

Cardiocerebral Resuscitation Improves Neurologically Intact Survival of Patients With Out-of-Hospital Cardiac Arrest

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Study objective: In an effort to improve neurologically normal survival of victims of cardiac arrest, a new out-of-hospital protocol was implemented by the emergency medical system medical directors in 2 south-central rural Wisconsin counties. The project was undertaken because the existing guidelines for care of such patients, despite their international scope and periodic updates, had not substantially improved survival rates for such patients during nearly 4 decades.

Methods: The neurologic status at or shortly after discharge was documented for adult patients with a witnessed collapse and an initially shockable rhythm. Patients during two 3-year periods were compared. During the 2001 through 2003 period, in which the 2000 American Heart Association guidelines were used, data were collected retrospectively. During the mid-2004 through mid-2007 period, patients were treated according to the principles of cardiocerebral resuscitation. Data for these patients were collected prospectively. Cerebral performance category scores were used to define the neurologic status of survivors, and a score of 1 was considered as "intact" survival.

Results: In the 3 years preceding the change in protocol, there were 92 witnessed arrests with an initially shockable rhythm. Eighteen patients survived (20%) and 14 (15%) were neurologically intact. During the 3 years after implementation of the new protocol, there were 89 such patients. Forty-two (47%) survived and 35 (39%) were neurologically intact.

Conclusion: In adult patients with a witnessed cardiac arrest and an initially shockable rhythm, implementation of an out-of-hospital treatment protocol based on the principles of cardiocerebral resuscitation was associated with a dramatic improvement in neurologically intact survival. [Ann Emerg Med. 2008;52:244-252.]

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INTRODUCTION

Background

Out-of-hospital cardiac arrest is a major public health problem and a leading cause of death.¹⁻³ In the absence of early defibrillation, survival rates in most areas of the world are dismal and have remained essentially unchanged for decades despite periodic resuscitation guideline updates.^{4,5}

A new approach to the treatment of out-of-hospital cardiac arrest, referred to as cardiocerebral resuscitation, was developed

by the University of Arizona Sarver Heart Center Cardiac Resuscitation Research Group.⁶⁻⁸ This resuscitation protocol had been shown to significantly improve neurologically intact 24-hour survival in realistic animal models of out-of-hospital cardiac arrest.⁹⁻¹⁴ Accordingly, in 2004, the emergency medical service medical directors in 2 rural Wisconsin counties implemented an out-of-hospital protocol for the treatment of out-of-hospital cardiac arrest, using the principles of cardiocerebral resuscitation.^{15,16}

The first published report of the use of cardiocerebral resuscitation in the out-of-hospital setting was limited to 1

Editor's Capsule Summary

What is already known on this topic

Uninterrupted cardiopulmonary resuscitation (CPR), especially closed chest compressions, has been shown to improve survival in animal models and limited case series.

What question this study addressed

Did implementation of out-of-hospital cardiocerebral resuscitation protocol that emphasized continuous CPR in 2 rural counties improve neurologically intact survival?

What this study adds to our knowledge

In this before-and-after observational study of 181 witnessed cardiac arrest patients with initially shockable rhythms, neurologically intact survival increased from 15% to 39% when the new protocol was introduced.

How this might change clinical practice

In training and during cardiac arrest resuscitations, emphasize the importance of providing continual chest compressions, minimizing the frequency and duration of interruptions as much as possible.

year's observations.¹⁶ Neurologically intact survival of witnessed-shockable patients (ie, those with a witnessed collapse and an initially shockable rhythm) improved from 15% to 48%.¹⁶ Although dramatic, these results were not convincing to many in the scientific resuscitation community because the new approach had been in place for only 1 year and the number of witnessed-shockable patients was small. There was also concern that a significant portion of the improved survival could be ascribed to the "Hawthorne effect," that is, the improved performance of individuals who knew they were being studied.¹⁷ Longer duration of follow-up might address some of these concerns.

Importance

The cardiocerebral resuscitation protocol deviated significantly from the American Heart Association and International Liaison Committee on Resuscitation 2000 Guidelines¹⁸ that were extant when the new protocol was first introduced. Even though some of cardiocerebral resuscitations' individual interventions were included in the American Heart Association 2005 Guidelines,¹⁹ cardiocerebral resuscitation still deviates from the current guidelines in its approach to delivery of chest compressions, airway management, and ventilation. Therefore, if extended experience with the use of cardiocerebral resuscitation in the out-of-hospital setting confirms its survival advantage in the treatment of witnessed-shockable patients, it is possible that cardiocerebral resuscitation will emerge as the standard by which the results of current and future resuscitation protocols for this group of patients should be judged. Additionally, the need for assisted ventilation in the initial

minutes of treatment of witnessed-shockable patients may well need to be reassessed.

Goals of This Investigation

This report compares neurologically intact survival in patients with a witnessed arrest and an initially shockable rhythm before and after implementation of an out-of-hospital cardiocerebral resuscitation protocol.

MATERIALS AND METHODS

Study Design

This is a before-and-after observational study of the effect on survival of a new out-of-hospital cardiac arrest management protocol. Data for a 3-year period before the implementation of the new protocol were collected retrospectively and are compared with observations prospectively collected for a 3-year period after the protocol was instituted. The project was approved by the institutional review board of Mercy Health System and approved for use by the Wisconsin EMS Bureau.

Setting

The emergency medical services (EMS) response in Rock and Walworth counties is a 2- or 3-tiered system for suspected cardiac arrest patients. The first responders to be radio dispatched are cardiocerebral resuscitation-trained law officers or EMS personnel who most often are equipped with automated external defibrillators. Second-tier municipal nonparamedic ambulances are usually also dispatched for each call. Paramedic or third-tiered responders participate in all cardiac arrest cases either as the primary responding unit or one called to assist in care.

Rock and Walworth counties have areas of 720 and 555 square miles, respectively. Their 2004 populations were 156,512 and 98,334, respectively. There are 582 first-responder law officers (sheriff and municipal police officers) in the 2 counties. Rock County has 2 municipal paramedic squads with 60 members, and Walworth County has 3 private paramedic squads with 50 members. The 22 municipal nonparamedic squads in the 2 counties have a total of 458 primarily volunteer emergency medical technicians.

Selection of Participants and Data Collection and Processing

Data on all patients experiencing a possible cardiac arrest were collected for 2 separate 3-year periods. For the control period, between 2001 and 2003, data was obtained retrospectively. The out-of-hospital treatment for these patients followed that advocated by the American Heart Association 2000 guidelines. For the project period, between mid-2004 and mid-2007, data was collected prospectively. These patients were treated in the out-of-hospital setting with a protocol based on cardiocerebral resuscitation. Data for each of these periods were obtained from EMS run reports, 911 dispatcher recordings, and emergency department (ED) and hospital records. During the

project period, conversations with rescuers were occasionally used to clarify data collected. Although automated external defibrillators were used in the control period, defibrillator/automated external defibrillator downloads were available only during the project period. Data on each patient were entered into a customized Microsoft Access (Microsoft Corporation, Redmond, WA) database.

An arrest was designated as “witnessed” if someone at the scene heard or saw the patient collapse. In a few instances, cases were considered witnessed if a definable activity of less than 1 or 2 minutes existed between last contact with the patients and their collapse. Initial rhythms were categorized as shockable (as read by the automated external defibrillator) or nonshockable. “Call-to-shock” intervals were calculated for the witnessed-shockable patients by using the time the 911 call was received and the time of the initial shock.

Patients were classified according to the Utstein style of presentations for reports of out-of-hospital cardiac arrest.²⁰ As presented in Figure 1, cases were excluded from the analysis of survival for the following reasons: (1) if information available indicated a noncardiac etiology for the arrest, (2) if the arrest was witnessed by EMS personnel, (3) if the patient was considered dead at the scene and out-of-hospital treatment was then either not initiated or prematurely terminated, (4) if resuscitation was terminated because of preexisting do-not-resuscitate (DNR) orders, (5) if the patient was younger than 16 years, (6) if there was insufficient information to determine the etiology of the arrest, and (7) if postresuscitation hypothermia was used. Exclusions were processed sequentially in the above order, with the earliest occurring exclusion assigned to each patient.

INTERVENTIONS

The cardiocerebral resuscitation out-of-hospital protocol (Figure 2) was reserved for cases in which the arrest was presumed to be cardiac in origin, ie, individuals with a sudden unexpected collapse, with absent or abnormal breathing. In all other situations, standard cardiopulmonary resuscitation (CPR) was used.

The cardiocerebral resuscitation protocol used 2 minutes of uninterrupted or continuous chest compressions at 100 per minute before each rhythm analysis±shock. Single instead of “stacked” shocks were used. Continuous chest compressions were resumed immediately after each analysis±shock. Pulse checks, when performed, were done only after 200 compressions during the obligatory pause for analysis of rhythm. Patients were not moved from the scene until 3 cycles of continuous chest compressions and analysis±shock were completed.

Initial airway management was delayed until a second rescuer was available and then was limited to placement of an oral-pharyngeal airway and administration of oxygen by nonrebreather mask. If the *initial* rhythm was shockable, insertion of an invasive airway and assisted ventilation were not performed until either return of spontaneous circulation or until after 3 cycles of continuous chest compressions and analysis±shock were completed. However, if the initial rhythm was nonshockable, invasive airway insertion and ventilation

were initiated after this first rhythm analysis. When positive-pressure ventilations were delivered, a rate of 8 to 10 per minute was recommended.

The technique of chest compressions was taught with a metronome to emphasize the importance of a rate of 100 per minute. Full chest recoil after each compression was stressed. In the field, a metronome was attached to most defibrillators used by responders.

If only 1 responder was on the scene, the defibrillator/automated external defibrillator pads were applied *before* chest compressions were initiated in an effort to minimize the pause between stopping compressions and shocking. When possible, automated external defibrillators were reprogrammed to comply with the protocol, and when this could not be done, EMS personnel were instructed to ignore the automated external defibrillator postshock instructions that did not follow the protocol. Paramedic responders used manual defibrillators.

There was no public campaign to instruct laypersons in “continuous chest compression” resuscitation. The single 911-dispatch center in Rock County gave standard CPR instructions to callers in the 2001 to 2003 period and chest-compression-only instructions after May 2004. None of the 3 911 centers in Walworth County gave CPR instructions of any type.

Outcome Measures

We evaluated the effect of the new cardiocerebral resuscitation protocol by comparing neurologically intact survival of witnessed-shockable patients during the 3 years (2001 to 2003) when Guidelines 2000 were in place with that observed during the 3 years when the cardiocerebral resuscitation out-of-hospital protocol was used.

The neurologic status of each survivor was determined at or shortly after hospital discharge and was obtained primarily from hospital records by the first author. In 2 cases, the patient’s attending or primary care physician was contacted for clarification. In 1 case, an individual who had seen the patient after discharge provided additional information. A cerebral performance category score^{20,21} was recorded for each survivor. A score of 1 denotes “good” cerebral performance; such individuals are conscious, alert, and able to work and live a normal life but may have had minor psychological or neurologic deficits. A cerebral performance category score of 2, indicating “moderate” disability, was assigned to patients who were conscious and alert, with sufficient cerebral function for independent activities of daily life. Although these individuals may have had hemiplegia, seizures, ataxia, dysarthria, dysphasia, or permanent memory or mental changes, they returned to their previous place of residence. A score of 3, or “severe” disability, was given if the patient was conscious but depended on others for daily support. Such individuals were usually institutionalized but may have been discharged home, requiring exceptional family effort because of their impaired brain function. Patients with a cerebral performance category score of 4 were unconscious and in a coma or vegetative state. Scores of 5 were not used because these individuals were considered

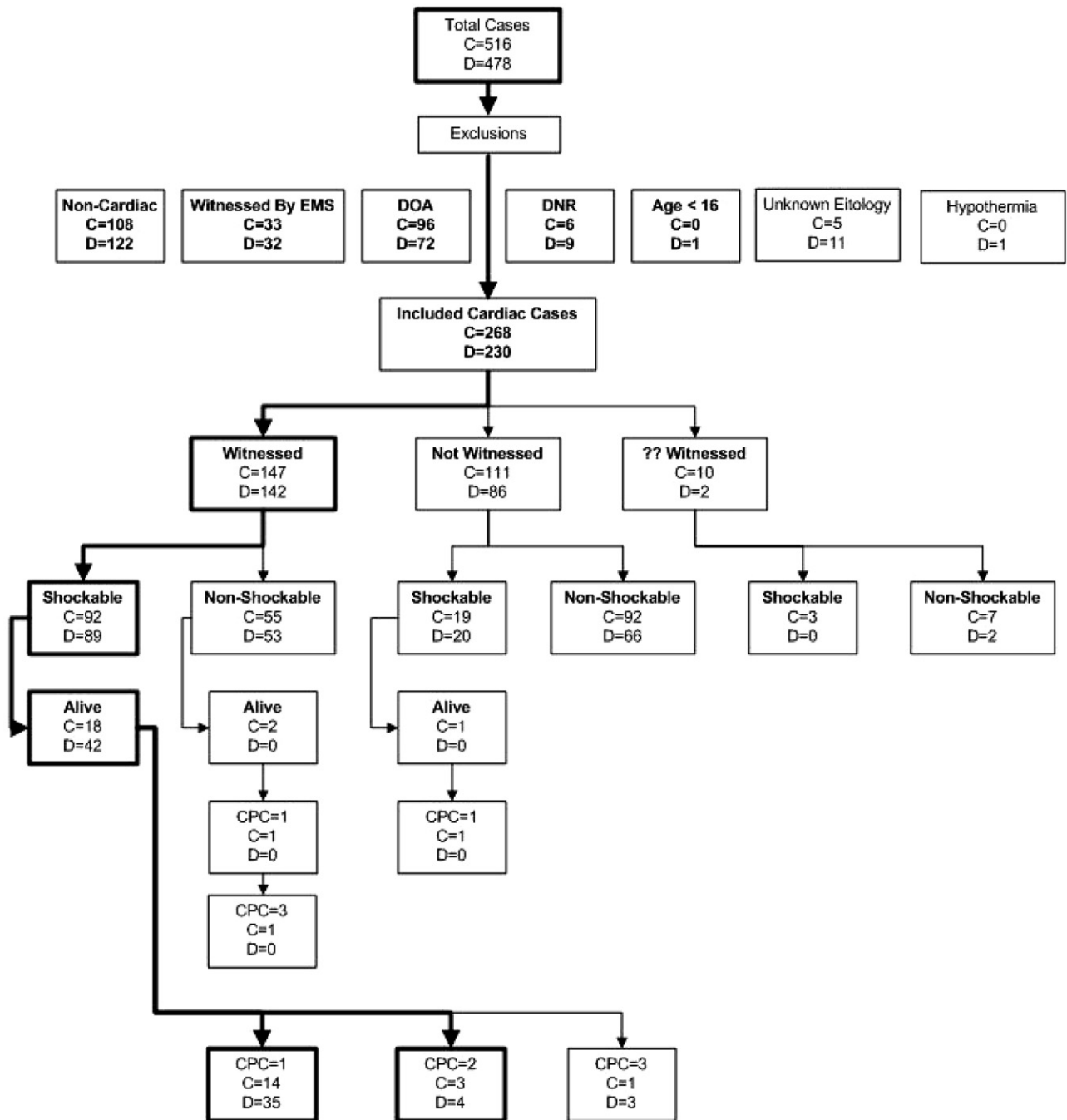


Figure 1. The number of patients in each subset of total cases is presented for the 3-year historical 2001 to 2003 period (C) and the 3-year (2004 to 2007) demonstration project period (D). Cases were excluded from analysis if the cause of arrest was noncardiac or could not be determined. Additional exclusions included the following: DOA cases were considered “dead on arrival,” and resuscitation efforts were either not initiated or were terminated in the field; DNR cases had DNR orders in effect; patient was younger than 16 years; the arrest was witnessed by EMS responder(s). An arrest was considered witnessed if collapse was either seen or heard. Initial rhythms were designated as shockable or nonshockable. The cerebral performance category (CPC) scores for survivors are presented.

nonsurvivors. In this report, “neurologically intact” was reserved for individuals with a cerebral performance category score of 1.

For each 12-month interval in the control and project periods, the total and surviving numbers of witnessed-shockable patients were tallied.

Primary Data Analysis

Data were analyzed with SPSS version 15.0 (SPSS, Inc., Chicago, IL), presenting descriptive statistics and frequencies. The comparisons between continuous variables were made by *t* test and the respective 95% confidence

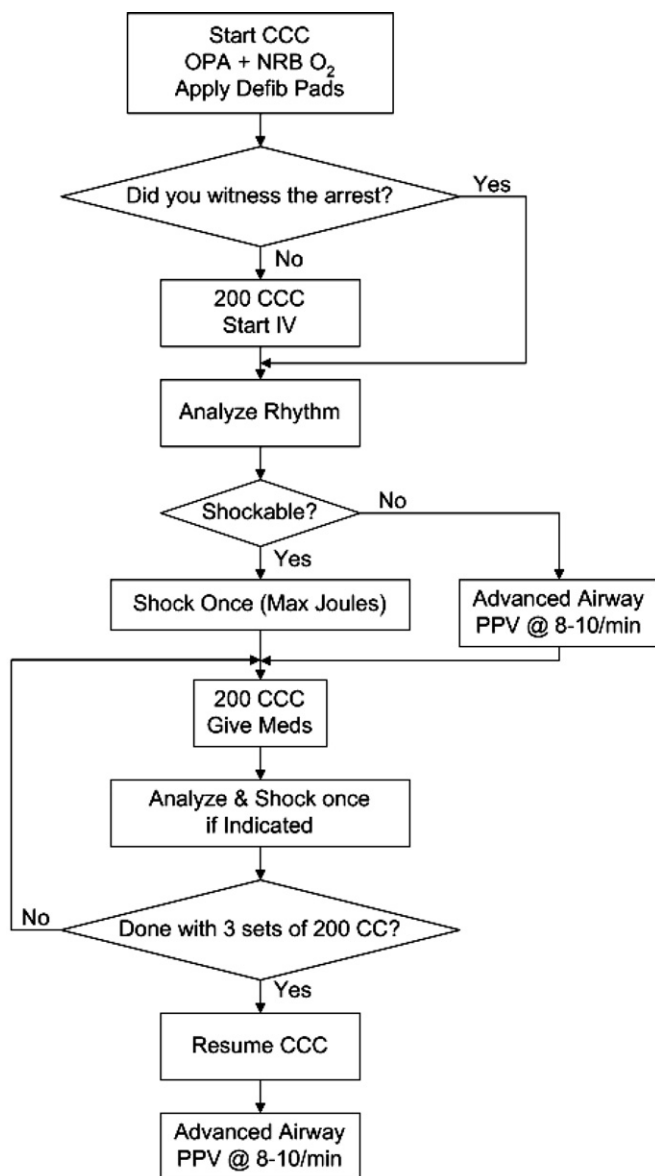


Figure 2. The cardiocerebral resuscitation protocol. CCC, Continual chest compressions; OPA, oral pharyngeal airway; NRB, nonrebreather mask; Advanced Airway, endotracheal tube or Combitube; PPV, positive pressure ventilations.

interval (CI) for the mean difference. Categorical data are expressed as proportions and 95% CI of difference between groups.

RESULTS

During the 3 years when the Guidelines 2000 were used, there were 92 adult patients with a witnessed arrest and an initially shockable rhythm. Eighteen of these 92 patients survived (20%), and 14 of these 92 (15%) survived neurologically intact. During the 3 years that the cardiocerebral resuscitation protocol was used, there were 89 such patients.

Forty-two of them survived (47%), and 35 of the 89 (39%) survived neurologically intact. The total, as well as the number of neurologically intact survivors, was different (Table 1).

The prevalence of arrests that were witnessed and witnessed arrests with an initially shockable rhythm were similar in the 2 groups (Figure 2). There was no difference between the 2 groups in age, sex, or the percentage of individuals receiving any form of bystander CPR (Table 1). The mean call-to-shock times were longer in the cardiocerebral resuscitation project period.

The annual number of witnessed-shockable patients and their outcomes in the control and project periods are presented in Table 2. Bystander CPR and survival numbers for type of bystander activity in the witnessed-shockable cases are presented in Table 3.

LIMITATIONS

Before-and-after observational studies are subject to a variety of confounding influences that may affect the validity of conclusions drawn, but because our conclusions involve only a comparison of the witnessed-shockable patients, only the potential confounders in this subgroup will be addressed. These include the validity and effect of exclusion criteria, the completeness of cases captured for the 2 periods, and other factors external to the compared protocols that may have erroneously been presumed to be similar.

We therefore reviewed all patients whose initial rhythm was shockable, witnessed or not, and asked whether the exclusion process (see Figure 2) would prejudice the results. A noncardiac arrest etiology was found in 2 control patients and 3 project patients. In one control patient, whose arrest was not witnessed and who died, clinical data to define the exact cause of arrest were not available. The other control patient died after a respiratory arrest and massive hemoptysis from lung carcinoma. The 3 excluded project patients died from subarachnoid hemorrhage, drowning, and pulmonary embolus. Thirteen control and 9 project cases were excluded because the arrest was witnessed by EMS rescuers, and all these cases were found to be valid. No control patients and 6 project cases were initially excluded for DNR reasons. After review, 2 project patients were reclassified as *not* true DNR because their DNR status had been initiated after the family had physician input about the futility of continuation of life support. The single patient who received hypothermia after resuscitation was excluded. None of these initially shockable patients were excluded for reasons of incomplete data, dead on arrival, or age. We therefore conclude that the exclusion criteria used did not artificially inflate the survival results in our project witnessed-shockable patients. If the 1 control case excluded for noncardiac etiology had not been excluded, the control survival rate would have decreased.

On the other hand, inappropriate exclusions could well introduce bias in the residual "presumed cardiac" group, which is the denominator in calculation of *overall* survival. This is one reason we specifically avoided presentation of a comparison of overall cardiac arrest survival rates.

Table 1. Characteristics of patients with a witnessed arrest and an initially shockable rhythm during the control period using Guidelines 2000 CPR and the project period using cardiocerebral resuscitation.

Characteristics	Three-Year Control Period			Three-Year Project Period			Group Comparison, 95% CI
	No.	Proportion	Mean	No.	Proportion	Mean	
Total cases	92			89			
Age			64.3			61.9	−6.4 to 1.5
Male sex	70	0.76		63	0.71		−0.2 to 0.1
Call to shock, min*			7.4			8.6	0.3 to 2.1
Bystander CPR/continuous chest compressions [†]	41	0.45		40	0.45		−0.1 to 0.2
Survivors, total No.	18	0.20		42	0.47		0.1 to 0.4
Survivors, cerebral performance category=1	14	0.15		35	0.39		0.1 to 0.4

*Data available for 69 control patients and 83 project patients.

[†]Data available for 91 CPR patients and 87 cardiocerebral resuscitation patients.

Table 2. The annual number of patients and their outcomes in the control and project periods for those patients whose arrest was witnessed and initial rhythm was shockable.

Year	Total Cases, No.	Survivor		Survivor Cerebral Performance Category 1	
		No.	%	No.	%
Control					
2001	26	6	23	5	19
2002	26	6	23	6	23
2003	40	6	15	3	8
Project					
2004	31	18	58	15	48
2005	24	9	38	7	29
2006	34	15	44	13	38

A second potential confounder is whether all arrest cases were captured during the data collection process. The EMS response in our area was such that virtually all cases in which resuscitation was attempted would have been treated by one of the paramedic squads. In addition, virtually all cases with ongoing resuscitation would have been transported to one of the 4 EDs. We relied on data found in EMS reports and hospital ED and inpatient medical records. Computerized logs for these sources were searched. Additionally, all transfers out from the hospitals were examined. In-field termination, except for patients who were obviously dead, was not operant during the 2 study periods. We are therefore confident that essentially all cases in which resuscitation was attempted were included in the data presented in Figure 2.

All data were collected and reviewed by the first author (M.J.K.), who was often not blinded to patient outcome. Every effort was made to be impartial and to diligently apply criteria in making decisions. However, with the exception of determination of cerebral performance category scores and defining “witnessed” status, any bias thus introduced would not affect the conclusions about survival in the witnessed-shockable groups. The cerebral performance category score criteria are well defined. In 3 cases during the project period, a determination could not be made from data available in medical records, and additional information was sought. This was not possible during the control period, which may have confounded distinctions

between scores of 1 and 2 during the control period but would not, because of the definitions, have misclassified cases with a score of 3.

Our study was not designed to address the effect of bystander CPR or continuous chest compressions on survival in the witnessed-shockable groups. During the project period, there was no formal effort made to educate lay public in continuous chest compression–only CPR, and we did not assess the adequacy of bystander efforts. Some type of bystander effort was present in 45% of both groups of witnessed-shockable cases (Table 3).

We also did not assess the quality of either CPR or cardiocerebral resuscitation performed by rescuers. CPR training during the control period occurred every 2 years per state protocol. During the project period, there was an intensive initial training program using a “train the trainer” approach, but subsequent training, including that of new members and retaining of existing rescuers, was left to the discretion of individual rescue squads and was neither monitored nor studied. We did not investigate adherence to protocols, and therefore feedback to rescuers about this was seldom performed. ED physicians were not trained in cardiocerebral resuscitation, and we did not study their use of Guidelines 2005 in the latter years of the project. Hospital intensive care protocols were not specifically altered to address cardiac arrest survivors during the 2 project periods. All of these factors could have influenced our conclusions.

Table 3. Types of bystander CPR performed and numbers of patients (in parentheses) surviving in each category for patients with a witnessed arrest and an initially shockable rhythm. CPR is Guidelines 2000 CPR.

Group	Total No.	None	CPR	911 CPR	CCC	911 CCC	Unknown	Percentage With CPR or CCC
Control	92 (18)	51 (10)	37 (8)	3 (0)	0	0	1 (0)	45
Project	89 (42)	49 (21)	21 (11)	1 (1)	5 (4)	11 (4)	2 (1)	45

Continuous chest compressions are continuous chest compression–only CPR. 911 CPR or continuous chest compressions are dispatcher-assisted instructions.

Other potential confounding issues still exist. We did not quantitate or study the influence of automated external defibrillator deployment between the 2 study periods, but the fact that call-to-shock times were longer in the project period suggests that earlier defibrillation did not bias our results. The ability to interview rescuers after a case in the project period but not the control period may have influenced the results, but this information would have affected only the “witnessed” status. The paucity of survivors in the groups other than witnessed-shockable argues against this being a significant confounder. We did not study the application of “inappropriate” shocks, but when defibrillator downloads or rhythm strips were available, these were compared with the run report data to confirm “shockable” status. Metronome usage was sporadic during the project period, and metronomes were not used during the control period. Finally, other than extending our project period to 3 years, we did not attempt to specifically address the influence a Hawthorne effect¹⁷ may have had on the observed improvement in survival.

DISCUSSION

Cardiocerebral resuscitation was first implemented in Tucson, AZ, in late 2003.^{8,22} Shortly thereafter, the 4 EMS medical directors in Rock and Walworth counties in south-central Wisconsin sent a delegation to Tucson to study their cardiocerebral resuscitation protocol. After an extensive review of the evidence supporting the use of cardiocerebral resuscitation in the out-of-hospital setting, a slightly modified protocol for use in a rural setting was developed.¹⁵ It was subsequently implemented in spring 2004 by these EMS medical directors as a demonstration project in an attempt to improve neurologically intact survival in cases of out-of-hospital cardiac arrest.

The original Tucson protocol was developed for an urban setting with paramedic EMS responders. In our rural setting, patients were often initially treated by nonparamedic rescuers who used automated external defibrillators and not manual defibrillators. We therefore had to reprogram multiple types of automated external defibrillators to follow the cardiocerebral resuscitation protocol. This was not always possible and therefore additional training was needed to address this issue. The Tucson protocol also had to be modified because our nonparamedics could not administer advanced life support medications. When should rescuers leave the scene to acquire such advanced care? We elected to continue resuscitation at the

scene for 3 cycles of continuous chest compressions±shock before moving patients. This decision was based on a risk-benefit analysis of the benefits of advanced life support drug administration versus the reduction of quality of chest compressions that inevitably accompanies moving the patient to an ambulance. The existing clinical evidence argued against advanced life support drugs improving survival,²³ and we believed that quality chest compressions were initially more crucial to survival.

This is the second published report of survival outcomes when cardiocerebral resuscitation is used in the out-of-hospital treatment of adult victims of presumed cardiac arrest. Our initial publication was limited to the first year’s data.¹⁶ The current report, in which observations were extended to a 3-year period, confirms the conclusion reached after the first year: compared with Guidelines 2000 management, the use of cardiocerebral resuscitation is associated with a significant improvement in neurologically intact survival in witnessed-shockable patients. Intact survival for these patients in the control, project first year, and project 3-year periods was 15%, 48%, and 39%, respectively.

The improvement in survival observed after introduction of the cardiocerebral resuscitation protocol could not be attributed to differences in age, sex, call-to-shock times, or use of hypothermia between the two 3-year periods. There was a relative reduction in survival when the first and the subsequent 2 years were compared (Table 2), which may have been due to the Hawthorne effect.¹⁷ Another equally plausible and probably coexisting explanation for this trend is the relative lack of retraining efforts that existed during the latter 2 years of the project.

The dramatic improvement in survival we report has recently been duplicated in a larger number of patients from a metropolitan area in Arizona, in which the survival to hospital discharge was tripled after metropolitan fire departments were instructed in the technique of cardiocerebral resuscitation.²⁴ The majority of individuals with out-of-hospital cardiac arrest have little or no chance of survival because their arrests are either not witnessed or their initial rhythm on arrival of the EMS is nonshockable. Therefore, only patients with a witnessed arrest and an initially shockable rhythm were compared in this report because they are the subset of “cardiac arrest” victims most likely to survive and therefore a group most likely to reflect the influence of a change in the interventional protocol.

Additionally, focusing on this group removes any bias introduced by a decrease in the overall incidence of fibrillatory arrests²⁵ or exclusion criteria used. Finally, this is the group of individuals whose underlying pathophysiology is best understood,^{26,27} most likely to be homogeneous, and one most often modeled in animal studies.

Survival at hospital discharge as an endpoint is becoming ever more common in clinical resuscitation studies. We elected to use a definition that is even more restrictive, ie, “neurologically intact survival” with a cerebral performance category score of 1, because of its clinical relevance. Although the cerebral performance category score is less accurate than sophisticated objective testing in defining neurologic status,²⁸ it is still widely used in clinical studies and is sufficient to define *relative* neurologic status at discharge among survivors. The data in Figure 2 allow calculation of survival in all categories of cerebral performance category scores.

The management strategy that cardiocerebral resuscitation advocates is based on a fundamental assumption: survival is improved when heart and brain perfusion is maximized. Chest compressions must be optimally performed and interrupted only by interventions considered more crucial than perfusion for survival. The detrimental effects of increased intrathoracic pressure on forward blood flow should be appreciated and minimized. A full discussion of the interventions embodied in cardiocerebral resuscitation and the rationale for their implementation are presented elsewhere.^{6,7,29,30}

Cardiocerebral resuscitation was first introduced by the University of Arizona Sarver Heart Center Resuscitation Research Group in late 2003.^{8,22} At that time, it was considered an unconventional management strategy because it advocated interventions that deviated significantly from the 2000 Guidelines. In part for this reason, it has been used in only a handful of other EMS systems. Nonetheless, the dramatic improvement in neurologically intact survival reported herein calls into question the universal validity of the airway-breathing-circulation CPR paradigm that has guided cardiac arrest resuscitation since the 1960s.

In conclusion, neurologically intact survival in adult patients with a witnessed arrest and an initially shockable rhythm was dramatically improved after implementation of an out-of-hospital protocol based on the principles of cardiocerebral resuscitation.

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