Original Article

Direct Transport to a Percutaneous Cardiac Intervention Center and Outcomes in Patients With Out-of-Hospital Cardiac Arrest

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Background—Practice guidelines recommend regional systems of care for out-of-hospital cardiac arrest. However, whether emergency medical services should bypass nonpercutaneous cardiac intervention (non-PCI) facilities and transport out-of-hospital cardiac arrest patients directly to PCI centers despite longer transport time remains unknown.

Methods and Results—Using the Cardiac Arrest Registry to Enhance Survival with geocoding of arrest location, we identified out-of-hospital cardiac arrest patients with prehospital return of spontaneous circulation and evaluated the association between direct transport to a PCI center and outcomes in North Carolina during 2012 to 2014. Destination hospital was classified according to PCI center status (catheterization laboratory immediately accessible 24/7). Inverse probability-weighted logistic regression accounting for age, sex, emergency medical services response time, clustering of county, transport time to nearest PCI center, initial heart rhythm, and prehospital ECG information was performed. Of 1507 patients with prehospital return of spontaneous circulation, 1359 (90.2%) were transported to PCI centers, of whom 873 (57.9%) bypassed the nearest non-PCI hospital and 148 (9.8%) were transported to non-PCI hospitals. Discharge survival was higher among those transported to PCI centers (33.5% versus 14.6%; adjusted odds ratio, 2.47; 95% confidence interval, 2.08–2.92). Compared with patients taken to non-PCI hospitals, odds of survival were higher for patients taken to the nearest hospital with PCI center status (odds ratio, 3.07; 95% confidence interval, 1.90–4.97) and for patients bypassing closer hospitals to PCI centers (odds ratio, 3.02; 95% confidence interval, 2.01–4.53). Adjusted survival remained significantly better across transport times of 1 to 5, 6 to 10, 11 to 20, 21 to 30, and >30 minutes.

Conclusions—Direct transport to a PCI center is associated with better outcomes for out-of-hospital cardiac arrest patients, even when bypassing nearest hospital and regardless of transport time. **(*Circ Cardiovasc Qual Outcomes*. 2017;10:e003414. DOI: 10.1161/CIRCOUTCOMES.116.003414.)**

Key Words: cardiopulmonary resuscitation ■ emergency medical services ■ out-of-hospital cardiac arrest ■ post-resuscitation care ■ regional systems of care

Out-of-hospital cardiac arrest (OHCA) is a major public healthcare issue affecting 200 000 to 400 000 Americans each year, with large variations in incidence, resuscitation practice, and outcomes between communities.[1,2] Regional systems of care involving centralization of postresuscitation care have been proposed to improve outcomes because multiple organ systems can be affected after OHCA that likely are best treated at regional centers with percutaneous cardiac intervention (PCI) and critical care capabilities.[3–6] There is consensus that a regional cardiac arrest center at a minimum must have (1) a cardiac catheterization laboratory that is immediately accessible 24/7 and (2) the capability to provide targeted temperature management (TTM).[5]

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WHAT IS KNOWN

- OHCA is a major public healthcare challenge affecting 200 000 to 400 000 Americans each year, with large variations in resuscitation care and outcomes
- Despite proposals for regional systems of care involving centralization of postresuscitation care to improve outcomes, evidence supporting bypassing the nearest non-PCI hospital to transport patients over longer distances directly to a PCI hospital is lacking.

WHAT THE STUDY ADDS

- Among OHCA patients who achieved return of spontaneous circulation in the prehospital setting, this study found an ≈3-fold higher odds of discharge survival among patients bypassing a nearer non-PCI hospital relative to patients taken to a non-PCI hospital.
- Chances of survival were significantly higher for patients taken directly to a PCI hospital across transport times of 1 to 5, 6 to 10, 11 to 20, 21 to 30, and >30 minutes.
- This study suggests that EMS personnel should consider taking OHCA patients who had restoration of circulation in the field directly to a PCI hospital, even when the transport time is estimated to be well beyond 30 minutes.

Although potentially related to differences in case-mix, several studies have shown wide variability but better outcomes in hospitals adhering to postresuscitation guidelines (including TTM and timely catheterization, prognostication, and withdrawal of care) compared with hospitals in which these processes of care are not routinely applied.[7–12] Nevertheless, evidence supporting bypassing the nearest non-PCI hospital to transport patients directly to a PCI center remains scarce and mostly limited to urban areas with short transport times.[13–16] Specifically, data on outcomes for patients who bypass a closer, local non-PCI hospital and who are transported for longer periods of time to arrive at specialized centers are warranted.[5,17]

Therefore, using prehospital cardiac arrest data from mixed urban–rural areas in North Carolina, we examined the association between direct transport to a PCI center and discharge survival and neurological outcome among patients with prehospital return of spontaneous circulation (ROSC). We hypothesized that direct transport to a PCI center is associated with better outcomes.

Methods

Study Setting

We used data from mixed urban–rural areas in North Carolina during 2012 to 2014. Cases from 16 counties (Alexander, Alleghany, Brunswick, Camden, Catawba, Durham, Forsyth, Mecklenburg, Pasquotank, Stanly, Stokes, Surry, Transylvania, Wake, Warren, and Yadkin) with complete registry enrollment throughout the study period were identified from the Cardiac Arrest Registry to Enhance Survival (CARES). In North Carolina, a data analyst reviewed all reported OHCA patients and provided feedback to and interacted with the emergency medical services (EMS) agencies for data quality assurance. This analyst monitored registry enrollment for each county and EMS agency together with a team of data consultants. The catchment population of these counties was 3 143 809 (2013), representing one third of the state population of North Carolina and half of all reported cases of OHCA from North Carolina to CARES.[18]

CARES is a voluntary, prospective clinical database of OHCA patients, established by the Centers for Disease Control and Prevention and the Department of Emergency Medicine at Emory University, Atlanta, GA, offering EMS agencies an opportunity for data entry, feedback, and quality improvement.[2,19] Dispatch center, EMS agency, and hospital data are collected and entered into CARES. The CARES data entry platform is in accordance with the international Utstein definitions for clinical variables and outcomes to ensure uniformity.[20] The North Carolina Regional Approach to Cardiovascular Emergencies Cardiac Arrest Resuscitation (RACE-CARS) program established data collection using the CARES registry platform as part of the HeartRescue project funded by the Medtronic Foundation in 2010. The RACE-CARS team was founded by leaders of the RACE program, the regional ST-segment–elevation myocardial infarction (STEMI) system of care team in North Carolina, and the RACE-CARS team facilitated coordination between hospitals and EMS agencies through implementation of a shared protocol that can be found online.[21]

Study Population

Eligible OHCA patients were identified through CARES. The CARES registry includes all patients with OHCA who received cardiopulmonary resuscitation or defibrillator shock by either bystanders, first-responders, or EMS personnel. This definition excludes patients with obvious signs of death (eg, rigor mortis) and patients with a do not resuscitate order, for whom a resuscitative effort was not initiated.[2] From the 16 counties in North Carolina with complete case capture during 2012 to 2014, we included arrests of presumed cardiac cause with prehospital ROSC and excluded EMS-witnessed cases or subjects with do not resuscitate orders, in agreement with Utstein guidelines for uniform cardiac arrest reporting.[20] Restricting our analyses to patients with prehospital ROSC minimized confounding from patients with an already moribund prognosis before hospital arrival. A physical location of the cardiac arrest was established for ≈97% of the patients, excluding patients with nongeocoded records (including post office boxes and other nonphysical locations. ArcGIS 10.2 software (Esri, Redlands, CA) was used to geocode each incident to the street-level address. Drive times were then calculated from each incident to (1) the destination hospital, (2) the nearest PCI center, and (3) the nearest non-PCI hospital using ArcGIS Network Analyst, which takes into account road network variables, such as speed limits, one-way streets, and other driving conditions.

Study Variables and Definitions

We assessed information on age; sex; arrest location (public versus residential area); witness status (unwitnessed, bystander- or EMS-witnessed); bystander cardiopulmonary resuscitation; EMS response time defined as the time interval between emergency dispatch center call and EMS arrival; initial rhythm assessed by EMS personnel; and whether patients were defibrillated by bystanders, first responders, or EMS personnel or not defibrillated before hospital arrival. In agreement with the CARES registry data dictionary, a first responder was defined as personnel who responded to the medical emergency after activation by the emergency dispatch center as part of a 2-tiered response team (first responder and EMS) but who were not the designated transporter of the patient to the hospital. First responders included police officers, firefighters, rescue squads, or life-saving crew members equipped with automated external defibrillators and trained to perform basic life support, including chest compressions and use of an automated external defibrillator. Bystanders were other people who were present and had alerted the emergency dispatch center but had not been dispatched, in accordance with the Utstein guidelines.[20] EMS personnel operating in the included counties work in 2-person teams, which consist of 1 paramedic trained in advanced life support plus 1 emergency medical technician. Alternatively, the EMS personnel team can consist of 2 paramedics. Use of TTM, coronary angiography, and PCI were reported.

Main Exposure Variables

Destination hospital was classified according to whether primary PCI was available on a 24/7 basis, with these hospitals being part of the RACE-CARS and HeartRescue regional systems of care initiatives.[21–23] Hospital locations were linked to the physical arrest location to estimate the drive (transport) time to (1) the destination hospital, (2) the nearest PCI center, and (3) the nearest non-PCI hospital and (4) the differential drive time (bypass time), defined as the difference in drive time between the nearest non-PCI hospital and the nearest PCI center.

Main Outcomes

Study end points were discharge survival and discharge survival with favorable neurological outcome (Cerebral Performance Category score of 1–2: no, mild, or moderate disability but independent in activities of daily living).

Statistical Analyses

Descriptive statistics were summarized using frequencies and proportions for categorical variables and median and 25% to 75% percentiles for continuous variables. Accordingly, χ^2 and Wilcoxon Mann–Whitney tests were performed. We used logistic regression to assess the association between destination hospital and outcomes, using propensity score inverse probability weights, including driving time to nearest PCI center, initial rhythm, and prehospital ECG information to account for potential confounding. These factors were anticipated to influence EMS' decision regarding to which hospital patients should be transported (PCI center versus non-PCI center). The RACE-CARS protocol and OHCA guidelines recommend obtainment of a 12-lead ECG as soon as possible after ROSC and to transport STEMI patients and selected cardiac arrest patients without STEMI (ventricular tachycardia/fibrillation) to PCI centers.[4,21] For this reason, inverse probability weights included initial heart rhythm and prehospital ECG information assessed by EMS personnel in addition to the estimated drive time to the nearest PCI center. Multivariable adjusted modeling further included patient age, sex, EMS response time, and clustering of county. Results are presented as unadjusted and adjusted odds ratio (OR) with 95% confidence intervals (CI). We additionally performed several sensitivity analyses: (1) we restricted our analyses to patients admitted to hospital and (2) to patients without STEMI; and (3) we evaluated the association between direct transport to a PCI center and outcomes using an instrumental variable approach, with differential drive time as instrument variable adjusted for patient age, sex, EMS response time, initial rhythm, prehospital ECG information, and clustering of county. Generalized linear regression models were estimated using a binomial distribution and log-link function with differential drive time as the instrumental variable. An instrument is a variable that does not itself belong in the explanatory equation and is (1) correlated with the endogenous explanatory variable (PCI center versus non-PCI center) but (2) is not biased from the same problem as the explanatory variable.[24] Using this approach, patients with comparable differential drive times were compared. In addition to the differential drive time (bypass) analyses, we also compared outcomes across increasing actual drive times between patients taken to a non-PCI hospital with patients taken to the nearest hospital with PCI center status and patients bypassing the nearest non-PCI hospital to a PCI center. Predicted probability of survival and survival with favorable neurological outcome were derived from logistic regression models. Data management were performed using SAS versions 9.2 and 9.4 (SAS Institute Inc., Cary, NC) and statistical analyses using STATA, version 13.0 (StataCorp, College Station, TX).

Ethics

The Duke University Medical Center Institutional Review Board approved the current study with a waiver of the requirement for written informed consent, and Health Insurance Portability and Accountability Act authorization was granted on the basis of (1) using existing central CARES registry data and under existing waivers of consent for CARES under the Emory Institutional Review Board, as well as the HeartRescue project, and (2) using aggregated and limited data.

Results

Patients

We included 1507 patients with prehospital ROSC (Figure 1): 1359 were transported to a PCI center and 148 to a non-PCI center. A total of 873 patients (57.9%) bypassed the nearest non-PCI hospital (median drive time 14 minutes [25%–75%; 10–20.5]), and of the remaining 634 patients who were transported to the nearest hospital, 486 (76.6%) were taken directly to a PCI center (median drive time 8.5 minutes [25%–75%; 5–13]) and 148 (24.4%) to a non-PCI hospital (median drive time 11 minutes [25%–75%; 6.5–18]). Among these 148 patients who were taken to non-PCI hospitals, 48.0% (N=71) were later transferred to a PCI center.

Characteristics

Patient age, sex, and rates of bystander cardiopulmonary resuscitation and bystander, first responder, and EMS defibrillation did not significantly differ between patients transported to PCI centers and patients transported to non-PCI hospitals (Table 1). Patients transported to PCI centers were more likely to have a public location of arrest (P=0.01) but less likely to have a witnessed arrest (P=0.05). The EMS response time was slightly longer for patients taken to a non-PCI hospital relative to patients transported to a PCI center. While the actual transport time to destination hospital did not differ between the 2 study groups, the estimated transport time to the nearest PCI center differed by a median time of ≈30 minutes between the 2 groups. Use of TTM

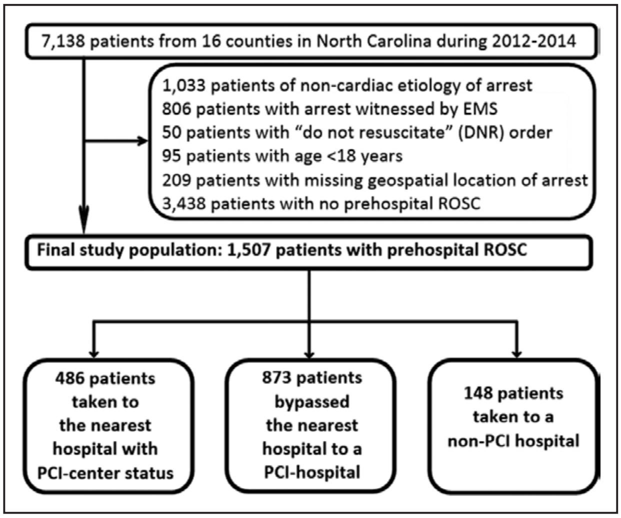

Figure 1. Patient selection flowchart. Data show selection of study population. DNR indicates do not resuscitate; EMS, emergency medical services; PCI, percutaneous cardiac intervention; and ROSC, return of spontaneous circulation.

Table 1. Characteristics According to Destination Hospital

Parameter	PCI Hospital (No. 1359	Non-PCI Hospital (No. 148)	*P* Value
Age, median (Q1–Q3)	65 (55–75)	67 (56–78)	0.06
Male sex, No. (%)	827 (60.9)	83 (56.1)	0.26
Public location of arrest, No. (%)	409 (30.1)	29 (19.6)	0.01
Witnessed arrest, No. (%)	882 (64.9)	108 (73.0)	0.05
Who initiated CPR			
Bystander-initiated, No. (%)	722 (53.2)	75 (50.7)	0.55
First responder–initiated, No. (%)	481 (35.4)	56 (37.8)	0.56
EMS-initiated, No. (%)	154 (11.3)	17 (11.5)	0.96
Missing, No.	2	0	
Defibrillation, No.	708 (52.1)	80 (54.0)	0.66
Missing, No.	1	0	
Who defibrillated the patient*			
Bystander defibrillation, No. (%)	59 (8.3)	4 (5.0)	0.30
First responder defibrillation, No. (%)	332 (47.0)	35 (43.8)	0.59
EMS defibrillation, No. (%)	316 (44.7)	41 (51.2)	0.26
Missing, No.	1	0	
EMS response time, min, median (Q1–Q3)	7.7 (5.9–9.9)	9.5 (6.6–13.4)	<0.01
Missing, No.	41	0	
Shockable first rhythm recorded by EMS, No. (%)	528 (38.9)	56 (37.8)	0.80
Missing, No.	2	0	
Patients taken to nearest hospital, No. (%)	486 (35.8)	148 (100.0)	<0.01
Drive time to destination hospital, min, median, (Q1–Q3)	10.8 (8.1–17.6)	11 (6.5–18)	0.06
Time to nearest PCI hospital, min, median (Q1–Q3)	10.8 (7.2–15.9)	39.7 (29.1–47.2)	<0.01
Temperature management initiated in field, No. (%)	1022 (75.8)	60 (40.5)	<0.01
Missing, No.	10	0	
Admitted to hospital from emergency room, No. (%)	1099 (80.9)	102 (68.9)	<0.01
Shockable first rhythm recorded by EMS,† No. (%)	486 (44.3)	43 (42.2)	0.68
Treated with temperature management,† No. (%)	669 (64.1)	41 (46.6)	<0.01
Missing, No.	9	14	
Treated with temperature management,‡ No. (%)	344 (71.4)	22 (56.4)	0.04
Examined with coronary angiography,† No. (%)	338 (35.7)	19 (22.1)	0.01
Missing, No.	151	16	
Transferred to PCI center,† No. (%)	…	68 (66.6)	…
Examined with coronary angiography,§ No. (%)	338 (35.7)	15 (22.7)	0.03
Missing, No.	151	2	
Coronary angiography within 24 h,‖ No. (%)	202 (63.1)	8 (53.3)	0.58
Missing, No.	18	0	
Treated with PCI,§ No. (%)	149 (13.6)	7 (10.3)	0.26
Missing, No.	152	2	
Treated with PCI‖, No. (%)	149 (44.1)	7 (46.7)	1.00

Data show characteristics according to destination hospital (PCI versus non-PCI hospital). Categorical variables are presented with numbers and percentages and continuous variables with medians and 25%–75% percentiles (first to third quartiles, Q1–Q3). CPR indicates cardiopulmonary resuscitation; EMS, emergency medical service; min, minutes; and PCI, percutaneous cardiac intervention.

*Among defibrillated patients.

†Among patients admitted to hospital from emergency room.

‡Among patients admitted to hospital from emergency room and with a shockable first rhythm recorded by EMS.

§Among patients admitted to a PCI center, either directly or transfer-in.

‖Among patients examined with coronary angiography.

and coronary angiography were significantly higher among patients taken directly to a PCI center relative to patients taken to a non-PCI hospital, whereas differences in the timing of angiography and use of PCI were modest (Table 1). The above characteristics remained largely similar between the 2 hospital groups, when excluding patients who were taken to the nearest hospital with PCI center status (Table I in the Data Supplement).

Association Between PCI Hospital Status and Outcomes

The discharge survival rate was higher among those directly transported to a PCI center relative to those taken to a non-PCI hospital (33.5% versus 14.6%; unadjusted OR, 2.95; 95% CI, 1.84–4.76). Similarly, the discharge survival rate with favorable neurological outcome was 29.4% versus 13.9% (unadjusted OR, 2.52; 95% CI, 1.57–4.06). After accounting for potential confounding using inverse probability weights as well as adjusting for age, sex, EMS response time, and clustering of county, transport to a PCI center remained significantly associated with better discharge survival and survival with favorable neurological outcome (Table 2). These results were consistent when adding patient age, sex, and EMS response time in the propensity score. Results were also consistent when trimming the propensity scores at the 90th, 95th, and 99th percentile (Table 2). When restricting the analyses to patients admitted to hospital (N=1201), significant differences in both outcomes remained: adjusted OR, 2.58 (95% CI, 2.14–3.11) and adjusted OR, 2.23 (95%

Table 2. Odds Ratios of Outcomes According to Destination Hospital

Outcomes	OR	95% CI
Discharge survival		
Unadjusted	2.95	1.84–4.76
Adjusted*	2.48	2.10–2.95
Adjusted†	2.96	2.44–3.57
Adjusted‡	2.70	2.11–3.48
Adjusted§	2.58	2.04–3.27
Adjusted‖	2.23	1.86–2.67
Discharge survival with favorable neurological outcome		
Unadjusted	2.52	1.57–4.06
Adjusted*	2.22	1.80–2.75
Adjusted†	2.63	2.08–3.34
Adjusted‡	2.36	1.78–3.13
Adjusted§	2.27	1.72–2.99
Adjusted‖	2.21	1.67–2.92

Data show outcomes reported as OR with 95% CI. Odds ratios for direct transport to a PCI hospital compared with a non-PCI hospital are reported. CI indicates confidence interval; EMS, emergency medical services; OR, odds ratio; and PCI, percutaneous cardiac intervention.

*Analyses are adjusted for potential confounding using inverse probability weights, including drive time to nearest PCI center, initial rhythm, and prehospital ECG information, as well as patient age, sex, EMS response time, and clustering of county are accounted for.

†Analyses that also includes age, sex, and EMS response time in the model for propensity scores.

‡, §, ‖Analyses for the propensity score weights trimmed at the 90th, 95th, and 99th percentiles.

CI, 1.71–2.92), respectively. Significant differences in survival also remained when only patients without STEMI were included, with a trend toward better neurological outcome at discharge (Table 3).

Table 3. Odds Ratios of Outcomes Among Patients Without STEMI According to Destination Hospital

Outcomes Among Patients Without STEMI Diagnosis	No. of Patients	Adjusted* OR	95% CI
Discharge survival			
Including patients with no ECG taken	1177	2.64	1.83–3.82
Including patients with ECG taken	795	1.74	1.05–2.91
Discharge survival with favorable neurological outcome			
Including patients with no ECG taken	1177	2.34	1.47–3.72
Including patients with ECG taken	795	1.44	0.85–2.43

Data show outcomes reported as OR with 95% CI. Odds ratio for direct transport to a PCI hospital compared with a non-PCI hospital among patients without STEMI diagnosis. CI indicates confidence intervals; EMS, emergency medical services; OR, odds ratio; PCI, percutaneous cardiac intervention; and STEMI, ST-segment–elevation myocardial infarction.

*Analyses are adjusted for potential confounding using inverse probability weights, including drive time to nearest PCI center, initial rhythm, and prehospital ECG information; patient age, sex, EMS response time, and clustering of county are accounted for as well.

Table 4. Odds Ratios of Outcomes in Relation to Increasing Bypass Time Intervals

Outcomes in Relation to Bypass Times	No. of Patients Compared	Adjusted* OR	95% CI
Discharge survival			
Bypass time† 1–5 min	480 vs 148	2.71	1.64–4.46
Bypass time 6–10 min	175 vs 148	2.71	1.83–4.00
Bypass time 11–20 min	156 vs 148	2.70	1.65–4.42
Bypass time >20 min	56 vs 148	3.19	1.64–6.22
Discharge survival with favorable neurological outcome			
Bypass time 1–5 min	480 vs 148	2.05	1.19–3.54
Bypass time 6–10 min	175 vs 148	2.62	1.67–4.10
Bypass time 11–20 min	156 vs 148	2.19	1.29–3.72
Bypass time >20 min	56 vs 148	2.34	1.43–3.85

Data show outcomes reported as OR with 95% CI. Odds ratios for patients who bypassed the nearest hospital to go to a PCI center (N=1021) are compared with patients taken to a non-PCI hospital (N=148). Increasing bypass times are compared with patients taken to a non-PCI hospital. CI indicates confidence interval; EMS, emergency medical services; OR, odds ratio; PCI, percutaneous cardiac intervention.

*Analyses are adjusted for patient age, sex, EMS response, clustering of county, initial rhythm, and prehospital ECG information.

†Bypass time is defined as the differential drive time between the nearest non-PCI hospital and the PCI center the patient was taken to.

Association Between Bypass to a PCI Center and Outcomes

Bypassing the nearest non-PCI hospital to arrive at a PCI center was associated with both better survival and favorable neurological outcome at discharge (Table 4). Results were consistent when applying instrumental variable methods, using differential drive time (bypass time) as an instrumental variable and adjusted for age, sex, EMS response time, initial rhythm, prehospital ECG information, and clustering of counties: adjusted OR, 2.60 (95% CI, 1.29–5.22) for survival; and adjusted OR, 2.24 (95% CI, 1.08–4.65) for survival with favorable neurological outcome. Across all drive time intervals (1–5, 6–10, 11–20, 21–30, and >30 minutes), patients taken to the nearest hospital with PCI-center status (N=486) and patients bypassing the nearest hospital to a PCI center (N=873) remained associated with better adjusted survival and favorable neurological outcome relative to those taken to non-PCI hospitals (Table 5). Even for patients bypassing the nearest non-PCI hospital to a PCI center with drive times >30 minutes (median drive time, 38.5 minutes [25%–75%; 34–46.5]), significant differences in survival and favorable neurological outcome remained (Figure 2 and Table 6).

Discussion

This study of 1507 OHCA patients with prehospital ROSC from North Carolina during 2012 to 2014 showed both increased survival and survival with favorable neurological outcome at discharge for patients transported to a PCI center compared with those taken to a non-PCI hospital. These differences remained significant after applying multivariable modeling using inverse probability propensity score weights,

Table 5. Odds Ratios of Outcomes According to Non-PCI Hospital, Nearest Hospital With PCI Capability, and Bypass of Nearest Non-PCI Hospital to a PCI Center

Outcomes	Adjusted* OR	95% CI
Discharge survival		
Nearest hospital PCI center vs non-PCI hospital	3.07	1.90–4.97
Bypass to PCI center vs non-PCI hospital	3.01	2.01–4.53
Discharge survival with favorable neurological outcome		
Nearest hospital PCI center vs non-PCI hospital	2.76	1.66–4.59
Bypass to PCI center vs non-PCI hospital	2.39	1.51–3.80

Data show outcomes reported as OR with 95% CI. Odds ratios for patients taken to the nearest hospital that had PCI-center status and patients bypassing the nearest non-PCI hospital to a PCI-center relative to patients taken to a non-PCI hospital are reported. CI indicates confidence interval; EMS, emergency medical services; OR, odds ratio; and PCI, percutaneous cardiac intervention.

*Analyses are adjusted for patient age, sex, EMS response time, clustering of county, initial rhythm, prehospital ECG information, and drive time intervals of 1–5, 6–10, 11–20, 20–29, and >30 min.

as well as when using an instrumental variable approach and when examining groups with increasing bypass and actual transport intervals.

Regionalization of care has been proposed to improve care and outcomes, but must be balanced with the inherent increase in transportation times for some patients.[3–6] Current studies focusing on the association between transport distance and outcomes are mainly limited to short drive times in urban settings, while current guidelines lack evidence supporting bypass, particularly in nonurban areas with longer transport distances.[5,6,13–16] While transport to and care at regional cardiac centers have been shown to benefit STEMI patients, only indirect evidence exists that regional systems of care improve care and outcomes for OHCA patients.[5–11,25,26]

We report data from a mixed urban–rural setting in North Carolina, in which a significant number of patients were transported over longer periods of time to arrive to a PCI center. Importantly, characteristics did not substantially differ between patients taken to a PCI center compared with those patients taken to the nearest non-PCI center. In addition, when applying inverse probability weights to account for several potential key factors that likely impacted the decision to which hospital the EMS personnel transported the patient, discharge survival and survival with favorable neurological outcome were considerably higher among patients taken to a PCI center relative to a non-PCI hospital. Furthermore, these differences remained when comparing patients taken to a non-PCI hospital to patients bypassing the nearest non-PCI hospital, even for patients with drive times exceeding 30 minutes (median time of 38.5 minutes [25%–75%; 34–46.5]). These findings suggest that implementation of protocols to transport patients after

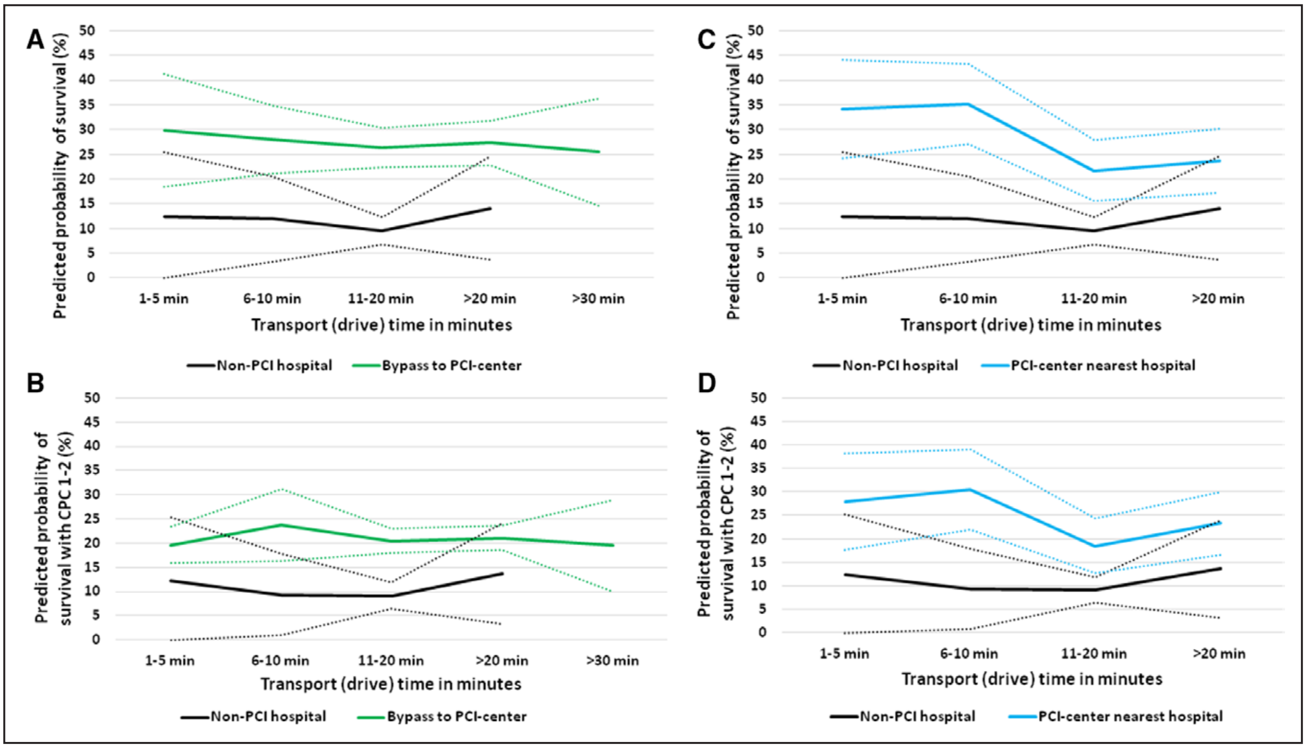

Figure 2. Predicted adjusted probability of survival and survival with favorable neurological outcome across transport (drive) time intervals. Data show [(**A**) and (**C**)] predicted probability of survival and [(**B**) and (**D**)] predicted probability of survival with favorable neurological outcome (cerebral performance category [CPC] score of 1–2) across transport (drive) time intervals. In **A** and **C**, solid lines represent predicted probability of survival for (**A**) patients bypassing the nearest non–percutaneous cardiac intervention (PCI) hospital to a PCI center versus patients taken to a non-PCI hospital and (**C**) patients taken to the nearest hospital with PCI-center status versus patients taken to a non-PCI hospital. In **B** and **D**, solid lines represent predicted probability of survival with CPC 1 to 2 for (**B**) patients bypassing the nearest non-PCI hospital to a PCI center versus patients taken to a non-PCI hospital and (**D**) patients taken to the nearest hospital with PCI-center status versus patients taken to a non-PCI hospital. Dotted lines represent 95% confidence intervals. Probability for each time interval group is adjusted for patient age, sex, emergency medical services (EMS) response time, and clustering of county, as well as initial rhythm and prehospital ECG information.

Table 6. Median Transport (Drive) Times With 25th to 75th Percentiles According to Destination Hospital and Drive Time Intervals

Destination Hospital and Drive Time Intervals	No. of Patients	Median Drive Time, min	25th Percentile, min	75th Percentile, min
Non-PCI hospital, 1–5 min	27	3	2	4
Non-PCI hospital, 6–10 min	40	7	6.5	8
Non-PCI hospital, 11–20 min	53	15	12.5	17
Non-PCI hospital, >20 min	28	23	21.5	26.5
PCI center nearest hospital, 1–5 min	110	3.5	2.5	4.4
PCI center nearest hospital, 6–10 min	189	7.5	6.5	8.5
PCI center nearest hospital, 11–20 min	149	13.5	11.5	15.5
PCI center nearest hospital, >20 min	38	22	21.5	25
Bypass to PCI center, 1–5 min	49	4	3	4.5
Bypass to PCI center, 6–10 min	154	8	7	9
Bypass to PCI center, 11–20 min	442	14	12	16.5
Bypass to PCI center, 20–29 min	149	24.5	22	26.5
Bypass to PCI center, >30 min	79	38.5	34	46.5

Data show median drive times with 25th to 75th percentiles in minutes according to destination hospital (non-PCI hospital, when a PCI center was the nearest hospital and when a non-PCI hospital was bypassed to a PCI center) and across drive time intervals of 1–5, 6–10, 11–20, and >20 min (for patients bypassing the nearest non-PCI hospital to a PCI center, the >20-min interval was further divided into 20–29 and >30 min). PCI indicates percutaneous cardiac intervention.

successful resuscitation from OHCA directly to PCI centers within these transport intervals may improve outcomes.

Consequently, our results have implications for EMS care and transport. Because acute coronary syndrome is a common cause of cardiac arrest, obtainment of a 12-lead ECG imminently after ROSC to detect whether ST-elevations are present is a class I recommendation in contemporary OHCA guidelines.[4,6] Furthermore, these guidelines state that because it is difficult to determine the final neurological status of comatose survivors, aggressive treatment of STEMI should begin as in non–cardiac arrest patients, regardless of coma or TTM. Cardiac arrest guidelines have been shared with and adopted by all PCI centers in North Carolina as part of the RACE (2005–2009) and HeartRescue RACE-CARS program (2010–2015). Moreover, because of the high incidence of acute coronary ischemia and poor diagnostic value of the initial ECG, consideration of emergent coronary angiography may be reasonable even in the absence of ST-elevations.[27,28] Despite these recommendations, a prehospital ECG is not always obtained, and STEMI patients complicated by prehospital arrest were previously less likely to be transported to a PCI center relative to STEMI patients without OHCA.[29] EMS personnel may not transport STEMI patients with a prehospital arrest over longer distance to a PCI center because of concern of hemodynamic instability or risk of rearrest. Our findings, however, support direct transport of patients with OHCA to PCI centers, even for those with drive times beyond 30 minutes.

When limiting our analysis to patients admitted to the hospital, significant differences in outcomes remained, which may be explained by differences in postresuscitation care. Despite the use of TTM and coronary angiography significantly differed between the 2 hospital groups, limited differences were found in early (<24 hours) versus later use of angiography and use of PCI. However, these latter analyses were limited by a low number of transfer in patients among those initially taken to a non-PCI hospital, and early angiography has previously been shown to improve outcomes.[30,31] Moreover, there may be other therapies given in parallel with PCI and temperature management that likely also improved outcomes among those taken to a cardiac center, including sedation, appropriate oxygenation, and ventilation strategies, establishment of extracorporeal circulation if required, optimization of hemodynamics, glycemic control and other guideline-recommended therapies in addition to timely neurological prognostication, and withdrawal of care.[4–6,11] While it is likely a combination of such therapies that benefit resuscitated patients, it is beyond the scope of this study to demonstrate which of these guideline-recommended in-hospital therapies that benefit patients the most. Nonetheless, our data support the transportation of resuscitated patients directly to hospitals, in which this bundle of care is offered, even for longer periods of drive time well beyond 30 minutes.

Limitations

Although our study is observational in nature, characteristics were largely similar between the study groups, and our findings were consistent when applying both inverse probability weighting and instrumental variable methods. Despite granular prehospital data, only limited in-hospital data were available, and consequently, we cannot point to which in-hospital therapies seem most beneficial, as noted earlier. Even though patients without STEMI also seem to benefit from direct transport to a PCI center, a considerable number of patients who did not have an ECG obtained in the prehospital setting limited these analyses. As such, the complete proportion of patients diagnosed with STEMI is not known.

We did not have data on use of medical air transport. However, a recent study from North Carolina looking at regional systems of care for STEMI patients showed that the use of medical air transport was infrequent.[29] Moreover, EMS personnel were trained in advanced life support, and most PCI hospitals were within 1-hour drive time, limiting the use of medical air transport, which generally results in longer delays. In addition, any use of medical transport that may differ between the study groups will likely be accounted for by the adjustment for clustering of county in our analyses.

We also do not have data on any rearrest episodes. However, our results were consistent when restricting our analyses to patients admitted to hospital. Finally, although only around 10% were transported to a non-PCI hospital in North Carolina, a total of 57.9% of the patients bypassed the nearest hospital to be transported further to a PCI hospital and had significantly better outcomes than patients who were taken to the nearest non-PCI hospital. Also, a considerably larger proportion of patients are not transported with bypass to a PCI hospital in other settings, stressing the potential importance of regionalization of care to improve outcomes.[8,32,33]

Conclusions

Direct transport to a PCI center was associated with significantly higher adjusted rates of discharge survival and survival with favorable neurological outcome relative to patients transported to a non-PCI hospital. Furthermore, findings were consistent when comparing patients who bypassed the nearest hospital to a PCI center with drive times well beyond 30 minutes. Thus, direct transport to a PCI center is associated with better outcomes in patients after successful resuscitation from OHCA. This suggests that implementation of protocols to transport resuscitated OHCA patients directly to PCI centers, when feasible, may improve outcomes.

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