Survival and Neurologic Outcome after Out-of-Hospital Cardiac Arrest: Results One Year after Regionalization of Post-Cardiac Arrest Care in a Large Metropolitan Area

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Abstract

Background. Post-resuscitation care of cardiac arrest patients at specialized centers may improve outcome after out-of-hospital cardiac arrest (OOHCA). This study describes experience with regionalized care of resuscitated patients. **Methods.** Los Angeles (LA) County established regionalized cardiac care in 2006. Since 2010, protocols mandate transport of nontraumatic OOHCA patients with field return of spontaneous circulation (ROSC) to a STEMI Receiving Center (SRC) with a hypothermia protocol. All SRC report outcomes to a registry maintained by the LA County Emergency Medical Services (EMS) Agency. We report the first year's data. The primary outcome was survival with good neurologic outcome, defined by a Cerebral Performance Category (CPC) score of 1 or 2. **Results.** The SRC treated 927 patients from April 2011 through March 2012 with median age 67; 38% were female. There were 342 patients (37%) who survived to hospital discharge. CPC scores were unknown in 47 patients. Of the 880 patients with known CPC scores, 197 (22%) survived to hospital discharge with a CPC score of 1 or 2. The initial rhythm was VF/VT in 311 (34%) patients, of whom 275 (88%) were witnessed. For patients with an initial shockable rhythm, 183 (59%) survived to hospital discharge and 120 (41%) had survival with good neurologic outcome. Excluding patients who were alert or died in the ED, 165 (71%) patients with shockable rhythms received therapeutic hypothermia (TH), of whom 67 (42%) had survival with good neurologic outcome. Overall, 387 patients (42%) received TH. In the TH group, the adjusted OR for CPC 1 or 2 was 2.0 (95%CI 1.2–3.5, $p = 0.01$), compared with no TH. In contrast, the proportion of survival with good neurologic outcome in the City of LA in 2001 for all witnessed arrests (irrespective of field ROSC) with a shockable rhythm was 6%. **Conclusion**. We found higher rates of neurologically intact survival from OOHCA in our system after regionalization of post-resuscitation care as compared to historical data. **Key words:** heart arrest; cardiopulmonary resuscitation; mortality; survival

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Introduction

Out-of-hospital cardiac arrest (OOHCA) is a major public health problem affecting approximately 300,000 people in the United States each year.[1] Despite known benefit of hospital-based interventions, including percutaneous coronary intervention (PCI) and therapeutic hypothermia (TH), there is large regional variation in outcomes of OOHCA throughout the country.[2] Furthermore, few areas have implemented regionalized systems[3], and survival rates from OOHCA remain low.[1,2]

The majority of patients admitted to the hospital after successful out-of-hospital resuscitation do not survive to hospital discharge and there is substantial variability in post-resuscitation care and outcomes.[4–7] Although prior focus has been on prehospital care as the sole determinant of outcome in patients with out-of-hospital cardiac arrest, there is growing evidence that post-resuscitation care is an important factor in patient survival and neurologic outcome.[3–5] Regionalized care, incorporating post-event care at

specialized receiving hospitals, has improved outcomes for patients with STEMI, stroke, and trauma. A similar approach has been advocated for post-resuscitation care,[6,7] and in 2010, the American Heart Association released a policy statement advocating regionalized cardiac care for OOHCA.[8] Several studies have demonstrated feasibility of regional cardiac arrest systems,[9–11] and the necessary infrastructure for development and implementation of cardiac arrest centers has been described.[12] However, the effect of regionalized post-arrest care delivered at multiple specialized centers on patient outcomes has not been established.

Specialized cardiac centers have the resources to provide systematic and advanced care to victims of OOHCA. Nearly half of all patients who present with OOHCA will have an acute coronary occlusion and the majority of cases are attributed to underlying cardiac disease.[13–15] PCI has been demonstrated to improve outcomes in patients presenting with OOHCA who have an acute coronary occlusion.[15] TH, when initiated in the out-of-hospital or in-hospital setting, improves neurologic function in patients with return of spontaneous circulation (ROSC) after cardiac arrest due to shockable rhythms.[16–18] There is limited evidence for TH for cardiac arrest victims with nonshockable rhythms, but studies including these patients demonstrate safety and suggest that there may be a benefit in nonshockable rhythms as well.[19–21]

In 2010, Los Angeles (LA) County initiated regionalized care for OOHCA, directing all patients with ROSC to designated receiving centers. These centers provide 24-hour/day percutaneous coronary intervention (PCI) capabilities and all have established hypothermia protocols. This study was designed to evaluate the proportion of patients who survived to hospital discharge and their neurologic outcomes from OOHCA in LA County after regionalization of care.

METHODS

Population and Setting

Los Angeles County is a large metropolis, comprising 88 cities spanning 4,084 square miles with a population of over 10 million. Emergency medical services (EMS) are provided by 32 municipal fire departments, 1 law enforcement agency, and 25 private ambulance companies with over 3,500 licensed paramedics throughout the county. There were 549,732 EMS responses and 466,195 patient transports in 2008. Patients who call 9-1-1 are transported to one of 72 emergency departments in the county. The LA County EMS Agency provides oversight of providers operating within the county, establishes protocols and procedures, and designates specialty care centers. This is a retrospective study of data from a registry maintained by the LA County EMS Agency. The study was reviewed and approved with exemption of informed consent by the institutional review board.

Study Design

In 2006, LA County established regionalized cardiac care with a total of 33 designated STEMI receiving centers (SRC) during the study period. A list of participating SRC is available in the supplemental materials online. The SRC are capable of providing immediate cardiac catheterization 24 hours per day, 7 days per week and have cardiovascular surgeons available. In addition, they are required to have a robust quality improvement program and internal policies for PCI, fibrinolysis, and TH. Since 2010, countywide protocols mandate transport of all OOHCA patients of presumed cardiac etiology with ROSC in the field to an SRC with an institutionally approved hypothermia protocol. Participating SRC were encouraged to institute therapeutic hypothermia (target temperature 32–34°C) within 6 hours of ROSC and to maintain it for a minimum of 20 hours. The decision to initiate or withhold TH was at the discretion of the treating physician. Per county policy, resuscitation on scene to achieve ROSC prior to transport is encouraged. For patients meeting criteria, termination of resuscitation (TOR) in the field has been supported by official policy since 2007. TOR is based on medical futility determined by paramedics in consultation with the base hospital physician and agreement of immediate family on scene.

Since April 2011, all SRC treating ROSC patients have reported their in-hospital mortality and neurologic outcome of these patients to a single registry maintained by the LA County EMS Agency. The database was queried for patients with ROSC treated from April 1, 2011 through March 31, 2012, representing the first year of available data since establishing regionalized care of such patients. All patients 18 years or older treated for OOHCA with ROSC transported to a designated SRC were included. Patients with traumatic cardiac arrest and patients < 18 years of age were excluded. Additionally, patients with termination of resuscitation in the field were not transported by protocol and, therefore, were not eligible for inclusion in the database.

Measurements

Study variables included age, gender, race/ethnicity, initial cardiac rhythm, arrest location, witness, bystander CPR, induction of hypothermia, and whether the patient received cardiac catheterization with or without PCI. The primary outcome of the study was survival to hospital discharge with good neurologic outcome, as defined by a Cerebral Performance Category (CPC) score at hospital discharge of 1 or 2. A

CPC of 1 corresponds to a return to normal or mildly impaired cerebral function and independence with activities of daily living (ADL). A CPC of 2 corresponds to moderate cerebral disability but sufficient function to remain independent with the ADL. The CPC scores documented by physician assessment at the time of discharge were abstracted from the medical record.

Individual SRC are responsible for reporting their data. Staff members charged with data entry abstract the data points from the patient's medical record, including prehospital care records. Greater than 90% of staff responsible for the data extraction and entry are registered nurses (RN) in the departments of emergency medicine, cardiology, and quality improvement. Completeness and accuracy of the entered data are continually reviewed by the EMS Agency, with verification performed during site visits. Quarterly SRC meetings are held for data review.

Analytical Methods

All data were entered into Microsoft Excel (Microsoft, Redmond, WA) and transferred to SAS 9.3 (SAS Institute, Cary, NC) for analysis. We report the neurologically intact survival rate as proportions with exact binomial confidence intervals. Adjusted odds ratios (OR) and their *p*-values were calculated using logistic regression and the chi-square test. Variables in the regression were selected based on prior knowledge of their contribution to cardiac arrest outcomes and entered simultaneously into the model. Model fit was determined by assessing the Hosmer-Lemeshow fit statistic. Outcomes among SRC were compared with ANOVA.

RESULTS

There were 927 patients with ROSC treated by 31 SRC, of which 822 had field ROSC and 105 had initial ROSC in the ED. The median number of patients treated at each SRC was 27, range 10–77. Paramedics bypassed a local hospital 27% of the time and 9 patients were transferred from a referral center via the 9-1-1 system.

The median age of the subjects was 69 years (IQR 57–80); 357 (38%) were female (Table 1). There were 342 patients (37%) that survived to hospital discharge. CPC scores were unknown in 47 patients. Of the 880 patients with known CPC scores, 197 (22%) had a CPC score of 1 or 2 at discharge. Ventricular fibrillation (VF) or ventricular tachycardia (VT) was the initial rhythm in 311 (34%), of whom 275 (88%) were witnessed arrests. For patients with an initial shockable rhythm, 183 (59%) survived to hospital discharge and 120 (41%) had survival with good neurologic outcome. Patient characteristics by outcome are presented in Table 2. There were no differences in neurologically intact survival rates among the SRC.

TABLE 1. Patient characteristics ($N = 927$)

	Total	
Characteristics	*n* (median)	% (IQR[a])
Age	69	57–80
Gender		
Female	357	38
Male	569	62
Race/ethnicity		
Black	121	13
Asian	114	12
Hispanic	214	23
White	435	48
Pacific Islander/Hawaiian	8	1
Other	22	2
Initial rhythm VF/VT	311	34
Witnessed arrest	768	83
Bystander CPR	349	38
Therapeutic hypothermia	387	42
Cardiac catheterization	225	24
PCI[b]	104	11

[a]Interquartile range.
[b]Percutaneous coronary intervention.

After exclusion of 162 patients who died in the ED and 92 patients who were already awake and responsive upon evaluation in the ED, there remained 673 patients whose neurologic recovery could have benefited from treatment at the SRC. One hundred ninety-nine (30%) of these 673 patients had a witnessed arrest with an initial shockable rhythm, of whom 71 (38%) were discharge with a CPC of 1 or 2. One hundred and sixty-five (71%) patients with shockable rhythms received TH, of whom 67 (42%) had survival with good neurologic outcome.

Overall, 387 patients (42%) received TH. The documented reasons TH was not initiated are given in Table 3. In the TH group, the adjusted OR for CPC 1 or 2 was 2.0 (95%CI 1.2–3.5, $p = 0.01$), compared with those who did not receive TH, adjusted for age, witnessed arrest, initial rhythm, and bystander CPR. Table 4 shows the results of the full model. The Hosmer-Lemeshow goodness-of-fit statistic for the model

TABLE 2. Patient characteristics by outcome ($N = 880$)

	CPC[a] 1–2 ($N = 197$)		CPC[a] ≥3 ($N = 683$)	
Characteristics	*n* (median)	% (IQR[b])	*n* (median)	% (IQR[b])
Age	61	51–73	70	60–82
Gender				
Female	54	27	286	42
Male	143	73	396	58
Initial rhythm VF/VT	120	71	171	27
Witnessed arrest	176	93	553	86
Bystander CPR	87	45	246	37
ROSC prehospital	182	93	579	87
Therapeutic hypothermia[c]	94	73	278	42

[a]Cerebral Performance Category.
[b]Interquartile range.
[c]Excluding patients awake and responsive in ED ($n = 790$).

TABLE 3. Reasons given for no therapeutic hypothermia ($N = 449$)

Reason given	Frequency	Percent
Bleeding	30	6.7
Ventricular arrhythmia	7	1.6
Temperature less than 35°C	10	2.2
Infection	13	2.9
Coma from drugs	1	0.2
Pregnancy	1	0.2
Chronic renal disease	24	5.4
Nonshockable rhythm	24	5.4
Futility[a]	70	15.7
Withdrawal of care	68	15.2
Other	31	6.9
Missing	170	38.0

[a]Includes patients with prior coma and patients who expired prior to initiation of TH.

corresponded to a *p*-value of 0.03. The regression was intended to assess the effect of TH, not to be a predictive model, and the variables included a priori as known confounders of this association. To mitigate the selection bias in favor of TH, we excluded those patients in whom TH was withheld for futility (patients with prior coma and those who expired prior to TH).

In the entire cohort, 225 patients (24%) underwent cardiac catheterization within 24 hours of arrival, of whom 104 (46%) had PCI. For the 261 patients with an EKG consistent with STEMI, these proportions were 64 and 40%, respectively. The median door-to-balloon time was 80 minutes (IQR 58–106).

DISCUSSION

To our knowledge, our study is the first to report neurologic outcomes in a large cohort of patients after out-of-hospital cardiac arrest in a regionalized system. We found that patients in LA County transported to SRC subsequent to regionalization of post-resuscitation care had significantly better outcomes than previously reported data. For comparative purposes, overall survival from VF arrest with good neurologic outcome was 6% in the city of Los Angeles in 2001.[22] In our group of patients with ROSC treated at regional centers, the proportion discharged with good neurologic outcome was 40%. Current protocols in LA County emphasize resuscitation on scene until ROSC or TOR for futility. This cohort is representative of the group in whom resuscitation was successful. Achieving ROSC is essential for survival, and the high proportion of field ROSC is likely a large contributor to the outcomes seen in this subgroup. However, interventions that have a significant impact on increased ROSC and survival to hospital discharge have not necessarily increased the proportion of survivors with good neurologic outcome.[23,24] Post-resuscitation care is an additional important factor in the survival and neurologic recovery of patients with coma after resuscitation from cardiac arrest.[3–5] In our cohort, after exclusion of patients who were awake and alert immediately after resuscitation, the remaining patients treated at the SRC had 38% survival with good neurologic outcome.

TABLE 4. Adjusted odds ratios for survival with good neurologic outcome

	Adjusted odds ratio (95% CI)[a]	
Therapeutic hypothermia	2.0	1.2–3.5
Shockable rhythm	4.7	2.9–7.7
Witnessed arrest	1.4	0.6–3.2
Bystander CPR	1.1	0.7–1.8
Age (per year)	1.0	1.0–1.0

[a]Adjusted odds ratio generated by the simultaneous entry of covariates in the logistic regression model.
Hosmer-Lemeshow goodness-of-fit statistics $p = 0.03$, Akaike Information Criterion = 469.1.

Systematic care and advanced interventions available at regional centers may improve outcomes of patients with ROSC. Superior outcomes have been linked to higher patient volume for many high-acuity conditions.[25–31] More recently, Carr et al. found that there was lower in-hospital mortality for patients admitted to the ICU after cardiac arrest in centers that treated a higher volume of post-arrest patients.[32] Rapid assessment and established critical care protocols likely contribute to the higher volume–improved outcome relationship. An early goal-directed approach to patients with ROSC has been proposed, given the physiologic characteristics of patients after ROSC are similar to patients with severe sepsis.[33,34] An immediate, systematic approach to optimization of physiologic parameters may be an important step in improving outcomes after OOHCA. As demonstrated with trauma and STEMI systems, this can be achieved through designated centers with established protocols.

Regional centers have the capacity for early, directed interventions. Sunde et al. developed a standard treatment protocol that included early PCI, which improved neurologic outcome, discharge rate, and 1-year survival.[35] Seventy-three percent of the patients in their study had coronary artery disease. Several other studies have demonstrated very high rates of obstructive coronary lesions in cardiac arrest patients with ROSC.[13–15] ECGs may not adequately predict which patients would benefit from early PCI, since ST-segment elevation has been shown to be insensitive in this patient population.[15] In our study, nearly one-quarter of the patients underwent cardiac catheterization and 11% had PCI. Thus, since rapid intervention in patients with an acute coronary obstruction is feasible in regional care centers, this may further improve outcomes of these patients.

As in prior studies, we found an association between TH and favorable neurologic outcomes. However, the proportion of patients receiving TH remains low

despite existing protocols at all SRC. This is consistent with other reports of underuse of this proven therapy throughout the country.[8] There is room for improvement. After implementation of regional cardiac resuscitation centers in Arizona, Bobrow et al. found an increased use of TH in eligible patients.[36] In our study, greater than 50% of patients who did not receive TH did not have documentation of a known contraindication to cooling. While we noted variability among hospitals in the frequency of TH, our study lacked the power to adjust for possible patient factors that may account, at least in part, for these differences.

It is likely that multiple additional factors have contributed to the improvement in outcomes from cardiac arrest in LA County. There have been other temporal system changes since 2001, including the implementation of a public access defibrillation program and an increase in bystander cardiopulmonary resuscitation (CPR). The bystander CPR rate in our study was 38% compared to 28% reported by Eckstein et al. in 2001.[22] In addition, TOR protocols were initiated in LA County in 2007 for patients with nonshockable rhythms after unsuccessful field resuscitation based on ACLS guidelines. Since these patients would not be transported and thereby not included in the data registry and the denominator of all patients with OOHCA, this will contribute to the increase in proportion of good neurologic outcomes.

This study has several limitations. A major limitation to quantifying the effect of regionalization on outcome after out-of-hospital cardiac arrest is our lack of a concurrent reference group. As such, our comparison is limited to historical data published in 2001 but incorporating data from the same EMS system, transporting patients to the nearest facility. Our analysis is not inclusive of all patients with cardiac arrest in LA County; this study was only designed to evaluate outcomes in the subset of patients with ROSC treated at the SRC. Patients who were not transported (met TOR criteria) and patients transported to a hospital other than a SRC were not included in this analysis. It is unlikely that patients with ROSC in the field would be transported to a non-SRC hospital because current protocols mandate transport of these patients to an SRC and protocol violations would be rare. We were unable to adjust for downtime (time from cardiac arrest to ROSC) as this was missing in the majority of patients and is likely to be inaccurate when reported.[37,38] The initial GCS after ROSC was recorded for 91% of patients, indicating GCS 3–5 in 756 (82%) patients and GCS 6–8 in 30 (3%) of patients, with 53 (6%) having a GCS greater than 8, but the timing of this assessment in relation to ED arrival was unclear and it was missing in 9% of the study cohort. We did not include this assessment in our regression analysis.

Although all SRC are required to meet the criteria set by the LA County EMS Agency, there is wide variety in institutional protocols for interventions such as TH. In this study, we did not assess the adequacy and variability of the TH, including when target temperature was reached and duration of cooling. There could be variability in prognostication as well, which may affect treatment rendered at the SRC. In regards to our evaluation of the association of TH and good neurologic outcome, although the Hosmer-Lemeshow goodness-of-fit statistic was <0.05, indicating poor model fit, our intent was to perform an exploratory analysis for the purpose of hypothesis generation. We incorporated known predictors in the model for the multivariable analysis, but given the observational nature of the study design, we are limited in our ability to identify which component of post-resuscitation care has the greatest impact in improving neurologically intact survival rates. Lastly, we are unable to determine which particular interventions, both in the field and at the SRC, resulted in the outcome benefit.

CONCLUSION

Outcomes from OOHCA improved in Los Angeles for patients treated at designated facilities after establishment of regionalized post-resuscitation care. The improvement in patient outcomes is multifactorial and likely includes an increase in bystander CPR, increased access to early defibrillation, emphasis on field resuscitation to maximize early ROSC, improved recognition of futile resuscitation leading to termination of efforts in the field in appropriate patients, and transport of patients to specialized centers with established treatment protocols, including induction of hypothermia in patients with ROSC.

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LOS ANGELES COUNTY STEMI RECEIVING CENTERS

Antelope Valley Hospital, Lancaster, CA
Beverly Hospital, Montebello, CA
Cedars Sinai Medical Center, Los Angeles, CA
Citrus Valley Medical Center–Intercommunity Campus, Covina, CA
Garfield Medical Center, Monterey Park, CA
Glendale Adventis Medical Center, Glendale, CA
Glendale Memorial Hospital and Health Center, Glendale, CA
Good Samaritan Hospital, Los Angeles, CA
Harbor–UCLA Medical Center, Torrance, CA
Hollywood Presbyterian Medical Center, Los Angeles, CA[a]
Huntington Memorial Hospital, Pasadena, CA
LAC + USC Medical Center, Los Angeles, CA
Lakewood Regional Medical Center, Lakewood, CA
Long Beach Memorial Medical Center, Long Beach, CA
Los Robles Hospital and Medical Center, Thousand Oaks, CA
Methodist Hospital of Southern California, Arcadia, CA
Northridge Hospital, Northridge, CA
Palmdale Regional Medical Center, Lancaster, CA
Pomona Valley Hospital Medical Center, Pomona, CA
Presbyterian Intercommunity Hospital, Whittier, CA
Providence Holy Cross Medical Center, Mission Hills, CA
Providence Little Company of Mary Medical Center, Torrance, CA
Providence Saint Joseph Medical Center, Burbank, CA
Providence Tarzana Medical Center, Tarzana, CA
Ronald Reagan UCLA Medical Center, Los Angeles, CA
San Antonio Community Hospital, San Antonio, CA
Santa Monica–UCLA Medical Center, Santa Monica, CA
St. John's Hospital and Health Center, Santa Monica, CA
St. Jude Medical Center, Fullerton, CA
St. Mary Medical Center, Long Beach, CA
Torrance Memorial Medical Center, Torrance, CA
Valley Presbyterian Hospital, Van Nuys, CA
West Hills Hospital and Medical Center, West Hills, CA
White Memorial Medical Center, Los Angeles, CA

[a]Newly approved in 2012.