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Association Between Treatment at an ST Segment Elevation Myocardial Infarction (STEMI) Center and Neurologic Recovery Following Out-of-Hospital Cardiac Arrest

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Abstract

Background—For patients resuscitated from out-of-hospital cardiac arrest (OHCA), the American Heart Association recommends regionalized care at cardiac resuscitation centers that are aligned with ST-elevation myocardial infarction (STEMI) centers. The effectiveness of treatment at STEMI centers remains unknown.

Objective—To evaluate whether good neurologic recovery following OHCA is associated with treatment at a STEMI center, and if volume of admitted OHCA patients is associated with good neurologic recovery.

Methods—We included patients in the 2011 California Office of Statewide Health Planning and Development database with a “present on admission” diagnosis of cardiac arrest. Primary outcome was good neurologic recovery at hospital discharge. Hierarchical multiple logistic regression models were used to determine the association between treating hospital and good neurologic recovery after adjusting for patient factors (age, sex, race, ethnicity, insurance type, and ventricular arrest rhythm) and hospital factors (hospital size, ICU bed days, trauma center designation, and teaching status).

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Study conception and design – BEM, JFH, DBD
Acquisition of data – BEM
Analysis and interpretation of data – BEM, MDW, JFH, DBD
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Results—We included 7,725 patients; two-thirds (5,202) were treated at a STEMI center and 1,869 (24%, 95%CI 23–25%) had good neurologic recovery. After adjustment, treatment at a STEMI center with ≥40 and <40 OHCA cases/year were associated with good neurologic recovery [OR 1.32 (95%CI 1.06–1.64) and 1.63 (95%CI 1.35–1.97), respectively]. Higher volume of admitted OHCA patients was associated with decreased odds of good neurologic recovery (adjusted OR per 10 patients 0.96, 95%CI 0.92–1.00) but this association was not statistically significant after excluding the highest-volume outlier.

Conclusions—Treatment at a STEMI center – regardless of its annual OHCA volume – following resuscitation from OHCA is associated with good neurologic recovery. Regionalized systems of care should prioritize STEMI centers as destinations for resuscitated OHCA patients.

Keywords

Heart arrest; Resuscitation; Survival

Introduction

Out-of-hospital cardiac arrest (OHCA) is common, occurring at an annual rate of 52.1 cases of OHCA treated by emergency medical services per 100,000 individuals.[1] Overall mortality is high, and outcomes vary significantly by region and hospital.[1–3] Multidisciplinary care including early cardiac catheterization and therapeutic hypothermia, improves neurologic outcomes among post-cardiac arrest patients.[4–7] As these evidence-based interventions have limited penetration,[7–11] the American Heart Association (AHA) recommends regionalized care for patients resuscitated from OHCA at level 1 cardiac resuscitation centers that are aligned with ST segment elevation myocardial infarction (STEMI) centers. In addition to providing 24/7 percutaneous coronary intervention, level 1 cardiac resuscitation centers also have the capability for therapeutic hypothermia and treat ≥40 patients annually with return of spontaneous circulation following OHCA.[12]

While regional systems of care for post-cardiac arrest patients have been developed ad hoc and implemented in limited areas in the United States,[12–14] the majority of patients resuscitated from OHCA are not treated at cardiac resuscitation centers.[15] Furthermore, despite the AHA recommendations, the effectiveness of treatment at cardiac resuscitation centers has not been demonstrated at the population level and requires evaluation prior to widespread implementation of regionalized care. We tested the hypothesis that treatment at a STEMI center would be associated with good neurologic recovery at hospital discharge among patients resuscitated from OHCA. We also evaluated the association between treatment at a STEMI center and good neurologic recovery and the association between hospital volume of resuscitated OHCA patients and good neurologic recovery.

Methods

We included all patients in the 2011 California Office of Statewide Health Planning and Development (OSHPD) Patient Discharge Database with a “present on admission” diagnosis of cardiac arrest (ICD-9-CM 427.5) or sudden death (ICD-9-CM 798). Per California Health and Safety Code Section 128736, all acute care hospitals in California (excluding Veterans

Affairs and military facilities) must submit data for every inpatient encounter to OSHPD. These data do not represent a sample, but rather surveillance data intended to have 100% coverage. As such, the data contained in the OSHPD database are very robust and widely used for research. We excluded duplicate entries resulting from patient transfers and patients for whom hospital data or neurologic outcome data were missing. This study was deemed exempt from review by our Institutional Review Board and was approved by the California Committee for the Protection of Human Subjects.

Data obtained from the OSHPD Patient Discharge Database included patient age, gender, ethnicity, zip code of residence, source of admission, disposition, source of payment, length of stay, diagnoses, "present on admission" codes, procedures, and treating hospital. Diagnoses include up to 25 conditions that "coexist at the time of admission, that develop subsequently during the hospital stay, or that affect the treatment received and/or the length of stay." Procedures include up to 21 procedures related to the patient's stay. Diagnoses and procedures were coded according to the ICD-9-CM.[16] Data regarding hospital size, number of intensive care unit (ICU) bed days, teaching status, and trauma center designation were obtained from OHSPD. Data regarding teaching status were obtained from the American Hospital Association.[17] We obtained a list of all hospitals with 24/7 percutaneous coronary intervention capability from the American Heart Association. Hospital-level data were merged with OSHPD patient-level data using a unique hospital identifier. Possible duplicate entries were identified by matching patient age, sex, and zip code of residence; these entries were hand-reviewed to identify transferred patients. For patients transferred from one hospital to another, the initial hospital providing care was considered the treating hospital. If the patient's length of stay was one day or less, however, the hospital accepting the patient transfer was considered the treating hospital.

Definitions

Ventricular arrest rhythm was defined as a "presenton admission" diagnosis of paroxysmal ventricular tachycardia (ICD-9-CM 427.1) or ventricular fibrillation/flutter (ICD-9-CM 427.4, 427.41, 427.42).

STEMI centers were defined as hospitals with 24/7 percutaneous coronary intervention capability. Because the AHA recommends that cardiac resuscitation centers treat an annual volume of at least 40 patients resuscitated from OHCA annually,[12] we divided STEMI centers into those that admitted <40 versus ≥40 cases in 2011. Our prior research indicates that nearly all of these hospitals had therapeutic hypothermia capability by 2011.[15]

Payer categories reported in the OSHPD data were consolidated into private, Medicare, public, and other insurance types. The public insurance category included Medi-Cal, indigent programs, and self-pay.

Outcomes

Our primary outcome was good neurologic recovery at hospital discharge, defined as discharge to home, residential care facility, prison, jail, or another hospital for non-acute/non-skilled care. Patients who left against medical advice were also considered to have good

neurologic recovery. Patients with all other dispositions, including death, were considered not to have good neurologic recovery.[18,19]

Analysis

Summary statistics were calculated for each variable. Univariable analyses were performed to evaluate the relationship between treatment at a STEMI center and good neurologic recovery. To account for correlation among patients treated at the same hospital, hierarchical models were used, with hospital modeled as a random effect.[20,21] A multiple logistic model was used to adjust for age, sex, race, ethnicity, insurance type, ventricular arrest rhythm, hospital size, ICU bed days, trauma center designation, and teaching status.[3,22,23] Because Los Angeles County emergency medical services protocols mandated the transfer of OHCA patients with prehospital return of spontaneous circulation to hospitals with a therapeutic hypothermia protocol in 2011,[14] an influence analysis excluding patients who resided in Los Angeles County was performed.

Because therapeutic hypothermia and cardiac catheterization have been most studied in patients with ventricular arrest rhythms,[6,9,18,24,25] we evaluated the effect of STEMI centers on patients with ventricular versus non-ventricular arrest rhythms. Subgroup analyses for patients with ventricular and non-ventricular arrest rhythms were performed, and the primary model was fitted with an interaction term for STEMI center status and ventricular arrest rhythm.

To evaluate the relationship between volume of admitted OHCA patients and good neurologic recovery, a hierarchical multiple logistic regression model was used to adjust for age, sex, race, ethnicity, payer category, ventricular arrest rhythm, hospital size, ICU bed days, trauma center designation, and teaching status. Our data included one high-volume outlier hospital, and an influence analysis excluding this hospital was also performed.

Hospital-specific adjusted odds ratio (compared to the average odds) of good neurologic recovery were calculated as the exponential function of the random intercepts derived from a hierarchical logistic regression model which included patient characteristics (age, sex, race, ethnicity, insurance type, and ventricular arrest rhythm).

To determine whether significant inter-hospital variation remained after adjusting for patient factors, random variance was estimated and likelihood ratio chi square test was used to test for significant component of variance due to hospital is zero.

Hypothesis tests were two-sided and assessed at a significance level of 0.05. All analyses were performed using Stata version 12.1 (StataCorp, College Station, TX), Excel 2010 (Microsoft, Redmond, WA) or SAS/STAT version 9.3 (SAS Institute, Cary, NC).

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Results

We identified 8,153 patients admitted to an acute care hospital in California with a “present on admission” diagnosis of cardiac arrest or sudden death. We excluded 205 duplicate entries resulting from patient transfers, 168 patients with incomplete or missing hospital data, and 55 patients with missing neurologic outcome data, yielding a study population of 7,725 patients. Overall, median age was 67 years (interquartile range 55–79 years), and 4,455 (58%) were male. Ventricular rhythms were reported in 2,131 (28%). (Table I)

Characteristics of treating hospitals are summarized in Table II. Of the 333 acute care hospitals in California, 54 (16%) were STEMI centers that treated ≥40 cases of OHCA in 2011 and 71 (21%) were STEMI centers that treated <40 cases of OHCA in 2011.

Overall, 1,869 (24%, 95% CI 23–25%) patients experienced good neurologic recovery following OHCA. In univariable analyses, treatment at STEMI centers with both ≥40 and <40 OHCA cases/year was associated with good neurologic recovery [OR 1.35 (95% CI 1.13–1.62) and OR 1.71 (95% CI 1.42–2.07), respectively]. These differences persisted after adjustment for age, race, gender, ethnicity, insurance type, ventricular arrest rhythm, hospital size, trauma center designation, and teaching status (Table III). Increasing age was independently associated with decreased odds of good neurologic recovery (Table III). Female sex and treatment at a level 1 or 2 trauma center were associated with a trend toward decreased odds of good neurologic recovery. The influence analysis excluding patients who resided in Los Angeles County yielded similar results for STEMI centers with both ≥40 and <40 OHCA cases/year (Table III).

While treatment at a STEMI center was associated with good neurologic recovery for patients with ventricular and non-ventricular arrest rhythms (Table IV), the effect was stronger among patients with a ventricular arrest rhythm (p=0.001).

Increasing hospital volume of patients resuscitated from OHCA was associated with decreased odds of good neurologic recovery (adjusted OR 0.96 per 10-patient increase, 95% CI 0.92–0.996), but this relationship was not significant when the highest-volume outlier hospital was excluded (adjusted OR 0.96, 95% CI 0.91–1.00). The adjusted odds of survival with good neurologic recovery by hospital volume are shown in Figure 1.

The use of therapeutic hypothermia, cardiac catheterization, and percutaneous coronary intervention differed between STEMI centers with ≥40 OHCA cases/year, STEMI centers with <40 OHCA cases/year, and non-STEMI centers (Table V).

Among STEMI centers, the unadjusted proportion of patients with good neurologic recovery ranged from 0% to 68% (interquartile range 20–33%). This variation persisted after adjusting for age, race, gender, ethnicity, insurance type, ventricular arrest rhythm, hospital

size, ICU bed days, trauma center designation, and teaching status ($p<0.0001$), indicating that a significant component of variance was due to the hospital.

Discussion

We found that treatment at a STEMI center following resuscitation from OHCA is associated with increased odds of good neurologic recovery. Our results are consistent with two smaller studies showing higher survival among resuscitated OHCA patients treated at hospitals with cardiac catheterization[19,26] and with two larger studies showing higher survival among OHCA patients transported to at tertiary or critical care hospitals.[27,28] These data suggest that patients resuscitated from OHCA would benefit from regionalized care at a STEMI center. Regionalized care improves processes of care in STEMI,[29] trauma,[30,31] stroke,[32] and critical illness,[33–35] and regionalized systems of care are well-developed for patients with STEMI.[29,36–39] Extending these existing systems to include resuscitated OHCA patients may facilitate improved neurologic outcomes among patients resuscitated from OHCA.

A relationship between case volume and outcome exists for other conditions requiring time-sensitive and critical interventions,[34,40,41] and the American Heart Association recommends that level 1 cardiac resuscitation centers treat at least 40 patients resuscitated from OHCA annually.[12] However, several prior studies evaluating the association between emergency department and hospital volumes of OHCA cases and survival yielded conflicting results,[2,19,26,42,43] and we found no independent relationship between volume of admitted OHCA patients and good neurologic outcome. Unlike prior studies which included relatively few facilities with over 40 OHCA patients per year,[2,19,26] our data included 64 hospitals that admitted ≥40 patients resuscitated from OHCA with the highest-volume hospital admitting 149 patients in one year, allowing us to better evaluate the volume-outcome relationship at high-volume centers.

Treatment at a level 1–2 trauma center was associated with a trend toward lower odds of good neurologic recovery. This phenomenon may be due to OHCA patients competing with trauma patients for limited critical care resources, the urban environments where these centers are located, or other factors. While this finding contrasts data from an Australian system in which the highest OHCA survival rates were seen at urban centers with cardiac and trauma designations,[19] it aligns with a prior report that patients with potential acute coronary syndromes who presented to the emergency department concurrently with a trauma activation experienced worse outcomes than those who did not.[44] These findings should be considered as regional systems of care that aggregate multiple specialty services within one hospital are developed.[45]

Our data do not allow us to identify the processes contributing to better neurologic recovery at STEMI centers. Similar to prior studies,[10,46] few patients in our population received cardiac catheterization or therapeutic hypothermia. Possible reasons for this low utilization include limited awareness of or agreement with the data supporting these interventions, perception of poor patient prognosis, lack of organized protocols, and concerns regarding cardiac catheterization outcome reporting.[47–49] Recent data suggest that the therapeutic

hypothermia target of 32–34°C recommended during the study period may be less beneficial than previously thought.[50–52] Therapeutic hypothermia, cardiac catheterization, and percutaneous coronary intervention were all performed more frequently at STEMI centers than at non-STEMI centers. These procedures may contribute to the higher rates of good neurologic recovery seen at STEMI centers. Further investigation is required to characterize other processes of care at STEMI centers that contribute to these improved outcomes and that contribute to the variability in outcomes among STEMI centers.

Our study has several limitations. We were unable to control for prehospital arrest characteristics such as witnessed arrest, bystander interventions, and cardiopulmonary resuscitation quality, which are associated with good outcomes.[3,22,53–56] We identified patients using a "present on admission" code for cardiac arrest and thus were unable to determine whether the cardiac arrest occurred in the prehospital or emergency department environment, although the overwhelming majority of cardiac arrests were likely prehospital. Furthermore, the number of unique patients we identified in the OHSPD database with a "present on admission" diagnosis of cardiac arrest or sudden cardiac death is consistent with the predicted number of OHCA cases with survival to hospital admission based on prior data.[1,3] We used discharge disposition as a surrogate for good versus poor neurologic recovery. No neurological functional outcome measure has been well validated in post-cardiac arrest patients.[57] Our classification aligns with the definitions of good neurologic recovery used in previous studies of post-cardiac arrest patients,[18,19] and it correlates with the Cerebral Performance Category score.[4,58] Because data were not available on all criteria in the AHA recommendations for cardiac resuscitation centers, we evaluated outcomes at STEMI that admitted ≥40 patients resuscitated from OHCA in 2011. Our prior data suggest that all of these hospitals had therapeutic hypothermia protocols in place by 2011, suggesting that they may meet AHA criteria for level 1 cardiac resuscitation centers.[15]

Conclusion

Treatment at a STEMI center – regardless of its annual OHCA volume - following resuscitation from OHCA is associated with good neurologic recovery. Regionalized systems of care should prioritize STEMI centers as destinations for resuscitated OHCA patients. However, the significant variation in outcomes between STEMI centers that persists after adjusting for known factors warrants further research to identify hospital-level factors associated with good neurologic recovery.

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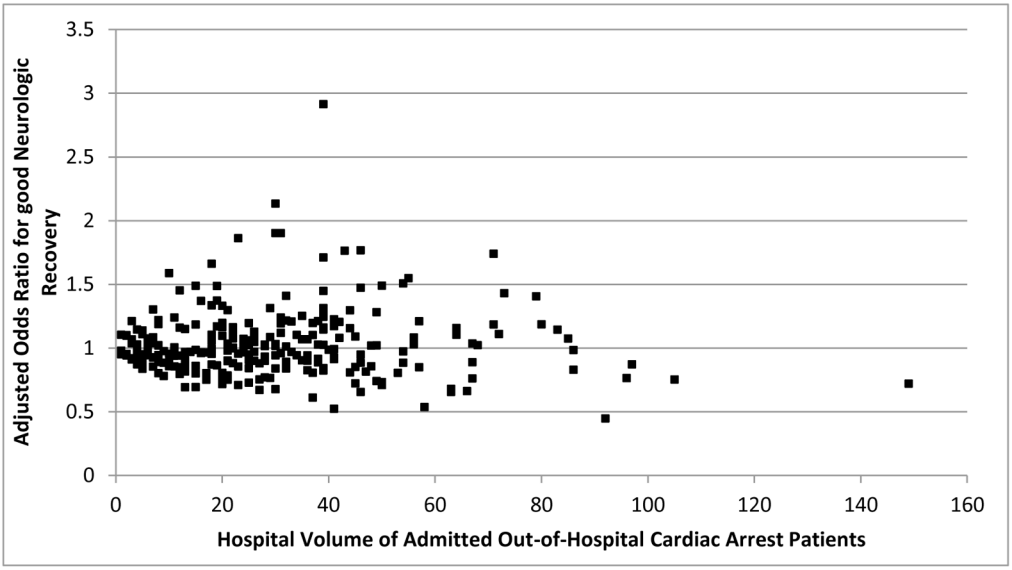

Figure 1.

Adjusted odds ratio of survival versus volume of admitted out-of-hospital cardiac arrest cases for each hospital. Odds ratios are adjusted for age, sex, race, ethnicity, ventricular arrest rhythm, and insurance type and represent the odds for each hospital compared to the average for all hospitals.

Table I

Patient characteristics.

	Treated at STEMI Center with ≥40 cases/year N=3,340		Treated at STEMI Center with <40 OHCA cases/year N=1,862		Treated at non- STEMI Center N=2,523	
Age*	65	(53–77)	69	(56–80)	68	(55–79)
Male sex	1,956	59%	1,120	60%	1,379	55%
Race						
White	2,131	64%	1,344	72%	1,570	62%
Black/African-American	447	13%	87	5%	345	14%
Asian/Pacific Islander	278	8%	224	12%	275	11%
Other	412	12%	177	10%	298	12%
Unknown	72	2%	30	2%	35	1%
Hispanic ethnicity	776	23%	314	17%	510	20%
Payer category						
Medicare	1,740	52%	1,073	58%	1,432	57%
Private	705	21%	406	22%	492	20%
Medi-Cal/Indigent/Self-pay	876	26%	357	19%	578	23%
Other	19	1%	26	1%	21	1%
Ventricular arrest rhythm	1,040	31%	586	31%	505	20%

*Data presented as median (interquartile range).

STEMI = ST segment elevation myocardial infarction

Table II

Hospital characteristics.

	STEMI Centers with ≥40 OHCA cases/year N=54		STEMI Centers with <40 OHCA cases/year N=71		Non-STEMI Centers N=208	
Total beds						
≤50	0	0%	1	1%	40	19%
51–100	0	0%	0	0%	35	17%
101–200	2	4%	21	30%	73	35%
201–350	17	31%	31	44%	40	19%
>350	35	65%	18	25%	20	10%
Trauma center designation						
Level 1	10	19%	3	4%	0	0%
Level 2	16	30%	9	13%	9	4%
Level 3	1	2%	4	6%	6	3%
Level 4	0	0%	0	0%	10	5%
None	27	50%	55	77%	183	88%
Teaching hospital	12	22%	6	8%	8	4%
Number of admitted OHCA patients*	56	(46–71)	29	(19–35)	13	(5–24)

*Data presented as median (interquartile range). Excludes hospitals with no admitted OHCA patients in 2011.

STEMI = ST segment elevation myocardial infarction; OHCA = Out-of-hospital cardiac arrest

Table III

Multivariable hierarchical logistic regression for good neurologic recovery.

Variable	All patients			Excluding Los Angeles Residents		
	Odds Ratio	95% CI	p-value	Odds Ratio	95% CI	p-value
Hospital type*			<0.0001			<0.0001
STEMI center with ≥40 OHCA cases/year	1.32	1.06–1.64		1.52	1.20–1.94	
STEMI center with <40 OHCA cases/year	1.63	1.35–1.97		1.79	1.45–2.19	
Age (per 10 years)	0.87	0.83–0.90	<0.0001	0.87	0.83–0.91	<0.0001
Male sex	1.12	1.00–1.25	0.05	1.12	0.99–1.28	0.08
White race	1.09	0.96–1.23	0.18	1.05	0.91–1.21	0.53
Hispanic ethnicity	1.03	0.90–1.18	0.68	1.01	0.85–1.20	0.94
Insurance†			0.31			0.29
Medi-Cal/indigent/self-pay insurance	0.94	0.80–1.10		0.91	0.75–1.09	
Medicare insurance	0.95	0.82–1.11		0.92	1.10	
Other insurance	1.54	0.89–2.66		1.56	0.82–2.97	
Ventricular arrest rhythm	1.97	1.75–2.21	<0.0001	2.01	1.76–2.30	<0.0001
Hospital size (per 50 beds)	0.99	0.96–1.03	0.75	0.98	0.94–1.01	0.21
ICU bed days (per 100 bed days)	1.00	1.00–1.00	0.97	1.00	1.00–1.00	0.58
Teaching hospital	1.03	0.78–1.38	0.82	1.00	0.74–1.37	0.98
Level 1–2 trauma center	0.83	0.68–1.02	0.08	0.88	0.70–1.10	0.25

STEMI = ST segment elevation myocardial infarction; OHCA = Out-of-hospital cardiac arrest; ICU = Intensive care unit

*The reference category for hospital type is non-STEMI centers.

†The reference category for insurance type is private insurance.

Table IV

Multivariable hierarchical logistic regression for good neurologic recovery by arrest rhythm.

Variable	Ventricular arrest rhythms			Non-ventricular arrest rhythms		
	Odds Ratio	95% CI	p-value	Odds Ratio	95% CI	p-value
Hospital type*			<0.0001			0.002
STEMI center with ≥40 OHCA cases/year	2.14	1.55–2.97		1.04	0.80–1.35	
STEMI center with <40 OHCA cases/year	2.19	1.62–2.97		1.45	1.16–1.82	
Age (per 10 years)	0.81	0.75–0.87	<0.0001	0.89	0.85–0.93	<0.0001
Male sex	1.24	1.02–1.52	0.03	1.08	0.94–1.23	0.28
White race	1.09	0.89–1.35	0.40	1.10	0.95–1.27	0.22
Hispanic ethnicity	0.89	0.69–1.14	0.36	1.08	0.91–1.27	0.40
Insurance†			0.34			0.18
Medi-Cal/indigent/self-pay insurance	1.20	0.92–1.56		0.83	0.67–1.02	
Medicare insurance	0.99	0.77–1.27		0.94	0.77–1.15	
Other insurance	1.70	0.67–4.33		1.37	0.69–2.71	
Ventricular arrest rhythm	--	--	--	--	--	--
Hospital size (per 50 beds)	0.97	0.92–1.03	0.33	1.01	0.96–1.05	0.79
ICU bed days (per 100 beds)	1.00	1.00–1.00	0.96	1.00	1.00–1.00	0.87
Teaching hospital	1.07	0.71–1.62	0.74	1.02	0.72–1.44	0.90
Level 1–2 trauma center	0.77	0.58–1.03	0.07	0.88	0.68–1.13	0.31

STEMI = ST segment elevation myocardial infarction; OHCA = Out-of-hospital cardiac arrest; ICU = Intensive care unit

*The reference category for hospital type is non-STEMI centers.

†The reference category for insurance category is private insurance.

Table V

Proportion of patients receiving selected interventions by hospital type.

	STEMI centers with ≥40 OHCA cases/year (N=3,360)	STEMI centers with <40 OHCA cases/year (N=1,882)	Non-STEMI centers (N=2,538)
Therapeutic Hypothermia	6.3% (5.5–7.2%)	7.8% (6.6–9.1%)	1.7% (1.2–2.2%)
Cardiac Catheterization	22.0% (20.6–23.5%)	27.1% (25.1–29.2%)	4.8% (4.0–5.7%)
Percutaneous Coronary Intervention	9.4% (8.5–10.5%)	11.5% (10.1–13.1%)	1.3% (0.9–1.9%)

Data are presented as percent with 95% Confidence Interval