Improved Patient Survival Using a Modified Resuscitation Protocol for Out-of-Hospital Cardiac Arrest

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Background—Cardiac arrest continues to have poor survival in the United States. Recent studies have questioned current practice in resuscitation. Our emergency medical services system made significant changes to the adult cardiac arrest resuscitation protocol, including minimizing chest compression interruptions, increasing the ratio of compressions to ventilation, deemphasizing or delaying intubation, and advocating chest compressions before initial countershock.

Methods and Results—This retrospective observational cohort study reviewed all adult primary ventricular fibrillation and pulseless ventricular tachycardia cardiac arrests 36 months before and 12 months after the protocol change. Primary outcome was survival to discharge; secondary outcomes were return of spontaneous circulation and cerebral performance category. Survival of out-of-hospital arrest of presumed primary cardiac origin improved from 7.5% (82 of 1097) in the historical cohort to 13.9% (47 of 339) in the revised protocol cohort (odds ratio, 1.19 to 2.70). Similar increases in return of spontaneous circulation were achieved for the subset of witnessed cardiac arrest patients with initial rhythm of ventricular fibrillation from 37.8% (54 of 143) to 59.6% (34 of 57) (odds ratio, 2.44; 95% confidence interval, 1.24 to 4.80). Survival to hospital discharge also improved from an unadjusted survival rate of 22.4% (32 of 143) to 43.9% (25 of 57) (odds ratio, 2.71; 95% confidence interval, 1.34 to 1.59) with the protocol. Of the 25 survivors, 88% (n=22) had favorable cerebral performance categories on discharge.

Conclusions—The changes to our prehospital protocol for adult cardiac arrest that optimized chest compressions and reduced disruptions increased the return of spontaneous circulation and survival to discharge in our patient population. These changes should be further evaluated for improving survival of out-of-hospital cardiac arrest patients. (Circulation. 2009;119:2597-2605.)

Key Words: cardiopulmonary resuscitation ■ emergency medical services ■ fibrillation ■ heart arrest ■ survival

It is estimated that between 250,000 and 450,000 patients die each year in the United States of sudden cardiac arrest, with the majority of these deaths occurring before the patient reaches the hospital. Despite years of research, the survival rate for out-of-hospital cardiac arrest remains poor. There have been tremendous advances in cardiac arrest theory within the past decade. One advance was succinctly summarized by Weisfeldt and Becker as the 3-phase time-dependent model for cardiac arrest resuscitation. This model describes how therapy for the cardiac arrest patient may differ, depending on how long the patient has been in cardiac arrest. The electric phase starts immediately after the arrest and lasts ~5 minutes. During this time, the myocardium remains highly receptive to electric cardioversion into a perfusing rhythm. This is followed by the circulatory phase, which also lasts ~5 minutes. As time passes without perfusion, ATP stores become depleted. Accompanying the decrease in ATP, myocardial ischemia produces CO2 and H+, creating an acidic environment. Cardioversion during this timeframe may convert a potentially salvageable rhythm to a terminal asystole or pulseless electric activity. With an optimal chest compression strategy providing improved coronary perfusion, ATP may be increased, thus creating a more ideal environment for successful electric cardioversion. The third phase, beginning ~10 minutes after arrest, is the metabolic phase. A treatment strategy to return the heart to a perfusing rhythm during this phase remains elusive. Attempts to find the best strategy to improve the survival rates for these patients remain challenging.

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The emergency medical services (EMS) system in Kansas City, Mo (KCMO), has monitored cardiac arrest survival for...
more than a decade. During this time, the survival rate showed no improvement despite the addition of automatic external defibrillators (AEDs) to first-responder vehicles. In 2005, the KCMO EMS system undertook a quality improvement program to improve the cardiac arrest survival rate for the system. The cardiac arrest protocol was revised using the precepts of the 3-phase time-dependent model of arrest. Central to this protocol was an effort to improve coronary perfusion pressure through increasing the quality of chest compressions, which in turn would create an optimal environment for defibrillation. We analyzed our data 1 year after the initiation of the new protocol and report the results here.

The purpose of this study was to describe the survival rates for out-of-hospital, witnessed cardiac arrest patients with a presumed cardiac origin who were in ventricular fibrillation under the revised protocol compared with a historical control group using standard American Heart Association emergency cardiac care 2000 guidelines (Figure 1).

**Methods**

This retrospective cohort study analyzed a revised cardiac arrest protocol for cardiac arrest patients in KCMO. All adult cardiac arrest patients were reviewed. Patients who had a cardiac arrest determined to be cardiac in origin that was witnessed and had ventricular fibrillation as a presenting rhythm on EMS arrival were included in the analysis. All arrests that were not cardiac in origin, not witnessed, or had a presenting rhythm other than ventricular fibrillation were excluded. Arrests that were witnessed by EMS providers were removed from analysis.

KCMO has a population of ~470,306 with a geographic area of 318 sq miles. The EMS system for the city uses first responders from the KCMO Fire Department and transport-capable advanced life support (ALS) from the Metropolitan Ambulance Services Trust. All responding fire vehicles have emergency medical technicians trained in basic life support and are equipped with AEDs. The Metropolitan Ambulance Services Trust is a modified public utility model, high-performance EMS agency that uses sophisticated call-demand analysis and a dynamic system status management for strategic placement of ambulances throughout the city. It is certified by the Commission on Accreditation of Ambulance Services. The dispatch center is staffed by paramedics who are certified in emergency medical dispatch. The emergency medical dispatch uses Advanced Priority Dispatch Systems version 11, gives compression-only prearrival instructions to callers with adult patients in presumed cardiac arrest (MPDS, Salt Lake City, Utah), and is certified by the National Academy of Emergency Medical Dispatch as a center of excellence for adherence to dispatch protocols and prearrival instructions. An automatic and simultaneous dispatch of first responders and ALS providers takes place on all cardiac arrest calls.

![Figure 1. AHA emergency cardiac care 2000 cardiac arrest protocol. BLS indicates basic life support; VF, ventricular fibrillation; VT, ventricular tachycardia; and PEA, pulseless electric activity.](http://circ.ahajournals.org/doi/abs/10.1161/01.CIR.0000327674.16845.40)
The Protocol

The revised cardiac arrest protocol was developed by the EMS section of the KCMO Health Department (Figure 2) using strategies implemented by the Tucson Fire Department and then in Wisconsin.11–14 The KCMO cardiac arrest protocol fits well with the “minimally interrupted cardiac resuscitation” model recently published by Bobrow et al.15 Specific changes were made to the prior protocol. The ratio of chest compressions to ventilation was increased from the previous advanced cardiac life support standard for 2 rescuers from 5:1 to 50:2. All cardiac arrest patients, unless the cardiac arrest was witnessed by the EMS or a reliable history of quality chest compressions was available before EMS arrival (such as an off-duty firefighter or healthcare practitioner), received 200 chest compressions at the 50:2 ratio before first rhythm analysis and shock. Paramedics changed to their manual ALS monitor/defibrillator (Zoll M series, Boston, Mass) if a first-responder AED was initially attached. A single biphasic shock at 120 J for initial defibrillation was delivered by the AED or manual defibrillator. Continuous oxygen was delivered through a nonrebreather mask with an oral airway between ventilations. Gentle ventilations were accomplished quickly. Immediate chest compressions were started after defibrillation with no pulse checks until the next rhythm analysis. Intubation was not attempted until after a third round of chest compressions (minimum, 600 total chest compressions) or return of spontaneous circulation. No more than 10 seconds was allowed to elapse for each intubation attempt, with a minimum of 100 chest compressions at a 50:2 ratio, between each attempt at intubation. A maximum of 3 attempts at intubation was mandated. Intravenous medication was started after the first set of chest compressions with standard dosages of resuscitation drugs. Paramedics could consider termination of resuscitation if appropriate. The KCMO EMS service termination of resuscitation protocol excludes any patients found in ventricular fibrillation and patients who had had ventricular fibrillation during their resuscitation. Candidates for termination of resuscitation had to have a presumed cardiac origin for the arrest and required approval of a certified EMS base station physician. The KCMO EMS service uses lidocaine and does not use amiodarone.

All ambulance and fire department personnel were instructed in the new protocol using didactic classroom settings and simulated practice sessions over a 3-month period from January to March 2006. The protocol was produced on laminated cards that were placed inside the AEDs and ALS monitors for reference. The revised protocol began April 1, 2006.

Data Collection

EMS data were collected by the EMS services (KCMO Fire Department and Metropolitan Ambulance Services Trust) and reviewed by the KCMO Health Department. By protocol, paramedics documented specific data on their patient care reports, including suspected time of arrest, location of the arrest, description of the location of arrest (ie, house, public building), whether the arrest was witnessed, any prearrival resuscitation attempts, use of a public-access AED, the presenting rhythm, any changes in the rhythm, and any significant immediate and past patient history. Return of spontaneous circulation was defined by the KCMO Health Department as a pulse in the field that was sustained to delivery of the patient to the emergency department. The patient care reports for the ambulance

Figure 2. Kansas City cardiac arrest protocol. TOR indicates termination of resuscitation.
service were optically scanned into a remote database. The database was routinely queried using multiple search strategies to reduce the possibility of missing cardiac arrest patients who were not coded as cardiac arrest. Fire Department care reports were queried on the KCMO Fire Department computer-aided dispatch system (Tiburon, Pleasanton, Calif). AED summaries from the KCMO Fire Department were downloaded to the KCMO Fire Department quality improvement manager. The ambulance and Fire Department databases were compared to further ensure no missing patient data.

Response times were recorded electronically and downloaded from the ambulance and Fire Department computer-aided dispatch systems. Response time intervals were calculated using “first keystroke” by the emergency medical dispatch or Fire Department dispatcher as time 0 and ambulance/fire apparatus arrival on the scene of the reported address as the end time. All computer-aided dispatches are synched daily to the atomic clock to minimize drift.

Hospital data included whether the patient was admitted from the emergency department and discharge status from the hospital for both cohorts. Neurological status on discharge using the cerebral performance category (CPC) rating system was not collected before the implementation of the revised protocol and is reported only for the revised protocol cohort. All patients were vetted against the city, county, and state death certificate databases to verify outcomes.

All cases of cardiac arrest, including adult, pediatric, medical, and traumatic injury, are deemed a public health issue in KCMO. Cardiac arrest cases are identified and have been continuously entered into the cardiac arrest database maintained by the EMS section of the KCMO Health Department (Microsoft Access, Redmond, Wash) for >15 years. Only adult (>17 years of age), nontraumatic cardiac arrest patients of presumed cardiac origin were included in this analysis.

Outcomes Measures
The primary outcomes were return of spontaneous circulation and discharge from hospital alive. Descriptive statistics are reported for the neurological status at the time of discharge for the revised protocol cohort. Patients were assigned a neurological status by nurses specifically trained in using the CPC score described by the Brain Resuscitation Clinical Trial II Study Group.16

This study of our quality improvement effort was exempted from review by the Institutional Review Board for Adult Health Sciences at the University of Missouri at Kansas City School of Medicine.

Data Analysis
All data were entered into a Microsoft access database (XP, Microsoft Corp, Redmond, Wash) maintained by the KCMO Health Department. The data were exported and analyzed with SPSS statistical software version 13 (SPSS, Chicago, Ill). The prevalence of cardiac arrest was calculated by dividing the total number of medical arrests by the total population of the city.

The revised protocol cohort contained all cardiac arrest case data collected from April 1, 2006, through March 31, 2007 (12 months). The historical cohort consisted of patients entered into the cardiac arrest database from January 1, 2003, through March 31, 2006 (39 months).

Continuous data were compared by use of a 2-tailed Student t test; categorical data were analyzed for heterogeneity by χ^2 analysis or Fisher exact test, with odds ratio for survival and 95% confidence intervals (CIs) calculated. Logistic regression analysis was performed and the Hosmer-Lemeshow goodness-of-fit test was used to ensure that the model had no significant lack of fit. Response times were not normally distributed and were compared by use of the Mann–Whitney U test. A value of P<0.05 was considered significant.

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

Results
In the historical cohort, 1466 patients were identified. Of these, 1097 (74.8%) were primary cardiac arrest patients, 207 patients (14.1%) were medical (not primary) cardiac arrest patients, 52 (3.5%) were pediatric medical cardiac arrests, 5 (0.34%) were pediatric trauma arrests, and 104 (7.0%) were adult traumatic cardiac arrests. The revised cohort contained 492 patients. Of these, 339 (69.1%) were primary cardiac arrest patients, 82 (16.66%) were medical (not primary) cardiac arrest patients, 31 (6.1%) were pediatric medical cardiac arrests, 4 (0.81%) were pediatric traumatic arrests, and 36 (7.3%) were adult traumatic arrests.

The prevalence of cardiac arrest for the city of Kansas City in the revised protocol cohort was 0.11 per capita.

Of the primary cardiac arrest patients, 345 patients (31.4%) in the historical cohort and 113 (33.3%) in the revised protocol cohort (P=0.52, NS) presented with a rhythm of ventricular fibrillation. Twenty-five and 6 EMS-witnessed ventricular fibrillation arrests in the historical cohort and revised protocol cohorts, respectively, were removed, leaving 143 (44.7%, 143 of 320) and 57 (53.3%, 57 of 108) primary, witnessed ventricular fibrillation patients in the historical and revised protocol cohorts for analysis. No statistical difference in baseline variables was found between the 2 cohorts, including mean age, proportion of male patients, proportion of witnessed arrest, bystander cardiopulmonary resuscitation (CPR), or response time intervals (Table 1). The median response time interval was less for survivors than for nonsurvivors in both cohorts but was not significantly different (historical cohort: 4.38 versus 5.21, P=1.63; revised protocol cohort: 4.44 versus 5.43, P=0.287).

The overall survival rate to hospital discharge of all adult cardiac arrest patients with presumed cardiac origin was greater in the revised protocol cohort (n=47, 13.9%) compared with the historical cohort (n=82, 7.5%) (χ^2=12.93, P<0.001, 1 df). One-hundred forty-three and 57 primary cardiac arrest patients with an initial rhythm of ventricular fibrillation were witnessed by someone other than an EMS provider in the historical and revised protocol cohorts, respectively. In this category, a significant improvement was found in return of spontaneous circulation, from 37.8% (n=54) in the historical cohort to 59.6% (n=34) in the revised protocol cohort (χ^2 =7.92, P=0.0051, 1 df). Survival to hospital discharge similarly improved from an unadjusted survival rate of 22.4% (n=32) in the historical group to 43.9% (n=25) (χ^2 =9.23, P=0.0024, 1 df) in the revised protocol cohort group (Table 2). Utstein templates of cardiac arrest survival are shown in Figures 3 and 4.

Table 1. Cardiac Arrests Cohorts

<table>
<thead>
<tr>
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<th>Historical Cohort</th>
<th>Revised Protocol Cohort</th>
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<tbody>
<tr>
<td>Male sex, n (%)</td>
<td>109 (76.2)</td>
<td>49 (86.0)</td>
<td>0.13*</td>
</tr>
<tr>
<td>Age, mean (SD), t</td>
<td>59.9 (14.2)</td>
<td>60.2 (14.5)</td>
<td>0.87†</td>
</tr>
<tr>
<td>Bystander CPR, n (%)</td>
<td>54 (37.8)</td>
<td>27 (47.4)</td>
<td>0.21*</td>
</tr>
<tr>
<td>RTL, median (interquartile range)</td>
<td>5:25 (4:14–7:12)</td>
<td>5:15 (4:20–6:26)</td>
<td>0.40‡</td>
</tr>
</tbody>
</table>

*χ^2 test.
†Student t test.
‡Mann–Whitney U test.
Of the 25 survivors in the revised protocol cohort, 20 (80%) were discharged with a CPC score of 1, 2 survivors with a score of 2 (8%), and 1 with a score of 3 (4%). Two patients were lost to follow-up (8%). The majority of patients in the revised protocol group had a good neurological outcome (CPC 1 and 2, 88%) on discharge from the hospital. It was further noted that the 1 patient with a CPC score of 3 had severe neurological deficits from a previous cerebrovascular accident, and his neurological outcome was most likely a return to baseline.

Patient survival after cardiac arrest with ventricular fibrillation was analyzed with logistic regression analysis. Variables included in the model were exposure to the new protocol, sex, witnessed arrest, bystander CPR, and endotracheal intubation. Exposure to the new protocol significantly improved survival for all patients with ventricular fibrillation not witnessed by EMS (odds ratio, 2.17; 95% CI, 1.26 to 3.73). Other factors that significantly affected survival in the multivariate regression model are shown in Table 3. Of particular interest, endotracheal intubation was associated with an increase in mortality in the model (odds ratio, 0.41; 95% CI, 0.24 to 0.70). No significant interaction effect was found between the variables.

**Table 2. ROSC and Survivors, Witnessed VF Patient Population**

<table>
<thead>
<tr>
<th>Preprotocol Cohort, n (%)</th>
<th>Postprotocol Cohort, n (%)</th>
<th>Unadjusted OR (95% CI)</th>
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<tbody>
<tr>
<td>Witnessed VF</td>
<td>143</td>
<td>57</td>
</tr>
<tr>
<td>ROSC</td>
<td>54 (37.8)</td>
<td>34 (59.6)</td>
</tr>
<tr>
<td>Discharge alive</td>
<td>32 (22.4)</td>
<td>25 (43.9)</td>
</tr>
</tbody>
</table>

OR indicates odds ratio; VF, ventricular fibrillation; and ROSC, return of spontaneous circulation.

**Discussion**

Despite decades of changing therapies for sudden cardiac arrest, survival remains dismally poor. The central theme of this protocol was to implement strategies that would improve the chances of survival according to the 3-phase model of

![Figure 3. Utstein template cardiac arrest survival: historical cohort. ROSC indicates return of spontaneous circulation; OHCA, out-of-hospital cardiac arrest.](http://circ.ahajournals.org/)

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cardiac arrest. Paramount to this is improving coronary perfusion pressure for all patients and establishing an optimal environment for successful defibrillation for those patients in ventricular fibrillation.

Immediate defibrillation on arrest from ventricular fibrillation has unquestionably been shown to improve survival and has excellent data supporting its use. The success of early defibrillation is well documented with the now universally quoted statistic of a decrease in survival of 8% to 10% for every minute passed after arrest. These findings have led to the proliferation of AEDs and initially showed promise as a mechanism for improving survival from sudden cardiac arrest. However, studies have now demonstrated that the patients most likely to benefit from this immediate defibrillation usually have extremely short intervals between arrest and defibrillation and experience arrests mostly in public places with immediate access to AEDs such as airports and casinos. Unfortunately, this scenario represents a small percentage of cardiac arrest patients. The typical cardiac arrest patient has a relatively prolonged downtime (usually beyond the 5-minute electric phase) with minimal resuscitative efforts during the first minutes. Therefore, the majority of cardiac arrest patients have not benefited from the addition of AEDs to EMS vehicles, with 1 report showing a decrease in survival. Although immediate defibrillation is lifesaving and beneficial to patients in the electric phase of cardiac arrest, it may be hazardous to patients in the circulatory phase. The myocardium is highly metabolic. Cardiac arrest is the ultimate insult to the myocardium, resulting in a substan-

Table 3. Logistic Regression Analysis

<table>
<thead>
<tr>
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<th>OR (Survival)</th>
<th>95% CI</th>
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<tbody>
<tr>
<td>KCCAP received</td>
<td>2.170</td>
<td>1.263–3.730</td>
</tr>
<tr>
<td>Female sex</td>
<td>1.762</td>
<td>0.988–3.141</td>
</tr>
<tr>
<td>Witnessed arrest</td>
<td>2.606</td>
<td>1.525–4.454</td>
</tr>
<tr>
<td>Bystander CPR</td>
<td>1.318</td>
<td>0.762–2.279</td>
</tr>
<tr>
<td>Patient intubated</td>
<td>0.409</td>
<td>0.239–0.699</td>
</tr>
</tbody>
</table>

OR indicates odds ratio; KCCAP, Kansas City Cardiac Arrest Protocol.
tial and severe energy deficit, especially during ventricular fibrillation arrest when the fibrillating heart still requires energy substrates, even more so than the normally beating heart. Substantial data show the gradual depletion of cellular energy substrates during cardiac arrest and degradation of the fibroblastic activity of the myocardium. Immediate countershock during the times of low-frequency fibrillation and loss of energy substrates have been shown to result in conversion to a nonsurvivable rhythm. Work by Cobb et al and Wik et al showed that chest compressions before defibrillation improved survival when EMS had a response time interval of 4 to 5 minutes. Perhaps even more important was the finding that chest compressions before defibrillation did not increase mortality for any patient, regardless of response time interval. From a prior study in our system, it was apparent that responder arrival to the patient’s side usually occurred during the cusp of the transition from the electric to circulatory phase or in the circulatory phase proper. Therefore, in the revised protocol, chest compressions were begun before attempted defibrillation in all cases except rescuer-witnessed sudden cardiac arrest.

Few data are available to support a 30:2 ratio of compressions to ventilation. It is well documented, however, that increased compressions improve coronary perfusion pressure, which directly affects survival in both animal and human studies. Studies from Seattle and Japan have shown that persons receiving continuous chest compressions from bystanders had higher survival rates that those who received standard CPR with a pause for ventilation. Kellum et al showed that a significant increase in survival of ventricular fibrillation cardiac arrest occurred when continuous chest compressions were adopted by rescue personnel in Wisconsin. This form of resuscitation was again shown to be beneficial in a published report of cardiac arrest in Arizona by Bobrow et al and in Michigan by Fales and Farrell. We also sought to decrease the amount of “hands-off time” when the patient receives no chest compressions and consequently no forward blood flow. It has been shown that when using pre-2005 standards, including AEDs, rescuers effectively provided chest compressions to cardiac arrest patients <50% of the time. The ratio of compressions to ventilation for the revised protocol was changed from the pre-2005 standard of 5:1 (and the 2005 standard of 30:2) to 50:2. This would allow rescuers to concentrate on doing optimal compressions and the paramedic to concentrate on immediate defibrillation, starting an intravenous line, administering drugs, and performing endotracheal intubation if needed. (In our system, 1 paramedic is on scene on the vast majority of calls).

Data are limited suggesting that aggressive ventilation or endotracheal intubation has any benefit for the cardiac arrest patient, regardless of the origin of the arrest. Although oxygen delivery to the myocardium is an important determinant of survival in cardiac arrest, we believe that aggressive chest compressions with passive oxygen delivery likely deliver adequate oxygenation to the patient. Using continuous insufflation of oxygen at 15 L/min through an endotracheal tube, Saissy et al were able to achieve equivalent oxygenation compared with mechanical ventilation in cardiac arrest patients. Animal studies showing improved survival with ventilation have several important limitations that make translation to the field questionable. Animals are typically paralyzed chemically and intubated before the study period and thus have no agonal respirations. In addition, these studies do not account for hands-off periods that occur during the act of intubating, nor do they account for the aggressive hyperventilation that occurs in the field. Hyperventilation has been shown to be ubiquitous in both out-of-hospital and in-hospital resuscitation. Aufderheide and Lurie have demonstrated that rescuers almost always significantly hyperventilate patients whether or not they are intubated. They further demonstrated that hyperventilation leads to decreases in survival because of the resultant increase in intrathoracic pressure, which decreases coronary perfusion pressure in cardiac arrest patients.

Evidence also exists that agonal breathing takes place during resuscitation and that, although airway obstruction may be an important factor for lay rescuers, it would be less a factor for professionals with airway adjuncts. With very limited data to support ventilations as a significant contributor to survival and evidence showing that the performance of intubation interferes with chest compressions and compromises optimal coronary perfusion, we restricted endotracheal intubation until cardiac resuscitation time was adequate. Rescuers placed an oral airway immediately to correct or prevent any upper airway obstruction and provided continuous flow of oxygen via a nonrebreather mask. Two “gentle” ventilations were delivered over 2 seconds, with rescuers forgoing ventilations if they were unable to achieve them during the 2-second timeframe. The 2 ventilations were thought to bridge the time between the switching of the compression providers and to offer some ventilatory support. It was thought that this small amount of ventilations would not produce the intrathoracic pressures outlined in the above studies and would be minimal risk to the patient. Paramedics were allowed to attempt endotracheal intubation after the first 3 series of 200 compressions were performed. In addition, with few data showing that endotracheal administration of cardiac arrest drugs is beneficial, coupled with the hyperventilation from paramedics forcing the volume of drug into pulmonary circuit, endotracheal administration of cardiac arrest drugs was prohibited. Furthermore, mortality increased in intubated patients in the regression model. It is difficult to assign this finding to any 1 reason. It may be due to the influences of hyperventilation or may be a result of the patient not responding to resuscitation strategies. On a few occasions, successfully resuscitated patients regained consciousness or had a gag reflex preventing endotracheal intubation. The current AHA recommendations leave the timing of endotracheal intubation to the discretion of the EMS medical director and continue to allow the endotracheal administration of cardiac arrest drugs.

Past studies have shown that a significant time delay of 5 to 28 seconds is introduced when an AED is used for analysis and shock delivery. This delay from rhythm recognition to shock delivery is detrimental to successful conversion of ventricular fibrillation. Paramedics are trained in rhythm recognition and are able to deliver a shock quickly to
the patient, decreasing the hands-off period and resultant decrease in coronary perfusion pressure. Previously, some EMS crews would rely on the AED even when a manual defibrillator was present. The revised protocol instructed the EMS crews to replace the AED with the manual defibrillator once the ALS unit arrived on scene to decrease the time of rhythm recognition and delivery of countershock.

We also incorporated immediate resumption of chest compressions after defibrillation without checking for pulse or rhythm in accordance with current AHA recommendations.

Study Limitations
Because this was a retrospective study, it is vulnerable to bias issues inherent in all retrospective studies. Furthermore, it is impossible to point to 1 change within the protocol that would produce such a dramatic rise in the cardiac arrest save rate. Most of the changes were made to develop a resuscitation strategy that followed the 3-phase model of resuscitation, to increase the coronary perfusion pressure, and to optimize the myocardial environment as much as possible before defibrillation. Although this study was retrospective, it is important to note that the same population was sampled during both of the phases and that no significant difference was found between the 2 cohorts.

We do not have CPC scores for our out-of-hospital survivors before the initiation of the new protocol, making optimal preprotocol and postprotocol changes more difficult to determine. We have not studied the effect of the hospital to which the patient was transported on survival; however, at the time of this study, no hospitals within the region were using hypothermia protocols for the resuscitated cardiac arrest patient.

It is possible that a Hawthorne effect was present for rescue personnel trying a new resuscitation protocol. During training in the new protocol, the importance of optimal chest compressions was emphasized, and it is possible that this would cause rescue personnel to focus more on technique and performance during the new protocol time period.

In addition, it was impossible to determine how closely paramedics and firefighters chose to follow the protocol. We relied solely on the patient care reports to extrapolate data and did not have any electronic data from the defibrillators used in this EMS system to show the rate or quality of chest compressions or no-flow periods.

Conclusions
A cardiac arrest protocol that emphasized strategies for increasing coronary perfusion pressure and optimizing defibrillation success, including mandatory preshock chest compressions, an increase in compressions rate to 50/2, delayed intubation, and strict use of manual defibrillators if available, resulted in an overall increase in survival to hospital discharge for sudden cardiac arrest patients and a nearly 2-fold increase in survival of witnessed ventricular fibrillation patients with a presumed cardiac origin. Further studies are warranted to look at the impact of the new 2005 AHA guidelines on survival, and further work is needed to benchmark best practices in cardiac arrest.

Disclosures
None.

References
This article adds to the growing body of research demonstrating the potential benefits of changes in basic resuscitation with increased emphasis on chest compressions and a deemphasis on ventilation. The study evaluated changes in an emergency medical services cardiac arrest protocol, advocating cardiopulmonary resuscitation before defibrillation for all adult out-of-hospital cardiac arrest patients, maintaining a 50:2 ratio of compressions to ventilation, restricting aggressive ventilation, and minimizing pauses for ventilation or other procedures. The rationale behind these changes was derived from the 3-phase model of cardiac arrest and based on the fact that the majority of our cardiac arrest patients are in the circulation phase of arrest when emergency medical services personnel arrive on scene. The outcome data demonstrate a nearly 2-fold increase in survival to hospital discharge of bystander-witnessed ventricular fibrillation arrest compared with a historical control treated under the 2000 emergency cardiac care guidelines. The increase in survival to hospital discharge also appears to be associated with excellent neurological outcomes. Physicians rarely rescue a cardiac arrest victim if out-of-hospital therapy has failed. Therefore, changes in the delivery of out-of-hospital resuscitation that improve survival are of great importance. Further study is required to evaluate the sustainability of these results and to investigate optimal therapy for the out-of-hospital cardiac arrest patient.
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