Take Heart America: A comprehensive, community-wide, systems-based approach to the treatment of cardiac arrest*

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Objectives: **To determine out-of-hospital cardiac arrest survival rates before and after implementation of the Take Heart America program (a community-based initiative that sequentially deployed all of the most highly recommended 2005 American Heart Association resuscitation guidelines in an effort to increase out-of-hospital cardiac arrest survival).**

Patients: **Out-of-hospital cardiac arrest patients in Anoka County, MN, and greater St. Cloud, MN, from November 2005 to June 2009.**

Interventions: **Two sites in Minnesota with a combined population of 439,692 people (greater St. Cloud and Anoka County) implemented: 1) widespread cardiopulmonary resuscitation and automated external defibrillator skills training in schools and businesses; 2) retraining of all emergency medical services personnel in methods to enhance circulation, including minimizing cardiopulmonary resuscitation interruptions, performing cardiopulmonary resuscitation before and after single-shock defibrillation, and use of an impedance threshold device; 3) additional deployment of automated external defibrillators in schools and public places; and 4) protocols for transport to and treatment by cardiac arrest centers for therapeutic hypothermia, coronary artery evaluation and treatment, and electrophysiological evaluation.**

Measurements and Main Results: **More than 28,000 people were trained in cardiopulmonary resuscitation and automated external defibrillator use in the two sites. Bystander cardiopulmonary resuscitation rates increased from 20% to 29% ($p = .086$, odds ratio 1.7, 95% confidence interval 0.96–2.89). Three cardiac arrest centers were established, and hypothermia therapy for admitted out-of-hospital cardiac arrest victims increased from 0% to 45%. Survival to hospital discharge for all patients after out-of-hospital cardiac arrest in these two sites improved from 8.5% (nine of 106, historical control) to 19% (48 of 247, intervention phase) ($p = .011$, odds ratio 2.60, confidence interval 1.19–6.26). A financial analysis revealed that the cardiac arrest centers concept was financially feasible, despite the costs associated with high-quality postresuscitation care.**

Conclusions: **The Take Heart America program doubled cardiac arrest survival when compared with historical controls. Study of the feasibility of generalizing this approach to larger cities, states, and regions is underway. (Crit Care Med 2011; 39:26–33)**

Key Words: heart arrest; cardiopulmonary resuscitation; compressions; defibrillation; hypothermia; survival; neurological function

Half a century after closed-chest cardiopulmonary resuscitation (CPR) was first described, cardiac arrest remains a leading cause of premature death for >350,000 patients annually in the United States alone (1–4). Recognizing the need for improved survival rates after cardiac arrest, the Take Heart America (THA) program was conceptualized in 2004 to improve survival from cardiac arrest by implementing all of the highest-level 2005 American Heart Association (AHA) CPR and Emergency Cardiovascular Care guidelines (5) together in a com-

***See also p. 194.**

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Work was performed in Anoka County, MN, and greater St. Cloud, MN, from November 2005 to June 2009.

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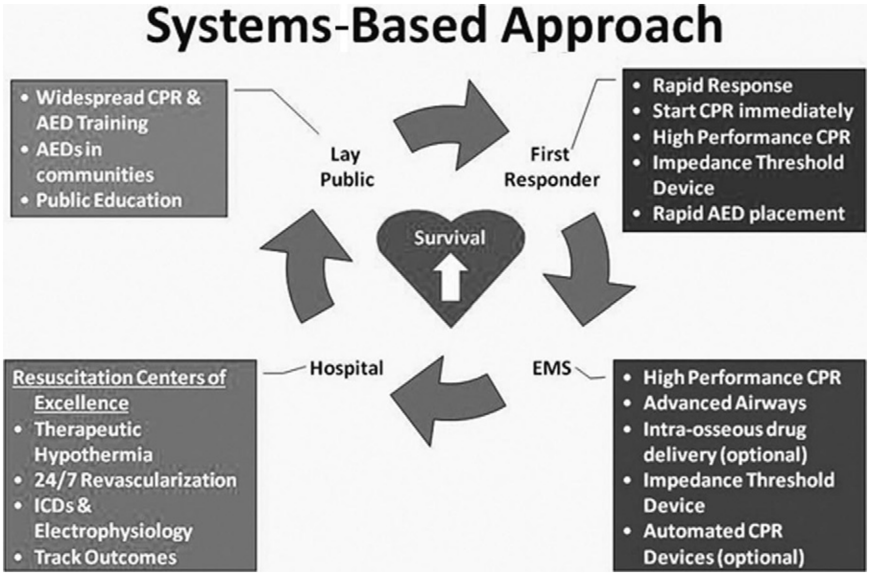

Figure 1. The comprehensive, community-wide, systems-based approach of the Take Heart America program. *CPR*, cardiopulmonary resuscitation; *AED*, automated external defibrillator; *EMS*, emergency medical services; *ICD*, implantable cardioverter defibrillator.

prehensive, community-wide, systems-based approach. The THA initiative was based on the treatment model of other complex disease states, like heart failure, leukemia, or human immunodeficiency virus infection, for which multiple therapies must be deployed simultaneously for successful cure or remission (6).

The THA initiative, described herein for the first time to our knowledge, is centered on optimizing the clinical interactions and synergy between multiple sequential interventions; the four general areas of care are shown in Figure 1. The interventions are focused on emergency medical services system rescuer defibrillation (7), comprehensive community-wide CPR and automated external defibrillator (AED) training (8), initiation and optimization of circulation as soon as possible once a patient is recognized to be in cardiac arrest (9–11), use of public access defibrillation (12), advanced life support (ALS) in the appropriate sequence once circulation has been provided for a minimum period of time (7, 12, 13), and then delivery of resuscitated patients to specialized cardiac arrest centers (CACs) that optimize postresuscitation care (14–19). Each of the interventions in the prehospital phase is directed toward increasing circulation to the heart and brain as soon as possible. For example, higher bystander CPR rates result in more rapid initiation of some circulation, whereas application of the impedance threshold device results in greater circulation to the heart and brain, based on previously described physiologic mechanisms (5). After resuscitation, interventions such as therapeutic hypothermia and percutaneous coronary interventions are centered on optimizing postresuscitation care to allow full recovery of the heart and brain.

The hypothesis tested by this translational research project is that out-of-hospital survival rates will increase without an increase in expenses or worsening of neurologic function when a comprehensive, community-wide, systems-based treatment approach is used to treat patients who have cardiac arrest. The purpose of this study was to compare survival to hospital discharge rates, the primary end point, the neurologic function of survivors at hospital discharge, and costs associated with care in CACs before and after implementation of the THA program in two demonstration communities in Minnesota.

MATERIALS AND METHODS

THA Demonstration Project Communities

The THA initiative in St. Cloud was reviewed and approved by the Institutional Review Board of St. Cloud Hospital (St. Cloud, MN). The THA initiative in Anoka County was approved by the Allina Hospitals and Clinics Institutional Review Board (Minneapolis, MN). The THA phase I initiatives were performed in greater St. Cloud, MN, which included the cities of St. Cloud, Waite Park, Sartell, Sauk Rapids, Cold Spring, St. Joseph, and St. Augusta, and in all of Anoka County. The population of greater St. Cloud, MN, is approximately 112,000 and the population of Anoka County, MN, is approximately 298,000.

Both greater St. Cloud and Anoka County provide a two-tiered response when 911 is called for a cardiac arrest. Police and fire departments operate under local medical direction in greater St. Cloud; ALS is provided by Gold Cross Ambulance, under medical control from the Mayo Clinic in Rochester, MN. In greater St. Cloud, Gold Cross Ambulance transports approximately 13,000 patients per year.

Anoka County Police and Fire operate under local medical direction; ALS is provided by Allina Medical Transportation, which is based in St. Paul, MN. Allina Medical Transportation provides basic life support, ALS, and scheduled transport to approximately 13,500 patients annually in Anoka County, MN.

Patient Enrollment Timeframes

In Anoka County, MN, control period data were collected from January 1, 2005 through December 31, 2005 (12 months). High-performance CPR (Table 1) was introduced to Anoka County emergency medical services personnel in December 2005; this new approach was fully implemented and became the standard of care in Anoka County by July 2006. Thus, in Anoka County, the intervention period data collection began July 1, 2006, and continued through December 31, 2007 (18 months). In January 2008, Anoka County ALS providers fully implemented the use of automated CPR devices and, as such, data from 2008 and beyond therefore were not included in this analysis.

In St. Cloud, MN, control period data were collected from December 3, 2004 through December 3, 2005 (12 months). High-performance CPR was introduced in St. Cloud in July 2006, and this approach was fully implemented by the end of 2006. In greater St. Cloud, the intervention-phase data collection began January 1, 2007, and continued through June 30, 2009 (30 months).

THA Infrastructure

Efforts to introduce the THA program in St. Cloud and Anoka County began in September 2005. A site coordinator, funded by the receiving hospital foundation at each site, helped establish collaboration and implement the THA initiative with city administrators, police and fire departments, school system administrators, survivors and survivor network organizations, ALS transport team members, hospital administration, and key clinicians in each CAC.

Table 1. High-performance cardiopulmonary resuscitation based on the 2005 American Heart Association CPR Guidelines recommendations

2005 American Heart Association Guidelines Recommendations	Class Level
Deliver effective compressions	I
Compress the chest 1.5 to 2 inches at a rate of 100/min	IIa
Minimize interruptions between compressions	IIa
Use of an impedance threshold device on advanced airway	IIa
Compression to ventilation ratio of 30:2 for basic life support and asynchronous ventilation at 10 mins once advanced airway is placed	IIa
Perform cardiopulmonary resuscitation for 2 mins after shock for ventricular fibrillation	IIa
Cardiopulmonary resuscitation for 2 mins before shock if ventricular fibrillation present for >4 mins	IIb
Allow full chest wall recoil	IIb
Perform 50% duty cycle for chest compression and pass relaxation	IIb
Rotate compressors every 2 mins in <5 secs	IIb
Ventilate with approximately 600 mL tidal volume/positive pressure breath	IIb
Maintain two-handed face mask seal during bag valve mask ventilation	Recommended but without specific class

Increasing Public Awareness, Community CPR Training, and AED Availability

THA staff in both sites worked with leaders in the community, including city council members, fire and police, ALS providers, hospital administrators, public school administrators, religious congregations, and local businesses to generate awareness about cardiac arrest and the THA program. Articles featuring patients who survived cardiac arrest were printed in local and statewide newspapers, including one on the benefits of therapeutic hypothermia after the first patient was cooled in St. Cloud Hospital in December 2005 (20).

Using the AHA CPR Anytime 25-min training kit (American Heart Association, Dallas, TX) (8), all tenth grade students in greater St. Cloud and their family members were taught how to perform CPR and use an AED. The educational initiative focused on starting chest compressions immediately, achieving adequate compression depth, ensuring the palm of the hand comes off the chest during the chest wall recoil phase to reach complete recoil (21, 22), and delivering mouth-to-mouth rescue breathing. Instructors emphasized the importance of performing hands-only CPR if lay rescuers did not want to perform mouth-to-mouth breathing. Cardiac arrest survivors played a key role in these activities either by actually providing CPR training in conjunction with trained instructors or by talking to the students. Additionally, bystander CPR training was provided to civic groups, city employees, and various businesses. A similar program was also initiated in Anoka County, a community that has worked with Allina's Heart Safe Community AED/CPR program since 2001. In 2008, THA initiated a pilot program called "CPR Goes to College," in which every student at St. Cloud State University was trained in CPR using the AHA's CPR Anytime kit. In addition, in 2008, public television in Minnesota produced and broadcasted a 30-min documentary on THA (http://www.takeheartminnesota.org/resources.htm).

AEDs were deployed in places where there was an increased likelihood of someone having a cardiac arrest, including schools, businesses, fitness centers, religious organizations, large supermarkets, and shopping centers. In addition, all first-responder vehicles (police, fire, sheriff) were equipped with AEDs. First-responder personnel were concurrently trained in high-performance CPR.

Cardiac arrest survivors also participated in creating public awareness. Survivors founded local survivor network chapters in greater St. Cloud and Anoka County, sponsored in part by the THA program to provide emotional and psychological support. Survivors and families played an active role in teaching bystander CPR and how to use an AED in their respective communities and participated in larger survivor organizations such as the Sudden Cardiac Arrest Association and the Sudden Cardiac Arrest Foundation.

First-Responder Training

First responders were taught what THA termed high-performance CPR. This curriculum focused on didactic and skills training related to the key AHA-recommended CPR techniques and devices that together more than double circulation during CPR (5, 7, 9, 10, 21–25). Training stressed the importance of 1) starting chest compressions immediately at a rate of 100 compressions per minute with a depth of 1.5–2.0 inches and a 30:2 compression-to-ventilation ratio; 2) applying the impedance threshold device (ResQPOD; Advanced Circulatory Systems, Roseville, MN) as soon as possible with a two-handed tight face mask seal applied continuously at all times; 3) a ventilation tidal volume of approximately 600 mL; 4) delivery of each breath rapidly over 1 sec; 5) full chest wall recoil; 6) 2 mins of CPR before analyzing cardiac rhythm followed by 2 mins of continuous CPR immediately after a single defibrillator shock; and 7) minimal interruptions in chest compressions. To accomplish full chest wall recoil, rescuers were taught to lift the palm of the hand slightly, but completely, off the chest at the end of the decompression phase, but to leave their fingers tips in contact with the chest to maintain hand position (21, 22). These interventions and their respective classes of recommendation in the 2005 AHA CPR Guidelines (5) form the core of high-performance CPR and are shown in Table 1. Training efforts, provided mainly by the respective ALS providers in each site, included the use of a demonstration video, a demonstration tool to show how poor CPR affects physiology, hands-on practice sessions, and a written test. Special emphasis was placed on the importance of getting to the scene and starting chest compressions as soon as possible, compressing to the recommended depth, and minimizing pauses by both basic life support and ALS providers.

ALS Training

On arrival at the scene, ALS personnel were trained to make sure adequate chest compressions were being performed, establish an advanced airway device, transfer the impedance threshold device to the advanced airway, and deliver chest compressions continuously with asynchronous ventilations at 10 breaths/min (5). Emphasis was placed on performing high-performance CPR for up to 30 mins on the scene, before transport, to optimize delivery of resuscitation care. Drugs were delivered per 2005 AHA Guidelines algorithms and in many cases were administrated using an intraosseous route to minimize the time to administration (5, 13). A single defibrillatory shock was delivered when indicated with CPR before and after each shock (7).

In addition, a new recognition program was established by city administrators, awarding first responders and ALS providers with a certificate and plaque recognizing their efforts each time a cardiac arrest patient was saved.

CACs

After successful resuscitation in the field, patients were transported to specialized CACs akin to a level I trauma center for postresuscitation care (14–19, 26). All patients underwent aggressive evaluation and treatment with interventional cardiology techniques (17) and placement of implantable cardioverter defibrillators (18) as indicated by the ST elevation myocardial infarction program criteria recommended by the American College of Cardiology (17–19).

Therapeutic hypothermia was used in all patients who were comatose or minimally responsive on arrival to the emergency department at St. Cloud Hospital (St. Cloud, MN), Unity Hospital (Anoka County, MN), or Mercy Hospital (Anoka County, MN), regardless of the presenting rhythm (15, 16, 27). Patients who experienced a cardiac arrest from noncardiac causes were also treated with hypothermia if they were comatose or minimally responsive (e.g., drug overdose, hanging, electrocution, pulmonary emboli) on hospital admission (15, 16, 27). Therapeutic hypothermia was induced using heat transfer pad technology (Arctic Sun; Medivance, Louisville, CO), with a target temperature of 33°C for 24 hrs (28). Rewarming was performed after a total of 24 hrs at the target temperature, over an 8-hr period, with a goal to rewarm at approximately 0.25°C/hr. The treatment protocol emphasized the goal of maintaining a mean arterial pressure with fluid and vasopressor support of 80–90 mm Hg (19).

All patients were considered for immediate cardiac catheterization and revascularization by on-call interventional cardiologists (17). When patients were brought to the cardiac catheterization laboratory, therapeutic hypothermia was initiated during or just after cardiac catheterization. Depending on the recommendation from the electrophysiologist, medical or implantable cardioverter defibrillator therapy or both was implemented before discharge (18). Neurologic function using a cerebral performance category and the overall performance category scoring systems was assessed by reviewing each survivor's medical record at the time of hospital discharge (29).

During the intensive care unit or cardiac care unit stay, a program manager from THA approached the family of each patient in St. Cloud Hospital. If interested, the family, and then the patient, would learn about and become involved with THA.

A financial analysis was performed on resuscitated cardiac arrest patients after the THA intervention in 2006–2007 to assess the costs associated with care for patients admitted to the hospital with a pulse in St. Cloud. Hospital billing records and cost data for all sequential out-of-hospital cardiac arrest patients delivered alive to the hospital during a 19-month period of time were reviewed by the St. Cloud Hospital chief financial officer. Analysis was performed related to revenues generated, direct costs, and direct margins (the difference between revenues generated/patient minus expenses paid) associated with the hospitalization, independent of physician charges. Direct costs included wages and benefits for hospital staff directly involved inpatient care; supplies, room and bed charges; and procedure charges and service charges, such as laboratory expenses, pharmacy, and imaging expenses. Direct costs did not include costs for hospital service center administrators or costs related to the THA coordinator. Further, physician revenue and expenses were not included in this financial analysis, because they are separate from the hospital-related revenues and expenses.

Primary Outcome and Statistical Analysis

Data were collected for every cardiac arrest patient transported to Mercy and Unity Hospitals by Allina Medical Transportation in Anoka County, MN (>95% of patients with out-of-hospital cardiac arrest in Anoka County), and for every cardiac arrest patient transported to St. Cloud Hospital, which is the hospital that received all patients from greater St. Cloud, MN. All data related to patients treated during the control period were gathered retrospectively, whereas during the intervention phase, data were gathered prospectively. The number of patients enrolled during the intervention phase in Anoka County was limited because in 2008 an automated CPR device was added to all ALS vehicles. For St. Cloud, data collection continued for 30 months to keep approximately the same before-and-after ratios of enlisted case numbers in the two counties. Patients were excluded from the THA analysis if they were younger than 18 yrs of age, had an identified noncardiac etiology of the cardiac arrest, were dead on arrival, or had prehospital do-not-resuscitate orders.

The primary outcome parameter was survival to hospital discharge, with the primary comparison between patients with out-of-hospital cardiac arrest occurring during a control period and after full implementation of the THA program (intervention period). Fisher's exact test was used for this end point. Odds ratios (ORs) and 95% confidence intervals (CIs) were also used to determine statistical significance for key primary and secondary end points. The most important secondary end point was the cerebral performance category score at hospital discharge (29). Other secondary end points included the bystander CPR rate, the hospital admission rate, the frequency of cardiac revascularization, implantable cardioverter defibrillator implantation, and the cost per patient discharged alive or dead from the hospital. Clinical data were gathered from emergency medical services reports and hospital records by retrospective review. The number of bystanders trained in CPR was tracked by the training program coordinators, and the frequency of bystander CPR in patients with a cardiac arrest was determined by a review of all medical records for patients with a cardiac arrest.

Additional statistical analyses were performed to test for site-to-site homogeneity of the OR related to the primary end point. A Mantel-Haenszel test was used to estimate the common OR. In addition, a logistic regression analysis was performed to determine the relative contributions of study group, age category, and site to the primary study outcome of survival to hospital discharge. Both forward and backward stepwise procedures were used.

RESULTS

Increased Public Awareness, Community CPR Training, and AED Availability

Between September 2006 and December 2008, there were 29 newspaper, magazine, and television stories about Take Heart St. Cloud and an additional 34 media stories about Take Heart Anoka County. From September 2006 to December 2008, a total of 28,041 citizens were trained in bystander CPR in the two Minnesota sites as part of the THA effort. In St. Cloud, all tenth grade high school students were trained using the AHA's CPR Anytime Kit; these students subsequently trained numerous family members and friends. In addition, >10,000 college students were trained as part of their physical education course curriculum in the "CPR Goes to College" program. Concurrently, in Anoka County, students and citizens were trained using both the CPR Anytime kit and more traditional methods of teaching CPR.

CPR and AED training both were provided to staff at the major supermarkets in greater St. Cloud and Anoka County. A total of 132 AEDs were distributed by the THA program in greater St. Cloud and Anoka County from July 2006 to December 2008.

First Responders and ALS

In 2006, all first responders and ALS providers in greater St. Cloud, MN (n = 465) and Anoka County, MN (n = 830) were trained in high-performance CPR (Table 1). In both sites, police and fire respond to the 911 call for help. All first responders in both sites were trained on and equipped with a face mask, resusci-

Table 2. Demographics of cardiac arrest patients during control and intervention periods

Demographics	Period: Control (n = 106)	Period: Intervention (n = 247)	*p*
Age, yrs (mean ± SD)	68 ± 14.6	62 ± 15.6	.003
Male	75 (71%)	173 (70%)	1.000
Presumed cardiac etiology: initial rhythm			.356
Ventricular tachycardia or ventricular fibrillation	29 (27%)	90 (36%)	
Pulseless electrical activity	20 (19%)	42 (17%)	
Asystole	51 (48%)	99 (40%)	
Unknown	6 (6%)	16 (6%)	

Table 3. Prehospital treatment of cardiac arrest patients during control and intervention periods

Treatment	Period: Control (n = 106)	Period: Intervention (n = 247)	Odds Ratio With 95% Confidence Intervals	*p*
Interval from 911 to advanced life support at the scene	7.5 ± 3.5	7.2 ± 3.6	Not applicable	.556
Bystander cardiopulmonary resuscitation	21 (20%)	72 (29%)	1.67 (0.96–2.89)	.086
Impedance threshold device use	9 (8.5%)	160 (64.8%)	Not applicable	

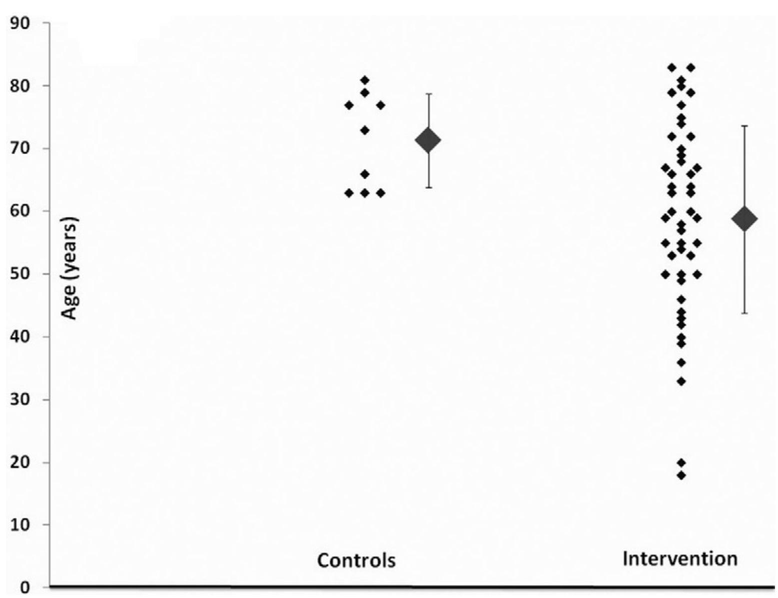

Figure 2. The ages of the survivors during the control and intervention phases. Data shown as individual cases (*small diamonds*) and mean ± SD (*large diamonds, whisker bars*).

tator bag, impedance threshold device, and AED. In greater St. Cloud, training was provided by the local ALS provider (Gold Cross Ambulance) and by staff at St. Cloud State University and St. Cloud Technical College. Training for first responders and ALS providers was similar. In Anoka County, Allina Medical Transportation paramedics trained the first responders.

The number of patients enrolled in both Anoka County and greater St. Cloud during the control and intervention periods is shown in Table 2. The average interval from receipt of the 911 call to arrival on the scene for ALS personnel was similar between the control period and the intervention period (Table 3).

Clinical Outcomes

Patient demographics during the control and intervention periods are shown in Table 2. The age in the intervention group was, on average, 5 yrs younger (p = .005) than in the control group. In addition, the average age of the survivors was also lower, as shown in Figure 2. The distribution of initial heart rhythms was not significantly different between groups (p = .34). Importantly, the study group (control vs. THA intervention) was found to be the only significant predictor (p = .013) of hospital discharge when simultaneously considering age category and site. It had an estimated OR of 2.6 in the statistical model used (95% CI 1.22–5.51).

Prehospital care was significantly different between the control and intervention periods. The number of patients treated with prehospital bystander CPR increased from 20% to 29%, and this difference trended toward significance (p = .066). An impedance threshold device was used on nine of 106 (8.4%) patients during the control period and in 157 of 247 (64%) patients during the intervention phase (Table 3).

Inhospital care was also significantly different between the control and intervention periods (Table 4). During the control period, nine of 37 (24%) patients admitted to the intensive care unit survived to hospital discharge vs. 48 of 95 (51%) in the intervention phase (p = .009, OR 3.05, CI 1.30–7.14). During the intervention period, once patients were admitted to the intensive care unit, 45% were treated with hypothermia, 46% underwent cardiac catheterization, and 23% were ultimately treated with an implantable cardioverter defibrillator. The percentage of patients treated with an implantable cardioverter defibrillator nearly doubled in the intervention phase. No survivors in the control period, but 12 survivors in the intervention period, had a preexisting implantable defibrillator at the time of the cardiac arrest. The percentage of patients admitted to the intensive care unit who were then discharged with an implantable cardioverter defibrillator was 14% in the control period and 25% in the intervention period (p = .17).

The aggregate rates of return of spontaneous circulation and survival to hospital discharge and the cerebral performance category scores at hospital discharge from the control and intervention periods are shown in Table 5. Whereas the intensive care unit admission rates did not vary between groups, the hospital discharge rates, the primary study end point, more than doubled from 8.5% to 19% after the THA program was implemented (p = .011, OR = 2.60, CI = 1.19–6.26). The neurologic outcomes for

Table 4. Inhospital treatment of cardiac arrest patients who survived to hospital admission

Treatment	Period: Control (n = 106)	Period: Intervention (n = 247)	Odds Ratio With 95% Confidence Intervals	*p*
Inhospital hypothermia	0 of 37 (0%)	44 of 95 (46%)	Not applicable	
Cardiac catheterization	8 of 37 (22%)	45 of 95 (47%)	3.26 (1.35–7.87)	<.001
Implantable cardiac defibrillator placed	5 of 37 (14%)	24 of 95 (25%)	2.16 (0.72–6.18)	.17

Table 5. Outcome of cardiac arrest patients during control and intervention periods

Outcome	Period: Control (n = 106)	Period: Intervention (n = 247)	Odds Ratio With 95% Confidence Intervals	*p*
Return of spontaneous circulation prehospital	40 (38%)	116 (47%)	1.46 (0.90–2.40)	.129
Admitted to intensive care unit	37 (35%)	95 (38%)	1.17 (0.71–1.93)	.551
Discharged alive from hospital	9 (8.5%)	48 (19%)	2.60 (1.19–6.26)	.011
Cerebral performance category score	1.63 ± 0.52	1.38 ± 0.70	Not applicable	.341

Table 6. Survivors to hospital discharge by initial rhythm

Initial Rhythm	Control (n = 106)	Intervention (n = 247)	Odds Ratio With 95% Confidence Intervals	*p*
Ventricular tachycardia or ventricular fibrillation	5 of 29 (17%)	37 of 90 (41%)	3.35 (1.10, 12.17)	.025
Pulseless electrical activity	1 of 20 (5%)	2 of 42 (5%)	0.95 (0.05, 58.96)	1.000
Asystole	1 of 51 (2%)	3 of 99 (3%)	1.56 (0.12, 83.64)	1.000
Unknown	2 of 6 (33%)	6 of 16 (37%)	1.20 (0.12, 17.01)	1.000

the survivors, determined at the time of hospital discharge, were similar between the control and intervention periods. The greatest gains were observed in patients with ventricular fibrillation as the initial heart rhythm (Table 6). In this subgroup, survival rates increased from 17% to 41% ($p = .025$). It is noteworthy that the proportions were similar between patients who survived a cardiac arrest in each of the two test sites, greater St. Cloud and Anoka County, in the control period (three of 39 [8%] and six of 68 [9%], respectively) and the intervention period (29 of 142 [20%] and 18 of 105 [17%], respectively). There was no evidence of a difference in ORs between sites.

Age was not found to be a reason for the improved outcome in the intervention group. Subjects were classified as being below the median (younger than 64 yrs) or greater than or equal to the median (64 yrs or older). For the category of ages younger than 64 yrs, the *p* value was .015 (Fisher's exact test; OR 4.32, 95% CI 1.23–23.17). For the category of ages 64 yrs or older, the *p* value was .483 (Fisher's exact test; OR 1.57, 95% CI 0.55–5.14). The test for homogeneity of OR revealed $p = .263$ (no evidence of different OR). The Mantel-Haenszel estimated common OR was 2.49 (95% CI 1.17–5.31).

Data from Table 5 can be used to calculate the number of patients needed to save one additional life. For the control group, this was calculated as follows: $10 \times (0.085) = 0.85$ expected survivors to hospital discharge. By contrast, for the intervention group, this was calculated as follows: $10 \times (0.190) = 1.90$ expected survivors to hospital discharge. Thus, the expected number of patients who need to be treated to save one more life is approximately ten patients.

CAC Clinical Outcomes and Financial Analysis

An analysis of the financial impact of the St. Cloud Hospital CAC was also performed. The revenues associated with billing for 69 sequential patients in 2006 treated with the bundle of postresuscitation care that, when clinically indicated, included hypothermia, cardiac revascularization, and implantable cardioverter defibrillator therapy were analyzed. Revenues averaged $57,783 per patient who survived to hospital discharge (n = 24), with a direct margin after direct costs of $20,684 per patient. Of the 69 patients, 56 were admitted to the intensive care unit. Of the 56 patients, 24 patients treated with hypothermia died, and eight patients not treated with hypothermia died. A total of 21 survived to hospital discharge and were treated with hypothermia, and three survived who did not require hypothermia. The difference in the direct margin after direct costs was minimal for survivors treated with hypothermia (average $20,367/patient) vs. survivors not treated with hypothermia (average $22,904/patient). For those patients who died in the hospital, including the emergency department (n = 45), the average revenue was $12,014, and the average direct margin was $3329.

DISCUSSION

The key aspects of the THA approach are focused on strengthening and coordinating each well-established, scientifically proven link in the chain of survival. Data from this first phase of the THA program demonstrate that implementation of this comprehensive, community-wide, systems-based approach resulted in more than doubling out-of-hospital survival rates when comparing historical controls to 2 yrs of full implementation. For every ten patients treated with the Take Heart program in the two Minnesota sites, one would expect one more survivor compared with outcomes before initiation of the program. Importantly, the data support the conclusion that implementation of the program doubled the number of neurologically intact survivors when compared to the program during the control period of time. The majority of survivors returned to their respective communities neurologically intact. As such, phase I of the THA program demonstrated proof-of-concept that a comprehensive, community-wide, systems-based approach to the treatment of cardiac arrest is both feasible and effective.

The combination of new technologies and approaches to the performance of

CPR and the preservation of postresuscitation organ function forms the core of the THA initiative. Although this approach resulted in a nonsignificant increase in return of spontaneous circulation and intensive care unit admission rate, it significantly increased (more than doubled) the number of patients who survived to hospital discharge with good neurologic outcome. Similar discrepancies between the relative increases in return of spontaneous circulation in the out-of-hospital setting and hospital discharge rates have recently been reported in support of the need for improved hemodynamics during CPR, delivery of a more viable patient to the hospital, improved hospital care, and longer and more definitive survival end points in the evaluation of future advances in the field (30). These findings are similar to approaches and outcomes in the treatment of other complex medical disease states. Like therapies for treatment of human immunodeficiency virus infection or leukemia, the current results suggest that it was the synergy between multiple interventions rather than a single intervention that accounted for the marked improvement during the intervention phase. None of the CPR interventions in the THA are unique or have been shown to double neurologically intact survival rates by themselves; however, in combination, they were shown to be life saving. As such, although we cannot say that the increase in bystander CPR rate from 20% to 29% achieved a "critical mass" effect in this study, we do know from others that starting circulation as soon as possible improves outcomes and that higher bystander CPR rates as a result of the combination of more lay rescuer training and more effective dispatcher-instructed CPR when 911 is called improves long-term outcomes (5). The authors believe that this systems-based approach, with each of its composite elements, is fundamental to the success of the program and the future treatment of cardiac arrest.

One of the keys to the success of the program was the opportunity to have a THA program manager at each site drive the requisite collaboration between the multiple partners and groups involved with the care of cardiac arrest patients in each geographic area. Without a program manager, it would not have been possible to coordinate all of the partnerships that made the program successful. Based on the success of the phase I program in St. Cloud and Anoka County, the THA initiative is being implemented in greater Austin, TX, and Columbus, OH, and throughout the state of Minnesota. One of the key goals is to demonstrate that this program can be effective in urban, suburban, and rural settings with larger geographical boundaries and with more diverse populations.

The clinical impact of the CAC concept has been previously described and demonstrated to be effective (14, 26, 31). The clinical data demonstrating that a higher percentage of patients admitted to the hospital also survived to hospital discharge (24% in the control period vs. 51% in the intervention period) provide further support for combining improved prehospital care with postresuscitation care in a CAC. The results from the financial analysis described herein demonstrated that the CAC concept was, at a minimum, cost effective. The hospital recorded a >$20,000 positive net margin after paying for expenses for each patient who was discharged alive, before taking into account overhead expenses. These results support the concept that specialized CACs are both clinically effective and cost effective. In addition, the favorable financial data significantly influenced the level of support by the three CAC receiving hospitals; all three provided substantial financial support for the THA efforts in greater St. Cloud, MN, and Anoka County, MN.

An unexpected observation in this study is that the patients who presented with a cardiac arrest of presumed cardiac etiology appear to be getting younger compared with those during the previous year, at least in the two test sites. During the intervention phase, the average age was 5 yrs younger than that during the control phase. Further, the average age of the survivors was >10 yrs younger, as shown in Figure 2. This observation suggests that some of the observed benefit from the THA initiative may be attributable to the differences in age between the two study groups. However, based on the results of a logistic regression analysis, implementation of the THA program was found to be the only significant predictor of hospital discharge. Taken together, these findings suggest that those patients who survive an out-of-hospital cardiac arrest are often in the prime of life, and the unexpected loss of this patient population is even more costly to society than previously considered.

This first report on the THA initiative has several limitations. First, it was a prospective analysis, but the interventions were not randomized or blinded, by design. The goal was not to test a single intervention but instead to test a combination of interventions at various stages in the treatment sequence needed to achieve optimal care (32). Thus, the impact of each individual intervention was not assessed, by design. Second, 911–to–on-scene times for basic life support were unreliable and therefore were not reported. There were multiple first-responder agencies in both sites that included some volunteer first responders, and there were often no commonly synchronized time clocks between basic life support and ALS agencies. Third, the rate of intraosseous drug infusion was not monitored. Fourth, baseline survival rates for patients with presumed cardiac arrest with any presenting heart rhythm were >8%, nearly twice the national average (1, 3), so it is unknown if this approach will work in locations with very poor baseline survival rates. Fifth, the number of patients who survived because of AED use by first responders was not reliably recorded. Finally, it is currently unknown if this approach can be generalized. The experience of Hinchey et al (33) suggests that the systems-based approach works in other regions. It is unknown if this systems-based approach will be successful in regions of the country that are mostly rural, mostly urban, or have a greater proportion of patients with more limited socioeconomic opportunities; each of these factors is known to affect outcomes.

CONCLUSIONS

Comprehensive translation of the 2005 AHA Guidelines into practice throughout two communities (with cost-effective, AHA-recommended interventions intended to optimize circulation and defibrillation during CPR and to preserve heart and brain function after cardiac arrest) resulted in a doubling in survival rates when compared with historical controls. Additional initiatives are underway to determine whether the THA program can be effectively expanded to larger cities and regions.

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