementation.” - from abstract

The epidemiology of cardiac arrests in schools.


Epidemiology of cardiac arrests in schools using a national registry.


Reviews current literature on treatment of cardiac arrest in children, with a focus on school AED programs. Estimates the impact of effective school AED programs and suggests best practices.


Review of current literature on AED programs in schools with a suggestion that these programs improve OHCA outcomes.


Provides details for constructing a model to evaluate the cost effectiveness of school AED programs in different communities.

6. Automatic CPR devices

Description:
Automatic CPR devices come in two main flavors. One works through compression of the chest and the other actually uses a hydraulic device to press on the sternum.

Assessment:
There may be a limited role for automatic devices such as long transportation of patients with ongoing CPR or delays in preparing the cath lab for cardiac arrest patients with evidence of STEMI.

Impact:
The impact is likely to be small.

Implementation:
The devices are costly and as the ASPIRE study demonstrated there may be harm with routine use of the devices.
Science:
There is no convincing demonstration of utility in improving outcomes in the prehospital setting.

Articles:

"Use of an automated LDB-CPR device as implemented in this study was associated with worse neurological outcomes and a trend toward worse survival than manual CPR. “ – from abstract


"In this pilot study, the results did not support the hypothesis that the introduction of mechanical chest compression in OHCA improves outcome.” – from abstract


This large randomized clinical trial showed no difference in survival among the group treated with the mechanical device compared to the manual CPR group.


"This series provides a description of the use of the LUCAS mechanical CPR device and examples of coronary imaging and intervention during mechanical CPR.” – from abstract

Continuous chest compression with an automatic mechanical device is feasible, safe, and might improve outcomes after in-hospital-resuscitation of PEA” – from abstract


“The use of mechanical chest compressions in the catheterisation laboratory allows for continued PCI or pericardiocentesis despite ongoing cardiac or circulatory arrest with artificially sustained circulation.” – from abstract


“Prolonged chest compressions may be necessary in some cardiac arrests. These cases suggest that automated chest compression devices may increase the chance of a favorable outcome in these rare situations.” – from abstract

7. Telecommunicator rapid dispatch

Description:
Rapid dispatch refers to dispatching of the first-in unit as soon as it is apparent that EMS help is needed. Once the unit is en route additional information about the call can be provided. For tiered-response EMS systems, additional units (such as paramedic units) may be added if needed once the first unit is dispatched. This may seem obvious and some may wonder why this isn’t done all the time. But rapid dispatch is the exception rather than the rule in most dispatch centers. The reason for the lack of rapid dispatch is the practice of gathering all available information BEFORE deciding on the level of response and the priority of the response. In addition some proprietary programs require dispatchers work through a complicated decision tree before EMS personnel can be dispatched. Such programs do not allow for shortcuts. Rapid dispatch is essentially a short cut dispatching program that strives to send emergency help as quickly as possible. Telecommunicators are trained to act when it is obvious that a medical emergency is present. The details on the nature of the emergency can be sorted out later.
Assessment:
Rapid dispatch saves time. And this will result in a higher survival rate.

Impact:
The impact is modest, perhaps a 5% increase in survival rate though the actual benefit will depend on the time saving.

Implementation:
Dispatch centers can decide which conditions merit rapid dispatch. In King County, the criteria for rapid dispatch are: suspected cardiac arrest, unconscious, chest pain, shortness of breath, ongoing choking, seizure, diabetic hypoglycemia, stroke symptoms, and major trauma. A reasonable standard is a median time of 30 seconds from the call pick up to dispatching the first-in unit for rapid dispatch conditions.

Science:
There are no studies to prove that rapid dispatch improves survival though it seems intuitive that the shortened response time will translate into higher survival. Anecdotally Seattle Fire Department instituted a rapid dispatch program in 2013 and shortened the interval from call received to dispatch of the first-in unit by 30 seconds.

Articles:

In a telecommunication center using proprietary dispatch protocols, it took over 3 minutes to dispatch EMS personnel to suspected cardiac arrests. When an experimental “pre-alert” system was implemented, the call processing time was reduced to approximately 2 minutes.


Retrospective cohort study showing a non-statistically significant increase in patient survival with faster dispatch processing times.


The median call processing time was approximately 2 minutes for calls beginning at a primary public safety answering point (PSAP) and transferred to a secondary PSAP.
2. Defibrillation

Strategies in this category relate to how to provide defibrillation as quickly as possible and how to encourage dissemination of automated external defibrillators throughout our society.

1. Increase Public Access Defibrillator (PAD) programs

Description:
The PAD concept is to place AEDs throughout the community – a kind of prepositioning of the device – so it can be used prior to the arrival of EMS personnel. PAD generally refers to AEDs that are placed in public locations. Typical locations are airport and other transportation facilities, exercise facilities, shopping malls, sporting venues, casinos, community centers. The use of AEDs in public settings is covered by good Samaritan laws.

Assessment:
The logic behind PAD is compelling. The challenges have to do with the minority of cardiac arrests in public places and the cost of AED not to mention training of personnel and maintenance of pads and batteries. The actual annual number of cardiac arrests in any given public site is very low. There may be some collateral benefit in that the public displays of AEDs may sensitize the public to what AEDs are and the role it plays thus increasing awareness of cardiac arrest and how to respond.

Impact:
PAD programs have a small but measurable impact.

Implementation:
The cost is high (AEDs generally sell for $1000-$1500 each) and there is maintenance costs of new batteries and pads (these must be replaced every 2-3 years).

Science:
Cardiac arrests in public locations comprise approximately 15% of all cardiac arrests. Among the public places some type of locations have a higher incidence of cardiac arrest compared to other locations. Sites with the highest incidence of cardiac arrest are transportation hubs, jails, shopping malls, sporting venues, golf courses, shelters, exercise facilities, and senior centers.

Articles:

“This study described the public locations of cardiac arrest and estimated the annual incidence of cardiac arrest per site to determine optimal placement of automatic external defibrillators (AEDs).” - from abstract

"The EMS of Seattle and King County developed a voluntary Community Responder AED Program and registry of PAD AEDs. During the 4 years, 475 AEDs were placed in a variety of settings, and more than 4000 persons were trained in cardiopulmonary resuscitation and AED operation. The proportion treated by PAD AED increased each year, from 0.82% in 1999 to 1.12% in 2000, 1.41% in 2001, and 2.05% in 2002 (P=0.019, test for trend)." - from abstract


One randomized trial studied the utility of PAD and found improved survival in the PAD sites compared to sites without PAD. No cost-effective studies of PAD have been done.


In King County the use of PAD has increased over 8 years and the most recent study reports 8.8% of all VF cardiac arrests had a PAD attached and deliver the first shock. It should be pointed out that police application of AEDs in this study were considered to be a PAD use.


There were 132 events involving an AED, 96 (73%) of which were due to cardiac arrest of cardiac etiology. Of 54 people who were witnessed to experience a cardiac arrest and presented with ventricular fibrillation or ventricular tachycardia, 21 (39%) survived to hospital discharge.

The most recent study comes from Hampshire, Great Britain. Deakin et al. describe the role of public access defibrillation in Hampshire (Heart Journal in press, 2014). Of 1035 cardiac arrests, only 44 (4.25%) in 34 different locations involved the caller knowing an AED was present at the scene and only 18 (1.7%) had an AED applied before trained personnel arrived. The authors conclude that PAD has had little impact on community cardiac arrest survival and is an unfulfilled promise.


"Public Access Defibrillation Programs should identify the site-specific incidence of arrest within their communities in order to provide legitimacy for funding and planning of programs. Training and availability of AEDs will reduce the time to first shock, thus strengthening the chain-of-survival and will save more lives." - from abstract


A post-market survey of home AED use found the devices to be safe and effective.

2. Train and equip police with AEDs

Description:
Rochester, MN has pioneered the involvement of police in responding to cardiac arrests. Since 1990 police have responded along with EMS personnel to all cardiac arrests – in fact they respond to all medical emergencies. Thus Rochester has a three-tiered EMS response system - police, EMT firefighters, and paramedics. The survival rates in Rochester are among the highest in the world. Other communities have tried police defibrillation programs with varied success.

Assessment:
In any given community there are generally twice as many police vehicles on the street as there are EMS vehicles ready for response. Plus police are “on the street” all hours of the day and night and there is no call out time to put on gear and leave a fixed station. Thus police should reach the patient sooner than EMS personnel. In Rochester this was achieved in half of cardiac arrests but other communities reported less success. In King County the police were involved in a minority of arrests. The reasons for the underwhelming spread of police defibrillation are multiple and involve dispatch center policies, culture, mission, cost,
extra training, and availability (this is especially a problem in busy departments). Our experience in King County points to dispatch centers as the largest impediment to effective dispatching of police to cardiac arrests. The tipping point for police to be dispatched to all cardiac arrests has not yet been reached.

**Impact:**
There is high potential to improve survival assuming there is high acceptance.

**Implementation:**
Very difficult due to a variety of issues including dispatch policies, culture, training, cost and leadership.

**Science:**
The initial studies from Rochester were observational in nature but provide compelling support for police involvement in cardiac arrests. A literature summary of police AED programs reports a mixed experience but overall a modest benefit. King County conducted a prospective pilot of police AEDs in two communities each with approximately 100,000 persons. The experience in King County was positive but the magnitude of the benefit was small.

**Articles:**

*After a 2-year pilot in the early 1990s, Rochester, MN permanently adopted a non-tiered cardiac arrest response model, where police and EMS personnel provide CPR and defibrillation to OOHCA victims. Rochester has one of the highest OOHCA survival rates in the world.*


*In Miami-Dade County police vehicles equipped with AEDs were dispatched simultaneously with EMS. Response times and survival from VF/VT rhythms improved significantly after police defibrillation was implemented.*

Police officers were trained in the use of and equipped with AEDs in Allegheny County, PA. Time from 9-1-1 call to first defibrillation decreased and survival increased significantly in those patients who were first shocked by police vs. EMS.


While this community did not see an improvement in survival with police defibrillation, they did find that the time intervals from 9-1-1 call to scene and 9-1-1 call to defibrillation were significantly shorter by 1.6 mins (p=0.05) and 4.8 mins (p=0.008), respectively.


Two cities in King County, WA implemented a 2-year pilot of training and equipping police officers with AEDs. Police involvement in resuscitations was measurable, but limited, due to challenges in achieving simultaneous police and EMS dispatch.


This literature review of police AED program implementation in several communities presents varied results in survival from OOHCA. However, a meta-analysis of survival and time from 9-1-1 call to defibrillation from all communities showed significant improvement with police AED programs, indicating great potential for the success of these programs.


One third of state police agencies surveyed equipped their vehicles with automated external defibrillators, and among those that did, most equipped only a minority of their fleet. Most state police agencies reported training their officers in automated external defibrillator usage and CPR. Increasing automated external defibrillator deployment among state police represents an important opportunity to improve first responder preparedness for cardiac arrest care.

-From the conclusion


The above two articles did not find a statistically significant improvement in survival after the implementation of their police AED programs.

3. Change building codes to require PADs

Description:
The rationale for building codes requiring AEDs is based on fire codes requiring sprinklers in public buildings. Several states require certain public facilities to have AEDs. For example Florida requires AEDs at all public and commercial exercise facilities. The federal government passed a law in 2000 requiring AEDs in federal buildings open to the public (reference 6).

Assessment:
It makes sense that certain locations should have AEDs. The legal route to make it happen through building codes or specific administrative laws is relative new.

Impact:
The impact is potentially large but it will take many years to implement.

Implementation:
The biggest impediment is cost and the resistance of business who perceive such “safety laws” as unfunded mandates.

Science:
Other than descriptive studies that define locations with a high incidence of cardiac arrest there are no data to support the benefit of mandatory AEDs at selected sites.


A primer for developing legislation related to public AED programs, with sample legislation sections included.


Review of the effectiveness of public access defibrillation programs, suggesting that targeting areas with high cardiac arrest incidence is most effective.


Two articles describing the pros and cons of PAD programs. Both concede that PAD programs may be effective if AEDs are placed in high impact areas, but the con article argues that these programs will have little impact at a population level.


Compilation of AED laws in all states. These data were current as of 2013.

4. Register AEDs and notify volunteers of cardiac arrests and location of AEDs

Description:
The goal of registering AEDs is for dispatch centers to have location information and potentially notify callers of nearby AEDs. This process can be manual (with the dispatcher verbally describing the location to the caller) or automated through web apps (such as PulsePoint – pulsepoint.org). In the PulsePoint system the recipient (who has downloaded the app on his or her smart phone) is sent a map with the location of the arrest
and nearby AEDs (which have previously been registered).

**Assessment:**
The PulsePoint system must be purchased by a dispatch center if the app is to be integrated into the dispatch system. PulsePoint currently only sends alerts about cardiac arrests in public locations. Issues of privacy have limited its use to public events. The PulsePoint Foundation intends to conduct a pilot with alerts provided for arrests in private homes. There is a cost for dispatch centers to utilize the PulsePoint system. Other limitations involve the person with a smart phone notification dropping everything and rushing to the site of the alert (and hopefully picking up a nearby AED).

**Impact:**
This is an evolving technology. Currently it offers limited utility.

**Implementation:**
The cost is relatively modest. The PulsePoint system initially costs a dispatch center about $10,000 and then about $5,000 annually. There is no cost to those who download the free app.

**Science:**
There are a few anecdotal reports of the dispatcher notifying callers of nearby AEDs (in one event in King County the dispatcher informed the caller that an AED was located in the house – the caller had forgotten about the AED – and it was attached prior to fire department arrival) and of the PulsePoint system activation where an app is used to notify a volunteer that a cardiac arrest is nearby. There are no data other than the anecdotal reports.

**Articles:**

   "A working link between emergency dispatch and an AED registry may provide an opportunity to improve resuscitation." - from abstract


   "Limited AED accessibility at the time of cardiac arrest decreased AED coverage by 53.4% during the evening, nighttime, and weekends, which is when 61.8% of all cardiac arrests in public locations occurred." – from abstract

“Although the new Mobile AED Map reduced the travel distance to access and retrieve the AED, it failed to shorten the time.” – from abstract


“Policy makers should consider strengthening PAD policies by enacting laws that can reduce the time from collapse to shock, such as requiring the strategic placement of AEDs in high-risk locations or mandatory PAD registries that are coordinated with local EMS and dispatch centers.” - from abstract


“Improvements of the SMS alert service by laypersons, the EMS, and through technical adjustments, could increase the number of laypersons who provide early aid.”-from abstract


Door-to-door surveying is a feasible, but time-consuming method for identifying AEDs in high employment areas. Few buildings reported having AEDs and few permitted visualization, which raises concerns about AED access. To improve cardiac arrest outcomes, efforts are needed to improve the availability of AEDs, awareness of their location and access to them.


Using social media and crowd sourcing, the authors engaged a mobile workforce to complete identification of AEDs in the community. This was a pilot, feasibility study.
3. Advanced Life Support

Strategies in this category relate to airway management and the role of medications.

1. Advanced airway management

Description:
There are two issues involving advanced airway control. The first is whether EMTs should learn the skill of laryngeal mask airway (LMA) placement and the second is whether endotracheal intubation is the preferred advanced airway for paramedics. The airway control currently provided by EMTs consists of an oral airway (which does not protect the airway) and a bag valve mask. The term advanced airway management refers to protection of the airway with an endotracheal airway (which provides complete protection) or a laryngeal mask airway (LMA) (which provides generally good airway control), which are currently provided by paramedics. In a cardiac arrest, advanced airway management prevents aspiration of saliva or vomit and ensures good oxygenation. In some systems paramedics are authorized to provide paralytic medication to facilitate the endotracheal intubation (especially if the patient has a gag reflex or is conscious or semi-conscious).

Assessment:
The debate is not whether endotracheal intubation (considered the gold standard of airway management) protects the airway but whether other types of airways (such as LMA) are just as (or almost as good as) endotracheal intubation. Advocates for teaching EMTs how to use LMAs argue that the skill is easy to teach and will protect the airway sooner than waiting for paramedics. (A skeptic could say that no advanced airway is needed and that good bag valve masking is sufficient.) This issue will likely never be studied in a controlled fashion, as some type of advanced airway is considered essential to insure adequate oxygenation and prevent aspiration. It might be possible to pilot test EMT placement of LMAs (perhaps in a before and after fashion or with contemporaneous controls). There are training cost and maintenance of skill issues with EMTs using LMAs.

Impact:
Advanced airways likely improve the outcome from cardiac arrest through prevention of aspiration and maintenance of adequate oxygenation. Theoretically if EMTs can proficiently learn this skill, there may be an improvement in survival.

Implementation:
Until there is evidence of EMTs safely using LMAs, implementation is mostly theoretical. There seem to be many strong opinions on the best type of airway making studies difficult.
Science:
There are several studies measuring the skill of paramedics in placing several types of airways. Some studies have questioned whether paramedics can reliably place endotracheal tubes and others have shown that paramedics, when properly trained, are as proficient as physicians in the skill. One study demonstrated that the interval from collapse to placement of advance airway was associated with survival. There have been no studies directly comparing, in a randomized fashion, endotracheal intubation with LMA or the type of advanced airway with basic airway control and the relationship to survival. There have been no studies of EMTs using LMAs,

Articles:

Conclusions drawn from large observational studies comparing basic and advanced airway methods are mixed and may be influenced by unmeasured confounders. There is sufficient clinical equipoise to support a randomized trial comparing basic and advanced airway interventions.


Large observational study (649,359 patients) from Japan found worse neurological outcomes for patients treated with an advanced airway compared to patients receiving basic airway management.


Data from a national cardiac arrest registry in Korea indicate that risk-adjusted survival to hospital discharge is no different for endotracheal intubation compared to bag-valve mask ventilation but that survival to discharge was worse for laryngeal mask airway compared to bag-valve mask ventilation.

Secondary analysis of data from the ROC PRIMED trial comparing advanced airway management techniques. Successful endotracheal intubation was associated with better patient outcomes when compared to supraglottic airway management.


Large observational study from Japan finds better neurological outcomes for patient treated with endotracheal intubation compared to laryngeal mask airway or an esophageal obturator airway.


Adjusted odds of survival were greater in patients intubated with paralytics compared to patients intubated without paralytics. These findings could explain the adverse relationship between intubation and survival reported in systems that do not use paralytic agents.


Paramedics did not perform endotracheal intubation as well as anesthetists, but their performance with endotracheal intubation and other airway management techniques was similar to performance by other medical professionals.


Faster intubation times may increase the odds of survival in prehospital cardiac arrest.


The protocol for a feasibility study which provides the template for a large-scale prospective randomized trial of airway management during OHCA.
2. Medications

Description:
It is widely believed that medications are vital to successful resuscitation. For decades, epinephrine and antiarrhythmic medications have been the pharmacological workhorses during resuscitation. Yet there are no randomized clinical trials showing the benefit of medications.

Assessment:
There are precious little data to support pharmacological intervention for patients in cardiac arrest. The Resuscitation Outcomes Consortium (ROC) Amiodarone, Lidocaine, or neither (Placebo) Study (ALPS) Trial is expected to finish in 2015 and will provide evidence whether antiarrhythmic therapy improves survival from refractory VF (VF which does not convert after one shock).

Impact:
A proven beneficial pharmacological intervention, assuming it is widely provided, would be very beneficial. Currently epinephrine is widely used for all cardiac arrests with many convinced it is beneficial (see article 2 above). An RCT of epinephrine versus placebo would be difficult to perform. The ROC is considering a dose response RCT of epinephrine.

Implementation:
Pharmacological therapy is currently the standard of care.

Science:
A Swedish study compared regular pharmacological therapy (epinephrine and antiarrhythmic medications) with no medication. There was no difference in survival (references 1 and 2).

Articles:

Prospective trial of 1183 patients with out-of-hospital cardiac arrest who were randomized to advanced cardiac life support (ALS) with IV drug administration versus ALS without IV drugs. Patients randomized to IV drugs had higher short-term survival, but no improvement in survival to hospital discharge or long-term survival.

Retrospective evaluation of trial described in reference #1 above comparing outcomes in patients who received epinephrine vs no epinephrine during ALS care. Recipients of epinephrine had improved short-term survival, but worse survival to hospital discharge, neurological status at hospital discharge and one-year survival.


Prospective trial of 534 patients with out-of-hospital cardiac arrest who were randomized to epinephrine versus placebo. Epinephrine recipients were more likely to achieve return of spontaneous circulation, but had no statistically significant improvement in survival to hospital discharge.


Prospective trial of 504 patients with out-of-hospital cardiac arrest due to ventricular fibrillation who were randomized to amiodarone or placebo in addition to all other standard resuscitation efforts. As compared with placebo, amiodarone recipients had a significantly higher likelihood of survival to hospital admission, but no difference in survival to hospital discharge.


Prospective trial of 347 patients with out-of-hospital cardiac arrest due to ventricular fibrillation who were randomized to lidocaine or amiodarone. As compared with lidocaine, amiodarone recipients were more likely to be admitted alive to hospital, with no differences between the two groups in survival to hospital discharge.


Observational study of 665 patients with out-of-hospital cardiac arrest due to ventricular fibrillation who did or did not receive IV procainamide as second-line therapy during the course of resuscitation. Procainamide did not have a definitive impact on rates of hospital admission or discharge.

Observational study of drug use among 264 Emergency Medical Service (EMS) agencies participating in the Resuscitation Outcomes Consortium, and encompassing more than 16,000 out-of-hospital cardiac arrests. Salient findings were the considerable variability in drug use among EMS agencies without a definitive improvement in survival to hospital discharge.


Observational study of 1721 patients with witnessed out-of-hospital cardiac arrest due to ventricular fibrillation who did or did not receive prophylactic lidocaine upon first return of circulation. Prophylactic lidocaine was consistently associated with a lower incidence of recurrent cardiac arrest, but without a definitive impact on survival to hospital admission or discharge.

3. Ratio of paramedics to population and optimal number of EMS responders

Description:
There is debate in the EMS world about the optimal ratio of paramedics to the population and the number or responders to a cardiac arrest. The range of responders is 2-7.

Assessment:
The ratio of paramedics to population relates to the issue of skill maintenance. It is assumed that the more advanced procedures performed - such as intubation and management of cardiac arrests - the better the skill. It is very difficult to study this assumption as skill proficiency results from a combination of training, continuing education and repetition.

Impact:
The impact is impossible to determine.

Implementation:
Changing staffing patterns in EMS agencies is difficult. In many communities EMS vehicles are staffed with two paramedics or one EMT and one paramedic. In communities that utilize a tiered-response the first-in vehicle is usually staffed with two EMTs and the second-in unit is staffed with two paramedics.
Science:
There are no data on either issue. A series of articles in USA Today described EMS systems in several communities and speculated that communities with fewer paramedics had higher survival rates owing to the higher skill levels.

Articles:


"...study the cognitive strategies used by expert paramedics to contribute to understanding how paramedics and the EMS system can adapt to new challenges” – from abstract


"Persistent past and current volume effects suggest that policy and managerial implications in EMS should be directed at retention efforts to take advantage of individual learning by paramedics” - from abstract


"Increased survival to hospital discharge may be associated with decreased response time interval and with the use of a two-tier EMS system as opposed to a one-tier system. The data available for this analysis were suboptimal.” - from abstract


“Survival from out-of-hospital cardiac arrest varies with the type of ambulance crew and length of experience after qualification. Experience in the field seems important as paramedics achieve better survival rates after just 1 year’s experience, while technicians need to have more than 4 years’ experience to improve survival.” - from abstract


"Compared with the one on-scene ELST group, the three on-scene ELST group was associated with the improved one-month survival with favorable neurological outcome from OHCA in Osaka City.” – from abstract
Strategies in this category relate to hypothermia and resuscitation centers.

1. Hypothermia

Description:
In 2002 two randomized controlled trials demonstrated improved survival and neurologic outcome in patients treated with hypothermia following successful resuscitation from VF cardiac arrest. Both studies implemented cooling in the hospital with a goal of 33 degrees Celsius for 24 hours. Compared to patients treated with usual care (a temperature ~37.3-37.6°C), subjects treated with hypothermia had improved survival and neurological outcome. As a result of these studies and subsequent supporting retrospective studies hypothermia was widely used. The initial trials were only for VF patients but hypothermia practice spread to all patients, regardless of rhythm, and even for patients prior to arrival at hospital and even patients who did not even have return of spontaneous circulation as it is the only post-resuscitation care modality to be shown to improve outcome.

Assessment:
The recent trial by Kim et. al. showed that prehospital hypothermia (administered after return of spontaneous circulation) is not of therapeutic benefit (reference 8). The recent trial by Nielsen et. al. showed that 36°C is comparable to 33°C in terms of survival and neurological recovery (reference 9). Nielsen’s study does not answer the questions of whether 36°C is equivalent to ambient air. The role of temperature management post resuscitation is unclear. Unanswered questions revolve around controlled 36°C versus ambient air (presumably with active control of fever), timing of hypothermia (intra-arrest? ED? ICU?), and the role of hypothermia for in-hospital cardiac arrest.

Impact:
A bit unclear at this point in light of the two recent studies.

Implementation:
Certainly for now (until there are more studies) 36°C is a reasonable goal of hospital instituted care. This should be easier to implement than hypothermia of 33°C.

Science:
Hypothermia became the standard of care but questions remain regarding timing, dose (temperature) and duration.

Articles:
Improved outcome for OHCA comatose survivors as compared to historical controls.


Preliminary study showing improved outcome after OHCA using mild hypothermia.


"...preliminary observations suggest that treatment with moderate hypothermia appears to improve outcomes in patients with coma after resuscitation from out-of-hospital cardiac arrest” - from abstract


"...Mortality at six months was 41 percent in the hypothermia group (56 of 137 patients died), as compared with 55 percent in the normothermia group (76 of 138 patients; risk ratio, 0.74; 95 percent confidence interval, 0.58 to 0.95). The complication rate did not differ significantly between the two groups.” - from abstract


"These pilot data suggest that infusion of up to 2 L of 4 degrees C normal saline in the field is feasible, safe, and effective in lowering temperature. We propose that the effect of this cooling method on neurological outcome after cardiac arrest be studied in larger numbers of patients, especially those whose initial rhythm is ventricular fibrillation.” – from abstract

"In adults who have been resuscitated from out-of-hospital cardiac arrest with an initial cardiac rhythm of ventricular fibrillation, paramedic cooling with a rapid infusion of large-volume, ice-cold intravenous fluid decreased core temperature at hospital arrival but was not shown to improve outcome at hospital discharge compared with cooling commenced in the hospital." – from abstract


"quality of evidence is very low" – from abstract


"use of prehospital cooling ...did not improve survival or neurological status among patients resuscitated from prehospital VF or those without VF." – from abstract


"In unconscious survivors of out-of-hospital cardiac arrest of presumed cardiac cause, hypothermia at a targeted temperature of 33°C did not confer a benefit as compared with a targeted temperature of 36°C.” - from abstract

2. Care mapping

Description:
Care mapping refers to treating cardiac arrest patients post resuscitation in a standardized fashion with meticulous blood pressure control, respiratory status, rhythm managements, fever control, and treatment of infections.

Assessment:
Care mapping seems to make sense in that post-resuscitated patients are unstable and often critically ill. Consistent and attentive
post-resuscitation care makes for good clinical practice, especially in the areas of oxygenation, ventilation, and hemodynamics.

**Impact:**
The impact is hard to determine.

**Implementation:**
Since post resuscitated patients are all admitted to intensive care units no extra costs are required.

**Science:**
This strategy is based on common sense that good and consistent clinical care will improve outcomes. Emerging studies have suggested improved outcomes with meticulous management of oxygenation, ventilation, and hemodynamics.

**Articles:**

   A summary of current hospital-based performance measures for treatment of sudden cardiac arrest, with suggestions for how to select appropriate performance measures and avoid potential pitfalls.


   Provides examples on how to create effective guidelines based on a process employed by the American College Cardiology and the American Heart Association. Also presents evidence from several studies that suggest adherence to guidelines in hospitals leads to better patient outcomes.


   In a review of studies examining guideline-based care of patients with coronary artery disease, the authors found a “dose-response” association between adherence to guidelines and performance measures and outcomes.


   Before-after study examining the effect of implementation of a standardized hospital
treatment protocol for out of hospital cardiac arrest found a significant improvement in discharge with favorable neurological outcome.


A 5-year, prospective, population-based study of the effect of evidence-based guidelines and community partnerships on outcomes for patients with cardiovascular disease. At the population level, one-year mortality was not changed, but outcomes at the individual patient level (e.g. re-hospitalization rates, survival) and provider level (e.g. prescribing patterns) improved.

3. Resuscitation centers

Description:
This strategy steers resuscitated patients (or even patients with ongoing CPR) to hospitals with a high volume of managing resuscitated patients. Presumably these hospitals might be designated as resuscitation centers or resuscitation centers of excellence though there is currently no national designation of such centers.

Assessment:
It would be difficult to study this issue as “sicker patients” may selectively be brought to designated resuscitation centers. Controlling for patient mix would be difficult.

Impact:
If data pointed to convincing benefit there may be a modest improvement in outcomes.

Implementation:
Implementation is a moot issue without better data.

Science:
There are no data to suggest that resuscitation centers perform better than non-designated hospitals or that hospitals managing a higher volume of resuscitated patients fare better than hospitals with lower volume. The belief that resuscitation centers may improve outcomes derives from data pointing to better outcomes for hospitals with high volume cardiac surgery compared to hospitals with lower volume.

Articles:

After the implementation of a regionalized cardiac care system in Los Angeles County, neurologically intact survival from OOHCA improved as compared to historical data.


Prospective observational study of post-resuscitation OOHCA patients transferred from an ED to a regional cardiac resuscitation center (CRC). While the patient sample size was small, the researchers found that one-third of patients transferred to CRCs survived with good neurological outcome.


This prospective observational study showed that implementation of a regionalized post-resuscitation cardiac care system was feasible and clinically effective.


A policy statement from the AHA outlining the justification for regional systems of care for OOHCA patients. It also describes the need for evidence-based guidelines and standards for the categorization, verification, and designation of various components of these systems.
4. Percutaneous coronary intervention (PCI)

Description:
PCI is acknowledged as beneficial for patients with proven ST elevation myocardial infarction (STEMI) as the cause of the cardiac arrest. What is less clear is the benefit of PCI for patients without STEMI.

Assessment:
For patients with ST-elevation, acute coronary catheterization appears to offer benefit.

Impact:
The impact is likely to be modest.

Implementation:
Implementation is limited by the need for 24/7 staffing of coronary catheterization laboratories. If cathing became standard of care it would likely lead to regionalization of post-resuscitation care to hospitals with cath capability.

Science:
There appears to be a growing consensus that emergency coronary intervention for acute ST-elevation myocardial infarction (STEMI) associated cardiac arrest is warranted and beneficial.


   Observational study of 72 consecutive patients admitted to hospital after out-of-hospital cardiac arrest (OHCA) who underwent emergency coronary angiography. About 50% of the patients presented with VF arrest, 32% had ST elevation on hospital admission, 29% ST depression and 17% had left bundle branch block (LBBB). The diagnosis of acute myocardial infarction was established in 27 (37.5%) patients. Of the patients with AMI, emergency percutaneous coronary intervention (PCI) was successful in 24 (33%). In a logistic regression analysis, the presence of coronary stenosis, recent occlusion or ruptured plaque and attempted PCI were not independent predictors of survival, thus making it uncertain whether PCI of occluded arteries in this patient population confers a favorable impact on outcome.

Observational study of 269 patients with cardiac arrest due to ventricular fibrillation or tachycardia without associated ST segment elevation of whom were treated with therapeutic hypothermia, 26% of whom in addition received early cardiac catheterization and 29% of whom had late catheterization. An acute coronary occlusion was discovered in 26% of patients with early cath and 29% of those receiving late cath; approximately one-third of both groups received percutaneous coronary interventions (PCI). Early cardiac catheterization was independently associated with a significant improvement in survival to hospital discharge.


Observational study of 714 patients with out-of-hospital cardiac arrest, 435 of whom had no obvious noncardiac cause for arrest and underwent immediate coronary angiography and percutaneous coronary interventions (PCI). An acute coronary lesion was found in 128 of 134 patients (96%) with ST segment elevation and in 176 of 301 patients (58%) without ST segment elevation. In a multivariate analysis, survival to hospital discharge was significantly higher in recipients of successful PCI (compared to those with no or failed PCI) regardless of their ECG presentation (ST segment elevation or not).


Retrospective study of 240 patients with out of hospital cardiac arrest due to ventricular fibrillation or tachycardia who received early (≤ 6 hours) or deferred (>6 hours) cardiac catheterization after hospital admission. Recipients of early rather than late catheterization were more likely to have ST segment elevation (75% vs 20%) on ECG, but the frequency and extent of identified coronary stenoses in those undergoing catheterization were similar in the two groups. Percutaneous coronary interventions (PCI) were performed in 62% of patients in the early group and 7% of those in the late catheterization group. In a propensity score-adjusted analysis, survival to hospital discharge was greater in recipients of acute than deferred cardiac catheterization.

This study focused on relating the findings on coronary angiography to presenting ECG findings in 91 patients with out-of-hospital cardiac arrest. Significant coronary artery disease was found on angiography in 86% of patients. Presumed acute coronary lesions were identified in 85% of patients with ST segment elevation and 33% of patients with other ECG patterns. The study concluded that even in the absence of ST segment elevation, acute culprit coronary lesions may be present as the potential trigger for cardiac arrest.


Observational study of 84 patients with no obvious noncardiac cause of out-of-hospital cardiac arrest who underwent immediate angiography. The majority of patients had cardiac arrest due to VF/VT (93%) and had ST segment elevation (42%) or left bundle branch block (21%) on ECG. On angiography, 48% of patients had evidence of a recent coronary artery occlusion, the majority of whom underwent successful angioplasty. Successful angioplasty was an independent predictor of improved survival to hospital discharge.


Observational study of 5958 patients in King County, WA with attempted resuscitation from out-of-hospital cardiac arrest among whom short and long-term survival outcomes were compared between recipients of an acute coronary intervention (PCI) and/or therapeutic hypothermia. In 80% of patients cardiac arrest was attributable to a cardiac cause; VF/VT was the presenting arrest arrhythmia in 70% of patients. Of the 1001 patients discharged alive from the hospital, PCI was performed in 38% and therapeutic hypothermia in 25%. Receipt of these interventions was associated with a significantly higher likelihood of survival to hospital discharge and survival at 5 years. The combination of PCI and hypothermia achieved better outcomes than either intervention alone.
5. EMS System

This includes a diverse set of strategies such as a registry for cardiac arrest and medical direction as well as how many responders are needed to provide optimal care.

1. Cardiac arrest registry

Description:
A cardiac arrest registry provides measurement of current performance and can identify areas within the system that require modification or change. If changes are made in the system, whether it be new protocols, further training, changes in operating procedures, etc., a registry provides the documentation of the desired outcomes. Registries can be simple collections of key demographic and performance information (20 or so variables) or it can be more comprehensive and involve numerous variables. The most comprehensive registries involve research databases with detailed data dictionaries maintained by the Resuscitation Outcomes Consortium communities. One of the mantras of the Resuscitation Academy is “measure, improve, measure, improve”. Most EMS programs in the US do not maintain a registry or participate in a multi-site registry.

Assessment:
It seems unnecessary to prove such a benefit since by definition one cannot show improved outcomes if one doesn’t measure them and the antecedent events and therapies leading to the outcome. There is currently no mandate to maintain a registry and there is no national registry. The closest registry to a national registry is CARES (Cardiac Arrest Registry to Enhance Survival). CARES, with initial support from CDC and Emory University, started in 2010. Currently 100 communities and 6 states participate in CARES (mycares.net).

Impact:
Potentially there is a huge impact with a national registry.

Implementation:
CARES is currently unable to accept new communities owing to resource constraints. There is no cost for communities to participate. Funding for CARES comes from a variety of organizations and foundations.

Science:
There are no data showing that cardiac arrest registries improve community cardiac arrest survival rates though it is widely believed that measuring cardiac arrest events and outcomes is the very first step on the journey to achieve improvement.
Articles:
"OHCA and IHCA registries are invaluable in advancing our understanding of resuscitation care, as well as variations in international practice." - from abstract

Describes the development of the Resuscitation Outcomes Consortium registry, including the case definition and description of key variables.

Describes the design of the CARES registry and provides a summary of the data collected during the first 5 years of existence.

Highlights the differences in key process and outcome measures across EMS systems from 5 countries. The authors cannot conclude whether the measured differences truly exist or if they are due to differences in the way data were collected and measured.

Shows that it is possible to establish a large cardiac arrest registry in a resource-limited setting.

2. Cardiac arrest as a reportable condition

Description:
Making cardiac arrest a reportable condition, much like many serious transmissible infectious diseases are reportable, would “jump start” the participation of EMS systems in cardiac arrest registries. It is assumed that when communities see their performance and measure it against other communities they will be motivated to improve (assuming peer communities are performing
better). Or perhaps a political spotlight shining on the relatively poor performance may bring about change. For communities currently participating in the CARES registry they are already reporting all cardiac arrests.

**Assessment:**
Reportable diseases currently fall into the domains of infectious disease and cancer. Registries are maintained at the state level and information is then shared so national surveillance and reporting can occur.

**Impact:**
The impact is potentially huge assuming there is data integrity.

**Implementation:**
An unfunded mandate for national reporting is likely to have little value since the integrity of the data will be less than optimal. For national reporting to lead to improvements at the local and state level resources are required to train staff and to maintain a reporting system.

**Science:**
There are no data showing a relationship to outcome. In the infectious disease world, it is assumed that good reporting of target diseases is the first step toward understanding and eradication or control.

**Articles:**

The CARES registry was developed for OOHCA surveillance, and it serves as an example of a surveillance registry that can provide benefit in evaluating OOHCA trends and ways to improve patient care.

3. Quality improvement (QI) for cardiac arrest

Description:
If “measure, improve” is the bedrock for increasing cardiac arrest survival, then an ongoing QI program is the vehicle to accomplish measurement.

Assessment:
QI activity can be large or small. At its very least QI is the means to engage in a cardiac arrest registry and at the most it is a means providing detailed feedback to all EMS providers present during a cardiac arrest.

Impact:
Ongoing QI has the potential to drive improved performance and thus improve survival rates.

Implementation:
QI is not without cost. A minimal QI program (for example, in order to maintain a local registry or to participate in CARES) would require about one hour of time for every cardiac arrest. This assumes there is a mechanism for event data to flow “automatically” to the person responsible for QI. To maintain a basic QI program for cardiac arrest in a population of 1 million requires 1 full-time employee. More comprehensive QI programs that go beyond merely maintenance of a registry will require more staff time. For example some EMS program have QI staff to analyze cardiac arrest events (ex post facto) and provide summary information about CPR metrics and care provided to the patient, and hospital outcome information. Communities with comprehensive QI collect voice recordings of the resuscitation, all ECG and other telemetry information, run reports, and hospital clinical information which are summarized and provided to the EMS providers.

Science:
There are no data showing a relationship between quality improvement programs and improved cardiac arrest survival. It is widely believed, however, that measurements achieved through QI lead to improvements.

Articles:

An argument that measurement is the foundation for EMS system improvement.
2. van Diepen S, Abella BS, Bobrow BJ, Nichol

Description of a comprehensive effort to implement guideline-based practices across many different EMS systems and improve overall survival within 5 years.


Analysis and targeted feedback related to the quality of CPR by prehospital providers led to improvements in resuscitation quality measures.


A before-after study assessing an initiative to improve prehospital provider CPR found an improvement in CPR quality and patient outcomes.


“It is feasible for a public health agency to implement a voluntary, statewide data-collection system and educational network to determine and improve survival from OHCA.” - from abstract


Incremental changes to the health care process, rather than changes by individual medical providers, will lead to improved outcomes.

4. QI for T-CPR

Description:
Quality improvement for T-CPR is the means to measure performance. Without ongoing QI the performance standards of T-CPR cannot be measured. Given the turnover in most dispatching agencies, constant training and reinforcement about individual and collective performance is likely to be necessary.
Assessment:
To be effective T-CPR requires ongoing measurement and feedback to the call receivers and dispatchers.

Impact:
If there is meaningful T-CPR QI, there is potential to dramatically increase survival rates.

Implementation:
QI is not without cost. At the very least the dispatch center must retrieve the digital recording of the every cardiac arrest call to determine the key performance metrics. More comprehensive would be a QI program that provided direct feedback to the telecommunicators.

Science:
There are no data showing a relationship to outcome. Measurement requires an ongoing QI program.

Articles:


Detailed review of TCPR calls with suggestions for metrics that should be measured by all dispatch agencies.
Extends the Utstein recommendations to include items all systems should measure to evaluate dispatch performance during cardiac arrest.


A review of the current literature does not show a survival benefit for TCPR, but does indicate that bystander CPR rates are improved.

Estimates the incidence of cardiac arrest calls among all emergency dispatch calls. Describes the percent correctly identified as cardiac arrest and discusses strategies for improved identification of cardiac arrest by call receivers.


A before-after analysis of a TCPR quality improvement program showed improvements in bystander CPR rates and patient outcomes.

Focuses on the rationale and evolving science behind dispatch CPR instructions, as well as some best practices for implementing and measuring dispatch-assisted CPR.


Shows how review of TCPR records can identify patient populations that may be underserved.


5. Create a culture of excellence

Description:
The term “culture of excellence” is a cliché, but it does contain an obvious truth. The expectations set by the leadership diffuse throughout the organization. In some EMS organizations, a culture of excellence is typified by the assumption that every patient in VF will be transported to the hospital with a pulse and blood pressure. When they “work” a cardiac arrest, they bring in the stretcher (during CPR) because they assume the patient will be resuscitated.

Assessment:
Medical and administrative leadership of EMS organizations range from the excellent to the terrible. It might be useful for academicians with business expertise to study EMS systems and help define the successful and less successful managerial models.

Impact:
The impact is potentially huge.

Implementation:
There are few proven formulas to create a culture of excellence. We know it is important but don’t know how to achieve it. Clearly leadership (medical and administrative) is a key factor.

Science:
There are no data showing a relationship between culture of excellence and cardiac arrest survival. This is primarily because there is no objective way to define a culture of excellence.

Articles:

Suggests that “Continuous quality improvement” allows for the maintenance of a “standard of excellence.”

Author poses these qualities to help EMS agencies thrive.


Statement on the evolution of EMS systems and quality.


Suggests a link between EMS officers’ management and patient care.

6. Establish a medical model

Description:
An EMS system based upon a medical model is one in which a medical director plays a large role in determining and supervising the quality of medical care. Specifically, a medical model of EMS is a system in which the medical director is responsible for the following 7 areas:

1. protocols for EMTs, paramedics, and dispatchers
2. medical supervision - online and offline
3. evidence-based practice
4. ongoing medical QI
5. training and continuing education
6. controlled substance policies
7. medical discipline

Assessment:
Lack of a medical model is like playing a symphony without a conductor. A medical model does not require that the physician director run the entire system. In fact, the less administrative involvement by the medical director, the better. The medical director should be responsible for the quality of medical care and establish high expectations and see that they are being met. The EMTs and paramedics must be accountable to the medical director for the quality of their care. The ideal system would have the administrative director responsible for budget, operations and personnel matters and the medical director responsible for patient care. And in the best of all words the two directors would work closely in partnership since their responsibilities complement each other. The medical director should not deal with hiring, though he or she should have a say in who is hired. The doctor should not fire anyone, though we expect him or her to work with the administrative director to limit, suspend, or refuse to medically assume
responsibility for an EMT or paramedic whose medical care is substandard. In Seattle and King County, there is a phrase that encapsulates the critical role of the medical director: The EMT or paramedic practices under the medical license of the medical director.

In essence, the clinical buck stops with the medical director.

**Impact:**
A strong medical model can have a huge impact on survival rates.

**Implementation:**
There is no guidebook to follow and probably many if not most EMS programs think they have a medical model. The test is whether the medical director has responsibility for all the seven areas above.

Medical directors are appointed in various ways. Whatever the process, the medical director must have the authority to supervise a system that uses a medical model of EMS care. The medical director must clearly state and constantly promote high expectations, and the EMTs and paramedics must be accountable to the medical director for their patient care.

It is desirable (though not always possible) that the medical director has an academic appointment and be jointly appointed by the EMS administrative director and by the academic dean or department chair. An academic appointment ensures accountability within a larger medical community (namely the medical school). Moreover, an academic physician is generally one who is committed to furthering learning, and one who probably has knowledge about epidemiological principles and research methodologies. This is not to say that every medical director must conduct research – far from it, but only that the director must understand the benefits and limitations of data, and know how to interpret (and not over interpret) this information. An academic medical director has access to all the expertise of an academic medical center and can turn to colleagues in cardiology, anesthesiology, pediatrics, obstetrics, trauma surgery, endocrinology, biostatistics, epidemiology, preventive medicine, health services, and toxicology to get answers about clinical issues and to seek help in guiding policy.

For communities that are geographically distant from an academic medical center, there are opportunities to create bridges with medical schools. Many deans and department chairs in emergency medicine would welcome a conversation with a community’s elected officials or its EMS administrative director and would be pleased to help establish a clinical appointment for the community’s medical director.
The EMS program can provide training opportunities for emergency medical residents and help partner with the medical school on EMS fellowships. The medical center can provide clinical expertise, communications expertise, database management, and managerial experience and can cooperate with local medical directors to establish regional consortia of EMS medical directors and programs. An academic medical center, after all, has a mission to serve the larger community, and the goodwill and reciprocity generated by this kind of effort can reap big dividends.

Science:
There are no studies of the relationship of the medical model or medical (or administrative) leadership and the quality of the EMS program.

Articles:

"...study demonstrated that EMS agencies with a paid medical director and agencies with medical director interaction with EMTs in the previous four weeks were more likely to have prehospital cardiovascular procedures in place" - from abstract


"We noted statistically significant variations in scope of practice by rural vs. urban setting, medical director involvement, and type of EMS service" - from abstract


Describes roles of EMS medical directors and models of EMS systems


...resource document provides a snapshot of the status of state EMS medical direction” - from abstract


This paper describes a curriculum for physician fellowship program for training in EMS core content.


American Board of Medical Specialties (ABMS) develops “core content” for emergency medical services (EMS) as a subspecialty of emergency medicine.
This category considers potentially promising but as yet unproven therapies for SCA.

1. **Develop defibrillators that can accurately detect the underlying cardiac rhythm while CPR is being performed.**

**Description:**
An AED that can detect VF with ongoing CPR would eliminate the need for pauses in CPR to determine rhythm. Current AEDs require that CPR cease for the algorithms to determine if VF is present. The time for this determination varies but can range from 10-15 seconds. If charging is required after VF is determined to be present, it may take another 10-15 seconds for the capacitor to fully charge. Thus the interval of no CPR can be up to 30 seconds before a shock can be delivered. The CPR fraction is an important predictor of which patients will achieve ROSC and survival. CPR fractions of 90% are targeted but difficult to achieve due to pauses. If the rhythm could be known and continuously available, the rescuer could charge during CPR and pause only for shock delivery (< 5 sec.). In addition, if an organized rhythm is achieved after shock and CPR is resumed until a pulse can be detected, then CPR artifact often masks the underlying rhythm which means the rescuer might not be aware of a refibrillation until the next time they pause for a rhythm check. The ability to monitor the patient during CPR and detect a transition in the rhythm from an organized rhythm to VF would allow immediate shock if desired. Furthermore the ability to monitor the rhythm during CPR allows therapeutic interventions to be anticipated and preparations to be made to apply them without stopping CPR for rhythm confirmation.

**Impact:**
Modest – such a technological advance would have no downside and might improve survival by reducing the amount of hands-off time (lack of chest compression) during a resuscitation.

**Implementation:**
It would be useful to demonstrate that such algorithms reduce the hands-off time during a resuscitation. More definitive proof would be a randomized clinical trial to measure the survival benefit. This would require a very large clinical trial and may not be warranted given the known physiology of cardiac arrest. If time could be saved such innovative technology would likely become standard of care for future defibrillators.

**Science:**
The methods to read through the ECG artifact to determine the underlying rhythm are currently under intense development (Articles 1-9 below). A method which uses cross-correlations of the ECG signal during CPR with a range of interrogating
waveforms has been developed by the Center for Progress in Resuscitation at the University of Washington (a collaboration of Medicine, Bioengineering, Electrical Engineering, and Public Health) (reference 1). This method has been licensed to Philips Healthcare and is in the process of being tested for FDA certification. Preliminary results demonstrate a 94% sensitivity for detecting VF during CPR and greater than 98% specificity. When employed in continuous analysis of the ECG, this method should allow confident knowledge of the rhythm at all times. Clinical availability is expected in some AED models within the next year.

**Summary:**
The use of this technology in defibrillators should soon be available. Other current published and proprietary methods employ filtering, wavelet analysis, and subtractive techniques. With the exception of the cross-correlation method, most methods have not proven accurate enough to eliminate the requirement for pauses to confirm the rhythm prior to shock or other interventions. When the ability to accurately determine the underlying rhythm during CPR is available, new protocols will need to be developed to take advantage of the ability to anticipate the next therapeutic intervention based on real time knowledge of the cardiac rhythm.

**Articles:**
   *This is the patent describing the method for using cross-correlations to determine the rhythm during CPR.*

   *Describes the use of an ‘adaptive matching pursuit’ algorithm for artefact removal with 97% sensitivity for VF and 79% specificity for non-shockable rhythms.*

Presents a method for analyzing the pauses for ventilations and is able to achieve a sensitivity of 96% for VF and a specificity of 97% for non-shockable rhythms


This paper describes a technique in which the force measurements from a pad under the rescuers hands during CPR are fed back into the system and subtracted from the ECG voltage values to increase the ability to detect VF during CPR.


Description of a method using only the ECG voltages with a Kalman filter tested on human data with 90% sensitivity for VF and 80% specificity for non-shockable rhythms.


The use of a digital adaptive filter to remove CPR artifact in a model system of human VF corrupted by CPR artifact which has been added to it.


Describes the use of a notch filter set at the frequency of chest compression delivery to remove those frequencies and leave other frequencies characteristic of VF untouched and a 90% sensitivity for VF is obtained.

A survey of methods with discussion of the inability to obtain a specificity for non-shockable rhythms of over 90% (95% is required by AHA/FDA).

2. Develop defibrillators to intelligently guide therapy (shock or continued CPR)

Description:
Most initial shocks are unsuccessful in defibrillating the heart, or the initial shock may be successful but last only seconds until the heart refibrillates. Defibrillator intelligent therapy would “read” the current VF waveform and based on information contained in the waveform recommend immediate shock or advise a period of CPR. The intelligent therapy could continue to read the waveform in real time and advise when the myocardial physiology was improved sufficiently to provide a durable and sustained conversion to a perfusing rhythm.

Assessment:
Such an intelligent defibrillator would be a welcome enhancement to the resuscitation armamentarium. Presumably the intelligent defibrillator would be able to calculate real time probabilities of any given shock being successful. Thus EMS personnel could see if the likelihood of success is rising or falling and adjust their therapy to try to maximize a higher likelihood of success. In addition, there are few proven strategies to improve survival beyond providing shock as early as possible and using CPR to enhance the response to shock. Epinephrine is presumed to be beneficial. Measures of cardiac physiology result in prediction of when the heart will best respond to shock. These tests will guide the way to comparing therapies and indicating which therapies are helping in any given situation and which are not. New therapeutic strategies should emerge from this experience.

Impact:
An intelligent defibrillator would have a large impact on survival rates.

Implementation:
As a software upgrade it could be possible to implement this rapidly. The software may require some changes in the signal processing framework, processors and noise reduction improvements of current defibrillators. Smaller units similar to pulse oximeter “add ons” might also be possible to upgrade older models. If the improvement in care is perceived as great enough, this would motivate the process of upgrading units currently in the field.

Science:
When survival rates in large VF resuscitation series are stratified by EMS response times, the survival for those whose response times are over 4 minutes is 15% to lower if shock is delivered as initial therapy when compared to CPR for 2 to 3 minutes prior to shock. Since it is difficult
to clinically determine the prior duration of VF in any single case it would be useful to have a measure that could identify those likely to respond to shock with an organized rhythm based on the ECG waveform features. Methods to do this have been developed and are based on the amplitude, frequency as determined by spectral analysis methods, and fractal dimension (a quantitative measure of ‘roughness’). The current science has the ability to stratify the probability of return of organized rhythm, return of spontaneous circulation and survival into groups to help guide therapy (CPR versus shock as initial therapy) but have yet to be proven to increase survival long term. The receiver operator characteristic curve (Resuscitation Outcomes Consortium) of these methods are approximately 0.85 to 0.90 and further improvements are possible. A reliable measure which would directly indicate the physiologic state of the myocardium could be used to follow the progress of therapies during the resuscitation and provide guidance as to when defibrillation should be applied with the expectation of having the greatest probability of conversion to a durable lasting perfusing cardiac rhythm.

**Summary:**
The there have been several efforts to develop a score predicting likelihood of shock success. Improvement in survival based on these methods has not yet been achieved. Improvement in the algorithms are needed to achieve increased accuracy and proof of effect on outcome will be required to catalyze the transition to predictive algorithms and new therapies based on them.

**Articles:**

   *The fractal dimension can be used to predict defibrillation success in VF arrest.*


   *The fractal dimension (which measures roughness of VF) is predictive of response to defibrillation.*

In patients with CPR lasting over 3 minutes there is an improvement in waveform measures indicating a positive effect of CPR on myocardium. The study demonstrates a rapid decline in frequency measures during 10 to 20 second pauses in chest compression.


The use of wavelet analysis with sophisticated machine learning algorithms is shown to produce a ROC curve with AUC of 85% when used alone and of 94% when used with end tidal CO2 measurements.


The use of Amplitude Spectrum Area (AMSA) to predict outcomes is described.

3. Develop an inexpensive “consumer” defibrillator

Description:
If one considers an AED as a ubiquitous public safety device then it follows that it should be available in almost every setting. Currently the cost of the AED and the lack of public appreciation of cardiac arrest prevent such a model of widespread, personal AED deployment.

Assessment:
Prevention of fires and the acceptance of smoke detectors may illuminate the situation with cardiac arrest. Many homes and businesses are equipped with smoke alarms and fire extinguishers even though the risk that a given structure will catch fire is exceptionally small. The fire extinguisher is not engineered to replace professional firefighting equipment, but rather intended as a practical intervention that may successfully treat the fire in its early stages. In combination, the cost of residential smoke alarms and extinguisher might be $100-200.

Impact:
The impact would be potentially huge.

Implementation:
Not applicable at this time
Science:
Such devices do not currently exist.

Articles:

"The cost-effectiveness of in-home AEDs is intimately linked to individuals’ risk of SCD. However, providing in-home AEDs to all adults over age 60 appears relatively expensive.” - from abstract


"If financial constraints were to lead to rationing of defibrillators, it might be preferable to provide more people with a less effective and less expensive intervention (in-home AEDs) instead of providing fewer people with a more effective and more costly intervention (ICDs).” - from abstract


"For survivors of anterior-wall myocardial infarction who were not candidates for implantation of a cardioverter-defibrillator, access to a home AED did not significantly improve overall survival, as compared with reliance on conventional resuscitation methods. (ClinicalTrials.gov number, NCT00047411 [ClinicalTrials.gov].)” - from abstract


Recounts legislation and the impact of AED cost on feasibility for public or home use.


4. Change FDA classification of public defibrillators

Description:
Current AEDs cost approximately $1,000 to $1,500. The materials to manufacture a personal AED are available and could support a cost of $100-$200. Yet AED convention - driven in part by safety concerns and regulation - introduces substantial expense so that AEDs typically cost many times the production costs. Could we consider a different paradigm that might enable a low-cost AED that would have a more limited scope of therapy and less rigorous performance standards? What would be the consequence if a “cheap” personal AED was engineered to provide only a single shock and would tolerate a 2% critical-failure rate?

Assessment:
The smoke alarm and fire extinguisher enable early treatment but do not prevent professional response from the fire department. Similarly in cardiac arrest, layperson AED use does not prevent EMS response so that standard care is still operational. Indeed EMS routinely has an active role in patients treated by layperson AED (reference 5). Thus, the deployment of a “cheap” personal AED with these distinct operating specifications would have a high likelihood to improve care, and a small chance that the patient receives the status-quo standard of care when there is a critical AED failure. If we consider the current status of community resuscitation - which is the greater shortcoming: a cheap AED that suffers a 2% failure rate but could “change the rules” and truly accelerate AED dissemination, and in turn enable a much broader reach of early defibrillation, while still providing for the status quo under the worst case scenario…. or the current strategy that realizes the AED promise in only a handful of cases using near-perfect technology that routinely outdistances the clinical requirements of the single-shock, layperson AED resuscitation?

Impact:
This would have a potentially huge impact as it would facilitate dissemination of AEDs.

Implementation:
Not applicable at this time.
Science:
It is unclear if such a classification change will occur.

Articles:

FDA announcement of AED regulation.


Opinion piece on why FDA should not make AEDs a Class III device.


One argument against the AED reclassification to Class III, as submitted for official FDA review.


Synopsis of Proposed 2013 FDA recommendation to make AEDs a Class III device.


By the end of the year, the FDA is expecting to reclassify AEDs as devices that will need extensive, and expensive, pre-market testing.

An editorial arguing for the relaxation of regulation in order to facilitate widespread dissemination of AEDs into homes and businesses.

5. Hemofiltration for post-resuscitation therapy

Description:
Hemofiltration is designed to remove toxins from the blood and there has been limited use in treating humans post cardiac arrest

Assessment:
Hard to assess as the therapy is currently considered experimental.

Impact:
Potentially beneficial in a small group of patients.

Implementation:
Costly and complicated to achieve in a timely fashion.

Science:
One randomized clinical trial from France showed improved survival and neurological outcome in patients treated with hemofiltration compared to patients with standard care.

Articles:

This trial randomized 61 patients admitted to hospital after out-of-hospital cardiac arrest due to ventricular fibrillation or asystole to one of 3 treatment strategies: high volume hemofiltration (HF), HF with hypothermia, or control. Compared to standard care (controls), recipients of HF with or without hypothermia had significantly better survival at 6 months.


Detailed case report of a patient who sustained a cardiac arrest due to ventricular fibrillation with severely impaired neurological status, who made a rapid and complete recovery after institution of hemofiltration therapy.
6. ECMO for cardiac arrest

Description:
Extracorporeal membrane oxygenation (ECMO) also called extracorporeal life support (ECLS) or ECPR (extracorporeal CPR) is a technique to provide cardiac and respiratory support by oxygenating the blood outside the body and returning it to the body. There are several types of ECMO depending on whether the heart can adequately maintain blood pressure. Cannulation can occur in the femoral artery and femoral vein or femoral vein and internal jugular vein or right atrium and ascending aorta (the latter is used for the most serious conditions). The major clinical use of ECMO is in respiratory failure, cardiogenic shock and as bridge therapy for cardiac transplantation and placement of a ventricular assist device.

Assessment:
ECMO has largely been a hospital and ICU-based procedure applied to critically ill patients. Most of the experience comes from pediatric patients. It may eventually play a role for cardiac arrest patients who have refractory VF. At this time ECMO is a hospital-based procedure though one might envision a prehospital ECMO-type device in the future.

Impact:
Probably limited to a few conditions (such as refractory VF) with application in tertiary care institutions.

Implementation:
Definitely not yet ready for wide-spread use. Many more case series need to be done to define the benefits and limitations of ECMO.

Science:
Use of ECMO post cardiac arrest is very “heroic” at the moment but several case series suggest it may play a role in limited circumstances.

Articles:

ECPR increases return of circulation and coronary perfusion pressure in a sheep model of ischaemic VF arrest. The authors support the development of a pilot trial into the effectiveness and feasibility of ECPR in the clinical setting.

2. Chen YS, Yu HY, Huang SC, Lin JW, Chi NH, Wang CH, Wang SS, Lin FY, Ko WJ. Extracorporeal membrane oxygenation support can extend the

Assisted circulation might extend the presently accepted duration of cardiopulmonary resuscitation in adult in-hospital cardiopulmonary resuscitation patients.


_CPR with ECLS led to more favourable patient outcomes after IHCA compared with OHCA in our patient group. The difference in outcomes for ECLS after IHCA and OHCA disappeared after adjusting for patient factors and the time delay in starting ECLS._ - from the abstract


"In this review, survival after ECPR was generally best after pediatric IHCA (38-57%), followed by adult IHCA (34-46%) and then adult OHCA (4-36%). ...[there appears to be] no consensus on the optimal conventional CPR duration before ECPR initiation. Future studies might focus on the indications for ECPR, which should maximize the survival potential after ECPR while reducing the overuse of this resource-intensive facility." - from the abstract

7. Detect blood flow during cardiac arrest

_Description:_

Chest compressions are delivered in order to provide perfusion when the heart is not pumping effectively. Clinical outcomes have been shown to clearly improve survival when high quality CPR is delivered. The actual determination of how effective chest compressions are in an individual patient has been difficult to assess accurately. A method which would provide a quantitative indication of the degree of blood flow and tissue perfusion being provided by CPR would give rescuers the ability to tailor CPR delivery to provide the best perfusion possible for each patient. When available in real-time, a measure of perfusion would allow for the adjustment of chest compression rate, depth, duty cycle, force and other factors so that perfusion could be optimized. If one considers “perfusion” to be composed of two parts, blood flow and oxygen delivery, then the ability to determine the presence of flow and oxygen saturation together would be optimum. This knowledge could also guide the delivery of ventilations and the need for additional airway interventions if the blood flow were known
to be adequate but the oxygenation was not. To be useful in the field these methods should be easy to apply and noninvasive.

Assessment:
A blood flow detector to help guide CPR would advance the clinical practice of resuscitation. It would allow the delivery of chest compressions to be adjusted for the individual patient to provide increased tissue perfusion. The methods exist but must be further developed so that they are robust enough to be applied where the cardiac arrests occur, the field. These methods also must be inexpensive and relatively simple to apply. In all probability there will be incremental advances until a clear leader emerges from the candidate methods.

Impact:
Potentially this could improve resuscitation outcomes by guiding CPR and therapy.

Implementation:
Awaits further development.

Science:
Some potentially useful technologies include plethysmography and ultrasound.

Articles:
An overview of the various technical methods to visualize the microcirculation with light and doppler.


A demonstration of how well these techniques work in assessing the microcirculation.


Examines the use of side stream dark field imaging during bypass and a comparison of pulsatile and non-pulsatile flow and the effect on tissue perfusion in human subjects.


Side stream dark field imaging is used during cardiac arrest and resuscitation of a 29 year old victim of drowning.


Uses the side stream method in sublingual measurements with a swine model and full instrumentation for experimental validation of this technique.

*This is an editorial on the subject of microvascular perfusion measurements.*


*Presents the thesis that transcranial Doppler imaging could be extended to the prehospital setting and should be considered.*


*This site has the reference material with appropriate links along with several very good videos showing the pulse brought out in the human face and arm, etc. using special imaging techniques called "Eulerian Video Magnification". These are software adaptations that allow one to see changes that are below our normal levels of perception.*


*Presentation of a case in which a patient was being monitored with cerebral tissue oxygen tension measurements during a cardiac arrest. Cerebral perfusion pressure is compared to tissue oxygenation.*

### 8. Ischemic post-conditioning therapy

**Description:**
Ischemic Post-ischemic conditioning (IPC) attempts to reduce cellular injury resulting from the reflow of blood after return of circulation. The strategy is to perform CPR for a brief period and then pause for a brief period, such as 15 seconds of CPR followed by 5 seconds without CPR. Presumably this will condition mitochondria within the cells and thus minimize the level of damage. This is experimental.

**Assessment:**
This intriguing therapy has been demonstrated in animal models but benefit in humans is to be determined.
**Impact:**
Could be large if proven effective in human cardiac arrest.

**Implementation:**
It might be relatively easy to accomplish with a change in the protocol for delivery of CPR.

**Science:**
All data come from animal studies.

**Articles:**

   This was a prospective study of pigs with protracted (15 minutes) untreated ventricular fibrillation who were randomized to receive standard CPR as compared with 4 controlled 20 second pauses during the first 3 minutes of CPR, followed by standard care measures in both groups. As compared with standard CPR, recipients of ischemic postconditioning (via "controlled interrupted CPR") had a comparable return of circulation and 24 hour survival, but manifested better left ventricular function and neurological status.


   This review article describes the pathophysiology of reperfusion injury and how it might be modified by post-ischemic conditioning.


   This was a prospective study of pigs with protracted (15 minutes) untreated ventricular fibrillation who were randomized to receive standard CPR with and without concomitant vasodilator therapy, as compared to post-ischemic conditioning (performed as described in reference #1 above) with and without concomitant vasodilator therapy, followed by standard care measures in all treatment groups. Compared
with standard CPR, recipients of postischemic conditioning and recipients of standard CPR with vasodilatory therapy had better left ventricular function after resuscitation, but only postischemic conditioning resulted in improved 48 hours survival and better neurological outcome.


IPC and cardiovascular vasodilation therapy during standard CPR improved post-resuscitation LVEF but only IPC was independently neuroprotective and improved 48 hour survival after 15 minutes of untreated cardiac arrest in pigs.


This is a position paper describing some of the potential mechanisms accounting for the effects of postischemic conditioning.


This review paper describes the role of mitochondria and the mitochondrial permeability transition pore (MPTP) in reperfusion injury and cardioprotection.

9. Point of care testing

Description:
Point of care testing refers to on-scene measurement of blood chemistries. The technology for measuring chemistries from micro drops of blood and having results in a few seconds or minutes exists currently. A consumer example of point of care testing is measurement of blood glucose. Candidate chemistries would be blood gases including pH and lactate levels.

Assessment:
Knowledge of selected blood chemistries could conceivably help to guide a resuscitation and inform rational post-resuscitation therapy. There have not been convincing studies yet to identify which chemistries would have utility.
**Impact:**
This technique could have a modest benefit by intelligently guiding therapy.

**Implementation:**
For now pilot studies might define blood chemistries with clinical utility.

**Science:**
Point of care testing exists in many clinical settings (emergency departments, ICUs, out-patient clinics, developing country health settings).

**Articles:**

   *Potassium levels are critical to proper cardiac conduction. Too high levels can lead to cardiac arrest and this is a common reason for arrest in dialysis patients.*


   *Lactate measurement is a valuable tool to determine metabolic acidosis during CPR and may be able to replace blood gas analysis in this situation.*


   *"The arterial admission lactate concentration after out-of-hospital ventricular fibrillation cardiac arrest is a weak measure of the duration of ischemia. High admission lactate levels are associated with severe neurological impairment. However, this parameter has poor prognostic value for individual estimation of the severity of subsequent functional neurological impairment."* - from abstract


   *"This article deals with the application of clinical ultrasonography (US) in resuscitation, presenting a simple codified US protocol usable during CPR to recognize reversible causes of cardiac arrest."*
Clinical US, using a well codified protocol, could effectively help to identify reversible causes in CA, even improving patients outcome.” - from abstract


"The positive clinical impact of using POC testing was consistently associated with a positive economic impact. POC blood gas analysis may be associated with decreased incidence of adverse clinical events or earlier detection of such events, resulting in significant cost savings.” - from abstract


"Multivariate logistic analysis showed that initial heart rhythm and pH levels were significantly higher in the GR [good recovery] group than in the non-GR group (ventricular tachycardia/VF rate: p = 0.055, 95% confidence interval [CI] 0.768-84.272, odds ratio [OR] 8.047; pH: 7.155 ± 0.139 vs. 6.895 ± 0.100, respectively, p < 0.001, 95% CI 1.838-25.827; OR 6.89).” - from abstract


Potential benefit of point of care testing for critically ill emergency department testing is described.

10. Develop a cardiac arrest detector

Description:
Approximately 50% of all cardiac arrests are unwitnessed. Though there may be someone in the immediate vicinity, the actual collapse is not seen or heard and thus the chances of a successful resuscitation fall dramatically. If a person at higher risk of cardiac arrest could wear (or have implanted) a cardiac arrest detector, then alarms could summon nearby help.

Assessment:
Potentially large, though one would likely have to determine who is at risk (currently not easy to do other than for some higher risk groups, for example, persons with coronary artery disease). Any wearable device would have challenges of all wearable items (remembering to put it on, tolerating it, battery replacements, etc.). Then there is the anticipatory anxiety that might be associated with such a device though this does not
appear to be a large concern among persons with implantable cardiovertor defibrillators.

**Impact:**
The impact is difficult to speculate.

**Implementation:**
The technology for such a device does not yet exist.

**Science:**
The technology for such a device does not yet exist.

**Summary:**
The challenge is to make such a detector totally accurate. False positives would quickly make the detector's alarms ignored - not unlike the boy who cried "wolf" too often.

**Articles:**
Appropriate articles were not found.

11. **Prevent the onset of ventricular fibrillation**

**Description:**
The concept of prevention is very straightforward. The best way to reduce death from SCA is to avoid the onset of VF. A medication or vaccination could conceivably prevent the onset of VF. Easier said than done especially since the trigger(s) of VF are so poorly understood. Only a small minority of patients have clearly defined causes for VF. These include patients with conduction defects (such as prolonged Q-T syndrome) and structural abnormalities in the heart (such as hypertrophic cardiomyopathy). Because of the increased risk of VF, these patients are candidates for implantable cardiovertor defibrillators (ICD). But for the vast majority of VF patients the specific triggering event is poorly understood. A majority of patients (perhaps as many as 80-90%) who have VF SCA have underlying ischemic heart disease (IHD). It is felt that an obstructed coronary artery leading to ST-elevation myocardial infarction (STEMI) leads to toxins or biochemical changes that in turn trigger VF. This may account for 20-25% of VF events. For other patients with ischemic heart disease it is believed that an episode of ischemia (with or without symptoms) may trigger VF. This likely accounts for 40-50% of VF events.

In the past forty years the incidence of VF has declined and this decline parallels the decline in the incidence of ischemic heart disease. Thus until the trigger(s) of VF are understood the best preventive strategy is to continue efforts to reduce the incidence of ischemic heart disease and assume such a decline will lead to a decline in VF. It is also possible that the incidence of IHD may increase in decades ahead due to dramatic recent increases in obesity and type II diabetes. Diabetes is a strong
risk factor for the development of IHD. Even though the triggers of VF are not understood it seems likely that the incidence of VF will fall as the incidence of IHD falls.

**Impact:**
The impact would be huge but it is mostly “a wish” at this time.

**Implementation:**
We are likely a long way from realizing this strategy.

**Science:**
There is much speculation at this time.

**Summary:**
There are no data pointing toward specific prevention of VF. It may be a long time until the triggers of VF are precisely identified and thus a specific preventive strategy seems remote.

**Articles:**

   *This observational study evaluated the incidence of out-of-hospital ventricular fibrillation (VF) in*

   Seattle over a period of two decades, during which time the annual rate of VF declined from 0.85 to 0.38 per 1000 persons.


   *This observational study compared the incidence of out-of-hospital ventricular fibrillation (VF) in Rochester, MN in patients with and without ischemic heart disease. While the incidence of VF associated with ischemic heart disease declined over the study period, this was not the case among patients without ischemic heart disease, in whom the incidence of VF increased slightly. These findings were taken to suggest that the decline in VF may be attributable to the impact of treatment strategies directed at coronary artery disease.*
Summary

Two interventions are unequivocally and strongly related to surviving SCA. The first intervention is CPR and the sooner it is started the higher the likelihood of survival. For all practical purposes the only way to achieve rapid initiation of CPR is for a bystander to start it. Telecommunicators have the opportunity to facilitate bystander CPR for most cardiac arrests. The challenge is how best to train telecommunicators and how to institute ongoing QI programs. The quality of CPR also appears to be related to survival. High-performance CPR, with its emphasis on letter-perfect CPR and minimal interruptions in chest compressions, appears to improve survival. The challenge is how to insure that all EMS personnel are trained in this procedure. The second intervention is rapid defibrillation. As with CPR the sooner a defibrillatory shock can be provided the higher the likelihood of survival. Efforts to disseminate automatic external defibrillators (AEDs) into homes and more public places will lead to more cardiac arrests receiving defibrillation prior to EMS arrival.

Interventions with insufficient scientific support are advanced life support skills such as medications. The issue of antiarrhythmic medication benefit is currently being evaluated by the Resuscitation Outcomes Consortium. There are also preliminary plans to test the benefit of epinephrine for cardiac arrest. An intervention whose role is unclear is hospital hypothermia. (A recent study suggests mild cooling to 36 degrees C. and prevention of fever - may define prudent clinical practice until the issue of cooling is definitively clarified.)

Until (and if) specific prevention of VF becomes a reality, the primary and secondary prevention of coronary artery disease will likely lower the incidence of VF.
### Appendix

**Articles describing the demographics and incidence of cardiac arrest.**


Articles about treatments and predictors of survival from cardiac arrest:


Articles about the Utstein template for reporting cardiac arrest:


Utstein Survival Report
All Agencies/National Data
Service Date: From 1/1/12 Through 12/31/12

Resuscitations Attempted 28404

Non-Cardiac Etiology 3288

Cardiac Etiology 25116

Unwitnessed Arrest 12824
*see page 2

Witnessed Arrest (Bystanders) 9653

Witnessed by 911 Responder 2639
*see page 3

Initial Rhythm Asystole 3296
Sustained ROSC in field = 929

Initial Rhythm VF/VT 3434
Sustained ROSC in field = 1817

Other Initial Rhythm 2923
Sustained ROSC in field = 1172

Expired in Field 798
Expired in ED 1763

Expired in Field 261
Expired in ED 1375

Expired in Field 457
Expired in ED 1494

Admitted to Hospital 735 (16 incomplete)

Admitted to Hospital 1798 (62 incomplete)

Admitted to Hospital 962 (25 incomplete)

Expired In Hospital 625

Expired In Hospital 649

Expired In Hospital 642

Discharged Alive 94

Discharged Alive 1087

Discharged Alive 295

Neurological Status
CPC 1 or 2 47
CPC 3 or 4 37
Unknown = 10

Neurological Status
CPC 1 or 2 952
CPC 3 or 4 95
Unknown = 40

Neurological Status
CPC 1 or 2 203
CPC 3 or 4 74
Unknown = 18

Cardiac Etiology Survival Rates
Overall: 10.0% (25116)
Bystander Wit'd: 15.3% (9653)
Unwitnessed: 4.1% (12824)
Utstein: 31.7% (3434)
Utstein Bystander: 37.3% (1922)

*Only data from the previous calendar year is fully audited. Data from the current calendar year is dynamic.