Most Important Outcomes Research Papers on Cardiac Arrest and Cardiopulmonary Resuscitation

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The following are highlights from the Circulation: Cardiovascular Quality and Outcomes Topic Review series. This series summarizes the most important articles, as selected by The Editor, that have been published in the Circulation portfolio. The objective of this series is to provide our readership with a timely, comprehensive selection of important articles that are relevant to the quality and outcomes, and general cardiology audience. The studies included in this article represent the most significant research related to cardiac arrest and cardiopulmonary resuscitation. (Circ Cardiovasc Qual Outcomes. 2014;7:335-345.)

Cardiac arrest is a common and treatable cause of death and disability. Each year ≈424,000 people experience emergency medical services (EMS)-assessed out-of-hospital cardiac arrest (OHCA) in the United States. The actual burden of OHCA is likely significantly higher because a substantial number go unassessed. In a prospective analysis of deaths in a US county, 5.6% of annual mortality was attributable to cardiac arrest. Many patients who suffer OHCA do not receive prompt cardiopulmonary resuscitation (CPR). Among those who receive CPR, a large number do not survive because of an inability to restore spontaneous circulation, or anoxic cerebral injury even after restoration of circulation. Nevertheless, when timely interventions are provided, a small proportion of patients (10.4% of all EMS-treated OHCA) recover to resume normal lives. The key therapeutic interventions that make the difference between life and death, metaphorically characterized as the 5 links in a chain of survival by the American Heart Association, include: (1) immediate recognition of cardiac arrest and activation of the EMS, (2) early CPR with emphasis on chest compression, (3) rapid defibrillation, (4) effective advanced life support, and (5) integrated postcardiac arrest care.

Resuscitation science has undergone major advances since the origins of modern CPR >50 years ago. The field continues to be dynamic with emergence of new therapies such as therapeutic hypothermia and improvements in systems of care. However, many questions remain on issues such as optimum compression rate, efficacy of chest compression only CPR (CCCP), dispatcher-assisted CPR, and benefits of postresuscitation measures such as hypothermia. A critical challenge also lies in the translation of resuscitation science into practice. To improve outcomes, each of the links in the chain of survival needs to be executed promptly and effectively. There remain several lacunae, which need to be overcome to develop an effective resuscitation system. For example, the failure to recognize cardiac arrest, low bystander rates of CPR, variation in CPR quality, defibrillator availability and use, EMS response, and variation in quality of postresuscitation care are all areas presented under investigation. Systematic assessment of resuscitation performance at community, first responder, and hospital levels are crucial to devise and institute targeted intervention.

In the following Topic Review for Circulation: Cardiovascular Quality and Outcomes, we focus on articles that address these challenges. We included articles that evaluate (1) the epidemiology of cardiac arrest and its outcomes, (2) the predictors of successful CPR, (3) community access to CPR and automated external defibrillators (AEDs), and (4) acute postresuscitation care.

Epidemiology of Cardiac Arrest and Its Outcomes

The incidence of cardiac arrest parallels the burden of cardiovascular illnesses, with cardiac arrest as the cause of death in >60% of patients with known coronary artery disease. Based on the data from the 2011 Resuscitation Outcomes Consortium, two thirds of OHCAs occur at home or at a residential location. Of ≈211,000 patients treated by EMS, 40.8% receive bystander CPR before EMS arrival, and 23% have ventricular arrhythmias as the initial rhythm. The incidence of cardiac arrest with an initial rhythm of ventricular fibrillation (VF), which carries a better prognosis, is decreasing over time; however, the overall incidence of cardiac arrest remains unchanged. Cardiac arrest continues to have a grave prognosis with an estimated survival of 10.4% for EMS-treated cardiac arrest of any rhythm and 31.7% for bystander-witnessed shockable rhythm. Another 209,000 cardiac arrests occur within the in-hospital setting, with <22.7% survival among adults.

There is wide regional and temporal variation in the incidence and outcomes of OHCA and in-hospital cardiac arrest. The incidence and outcomes are influenced by several determinants, such as variation in risk factors, socioeconomic differences, differences in bystander CPR, EMS response, and provision of acute and postresuscitation care. The following section summarizes studies describing the epidemiology of cardiac arrest and its outcomes.

Survival Trends in Pediatric In-Hospital Cardiac Arrests: An Analysis From Get With The Guidelines–Resuscitation

Summary: There are limited data on survival trends among pediatric patients who suffer an in-hospital cardiac arrest. The authors analyzed the Get With The Guidelines (GWTG)-Resuscitation registry to evaluate children (<18 years of age) with in-hospital cardiac arrest between 2000 and 2009 at hospitals with >3 years of participation and >5 cases annually. Outcomes measured were acute and postresuscitation survival and neurological disability. Of the 1031 pediatric in-hospital cardiac arrests from 12 hospitals, the initial cardiac arrest
rhythm was asystole or pulseless electric activity (PEA) in 84.8% of children and VF or pulseless ventricular tachycardia (VT) in 15.2%. The proportion of cardiac arrests with specifically PEA increased from 26.6% during 2000 to 2003 to 70.3% during 2007 to 2009 (P<0.001). Over time, the proportion of newborns also increased, as did the proportion with arrest in the intensive care unit, patients on mechanical ventilation and vasopressors. Conversely, the prevalence of heart failure (HF), respiratory insufficiency, and baseline depression in neurological status among children with cardiac arrest decreased. Overall, 34.8% survived to hospital discharge. Risk-adjusted rates of survival to discharge increased from 14.3% in 2000 to 43.4% in 2009 (P for trend=0.02). This improvement was observed across age groups and initial cardiac arrest rhythm. Acute resuscitation survival increased from 42.9% to 81.2% (P for trend=0.006). Postresuscitation survival increased over time but was not significant (P=0.17). There was no change in postcardiac arrest neurological disability. The use of extra-corporeal membrane oxygenation during resuscitation increased from 8.1% in 2000 to 2003 to 14.3% in 2007 to 2009 (P for trend=0.004); however, its use was not associated with overall survival to discharge.

**Conclusion:** The authors highlight an improvement in post-in-hospital cardiac arrest survival from 2000 to 2009. Improvement in acute resuscitation survival chain is likely an underlying reason for the betterment in outcomes. An important finding is the increased proportion of cardiac arrests due to PEA and a corresponding decrease in cardiac arrests due to asystole and VF/pulseless VT. As acknowledged by the authors, higher levels of monitoring may have led to earlier detection of cardiac arrest (specifically PEA). The improvement in survival is even more significant given the poor prognosis of PEA arrest; however, the proportion of arrests due to asystole, which carries an even worse prognosis, decreased as well.12–14

**Nationwide Improvements in Survival From Out-of-Hospital Cardiac Arrest in Japan**

**Summary:** There is global variation in the incidence and outcomes of cardiac arrest.1 Japan has experienced a dramatic increase in public access to AEDs,16 with a continued push for citizen CPR training. This study describes trends in post–cardiac arrest survival in the United States using the Nationwide Inpatient Sample (NIS) database from 2001 to 2009. Patients hospitalized with cardiac arrest were identified using the International Classification of Diseases, 9th Edition, Clinical Modification (ICD-9-CM) code 427.5. The primary end point was inhospital mortality. The analysis was stratified by age, sex, race, and the Charlson Comorbidity Index. A total of 1190860 patients were hospitalized with a diagnosis of cardiac arrest in the United States from 2001 to 2009. The in-hospital mortality rate declined each year from 69.6% in 2001 to 57.8% in 2009 (P<0.001) despite the fact that the proportion of patients with higher comorbidity scores increased over time (Charlson Comorbidity Index ≥4 increased from 5.1% to 12.4%). Mortality declined in all subsets of patients by sex, age, race, and comorbidity index. This decrease in mortality was more prominent in patients with higher comorbidity index and black race. In multivariate analysis, older age, female sex, higher comorbidity index, nonwhite race, and earlier year were independent predictors of increased risk of in-hospital death.

**Conclusion:** This study shows a declining trend in mortality from cardiac arrest. The drivers of this decline are likely multifactorial, including improvements in the chain of survival, but the nature of the study data precludes assessment of individual determinants. The reported mortality rates are much lower than those reported from the GWTG-Resuscitation registry15 and another analysis using the California State Inpatient Database database.20 There are certain limitations to this administrative data–based study. The authors used the ICD code 427.5 in either primary or secondary discharge diagnosis category, and hence the location of cardiac arrest could have been either in-hospital or outside. The usage of this code in any discharge diagnosis category is not validated.21–23 In addition, patients with cardiac arrest secondary to ventricular arrhythmias may have been coded using specific ICD code such as VF (427.41) instead of the cardiac arrest ICD code.24

**Association Between a Hospital’s Quality Performance for In-Hospital Cardiac Arrest and Common Medical Conditions**

**Summary:** The benefit of an additional publically reported inpatient survival measure for cardiac arrest is unknown. The authors examined the relationship between hospitals’ survival rate for cardiac arrest and their mortality rate for 3 publicly reported conditions: acute myocardial infarction, HF, and pneumonia, with the hypothesis that a strong correlation may suggest that an additional measure would be redundant. This study used the GWTG-Resuscitation registry25 (2007–2010) and, using hierarchical logistic regression and adjusting for confounders, calculated hospitals’ risk-standardized survival-to-discharge rates for in-hospital cardiac arrest. The Centers for Medicare and Medicaid Services Hospital Compare Website was used to obtain 30-day risk-standardized mortality rates for acute myocardial infarction, HF, and pneumonia for the same time period. Outcomes were linked at the hospital level through American Hospital Association identification numbers. Weighted Pearson correlation coefficients were adopted to compare performance. The final cohort consisted of 26270 patients enrolled from 130 US hospitals presenting with in-hospital cardiac arrest. The survival rate varied across hospitals (median risk-standardized rate, 22.1%; interquartile range, 19.7–24.2%). There was no significant association between hospitals’ outcomes for cardiac arrest with their outcomes for acute myocardial infarction (correlation, −0.12; P=0.16), HF (−0.05; P=0.57), or pneumonia (−0.15; P=0.10).
Incidence, Causes, and Survival Trends from Cardiovascular-Related Sudden Cardiac Arrest in Children and Young Adults 0 to 35 Years of Age: A 30-Year Review

Summary: Sudden cardiac arrest (SCA) in the pediatric and young adult population is poorly characterized. Previous incidence estimates range from 0.5 to 20 per 100,000 person-years, and the contribution of specific causes is unknown. Meyer et al. derive population-based estimates of age- and cause-specific incidence of SCA in young populations using both standard logistic regression and segmented regression of interrupted time series data. The percentage of patients with OHCA with nonshockable rhythms increased from 64% to 69% between periods; however, the distribution of arrests attributed to asystole (65%) and PEA (35%) remained similar over time. Patient demographic and resuscitation characteristics were comparable except for the percentage of patients receiving bystander CPR, which was lower in the earlier period (48% versus 57%). One-year survival increased from 2.7% to 4.9% after guideline revision and was found to be significantly higher after covariate adjustment by regression analyses. No progressive temporal trends in survival were identified over the full 10-year period.

Conclusion: Through the use of multiple analytic methods, including the demonstration that 1-year survival increased rapidly after the institution of new resuscitation protocols, the authors provide support for new guideline recommendations for persons with cardiac arrest from nonshockable rhythms. Findings are particularly important in that nonshockable rhythms comprise an increasing percentage of cardiac arrest cases. Findings will need to be replicated in settings without long-established and data-driven emergency medical systems and will need to demonstrate greater assurances about residual confounders. In this instance, bystander resuscitation was much more common in the latter period, as was the total percentage of arrests from nonshockable rhythms.

Impact of Changes in Resuscitation Practice on Survival and Neurological Outcome After Out-of-Hospital Cardiac Arrest Resulting From Nonshockable Arrhythmias

Summary: Among patients with OHCA, survival from shockable arrhythmias (VT/VI/forelemental shock) has improved in recent years after the implementation of guidelines increasing the time devoted to chest compression during resuscitation. These changes include reducing the number of back-to-back rhythm analyses/shocks, eliminating rhythm and pulse checks after each shock, and increasing the ratio of chest compressions to ventilations. To test whether these guidelines have resulted in improved outcomes for nonshockable rhythms (asystole and PEA), the authors studied 3960 patients with nontraumatic OHCA from nonshockable rhythms in Kings County, WA. From January 2000 to January 2005, 1774 patients were included (preguideline revision), and 2186 patients were included from January 5 to March 10 (postguideline revision). The primary outcome was 1-year survival. Differences in survival between the 2 time periods were assessed using both standard logistic regression and segmented regression of interrupted time series data. The percentage of patients with OHCA with nonshockable rhythms increased from 64% to 69% between periods; however, the distribution of arrests attributed to asystole (65%) and PEA (35%) remained similar over time. Patient demographic and resuscitation characteristics were comparable except for the percentage of patients receiving bystander CPR, which was lower in the earlier period (48% versus 57%). One-year survival increased from 2.7% to 4.9% after guideline revision and was found to be significantly higher after covariate adjustment by regression analyses. No progressive temporal trends in survival were identified over the full 10-year period.

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Advance Directives in Community Patients With Heart Failure

Summary: HF carries a median mortality of 5 years in the community, though little is known about the completion of advanced directives (ADs) in this population. ADs include living wills and other documents specifying preferences for healthcare decisions in the event of severe illness and incapacity. The authors enrolled 608 patients with a diagnosis of HF from Olmsted County, MN, to assess AD completion at the time of enrollment, predictors of AD completion, content of ADs, and association of AD completion with care received in the last month of life. Data were abstracted from medical records via a centralized medical record linkage system in the Rochester Epidemiology Project. Consent rate for participation was 74%. Among included patients, the mean age was 74 years, 55% were men, 50% had preserved ejection fraction, and 65% had functional class III or IV symptoms. Nonconsenting patients were older (78.6 years) and more likely to be women (53.4%). Overall, 41% had an AD completed at the time of enrollment. Among patients with ADs, 90% designated a proxy decision maker, but only a minority commented on preferences for CPR (41.4%), mechanical ventilation (38.6%), artificial nutrition/hydration (38.6%), and hemodialysis (10%). In adjusted analysis, AD completion was more likely among persons who were older and had a history of malignancy or renal dysfunction. Age was the most powerful predictor of AD completion (60.7% completion in persons ≥80 years, 31.3% completion in persons 60–79 years, 13.6% completion in persons <60 years). Among the 164 persons dying after a median follow-up of 1.8 years, those having an AD specifying limits to care less frequently received mechanical ventilation in the last month of life (odds ratio [OR], 0.26; 95% confidence interval [CI], 0.07–0.88).

Conclusion: The low use of AD among community-dwelling persons with HF is not surprising, considering that AD use is also low among persons with LV assist devices and critical or terminal illness. What is most noteworthy is the powerful effect of age on AD completion. Targeted efforts to increase AD use among younger patients with HF, therefore, seem to be particularly important, as this population experiences considerable morbidity and mortality despite its young age. Furthermore, additional attention should be directed to increasing the proportion of ADs with specific commentary on preferences for end-of-life care.

Important Papers on Cardiac Arrest and CPR

Conclusion: This study demonstrates no significant correlation between hospitals’ cardiac arrest survival rates and 30-day mortality rates for 3 publicly reported common medical conditions. Thus, there is substantial variation in survival rates of cardiac arrest across hospitals, public reporting of outcomes could provide additional novel information about hospital-wide effects on quality. These findings are important and may drive resuscitation-specific interventions to improve in-hospital cardiac arrest survival. As the authors note, limitations include the fact that adjustments could not be made for severity of illness, and they were able to compare cardiac arrest survival with mortality outcomes for only a few conditions. Lastly, data are lacking in regard to functional/neurological status at discharge and on hospital variation in their treatment regarding end-of-life care, which are important variables in this population.
Predictors of Successful Cardiopulmonary Resuscitation

What constitutes high-quality CPR remains elusive. Since CPR was first described more than half a century ago, it has undergone numerous modifications to become possibly too complex to teach to nonmedical personnel. In addition, resuscitation efforts represent tradeoffs in reality, for example, increased depth of compression often leads to reductions in the rate of compression, and the benefits derived from CPR are often nonlinear. For example, although public CPR campaigns have used the slogan “push hard and fast,” as the rate of chest compression surpasses a certain threshold, forward blood flow and cerebral perfusion pressure actually decrease. It has also been well documented that CPR performed in actuality fails to meet the quality standards proposed by guidelines even when performed by well-trained providers.37,38 Thus, the question is not only one of what is ideal but also what is feasible.

In the following section, we review research aimed at improving survival after OHCA by examining the details of what constitutes quality CPR. We examine multiple tradeoffs including the pauses in chest compressions to administer defibrillation shocks45 and ventilation,40 details in chest compression rates and other specific measures,4142 and assessment of new AEDs.46 Finally, we examine articles that weigh in on one of the largest debates in the past decade—forgoing ventilation rescue breaths by lay bystanders.44,45

Chest Compression Alone Cardiopulmonary Resuscitation Is Associated With Better Long-Term Survival Compared With Standard Cardiopulmonary Resuscitation

Summary: Authors compared dispatcher-assisted chest compression alone versus conventional CPR (chest compression interposed with rescue breathing) and its effect on long-term survival. This study used a retrospective cohort design, with patients combined from 2 randomized trials from 2004 to 2009—the Dispatch Assisted Resuscitation Trial (DART)46 and the Swedish Trial on Telephone Assisted CPR (TANGO)47—both of which compared survival to hospital discharge in patients >18 years of age with OHCA, and found no difference in outcome between the 2 types of CPR. The primary outcome in this combined study was long-term survival, obtained from the national/state death records through 2011. The Kaplan–Meier product limit method, in addition to Cox multivariable regression (adjusting for sociodemographics, initial rhythm, pathogenesis and location of arrest, witnessed status, and interval from call receipt to EMS arrival), was used to evaluate survival (at 1, 3, and 5 years) according to the type of CPR instruction. The final cohort consisted of 2496 participants (median age, 66 years), of whom 1243 (50%) were randomly assigned to chest compression alone and 1253 (50%) to conventional CPR. There were no significant differences in baseline factors between the 2 CPR groups. The study also reported 2260 deaths in long-term follow-up over 1153.2 person-years. Overall survival at 1, 3, and 5 years was 11%, 10.6%, and 9.4%, respectively. In the multivariate analysis, chest compression alone CPR was correlated with a significantly lower risk of death after adjustment for important confounders (adjusted HR, 0.91; 95% CI, 0.83–0.99; P<0.02).

Conclusion: This study indicates that patients with OHCA receiving dispatcher-assisted chest compression alone CPR have a significantly better long-term survival than those with conventional CPR. These results support chest compression alone CPR to be considered the dominant approach for adult patients for whom dispatchers suspect cardiac arrest. Limitations include the fact that the individual trials were not designed to ascertain long-term outcomes or be combined; data were missing in functional status and quality of life, which are important outcomes in this patient population; and subjects with OHCA associated with trauma, asphyxia, and drowning were excluded and thus the results may not apply to these groups of patients.48

Quantifying the Effect of Cardiopulmonary Resuscitation Quality on Cardiac Arrest Outcome: A Systematic Review and Meta-Analysis

Summary: The extent to which CPR quality affects survival in cardiac arrest remains poorly understood, and guidelines on chest compression rate, depth, and ventilation rate have been largely based on consensus.46,47 To measure the effects of CPR quality on cardiac arrest outcomes, investigators performed a systematic review and meta-analyses of clinical studies of CPR on adult patients with cardiac arrest in which survival was reported either as return of spontaneous circulation (ROSC) or survival to admission or discharge. Investigators identified 603 abstracts of which 10 studies met the inclusion criteria, representing 77 in-hospital and 1815 OHCA events. Estimates of survival rate were grouped by CPR metrics: chest compression rate, depth, no-flow fraction (time without chest compressions), and ventilation rate; the pooled effect was estimated by a random-effect model. Results showed that survival was significantly associated with deeper chest compressions, with a mean differences of 2.44 mm (95% CI, 1.19–3.69; P<0.001; n=6 studies; heterogeneity, F=0.0%; P=0.9). No overall difference in mean chest compression rate between survivors and nonsurvivors was found. However, survival was correlated with chest compression rates closer to 85 to 100 compressions per minute (cpm; absolute mean difference from 85 cpm=−4.81 cpm; 95% CI, −8.19 to −1.43; P=0.005; absolute mean difference from 100 cpm=−5.04; 95% CI, −8.44 to −1.65; P=0.004; n=6 studies; heterogeneity, F<49%; P>0.2). Neither no-flow fraction (n=7 studies) nor ventilation rate (n=4 studies) was significantly associated with changes in survival rates.

Conclusion: This study found that only slightly deeper average chest compressions were associated with increased survival, but found no association with survival for no-flow fraction, ventilation rate, and mean chest compression rates. This last negative result may be because of the use of means and aggregation, which mask the minute-to-minute variations in resuscitation. Investigators used an additional approach to assess mean chest compression rate by comparing it against guidelines and found that a mean rate closer to the range established by guidelines was significantly correlated with survival. Unfortunately, the study is unable to assess whether the range proposed in guidelines represent an optimum. It also assumed that CPR metrics are independent, but in reality, increased rates of compression have been shown to be correlated with decreased depth.49 Despite these limitations, this study represents a key step in quantifying and specifying exactly which aspects of CPR are essential to improving survival—precisely because efforts in resuscitation are often a tradeoff among competing elements.42

Relationship Between Chest Compression Rates and Outcomes From Cardiac Arrest

Summary: Although current guidelines for CPR recommend chest compression rates of 100 to 120 cpm,46,49 there is little data on the association between rate and outcomes during OHCA. Thus, the authors used data from Resuscitation Outcomes Consortium,1,12 a network of regional research centers across North America (2005–2007), to examine (1) the relationship between chest compression rate used by EMS providers (categorized as <80, 80–140, and >140 cpm) and ROSC and survival to discharge; and (2) the association of actual delivered chest compressions per minute (categorized <75, 75–100, and >100 cpm) with ROSC and survival to discharge. Data were abstracted from monitor defibrillator recordings during CPR given by EMS providers in OHCA. The final cohort consisted of 3098 subjects ≥20 years of age with OHCA. The mean age of patients enrolled was 67±16 years, with 8.6% surviving to hospital discharge. The mean compression rate was reported as 112±19 per minute for the first 5 minutes of CPR. In the categorical analysis
Comparison of Outcomes After Use of Biphasic or Monophasic Defibrillators Among Out-of-Hospital Cardiac Arrest Patients: A Nationwide Population-Based Observational Study

Summary: Biphasic defibrillators are gradually replacing monophasic defibrillators in the treatment of OHCA. Although biphasic defibrillators are smaller and more portable, whether they are associated with improved patient safety and outcomes is unknown. Using a nationwide, prospective registry of OHCA patients transferred by EMS, this study compared outcomes among all patients treated with monophasic (n=8224) and biphasic (n=12 948) defibrillation in Japan between 2005 and 2007. Survival with minimal neurological impairment was 12.8% in the biphasic group compared with 11.6% in the monophasic group (P=0.011), but this difference was after controlling for confounders (OR, 1.07; 95% CI, 0.91–1.26). There were no differences between the 2 groups in secondary outcomes, such as survival at 1 month and ROSC before hospital arrival. Similar results were found in confirmatory propensity score analyses.

Conclusion: Although biphasic defibrillators will continue to replace monophasic defibrillators because of the former’s greater convenience and portability, this study showed no outcome-based reason for the change. This finding contradicts previous observational studies that suggested superiority of biphasic defibrillators in surrogate outcomes, such as the probability of terminating VF. Notable strengths of this study include its prospective design, use of a comprehensive population-based sample, and systematic collection of hard clinical outcomes.

Chest Compression-Only Cardiopulmonary Resuscitation for Out-of-Hospital Cardiac Arrest With Public-Access Defibrillation: A Nationwide Cohort Study

Summary: Conventional CPR, which uses rescue breathing, remains the standard, although animal and clinical reports have shown that CCCPR may be more effective than conventional CPR in the early phase of cardiac arrest. Especially among cases where public-access defibrillators can deliver fast defibrillation, CPR would only be needed for the early phase immediately after collapse. Thus, to test whether CCCPR is more effective than conventional CPR for patients with OHCA who are shocked with public-access AEDs, investigators used a prospective, population-based observational study covering the whole population of Japan (2005–2009) where AEDs have successfully penetrated public spaces. The main outcome was favorably 1-month survival, and multivariable logistic regression was used to assess the correlation of type of CPR and neurological outcomes. During the 5 years examined, the registry included 1376 witnessed OHCA of cardiac origin in individuals who received CPR and shocks with public-access AEDs by bystanders. Among them, 506 (36.8%) received CCCPR and 870 (63.2%) received conventional CPR. The CCCPR group had a significantly higher rate of 1-month survival with favorable neurological outcome (40.7%; 206 of 506) compared with the conventional CPR group (32.9%; 286 of 870; adjusted OR, 1.33; 95% CI, 1.03–1.07).

Conclusion: Compression-only CPR is more effective than conventional CPR for patients with witnessed out-of-hospital arrest and who were shocked with public-access defibrillation. This conclusion supports the overall trend toward promoting CCCPR for bystanders. However, the applicability of this study is notably limited to those with cardiac arrest due to VF who received defibrillation—a combination that only occurred in 3% of all bystander-witnessed OHCA. Nonetheless, the simplification of CPR to compression-only may increase the rate of early CPR delivery by bystanders, ultimately improving the overall population survival.

Duration of Ventilations During Cardiopulmonary Resuscitation by Lay Rescuers and First Responders: Relationship Between Delivering Chest Compressions and Outcomes

Summary: Interruption in chest compressions results in markedly lower perfusion pressure for the brain tissue and heart muscle. This relationship has been cited as a chief reason to minimize time interruption by mouth-to-mouth ventilation by lay rescuers performing CPR, and present guidelines allow a maximum of 5 seconds to give 2 breaths. To assess whether trained lay rescuers can follow such guidelines, and to evaluate the correlation between duration of interruption and survival, investigators studied data from the prospective Amsterdam Resuscitation Study (ARREST). The data documented OHCA recordings from AEDs, which gave commands to rescuers on compression/ventilation ratio of 30:2 in accordance to the 2005 CPR guidelines, impedance, and transducer information, as well as allowed for measurement of compression and ventilation performed. From 199 AED recordings, investigators found that the median interruption time for 2 ventilations was 7 seconds (interquartile range, 6–9 seconds). For a single ventilation period, 21% of rescuers took <5 seconds and 83% took <10 seconds. Rescuers also delivered >70 cpm in 88% of cases and on average performed chest compressions during 65% of the period when CPR was performed (chest compression fraction; interquartile range, 59% to 71%). Survival was 25% and not associated with duration of ventilation pauses when controlled for covariates such as witnessed collapse and time interval from emergency call to attachment of an AED.

Conclusion: These findings suggest that although CPR performed by trained lay rescuers was not fully compliant with the present guidelines, it was nonetheless better than previously believed. Investigators further suggest increasing the ceiling for duration of pause for ventilation to 10 seconds, which seems to be the reality of CPR performed and did not adversely affect survival in this study. However, the study design was limited by including police and firefighters, who were involved in multiple cases studied, to be grouped under the definition for lay rescuers despite being frequently re-trained for CPR. Studying AED recordings have the additional challenge of identifying actual ventilation provided. In most cases, ventilation is identified via changes in impedance; however, some cases had only “the absence of compression” and no direct evidence of ventilation. Most devices also did not record the quality of compressions and ventilation. Interestingly, the study found no survival benefits to strictly
observing the ventilation time limits in present guidelines. It suggests that the rapid insufflation required by guidelines may carry its own risks, such as decreased efficacy in ventilation by increasing the risk of gastric dilatation. Overall, this study is a key step in reconciling reality and guidelines.

**Perishock Pause: An Independent Predictor of Survival From Out-of-Hospital Shockable Cardiac Arrest**

**Summary:** The American Heart Association guidelines underscore the importance of minimizing interruptions during CPR. One source of interruption arises from the compulsory rhythm analysis and defibrillatory shock for shockable cardiac arrest. Thus, the authors sought to investigate whether the time spent in the perishock period (encompassing preshock, rhythm analysis, and postshock pause) has an effect on survival to hospital discharge after OHCA. Using data from Resuscitation Outcomes Consortium spanning December 2005 to June 2007, the authors analyzed 815 patients (mean age, 64 years; 79% men) who had an OHCA and presented with a first shockable rhythm of VF or pulseless VT and with available CPR process data for ≥1 shock (up to 11 shocks were included in analyses). Longest perishock pause in the first 3 shocks for each patient was used for the multivariable models. The mean EMS response time was 5.9 minutes; the median preshock pause was 15.6 seconds; and the median postshock pause was 8.3 seconds. Adjusting for predictors of survival (age, sex, public location, witness status, bystander CPR, and time from 911 dispatch to first vehicle arrival), the odds of survival were lower for patients with preshock pause ≥20 seconds versus <10 seconds (OR, 0.47; 95% CI, 0.27–0.82) and perishock period ≥40 seconds versus <20 seconds (OR, 0.54; 95% CI, 0.31–0.97). Every 5 second increase in preshock pause decreased survival by 18%. There was no effect of postshock pause on survival.

**Conclusion:** The study demonstrates a significant effect of perishock pause on survival with the effect solely driven by preshock pause length, making a case for targeted intervention. The authors note that AEDs in automatic mode had longer preshock pauses, thus highlighting the need for improvements in AED technology. As acknowledged by the authors, the study is limited by a lack of information on other CPR metrics, such as compression depth, rate and fraction, and also subsequent postresuscitation care, which can significantly influence outcomes.

**Community Access to CPR and Automated External Defibrillators**

Bystander CPR increases the survival rate of OHCA patients by 2- to 3-fold, although only one third of cardiac arrests receive bystander CPR. These low rates have prompted the recent 2013 scientific statement from the American Heart Association, urging for an increased emphasis on CPR training in the community. Large-scale contemporary CPR programs that target academic institutions and at-risk populations are underway and have been successful thus far. However, even after training, laypersons may not participate in bystander CPR because of panic or anxiety during the event, fear of injuring the victim, fear of performing CPR incorrectly, fear of liability, and not wanting to perform mouth-to-mouth resuscitation. Similarly, although AEDs dramatically improve survival in cardiac arrest patients with shockable rhythm, the bystander use of AEDs is low. As public AED availability has increased significantly in the past few years within many hospital and community settings, continued education will help improve the odds that a bystander will engage in CPR efforts, including AED use. The following section is a collection of up-to-date articles addressing issues related to community access to CPR and AED delivery.

**A Crowdsourcing Innovation Challenge to Locate and Map Automated External Defibrillators**

**Summary:** Given the prevalence of mobile phones and phone apps, crowdsourcing may be used to create a map of public-access AEDs. MyHeartMap Challenge study was designed as a competitive treasure hunt for AED devices over 8 weeks to create a map of nonmobile AEDs in Philadelphia County, as well as to assess the feasibility of such an approach. A dedicated Website, Facebook, Twitter, Foursquare, radio, and local newspapers ads were used to publicize the event. The Website and a mobile app were used to register teams and to gather data. Each team provided detailed demographic information of its members and the GPS coordinate and exact address of each AED and whether the AED was functional or publically accessible. Data were validated by comparing the GPS coordinates of known devices to those of submitted photos, address, and building coordinates on Google Maps. Investigators further used in-person verification to confirm that 99% of AED locations were valid and that data falsification or gaming was negligible. The challenge led to the identification of 852 unique AEDs of which 376 (44%) were previously unknown. AEDs were located in 528 buildings in all ZIP Codes. Buildings with the highest concentrations of AEDs were gyms (19%); schools (16%); and offices (11%; N=57). Most devices were located on the first floor of buildings (45%; N=385), near the entrance (16%; N=140), copy rooms (10%; N=85), security areas (8%; N=72), and office spaces (5%; N=44). Across the 203 of 313 teams reporting data, 59.31% of participants were students, and 42.22% worked in medically related fields. The most common motivation was contribution to an important cause (71%; N=144), followed by fun (58%; N=117) and money ($10,000 major prize and other smaller prizes; 43%; N=88). Older participants (>41 years; N=1025) submitted more AEDs compared with younger participants (18–40 years; N=404; P=0.01).

**Conclusion:** The study used crowdsourcing to create an AED map of Philadelphia County, which was highly reliable. This study was limited by several elements. First, the in-person validation technique to verify AED locations was labor-intensive and likely challenging to scale broadly. Second, the study took place in an urban area, which more easily lends itself to crowdsourcing than in rural or suburban regions. Furthermore, the total number of AEDs in the area remains unknown; thus, the true efficacy of crowdsourcing is unclear. Finally, the resultant map by this technique is a snapshot, and the method for its maintenance remains unclear. Nevertheless, the study method was novel and improved the accuracy of AED maps.
time to first DA-CPR chest compression was 176 seconds. Language barriers (median, 59 seconds; n=13) and caller leaving the phone (median, 43 seconds; n=27) were greatest delays in the provision of first DA-CPR chest compression when cardiac arrest was recognized. Lastly, older patients were less likely to receive DA-CPR (P=0.06).

Conclusion: Dispatchers were able to quickly recognize cardiac arrest in the vast majority of cases, particularly when they were able to assess consciousness and breathing. However, in nearly 40% of cases when the dispatcher was able to assess consciousness and breathing and provided instructions, chest compressions were not performed—23.4% of these lost opportunities were potentially modifiable. Furthermore, there continues to be no benchmark time between cardiac arrest event and start of DA-CPR compressions, thus making quality improvement more difficult. Efforts need to be made to educate dispatchers to act in a timely manner, to improve recognition of agonal or abnormal breathing, and to improve basic foreign language skills.65

The Effectiveness of Ultrabrief and Brief Educational Videos for Training Lay Responders in Hands-Only Cardiopulmonary Resuscitation: Implications for the Future of Citizen Cardiopulmonary Resuscitation Training

Summary: CPR may be more broadly taught with short informational videos instead of formal courses. The authors studied the effect of Hands-Only CPR videos on how likely people will attempt CPR in a cardiac arrest scenario and the skill level attained versus untrained individuals. They conducted a prospective trial of 336 adults, divided into 4 groups with different levels of training: receiving no training (control), viewing a 60-second video, viewing a 5-minute video, and viewing an 8-minute video plus manikin practice. All videos demonstrated compression-only CPR and were produced by the American Heart Association. Half of the subjects were randomly assigned to be tested immediately and the other half was tested after a 2-month delay to check for retention. When tested subsequently, only 0.7% (P=0.01) of trained subjects did not perform CPR in a cardiac arrest scenario compared with 23.5% of controls. All experimental groups had significantly higher average compression rates and greater average compression depth compared with the control group (both P<0.001).

Conclusion: Short Hands-Only CPR videos increase the likelihood of the general public to perform CPR and show superior CPR skills in the event of an OHCA compared with untrained individuals. This effect was comparable even with the 60-second training video in comparison to the 8-minute video with manikin practice. Although short instructional videos on CPR showed some potential in promoting skill retention, the study did not examine retention longer than 2 months and, furthermore, only placed subjects in an anticipated cardiac arrest scenario, both of which may have biased the results. Nevertheless, this study provides evidence regarding the short-term effectiveness of short CPR videos. These short clips potentially move CPR education from formal courses into the realm of public advertisement. Further studies are needed to see if short videos can promote retention over longer periods of time.66

Automated External Defibrillators Inaccessible to More Than Half of Nearby Cardiac Arrests in Public Locations During Evening, Nighttime and Weekends

Summary: AEDs have limited use despite wide penetration in the community, raising the question of what is limiting AED access beyond coverage and proximity to the machines. The authors conducted a retrospective analysis of OHCAs across Copenhagen, Denmark, from 1994 to 2001. They noted the time and location of all cardiac arrests in public locations and how the setting related to the location and accessibility of all AEDs linked to the emergency dispatch center. There were 1864 cardiac arrests in public locations during this time period, with 61.8% occurring during evening, nighttime, or weekends. There were 552 registered AEDs, with 9.1% accessible at all hours and 96.4% with access limited to weekday daytime. Thus, although 28.8% of all cardiac arrests were <100 meters of an AED, limited accessibility decreased AED coverage of cardiac arrest by 4.1% during weekday daytime and by 53.4% during the evening, nighttime, and weekends.

Conclusion: AEDs were especially inaccessible during the off hours when most cardiac arrests occurred. This study underscores the importance of considering AED access in addition to placement and dissemination. The issue of how to deliver timely defibrillation remains a broad challenge beyond Denmark and is likely worse in many other areas where AED penetration remains low.67

Barriers and Facilitators to Learning and Performing Cardiopulmonary Resuscitation in Neighborhoods With Low Bystander Cardiopulmonary Resuscitation Prevalence and High Rates of Cardiac Arrest in Columbus, OH

Summary: A qualitative community-based participatory approach was used in Columbus, OH, to identify factors that influence the learning and application of CPR by bystanders in areas with higher rate of OHCA and lower CPR rate. Data from 2 registries and OHCA surveillance were used to select 3 neighborhoods with higher rates of OHCA. Promotion via flyers in local stores and radio ads was followed by snowball sampling to recruit participants (N=42), forming 2 focus groups in each of the 3 neighborhoods. A 90- to 120-minute discussion was conducted in each focus group to elicit, identify, group influencing factors extracted from dynamic comments. Sociodemographic characteristics of participants were also gathered through a survey. Three key barriers to learning CPR were identified: financial difficulties, lack of information, and lack of motivation. Bystanders in low-income neighborhoods were found to be twice as unlikely to perform CPR, with the 4 themes in barriers to performing CPR being consequences (eg, risk to personal health and probable legal consequences), emotions (disconnection from the community or fear of hurting someone), feeling of lack of knowledge (uncertain of changing guidelines), and situational (lack of trust toward strangers or violence in the neighborhood). The 3 facilitators to learning and teaching CPR were motivation by family, self-preservation aspects, emotional factors (eg, building up social capital among community), and economic incentives (providing refreshments, child care, certification cards, and free CPR courses).

Conclusion: The study found that bystanders in primarily low-income black neighborhoods were less likely to perform CPR. Results from this study must be interpreted keeping in mind some limitations. Snowball sample can easily lead to selection bias, which is likely reflected in the fact that 68% of participants had CPR training. Furthermore, 85% of participants were women, which is unlikely to represent bystander composition. Nevertheless, the study reveals possible underlying causes of this disparity in CPR application across neighborhoods and suggests that teaching alone would not dramatically increase the use of CPR if other issues such as neighborhood safety were ignored.68

Impact of Onsite or Dispatched Automated External Defibrillator Use on Survival After Out-of-Hospital Cardiac Arrest

Summary: In patients with OHCA, AEDs placed in public places (onsite AEDs) have been shown to reduce time to shock and improve survival in specific study locations. Similar benefits have been attributed to AED use among first responders, such as firefighters or
policemen (dispatched AEDs). Berdowski et al⁵⁹ measured the benefits of onsite and dispatched AED use in a real-world setting. Their population-based cohort included 2833 consecutive patients with nontraumatic OHCA in 1 province in the Netherlands. Onsite AEDs were applied in 128 cases (5%), dispatched AED in 478 (17%), and no AED in 2227 (79%). Compared with 11 minutes without AED use, the time to first shock was reduced to 4.1 minutes with onsite AED and 8.5 minutes with dispatched AED. Neurologically intact survival was 49.6% among patients treated with onsite AED compared with 14.3% without AED, and this difference remained significant after adjusting for confounders (adjusted OR, 2.72; 95% CI, 1.77–4.18). However, there was no reduction in mortality for patients treated with a dispatched AED (unadjusted OR, 1.07; 95% CI, 0.82–1.39).

Conclusion: The use of onsite AEDs in a real-world setting doubled neurologically intact survival, an effect likely attributable to a significant reduction in time to first shock from 11 to 4.1 minutes. This effect is consistent with that observed in a previous randomized controlled trial.⁶⁰ Further increasing the density of onsite AEDs may enhance this potential benefit. In contrast with previous studies showing a survival benefit,⁶⁰⁻⁶² dispatched AEDs only marginally reduced time to shock and did not improve outcomes in this cohort. This result calls for further critical evaluation of systems of dispatched AEDs.⁶³

Identifying Locations for Public Access Defibrillators

Using Mathematical Optimization

Summary: The rate of AED use before EMS arrival is <3%, partially because of the poor distribution of AEDs. This study used mathematical optimization for AED placement based on a retrospective observational study of consecutive EMS-attended cardiac arrests and AED placement map and population data of Toronto, Canada. Assuming that bystanders would walk a maximum distance of 100 m to an AED (1.5 minutes), investigators found that the coverage of OHCA by current AED distribution is 23%. Cardiac arrest events occurred with an average distance of 281 m from the nearest AED. Investigators then optimized by the maximal covering location problem method in testing the hypothetical situation of adding a variable number of AEDs (20, 40, 60, 80, or 100) to the 1669 existing public AEDs. Results by this technique were found to be superior to those of a simulated population-guided model (P<0.01). An additional optimization model resulted in 32% coverage with an average distance of 262 m. The 19-m reduction is significant because it effectively reduced 38 m of commuting or 30 seconds in response time and likely increases the probability that a bystander would make the trip to receive the device.

Conclusion: Public-access AED allocation can be enhanced to increase coverage and reduce the distance a lay responder needs to travel. This study did not model local physical obstacles and human factors such as training in AED use or awareness of AED locations; it also did not confirm the assumption that bystanders are unlikely to walk >100 m to retrieve AEDs. However, mathematical optimization may be a good initial step in planning AED locations and can be expanded to include additional access variables, such that it may ultimately improve outcomes with better AED placement.⁶⁴

Acute Post-Resuscitation Care

Advanced cardiovascular life support guidelines recommend several overarching goals to ensure optimal acute postresuscitation care: (1) provision of cardiorespiratory support to optimize tissue perfusion, (2) transport of prehospital cardiac arrest patients to hospitals with an appropriately equipped critical care unit, (3) attempting to identify and treat the precipitating cause of arrest such as acute myocardial ischemia, and (4) institute measures such as antiarrhythmic therapy to prevent recurrence.⁶⁵ Recently, mild hypothermia has emerged as a key goal in acute postresuscitation care to improve patient outcomes. Among patients who survive an OHCA due to VT/VF with poor neurological recovery (Glasgow Coma Scale score <8), 2 well-designed randomized trials suggest that 24 hours of cooling to 32°C to 34°C on hospital arrival would increase neurological recovery, reduce disability, and improve survival at 6 months, although more recent trials have questioned these benefits.⁶⁶⁻⁶⁸ Here, we review studies evaluating the aspects of acute postresuscitation care with a focus on the relatively novel intervention of therapeutic hypothermia.

Is Hypothermia After Cardiac Arrest Effective in Both Shockable and Nonshockable Patients?: Insights From a Large Registry

Summary: Mild hypothermia improves cognitive function and survival in cardiac arrest from shockable rhythm (VT/VF), but the benefit of mild hypothermia in PEA or asystole is uncertain. Accordingly, the authors analyzed data from 1145 consecutive OHCA survivors (708 initial VT/VF and 437 initial PEA) collected between 2000 and 2009 to examine the association of mild hypothermia with good neurological outcome at hospital discharge using logistic regression analysis. Neurological outcome was assessed using Cerebral Performance Category scale, which classifies neurological recovery on a scale of 1 to 5 with scores 1 to 2 reflecting good neurological recovery (recovery of consciousness with no or moderate disability). Among patients with VT/VF, >55% were caused by cardiac causes, whereas among those with PEA/asystole, only 10% to 12% were due to cardiac causes. Overall 65% of patients with an initial VF/VT rhythm and 60% with PEA/asystole received mild hypothermia. Before induction of hypothermia, both groups had similar baseline characteristics, including body temperature. Good neurological recovery at discharge was higher in those with VT/VF (39% versus 16% in PEA/asystole; P<0.01). After adjustment for differences in other clinical characteristics, mild hypothermia was independently associated with increased odds of good neurological outcome at discharge among patients with initial VT/VF (OR, 1.90; 95% CI, 1.18–3.06) but not in patients with initial PEA/asystole (OR, 0.71; 95% CI, 0.37–1.36).

Conclusion: This large observational study confirms the findings of randomized control trials⁶⁶⁻⁶⁸ showing that survival after a cardiac arrest due to VT/VF improves with mild hypothermia during the first 24 hours. Previous meta-analyses suggested that therapeutic hypothermia in patients with PEA/asystole is associated with a 15% reduction in mortality at 6 months but conferred no benefit with regard to neurological recovery.⁶⁹ However, the included studies were small, prone to bias, and of questionable quality. This study, based on a substantial population, suggests that hypothermia does not offer any benefit if the initial rhythm is PEA or asystole. In many cases of PEA/asystole, a noncardiac pathology resulted in cardiac arrest, which may explain the differential findings.⁷⁰

Hypothermia in Comatose Survivors From Out-of-Hospital Cardiac Arrest: Pilot Trial Comparing 2 Levels of Target Temperature

Summary: Although guidelines recommend mild hypothermia (32–34°C) during the first 24 hours for comatose patients after cardiac arrest, the optimal temperature is uncertain. Whether more aggressive hypothermia to 32°C compared with 34°C leads to improved survival is unknown. Accordingly, the authors randomized patients with coma-tose cardiac arrest (n=36; 26 with VT/VF and 10 with asystole/PEA) to mild hypothermia at 32°C or 34°C (n=18 in each treatment arm). The target temperature was maintained for 24 hours before rewarming. The primary outcome was survival free from severe dependence as measured by a Barthel Index score >60 points at 6 months. Individuals are scored on 10 activities to give a score of 0 (totally dependent) to 100 (fully independent), with a score >60 indicating independence with self-care. The study showed that 8 of 13 patients with initial shockable rhythm assigned to 32°C (61.5%) were alive free from severe dependence at 6 months compared with 2 of 13 (15.4%) assigned to...
Therapeutic Hypothermia After Out-of-Hospital Cardiac Arrest: Evaluation of a Regional System to Increase Access to Cooling Circulation

Summary: Therapeutic hypothermia in comatose patients after cardiac arrest improves neurological recovery and survival, but is underutilized despite its efficacy. Transferring patients to hospitals with necessary expertise and facilities to rapidly implement hypothermia may improve utilization. The authors report findings from the Cool It program, which regionalized therapeutic hypothermia in a network of hospitals in Minneapolis with all postarrest comatose patients transferred to a central hospital capable of therapeutic hypothermia. Between 2006 and 2009, 140 OHCA patients who remained comatose postresuscitation of spontaneous circulation were treated at the central hospital with therapeutic hypothermia. Of the 140 patients, 75% were transferred from a peripheral hospital, and 25% directly presented to the central hospital. Patients with non-VF arrest or cardiac arrest incidence and outcome.

Conclusion: This study proposes regionalization of care as a method to increase the proportion of patients who received therapeutic hypothermia among patients with comatose cardiac arrest. It suggests that such an approach can be incorporated into existing care networks to achieve prompt treatment. However, these findings must be interpreted with caution. First, patients with shock and PEA/asystole were transferred although there is no strong evidence to suggest that these patients benefit from hypothermia. Furthermore, this study is a descriptive analysis only. A well-designed randomized trial is required to determine whether benefits of such an approach exceed the cost and resource expenditure associated with regionalization.

Implementation of the Fifth Link of the Chain of Survival Concept for Out-of-Hospital Cardiac Arrest

Summary: In 2010, the American Heart Association recommended adding a fifth link, postresuscitation care in a regional center, to the chain of survival concept for OHCA. Postresuscitation care in this context includes advanced ventilator and hemodynamic support such as extracorporeal membrane oxygenation and intra-aortic counterpulsation, therapeutic hypothermia, and early coronary angiography. To study the impact of implementation of this fifth link on favorable neurological outcomes for patients with OHCA, the authors leveraged data from a multicenter prospective cohort study involving all eligible OHCA patients in the suburban/rural Aizu region of Japan.

The proportion of patients achieving a favorable neurological outcome 1 month after arrest (defined as moderate or better cerebral disability) was evaluated before (January 2006 to April 2008) and after (January 2009 to December 2010) implementation of the fifth link, which involved direct transport from field to a regional tertiary center, or secondary transport from an outlying hospital to a regional center after ROSC. Using data from 1482 out-of-hospital arrests, the authors found an improvement in 1-month survival with favorable neurological outcome from 0.5% to 3% in the latter era. After adjusting for multiple confounders, the odds for favorable neurological outcome at 1 month were 0.9 for early access to emergency care, 3.1 for bystander resuscitation, 14.7 for early defibrillation, 1.0 for early advanced life support, and 7.8 for postresuscitation care (fifth link).

Conclusion: The most striking finding is the dismally low proportion of patients surviving 1 month after OHCA with a favorable neurological outcome. Even with the fifth link, 97% of persons meeting the study criteria fail to survive with meaningful neurological recovery. As the authors note, it is possible that outcomes were particularly poor given the rural/suburban nature of the study population, which may delay emergency medical system response times compared with more geographically restricted urban settings. In light of the 2 recent trials of therapeutic hypothermia showing questionable benefit, the American Heart Association will need to reconsider the inclusion of this expensive and resource-intensive procedure as a component of the fifth link in the chain of survival during the future revisions of resuscitation guidelines.

Disclosures None.

References


