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Increasing Use of Cardiopulmonary Resuscitation During Out-of-Hospital Ventricular Fibrillation Arrest
Survival Implications of Guideline Changes

Thomas D. Rea, MD, MPH; Michael Helbock, MICP; Stephen Perry, MICP; Michele Garcia, MD; Don Cloyd, MICP; Linda Becker, MA; Mickey Eisenberg, MD, PhD

Background—The most recent resuscitation guidelines have sought to improve the interface between defibrillation and cardiopulmonary resuscitation; the survival impact of these changes is unknown, however. A year before issuance of the most recent guidelines, we implemented protocol changes that provided a single shock without rhythm reanalysis, stacked shocks, or postdefibrillation pulse check, and extended the period of cardiopulmonary resuscitation from 1 to 2 minutes. We hypothesized that survival would be better with the new protocol.

Methods and Results—The present study took place in a community with a 2-tiered emergency medical services response and an established system of cardiac arrest surveillance, training, and review. The investigation was a cohort study of persons who had bystander-witnessed out-of-hospital ventricular fibrillation arrest because of heart disease, comparing a prospectively defined intervention group (January 1, 2005, to January 31, 2006) with a historical control group that was treated according to previous guidelines of rhythm reanalysis, stacked shocks, and postdefibrillation pulse checks (January 1, 2002, to December 31, 2004). The primary outcome was survival to hospital discharge. The proportion of treated arrests that met inclusion criteria was similar for intervention and control periods (15.4% [134/869] versus 16.6% [374/2255]). 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). Adjustment for covariates did not alter the survival association.

Conclusions—These results suggest the new resuscitation guidelines will alter the interface between defibrillation and cardiopulmonary resuscitation and in turn may improve outcomes. (***Circulation***. 2006;114:2760-2765.)

Key Words: cardiopulmonary resuscitation ∎ defibrillation ∎ fibrillation ∎ heart arrest

Out-of-hospital cardiac arrest is a substantial public health burden, accounting for up to 10% of total mortality in the United States.[1] In the community, ventricular fibrillation (VF) is the most common initial cardiac arrest dysrhythmia.[2] Although resuscitation is attempted in hundreds of thousands of VF out-of-hospital cardiac arrest victims annually in North America and Europe, survival after VF arrest is <20% in most communities.[3,4] A critical measure of evidence from observational and randomized studies has established the tenets for successful resuscitation. These tenets, termed "the links in the chain of survival," include early activation of emergency care, early cardiopulmonary resuscitation (CPR), early defibrillation, and early advanced life support measures.[5] The interface between CPR and defibrillation may be especially critical for successful resuscitation of VF arrest.[6] Evidence suggests that CPR may facilitate the mechanical function of the heart after defibrillation.[7] Specifically, animal studies indicate that interruptions or delays in CPR immediately before or after defibrillation result in less frequent return of spontaneous circulation and lower likelihood of survival.[8,9]

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In past guideline-directed protocols, VF arrest was treated with up to 3 successive (stacked) shocks followed by a pulse check before (re)initiation of CPR.[10] When directed by the automated external defibrillator (AED), activities of rhythm reanalysis, stacked shocks, and pulse check delay CPR after the shock by ≈30 seconds while having relatively low yield with regard to producing and detecting a pulse.[11–13] Thus, relative to traditional resuscitation protocols, care that eliminates rhythm reanalysis, stacked shocks, and postshock pulse checks may provide CPR earlier after defibrillation and increase the relative proportion of time spent performing CPR during resuscitation of VF cardiac arrest. To this end, the most recent guidelines from the American Heart Association

AED protocol during the control period
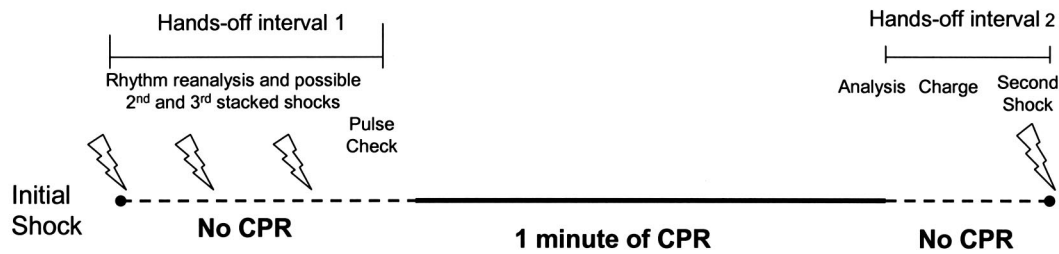
AED protocol during the intervention period

Figure 1. Schematic of AED resuscitation protocols during control and intervention periods.

and International Liaison Committee on Resuscitation advocate such an approach with hopes of improving survival from VF arrest.[5,14]
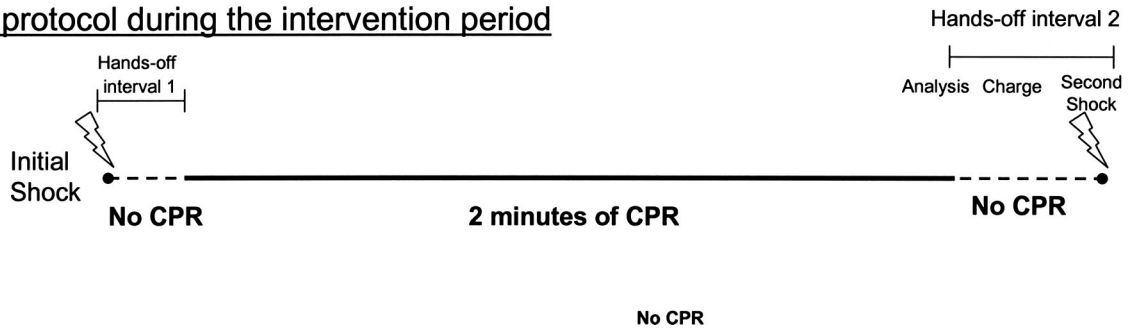
On the basis of local evaluation and other published reports, we instituted a change in the VF resuscitation protocol beginning January 1, 2005, that provided a single shock without rhythm reanalysis, stacked shocks, or postdefibrillation pulse check, while the period of CPR between rhythm analyses was extended from 1 to 2 minutes. We hypothesized that this protocol change would increase survival status at hospital discharge by providing CPR earlier after the shock and increasing the proportion of time spent performing CPR.

Methods

Study Design and Setting

The investigation was a cohort study that compared a prospectively defined intervention group with a historical control group. The study was approved by the appropriate Human Subjects Review Committee. King County, Washington (excluding Seattle), has a population of 1.2 million residents, covers ≈2000 square miles, and includes urban, suburban, and rural areas. The emergency medical services (EMS) system in the study community is a 2-tiered response system that is activated by calling 9-1-1. The first tier consists of emergency medical technician (EMT) firefighters who are trained in basic life support, including automated defibrillation. The second tier consists of paramedics who are trained in advanced life support, including intubation, intravenous medications, and manual defibrillation. Both tiers are dispatched simultaneously in the case of a suspected cardiac arrest. The EMTs arrive on scene an average of 5 minutes after dispatch. Paramedics arrive an average of 5 minutes after EMTs. Traditionally, EMS personnel follow the American Heart Association guidelines for management of cardiac arrest, which includes analyzing the rhythm as soon as possible and, if indicated, attempting defibrillation.

Intervention

Each fall, as part of required continuing education, the 3000 EMTs of the study community demonstrate CPR and AED competency to achieve certification. This training includes a didactic session followed by hands-on skills performance by each EMT. Although prior years had included emphasis on proper CPR and AED technique, retraining during the fall of 2004 involved a considerable change in the resuscitation protocol. In contrast to the past protocol, the new protocol provided a single shock without rhythm reanalysis or postdefibrillation pulse check, while the period of CPR between rhythm reanalyses was extended from 1 to 2 minutes (Figure 1). The EMTs maintained the prior practice of a 15:2 compression-to-ventilation ratio. Along with personnel training, the AEDs were reconfigured to support the change in protocol. The new protocol was formally implemented January 1, 2005.

Study Population

In accordance with the Utstein template,[15] the study population consisted of persons who had bystander-witnessed out-of-hospital VF cardiac arrest because of heart disease between January 1, 2002, and January 31, 2006. The control population, chosen a priori, consisted of eligible arrests that occurred during the 3 years before the change in the resuscitation protocol (January 1, 2002, to December 31, 2004), whereas the intervention group consisted of arrests that occurred during the first 13 months after the protocol change (January 1, 2005, to January 31, 2006).

Data Collection and Definition

The EMS division of the study community has maintained an ongoing registry of each treated cardiac arrest since 1976.[16] The EMS medical incident reports, the electronic AED recording, and the dispatch tape are reviewed to determine patient demographics (age and sex), event circumstances (witness status, location, citizen CPR status, and arrest before EMS arrival), EMS response intervals, presenting rhythm, and immediate outcome (admission to hospital versus death). Hospital records are used to determine survival status at hospital discharge and neurological status at discharge. For cases in which the electronic ECG recording is not available, a presenting EMS rhythm of VF was determined if the patient received a shock after the initial AED analysis.[17] The cause of the arrest is determined
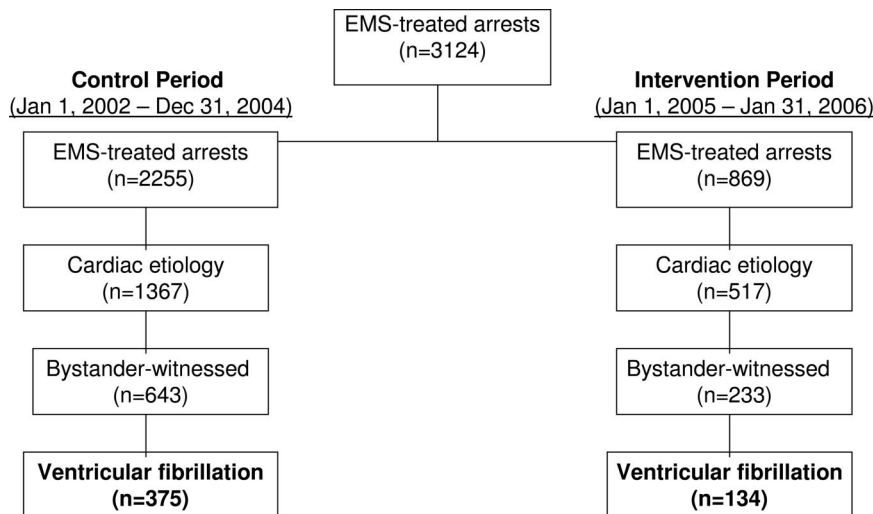
Figure 2. Study population according to time period.

by all available sources of information, including EMS report forms, hospital records, and death certificates. Using this approach, ≈90% of VF cardiac arrests are classified as resulting from underlying heart disease. The variable definitions and data collection approach were constant during the period of study.

Outcomes

The primary outcome was survival status at hospital discharge. We also assessed discharge destination (home versus nursing or rehabilitation facility) and neurological status at discharge based on hospital record review using Cerebral Performance Category. A Cerebral Performance Category score of 1 or 2 was classified as favorable neurological status.[15,18] Using the electronic AED record, we assessed the timing of CPR between the first (stack of) shock(s) and the second (stack of) shock(s) to help determine whether the protocol changes influenced the timing and quantity of CPR. Specifically, we assessed the time interval between the first shock and the start of CPR (hands-off interval 1), the total time spent performing CPR between the first and second shock, the interval between the completion of CPR and the second (stack of) shock(s) (hands-off interval 2), and the total time between the first (stack of) shock(s) and the second (stack of) shock(s) (hands-off interval 1+CPR interval+hands-off interval 2).[19] This review used both the real-time electronic ECG and the audio recording information to assess CPR timing. Prior study has indicated good interreviewer reliability with regard to the timing of CPR with this approach.[11]

Analysis

We used descriptive statistics to assess characteristics according to study period. Time intervals for CPR were compared with the *t* test for independent samples. When appropriate, these intervals were log-transformed to account for their nonnormal distribution. The proportion of patients who survived to hospital discharge during the intervention and control periods was compared with a χ^2 statistic. We used logistic regression to determine the survival association of the intervention period compared with the control period while adjusting for potential confounders. A simple model adjusted for age and gender. A full model adjusted for age, gender, location (home, public, or medical facility), citizen CPR status (yes/no), and first-tier and second-tier response intervals from call receipt to scene arrival, because these covariates have previously predicted survival.[16] Analyses were conducted with STATA 8.0 (College Station, Tex).

The authors had full access to the data and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

Results

Overall during the study period, a total of 3124 persons were treated by EMS for out-of-hospital cardiac arrest. The pro-

portion of all EMS-treated arrests that were determined to be bystander-witnessed VF arrests due to heart disease was comparable between the 2 study-period groups (16.6% [375/2255] during the control period and 15.4% [134/869] during the intervention period; Figure 2). Patient, circumstance, and EMS response characteristics were similar between the intervention and control time periods among the study population (Table 1).

The electronic AED recording was available for review in 256 of 509 cases, with similar proportions available during the 2 study periods (51.5% for the intervention period and 49.9% for the control period). Those with and without the electronic AED recording were similar, for example, with regard to gender (77% versus 79% male), average age (61.8 versus 63.4 years), home location (55% for both), and average first-tier response from call receipt to scene arrival (5.6 minutes for both). Among those with an electronic AED recording, the median interval between the first shock and subsequent onset of CPR was 7 seconds during the intervention period compared with 28 seconds during the control period (Table 2). The period of CPR was greater during the intervention period (median 91 versus 54 seconds). Among those who required 2 (sets of) shocks without intervening return of circulation, the median proportion of time spent

TABLE 1. Characteristics According to Study Period

Characteristic	Control Period, 2002–2004 (n=375)	Intervention Period, 2005–2006 (n=134)
Age, y, mean (SD)	62.7 (15.7)	62.5 (16.8)
Male, % (n)	78.4 (294)	76.1 (102)
Home location, % (n)	55.7 (209)	52.2 (70)
Citizen CPR, % (n)	67.5 (253)	72.4 (97)
EMT response interval, min, mean (SD)*	5.6 (2.3)	5.7 (2.7)
Medic response interval, min, mean (SD)*	9.7 (5.4)	9.5 (4.5)
Intubation, % (n)	95.7 (359)	96.2 (129)

$P>0.05$ for all comparisons between control and intervention periods.
*From call receipt to scene arrival.

TABLE 2.   CPR Process Measures According to Study Period

CPR Measure	Control Period, 2002–2004 (n=187)	Intervention Period, 2005–2006 (n=69)
Hands-off interval 1, s, median (25th, 75th percentile)*	28 (20, 41)	7 (5, 9)
CPR interval, s, median (25th, 75th percentile)*	54 (25, 100)	91 (71, 125)
Hands-off interval 2, s, median (25th, 75th percentile)	21 (17, 29)	20 (15, 33)
CPR proportion, mean (SD)*	0.48 (0.24)	0.69 (0.22)

*$P<0.05$ for comparison between control and intervention periods.

performing CPR between the (stacks of) shocks was 68% during the intervention period compared with 49% during the control period.

Overall, survival to hospital discharge was 36.0%. Survival to hospital discharge was significantly greater during the intervention period than during the control period (45.5% versus 32.8%, $P=0.008$; Table 3). Discharge to home as opposed to nursing home or rehabilitation center was similarly more common in the intervention period (36.6%) than in the control period (25.6%). The better hospital survival during the intervention period corresponded to a greater proportion with return of circulation at hospital arrival (end of EMS care; Table 3). In logistic regression models, the odds of survival to hospital discharge for the intervention period compared with the control period was 1.75 (95% CI, 1.16 to 2.64) adjusted for age and gender and 1.75 (95% CI, 1.14 to 2.69) in the fully adjusted model.

Among survivors (those discharged alive from the hospital), details about hospital care and outcome were available for 85% (157/184), 87% during the control period and 82% during the intervention period. Among survivors, hypothermia therapy occurred in 6% during the intervention period and 6% during the control period, whereas coronary catheterization within 6 hours of the arrest occurred in 40% during the intervention period and 56% during the control period. Among survivors, a Cerebral Performance Category score of 1 or 2 at hospital discharge was recorded for 92% during the intervention period and 84% during the control period.

Discussion

In this cohort investigation of bystander-witnessed out-of-hospital VF cardiac arrest due to heart disease, survival to hospital discharge was substantially better after a change in the EMS resuscitation protocol that eliminated immediate postshock rhythm reanalysis, ensuing stacked shocks, and

TABLE 3.   Prehospital and Hospital Outcome for Intervention Compared With Control Period

Outcome	Control Period, 2002–2004 (n=374)	Intervention Period, 2005–2006 (n=134)
Spontaneous circulation at hospital arrival	59.6 (223)	73.9 (99)
Hospital survival	32.8 (123)	45.5 (61)
Home discharge location	25.6 (96)	36.6 (49)

Values are % (n).

$P<0.05$ for all comparisons between control and intervention periods.

postdefibrillation pulse checks, while the subsequent CPR interval was extended from 1 to 2 minutes. Hospital survival was 46% during the intervention period compared with 33% during the control period. The survival improvement corresponded to a decrease in the interval from shock to onset of CPR and an increase in the duration of CPR between rhythm analyses.

With the widespread EMS implementation of AEDs, the interval from collapse to defibrillation has decreased in many communities.[20] Despite this, the survival benefit of this implementation in some communities has been modest or even questionable, falling short of expected gains.[21–24] In the present study community, for example, equipping the first-tier EMS with AEDs resulted in a nearly 3-minute average reduction in the interval from call receipt to scene arrival of the defibrillating EMS vehicle, a reduction that would have predicted an absolute 10% improvement in survival[25]; however observed survival improved by <5%.[16] Stimulated in part by such findings, additional research has demonstrated a critical interface between CPR and defibrillation whereby performance of CPR immediately before and after defibrillation may be vitally important for resuscitation[7–9]; yet, under past guideline-directed resuscitation protocols, the AED inhibited and interrupted CPR, especially during the critical perishock period.[11–13]

The intervention protocol implemented in the present study was designed to reduce previously observed delays in CPR after a shock while increasing the relative proportion of time spent performing CPR.[11] The results suggest that the changes in the AED protocol did indeed produce the desired changes in the CPR process. These changes in turn corresponded to increases in return of circulation at the end of EMS care, survival to hospital discharge, and home disposition among hospital survivors. Hence, one interpretation of the findings is that the change in the protocol produced a greater likelihood of survival by favorably affecting CPR timing and quantity. Importantly, the intervention-period protocol is largely consistent with the recently published guidelines from the American Heart Association and International Liaison Committee on Resuscitation.[5,14] If the magnitude of benefit observed in this experience extends to other communities, thousands of additional patients may be successfully resuscitated as other EMS systems implement the new guidelines.[3,4]

Other factors, however, need to be considered as potential explanations for the results. Given the design of this investigation, the results could be attributed to a Hawthorne effect whereby EMS personnel, because they were being observed,

provided generally "better" resuscitation care during the intervention period independent of the specific protocol changes.[26] The present study community's EMS system has a long-standing program of cardiac arrest surveillance and review, however. Although the protocol changed, there was no change in the quantity of training annually dedicated to cardiac arrest care during the intervention period compared with the control period. Moreover, the observed improvement occurred in a community in which survival historically is quite good, and survival during the 3 years of the control period was comparable to the 15-year average (1990–2004).[27]

Disproportionate surveillance or unexplained confounding between the 2 study time periods could potentially explain the results. The surveillance approach was identical throughout the study, however, and the proportion of total arrests eligible for analysis was similar between time periods. We a priori limited the analysis to those with bystander-witnessed VF arrest because of heart disease, because this approach restricts the assessment to a more homogenous group whom the protocol change might be expected to most affect. Moreover, analytical models comparing intervention and control periods that adjusted for other established predictors of survival produced very similar results.

Developments in hospital care could potentially explain the results; specifically, hypothermia and potentially emergent revascularization can improve survival after cardiac arrest.[28–30] Although the information was available only for survivors, we did not observe differences in the frequencies of these treatments between the 2 time periods that would account for the findings.

The present study has limitations. As noted, the study was not a randomized trial, and the improvement could have been due to a nonspecific Hawthorne effect or other temporal developments. The findings occurred in a community served by a mature, 2-tiered EMS system with an EMS infrastructure of cardiac arrest training and review. The intervention protocol maintained a "shock first" approach with a 15:2 compression-to-ventilation ratio for the first-tier EMS providers. The specific characteristics of the EMS system and/or the protocol should be considered when one gauges the generalizability of the findings. Although we had complete primary exposure and outcome data, we had limited information regarding CPR process on a subset of patients. We were unable to capture information about potentially important aspects of CPR, such as ventilation volume and rate or compression depth and rate.[31] Although there was good evidence that the intervention changed the timing and relative quantity of CPR, the change in the protocol may also have influenced unmeasured CPR characteristics that may have contributed to the observed survival improvement.

On the surface, the resuscitation paradigm described by the links in the chain of survival is straightforward. Yet, resuscitation is a dynamic set of actions during which the optimal integration of these links can be challenging, especially when their interdependent effects are not well understood. As a consequence, improvements in one link may inadvertently and adversely affect another link. Newly released international guidelines have sought to optimize the balance between earlier AED defibrillation and AED-attributed delays and

interruptions in CPR. The present study suggests this new guideline–directed approach will indeed alter the interface between defibrillation and CPR and in turn may improve clinical outcomes. If confirmed by other investigations, the findings underscore the critical importance of focused research that helps explain the physiology of both the arrest and its treatment. Only with this understanding can iterative but important advances be achieved in clinical care aimed at reducing the burden of out-of-hospital cardiac arrest.

Disclosures
None.

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CLINICAL PERSPECTIVE

Thousands of persons are treated for ventricular fibrillation arrest each year, but relatively few survive. Traditionally, treatment has included up to 3 stacked shocks, postshock pulse checks, and 1-minute intervals of cardiopulmonary resuscitation (CPR); this approach limits CPR. New guidelines for resuscitation of ventricular fibrillation arrest have eliminated rhythm reanalysis, stacked shocks, and postshock pulse checks and extended the interval of CPR to 2 minutes between rhythm analysis to improve the interface between defibrillation and CPR and increase the proportion of time spent performing CPR. The present study evaluated the potential survival impact of these guideline changes. The results demonstrate a potentially important survival benefit of the new compared with the traditional guideline–directed approach. The findings suggest that communities and medical providers may want to move quickly to adopt and evaluate the new guidelines in an effort to meaningfully improve survival after ventricular fibrillation arrest.