Intrastate Variation in Treatment and Outcomes of Out-of-Hospital Cardiac Arrest

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ABSTRACT

Objective: Our objective was to analyze and compare out-of-hospital cardiac arrest (OHCA) system of care performance and outcomes at the Medical Control Authority (MCA) level in the state of Michigan. We hypothesized that clinically and statistically significant variations in treatment and outcomes of OHCA exists within a single U.S. state. **Methods**: We performed a retrospective, observational study of all non-traumatic EMS-treated OHCA from the state of Michigan CARES registry for 2014–2015. Geocoding of the OHCA incident address was used to assign records to individual MCAs. MCA-based demographics, arrest characteristics, system of care performance and outcomes were quantified and compared. Associations between demographics, system of care parameters, and outcomes were examined at the MCA level. **Results**: A total of 8,115 records with complete data were available for analysis. Eleven MCAs met study inclusion criteria of >100 cases, producing a final sample size of 7,788 records (96%). Statistically significant variations in survival to hospital discharge ranged from 4.5% to 15% ($p < 0.001$) (Adjusted odds ratio [AOR] range 0.6–2.0) and survival with good neurologic outcome 2.7–12.5% ($p < 0.001$; AOR range 0.5–2.2,) were observed across MCAs. Bystander CPR ranged from 32% to 53% ($p < 0.001$) and bystander AED application ranged from 3.5% 11.5% ($p < 0.05$). Of patients admitted to the hospital alive, 29–68% received targeted temperature management. In hospital mortality ranged from 53.1% to 73.9% ($p < 0.05$). **Conclusion**: Significant intrastate variability in OHCA system of care performance and outcomes currently exist and are similar to what has been previously reported across North America almost a decade ago. This degree of variability highlights the opportunity to optimize modifiable factors within local systems of care to improve OHCA outcomes. **Key words**: out-of-hospital cardiac arrest; EMS oversight; systems of care

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Introduction

More than 350,000 non-traumatic out-of-hospital cardiac arrests (OHCA) occur annually in the United States (U.S.), with an overall survival rate of approximately 11% for those who receive treatment (1). Wide variations in both treatment and outcomes of OHCA have been previously described throughout North America (2–6). Most notably, in an analysis of the Resuscitation Outcomes Consortium (ROC) from 2008, Nichol et al. described a 5-fold difference in survival to hospital discharge among 10 participating sites from the U.S. and Canada (2). More recently, Girotra et al. found marked variation in both bystander cardiopulmonary resuscitation (CPR) and survival with functional recovery rates across more than 130 U.S. counties participating in the Cardiac Arrest Registry to Enhance Survival (CARES) (3).

OHCA represents a unique disease state because survival is highly dependent on the performance of the system of care as a whole, which includes the actions of lay persons, medical dispatch, emergency medical services (EMS) personnel, and hospital physicians and staff (7). The state of Michigan EMS system consists of >60 Medical Control Authorities (MCA) that are organizations designated by the Michigan Department of Health and Human Services (MDHHS) with the responsibility of EMS oversight in their geographic areas. This includes supervision and coordination of local EMS; provision of medical direction; establishment of written practice-protocols; protocol circulation for review and MDHHS approval; education of clinicians, EMS providers, and hospitals on protocols; and assuring protocol adherence (8).

The MCA model provides a unique opportunity to perform an OHCA system of care analysis. With this in mind, our objective was to analyze and compare OHCA system of care performance and outcomes at the MCA level within the state of Michigan. We hypothesized that clinically significant statewide variations in both treatment and outcomes of OHCA exist and are similar to those previously described across North America.

METHODS

Study Design and Population

We performed a retrospective, observational study, using prospectively collected data, of all non-traumatic OHCA who received resuscitative efforts by EMS from the state of Michigan CARES registry for years 2014–2015. Victims of trauma, records with an incomplete incident address, and records with missing data for survival to hospital discharge status or neurologic outcomes were excluded. We also excluded all records where EMS efforts were terminated due to a do-not-resuscitate (DNR) order. A minimum of 100 OHCA cases were required during the study period to include an MCA in the analysis. The study was approved by the University of Michigan Institutional Review Board.

Cardiac Arrest Registry to Enhance Survival (CARES)

CARES was developed in 2004 as a collaborative effort between Emory University and the Centers for Disease Control and Prevention to serve as a central repository for cardiac arrest data from EMS systems throughout the U.S. (9). The registry utilizes the Utstein style of OHCA reporting and includes variables from prehospital care through hospital discharge (10). There are currently 20 statewide registries and an additional 64 communities in 22 states participating in CARES, including more than 1,400 EMS agencies and 1,800 hospitals, which covers a population of 106 million (11). Further details of CARES development, design, and data elements have been previously published (9).

During the study period, the following data elements were required for reporting: incident date, address, patient name, age, date of birth, gender, race/ethnicity, responding EMS agency, destination hospital, arrest location, witnessed status, arrest after arrival of 911 responder status, presumed etiology, resuscitation attempted status, who initiated CPR, whether an AED was applied prior to EMS arrival, who first applied the AED, who first defibrillated the patient, first documented rhythm, whether ROSC was achieved, whether hypothermia was initiated in the field, whether hypothermia was continued or initiated in hospital, hospital outcome, discharge location, and neurologic status at the time of hospital discharge (12).

Michigan is one of 20 statewide registries contributing to CARES. Through 2015, there were 30 MCAs, 103 EMS agencies, and 92 hospitals contributing data to the Michigan CARES registry, which equates to a total coverage of approximately 60% of the state population. Additionally, Michigan has a full-time state coordinator who is responsible for record auditing, overseeing of data collection, and training EMS agencies and hospitals on CARES data entry.

System of Care Definition

Individual systems of care within Michigan were defined by MCA. MCAs were created by the state of Michigan as the official oversight organizations for EMS in their areas. The MCA is made up of hospitals within a designated geography that provide medical oversight to all EMS agencies functioning within that geography. They are generally one county, but may include more than one county. Any EMS agency that operates in an MCA must abide by the protocols of the MCA, their clinical care guidelines or agency structural requirements such as staffing or certification. However, clinical care in most cases is provided under protocols developed at the state level. The multiple hospitals, EMS agencies, their EMS staff, and the citizens receiving service are all definable by MCA. This creates a unit of measurement that encapsulates the entire system of care for OHCA. MCA's vary by population size, degree of urbanicity, number and type of EMS services, and number and type of hospitals.

OHCA Geocoding

Geocoding of OHCA incident addresses was used to assign records to the appropriate MCA. Each record contained the street address of the OHCA location. The addresses were first converted to latitudinal and longitudinal coordinates using an online service (13) based on the locations API in Bing Maps REST Services (14). Second, a color-coded map of Michigan was created such that each MCA was represented by a distinct color based on MCA boundaries. Third, each record was mapped onto a pixel within the map using its latitudinal and longitudinal coordinates and the coordinates of 2 geographically known points on the map called *anchor points.* The color of the pixel was then used to identify the corresponding MCA for each record. Some MCAs have boundaries that cross county boundaries. For such MCAs, separate close-up maps were used to specify appropriate boundaries and ensure appropriate color-coding of coverage areas. Finally, the geocoding was automated using MATLAB.

Study Variables

Individual MCA patient demographics and arrest characteristics were collected including: age, gender, race (White, Black, Hispanic/Latino, Other, or Unknown), location of the OHCA (Home/residence, Nursing home/health care facility, Public location, or other), whether the arrest was witnessed (yes/no), and first documented rhythm (i.e., shockable rhythm [defined as ventricular fibrillation, ventricular tachycardia, or unknown shockable]; or unshockable rhythm [defined as asystole, idioventricular/pulseless electrical activity, or unknown unshockable]).

System of care variables included bystander (defined as a lay person, layperson family member, or lay person medical professional) CPR and bystander automated external defibrillator (AED) use, first responder AED use, total EMS response time (defined as interval from 9–1-1 call to EMS arrival on scene), and hypothermic targeted temperature management (HTTM) application rate (defined as the number of patients who survived to hospital admission and received HTTM).

Outcome Measures

The primary outcome measure was survival with good neurologic outcome (defined as a cerebral performance category (CPC) score of 1 or 2 at the time of discharge). Secondary outcome measures included return of spontaneous circulation (ROSC) rates; survival to hospital admission rates (defined as the proportion of those treated who are admitted to the ICU, CCU, or the medical floor); survival to hospital discharge rates (defined as the proportion of those treated who are discharged to their home, a rehabilitation facility, a long term care facility, or nursing home); in-hospital mortality rates (defined as the proportion of those admitted who die in hospital); and the proportion of those admitted who survive with good neurologic outcome (CPC score 1 or 2). Since OHCA is a time sensitive condition, with outcomes dependent rapid delivery of care, a supplemental analysis was performed excluding all patients with EMS-witnessed OHCA. This step was taken to ensure the study outcomes were not confounded by an uneven distribution of EMS-witnessed OHCA across MCAs.

Statistical Analyses

Analyses focused on the MCA as the focal independent variable, and chi-squared analysis were used to examine between-MCA differences in patient demographic, arrest characteristic, and system of care variables. Associations between the categorical MCA variable and the MCA outcome variables were tested with bivariate and multiple logistic regression analysis (15). Covariates in multiple logistic regression models included age, gender (0 = male, 1 = female), race (1 = white, 0 = all others), arrest witnessed (0 = no, 1 = yes), arrest location (1 = home/residence, 0 = all other locations), first monitored rhythm (0 = unshockable, 1 = shockable). For all outcomes, each MCA was compared to all other MCAs combined. Unadjusted and adjusted odds ratios are reported, and an alpha level of .05 was used for all analyses. Analyses were conducted with the SPSS statistical software package (version 22.0, IBM Corp, 2013).

Results

The study period included a total of 8,185 records, of which 70 (0.9%) were excluded due to an incomplete primary outcome or incomplete incident address information. A total of 7,788 records (96%) were included in the analysis from 11 MCAs meeting study inclusion criteria of ≥100 OHCA for the study period (Figure 1). Pediatric patients (age $<$ 18) comprised 2.7% of the study population.

Details of MCA population characteristics are located in Table 1. All patient demographics (age, gender, race) and arrest characteristic variables (location, witnessed status, initial rhythm) differed significantly across MCAs ($p < 0.05$).

Data on system of care variables are located in Table 2. Statistically significant variation for all variables (bystander CPR, bystander AED application, EMS response time) was observed across MCAs. Of note, bystander CPR rates varied from as low as 32% to as high as 53% of cases across MCAs ($p < .001$). Additionally, bystander application of AEDs varied from 3.5% of all cases to as high as 11.5% across MCAs ($p < 0.05$).

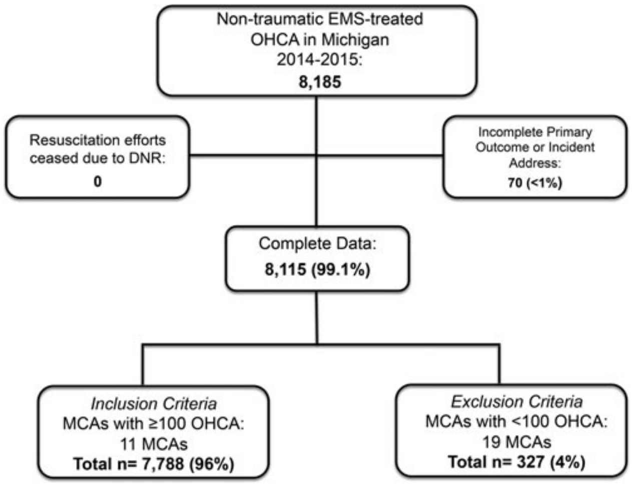

Figure 1. Flow diagram of study inclusion/exclusion criteria. Note: EMS = *Emergency medical services*; OHCA = *out-of-hospital cardiac arrest*; DNR = *do not resuscitate order*; MCA = *Medical Control Authority*.

Table 3 contains MCA outcomes data. All outcomes including ROSC, survival to hospital admission, survival to hospital discharge, and survival with good neurologic outcome (CPC 1 or 2) varied significantly across MCAs. Importantly, over a 4-fold variation in unadjusted survival with good neurologic outcome (2.7–12.5%) was observed (Figure 2). After covariate adjustment, this variation remained significant, as the AOR range was from 0.5 to 2.2. With exclusion of EMS-witnessed OHCA, variation across all outcomes remained significant (Supplemental Table 1).

As seen in Table 4, MCA application of HTTM and in-hospital mortality rates varied significantly ($p < 0.05$). Importantly, the percentage of patients admitted who survive with good neurologic outcome varied significantly across MCAs from as low as 16% to as high as 37% ($P < 0.05$).

Discussion

In this retrospective analysis of CARES data from nearly 8,000 prospectively collected OHCAs in the state of Michigan, significant variations in both treatment and outcomes were identified. Bystander CPR and bystander AED application rates ranged from 32% to 53% and 3.5% to 11.5%, respectively. A four-fold variation in survival with good neurologic function (2.7–12.5%) was observed throughout the state.

Survival of OHCA is dependent on the performance of the system of care as a whole, which includes the actions of lay persons, medical dispatch, EMS personnel, and hospital physicians and staff (7). The EMS system in the state of Michigan consists of greater than 60 MCAs that provide EMS oversight to a defined geographic area. This unique structure provides an opportunity to define and compare individual systems of care within a single U.S. state.

Regional variations in bystander CPR and AED application rates have been previously described. In a recent analysis of CARES data from 132 U.S. counties, Girotra et al. found bystander CPR and bystander AED application rates ranging from approximately <5–65% and 0–7%, respectively (3). We observed similar but less extreme variations among MCAs in Michigan (bystander CPR rates: 32–53%; AED application rates: 3.5–11.5%). This provides evidence to support the hypothesis that bystander involvement in OHCA varies greatly on state level and thus an important target for intervention.

Girotra et al. also found marked variation in survival with good neurologic function (3). The mean survival with CPC 1 or 2 at the time of hospital discharge in their analysis was 7.8% and ranged from 0.8–20.1% across U.S. counties. In the present analysis, mean survival with CPC 1 or 2 at the time of hospital discharge was 6.7% and ranged from 2.7–12.5% throughout Michigan. Even after covariate adjustment, the previously observed differences between each MCA and all other MCAs combined remained statistically significant, and the AOR range was from 0.5 to 2.2. Similarly, nearly a decade ago, Nichol et al. described marked variation in survival to hospital discharge (3–16%) among sites participating in the ROC (2). We found strikingly similar variation in survival to hospital discharge (4.5–14.8%) across the MCAs in Michigan, which also remained statistically significant after adjustment for non-modifiable covariates (AOR 0.6–2.0).

An important additional outcome presented in our analysis is the proportion of patients admitted to the hospital who survived to discharge with good neurologic function (CPC 1 or 2). Overall, approximately 27% of all patients admitted to the hospital were discharged with a CPC 1 or 2. This ranged from approximately 16 to 37% across MCAs. Factors that may be responsible for this finding include MCA variations in bystander CPR and AED rates, EMS response times, which ranged from 5 minutes to 9.4 minutes, and variations in hospital care including the application of HTTM (29–68%). However, it is important to note that we do not have data on why HTTM was not utilized (i.e., cases where it was not indicated such as individuals who were conscious following resuscitation). Additionally, reporting of EMS response times, defined as time of 9–1-1 call to EMS arrival on scene, was not mandatory in CARES during the study period. Approximately 64% of all cases had complete data for EMS response time, with one MCA only providing data for 9% of cases.

Overall, these findings support our hypothesis that clinically significant variations in OHCA treatment and outcomes exist between predefined systems of

TABLE 1. Medical Control Authority patient demographics and cardiac arrest characteristics

Characteristics	Overall (n = 7788)	MCA A (n = 1806)	MCA B (n = 1486)	MCA C (n = 1367)	MCA D (n = 898)	MCA E (n = 633)	MCA F (n = 513)	MCA G (n = 324)	MCA H (n = 254)	MCA I (n = 264)	MCA J (n = 137)	MCA K (n = 106)	
Age													$p < 0.05$
Mean (SD), yr	62.9 (19.5)	60.4 (20.4)	65.6 (19.2)	64.4 (19.1)	61.4 (19.8)	63.0 (18.4)	64.8 (19.4)	60.3 (19.8)	63.8 (17.3)	61.3 (19.7)	58.9 (22.2)	64.7 (19.3)	
Missing, %	<1	<1	0	0	0	0	0	0	0	0	0	<1	
Gender, %													$p < 0.05$
Male	59.5	54.8	57.5	59.5	61.5	62.6	66.3	62.9	62.6	62.9	59.1	68.9	
Missing, %	0	0	0	0	0	0	0	0	0	0	0	0	
Race, %													$p < 0.05$
White	45.7	7.3	55.1	44.9	73.4	58.5	35.3	62.9	65.4	84.8	67.9	89.6	
Black	23.2	58.4	15.9	11.6	16.3	12.9	3.9	14.2	4.0	5.7	27.7	<1	
Hispanic/Latino	1	<1	<1	<1	3.7	<1	<1	<1	<1	1.5	2.9	7.5	
Other	<1	1.2	<1	<1	<1	1.4	<1	<1	1.2	<1	0	1.9	
Unknown	29.3	32.7	27.9	42.3	6.0	26.5	60.4	21.6	29.1	7.2	1.5	0	
Location of Cardiac Arrest, %													$p < 0.05$
Home/Residence	71.5	77.4	67.4	68.3	70.9	69.5	68.6	76.2	71.3	74.2	75.2	73.6	
Nursing home/health care facility	17.9	14.7	22.6	22.0	16.9	17.1	19.9	12.7	14.9	10.9	8.8	10.4	
Public	9.5	7.6	8.9	8.0	11.1	12.3	8.8	9.3	12.6	13.6	15.3	14.2	
Other	1.1	<1	1.1	1.7	1.1	1.1	2.7	1.8	1.2	1.1	<1	1.9	
Missing, %	0	0	0	0	0	0	0	0	0	0	0	0	
Arrest Witnessed, %													$p < 0.05$
Yes	44.7	35.2	45.6	43.5	45.3	48.9	55.9	54.3	53.1	58.7	43.1	44.3	
Missing, %	<1	0	0	0	<1	0	0	0	0	0	0	0	
First Documented Rhythm, %													$p < 0.05$
VF, VT, Unknown Shockable	17.4	11.9	17.6	17.1	22.4	20.7	20.3	15.4	18.5	24.2	14.6	23.6	
Asystole	46.4	31.2	53.6	59.5	45.2	51.2	45.2	26.9	57.5	51.9	43.1	46.2	
Idioventricular/PEA	17.4	8.2	22.3	20.0	15.7	21.9	27.3	8.9	20.5	17.4	23.4	22.6	
Unknown Unshockable	18.8	48.6	6.5	3.4	16.7	6.2	7.2	48.8	3.5	6.4	18.9	7.6	
Missing, %	0	0	0	0	0	0	0	0	0	0	0	0	

Note: MCA = *Medical Control Authority*; SD = *Standard Deviation*; VF = *ventricular fibrillation*; VT = *ventricular tachycardia*; PEA = *Pulseless Electrical Activity*.

TABLE 2. Medical Control Authority system of care characteristics

Characteristics	Overall (n = 7788)	MCA A (n = 1806)	MCA B (n = 1486)	MCA C (n = 1367)	MCA D (n = 898)	MCA E (n = 633)	MCA F (n = 513)	MCA G (n = 324)	MCA H (n = 254)	MCA I (n = 264)	MCA J (n = 137)	MCA K (n = 106)	
Bystander CPR, %	40.8	32.1	42.5	37.9	46.9	51.7	39.7	49.2	44.5	47.9	32.7	52.7	$p < 0.05$
Missing, %	<1	<1	0	0	0	0	0	0	0	0	0	0	
Overall AED applied, %	33.2	9.7	35.9	16.7	64.3	47.7	28.8	70.2	53.7	46.6	57.5	52.7	$p < 0.05$
Missing, %	<1	0	0	<1	2.5	0	0	0	0	0	0	0	
Who Applied AED, %													$p < 0.05$
Bystander	7.3	5.2	8.8	7.5	7.9	6.5	8.8	11.5	9.6	4.7	3.5	7.7	
First Responder	25.3	4.6	27.1	8.6	56	40.5	19.9	58.7	43.2	41.1	51.3	50.5	
Other, %	<1	0	0	<1	<1	<1	0	0	<1	<1	2.7	0	
911 Call to Ambulance on Scene (minutes)	7.3	5.1	6.3	6.4	8.0	8.7	6.2	9.4	8.3	8.0	5.9	8.6	$p < 0.05$
% Reporting	63.5	8.8	68.2	71.0	97.2	96.1	55.8	62.7	99.2	100	100	78.3	
Destination Hospitals, n	86	12	18	14	5	8	9	2	8	2	2	6	
Missing, %	<1	<1	0	0	0	0	0	0	0	0	0	0	

Note: MCA = *Medical Control Authority*; CPR = *cardiopulmonary resuscitation*; AED = *automated external defibrillator*.

TABLE 3. Primary and secondary outcome measures across Medical Control Authorities

Outcome Measures	Overall (n = 7788)	MCA A (n = 1806)	MCA B (n = 1486)	MCA C (n = 1367)	MCA D (n = 898)	MCA E (n = 633)	MCA F (n = 513)	MCA G (n = 324)	MCA H (n = 254)	MCA I (n = 264)	MCA J (n = 137)	MCA K (n = 106)
Sustained ROSC, %	27.4	11.5	29.0	26.8	34.9	34.3	40.0	30.6	39.4	40.2	41.6	26.4
OR [95%CI]	—	0.2 [0.2–0.3]*	1.1 [0.9–1.2]	1.0 [0.9–1.1]	1.5 [1.3–1.7]*	1.4 [1.2–1.7]*	1.8 [1.5–2.2]*	1.2 [0.9–1.5]	1.8 [1.4–2.3]*	1.8 [1.4–2.3]*	1.9 [1.4–2.7]*	0.9 [0.6–1.5]
AOR [95%CI]	—	0.3 [0.2–0.4]*	1.0 [0.9–1.2]	1.0 [0.9–1.1]	1.2 [1.1–1.5]*	1.3 [1.1–1.5]*	1.9 [1.5–2.3]*	1.0 [0.8–1.3]	1.5 [1.2–2.0]*	1.3 [1.0–1.7]*	1.9 [1.3–2.7]*	0.7 [0.5–1.2]
Missing, %	<1	0	0	0	<1	0	0	0	0	0	0	0
Survival to Hospital Admission, %	25.2	17.4	25.9	23.5	28.4	28.1	36.8	25.0	28.0	35.2	31.4	28.3
OR [95%CI]	—	0.5 [0.4–0.6]*	1.0 [0.9–1.2]	0.9 [0.8–1.0]	1.2 [1.0–1.4]*	1.2 [0.9–1.4]	1.8 [1.5–2.2]*	1.0 [0.8–1.3]	1.1 [0.9–1.5]	1.6 [1.3–2.1]*	1.4 [0.9–2.0]	1.2 [0.8–1.8]
AOR [95%CI]	—	0.7 [0.6–0.8]*	1.0 [0.9–1.2]	0.9 [0.8-–1.1]	1.0 [0.9–1.2]	1.1 [0.9–1.3]	1.8 [1.5–2.2]*	0.9 [0.7–1.1]	1.0 [0.8–1.4]	1.2 [0.9–1.6]	1.3 [0.9–2.0]	1.0 [0.6–1.6]
Missing, %	0	0	0	0	0	0	0	0	0	0	0	0
Survival to Hospital Discharge, %	8.4	4.5	7.9	6.8	12.0	9.5	14.8	11.7	10.2	11.4	11.7	8.5
OR [95%CI]	—	0.4 [0.3–0.6]*	0.9 [0.7–1.1]	0.8 [0.6–0.9]*	1.6 [1.3–2.0]*	1.1 [0.9–1.5]	2.0 [1.5–2.6]*	1.5 [1.0–2.1]*	1.2 [0.8–1.9]	1.4 [0.9–2.1]	1.4 [0.9–2.5]	1.0 [0.5–2.0]
AOR [95%CI]	—	0.6 [0.5–0.8]*	0.9 [0.7–1.1]	0.8 [0.6–0.9]*	1.3 [1.0–1.6]*	1.0 [0.7–1.3]	2.0 [1.5–2.7]*	1.4 [0.9–2.0]	1.1 [0.7–1.8]	0.9 [0.6–1.5]	1.5 [0.8–2.7]	0.9 [0.4–1.8]
Missing, %	0	0	0	0	0	0	0	0	0	0	0	0
Survival with CPC 1 or 2, %	6.7	2.7	6.5	5.0	10.1	8.2	12.5	9.9	7.1	9.5	11.6	6.6
OR [95%CI]	—	0.3 [0.2–0.4]*	1.0 [0.8–1.2]	0.7 [0.5–0.9]*	1.7 [1.3–2.2]*	1.3 [0.9–1.7]	2.1 [1.6–2.8]*	1.6 [1.1–2.3]*	1.1 [0.7–1.7]	1.5 [0.9–2.3]	1.9 [1.1–3.2]*	1.0 [0.5–2.1]
AOR [95%CI]	—	0.5 [0.4–0.7]*	0.9 [0.7–1.2]	0.7 [0.5–0.9]*	1.3 [0.9–1.6]	1.1 [0.8–1.5]	2.2 [1.6–3.1]*	1.5 [0.9–2.2]	0.9 [0.5–1.5]	0.9 [0.6–1.4]	1.9 [1.1–3.5]*	0.8 [0.3–1.7]
Missing, %	0	0	0	0	0	0	0	0	0	0	0	0

Note: Results are from eleven bivariate and multiple logistic regression analyses comparing the odds of each outcome for an individual MCA compared to all other MCAs combined. MCA = *Medical Control Authority*; ROSC = *return of spontaneous circulation*; OR = *odds ratio from bivariate logistic regression analysis*; AOR = *adjusted odds ratios from multiple logistic regression analysis*; CPC = *cerebral performance category*.
*$p < 0.05$.

TABLE 4. Hypothermic targeted temperature management application and neurologic outcome

	Overall (n = 1960)	MCA A (n = 314)	MCA B (n = 385)	MCA C (n = 321)	MCA D (n = 255)	MCA E (n = 178)	MCA F (n = 189)	MCA G (n = 81)	MCA H (n = 71)	MCA I (n = 95)	MCA J (n = 43)	MCA K (n = 30)
HTTM Application, %	45.0	38.9	45.3	29.3	68.2	41.6	39.7	49.4	49.3	53.8	62.8	60.0
Missing, %	<1	<1	<1	0	<1	<1	<1	0	0	0	0	<1
% Patients with shockable rhythm receiving HTTM	24.1	10.2	24.8	14.9	11.9	30.5	23.1	40.0	21.3	34.4	35.0	28.0
Missing, %	<1	0	<1	0	0	<1	<1	0	0	0	0	<1
In-hospital Mortality, %	66.6	73.9	69.6	71.0	57.6	66.3	59.8	53.1	63.4	67.7	62.8	70.0
OR [95%CI]	—	1.5 [1.1–2.0]*	1.2 [0.9–1.5]	1.3 [0.9–1.7]	0.6 [0.5–0.8]*	1.0 [0.7–1.4]	0.7 [0.5–0.9]*	0.5 [0.3–0.9]*	0.9 [0.5–1.4]	1.1 [0.7–1.6]	0.8 [0.4–1.6]	1.2 [0.5–2.6]
AOR [95%CI]	—	1.1 [0.8–1.4]	1.2 [0.9–1.6]	1.3 [0.9–1.7]	0.8 [0.6–1.1]	1.1 [0.8–1.6]	0.7 [0.5–0.9]*	0.6 [0.4–0.9]*	0.8 [0.5–1.4]	1.5 [0.9–2.5]	0.8 [0.4–1.5]	1.1 [0.5–2.6]
Missing, %	0	0	0	0	0	0	0	0	0	0	0	0
% Admitted who Survive with CPC 1 or 2	26.5	15.6	24.9	21.5	35.7	29.2	33.9	29.2	25.4	26.9	37.2	23.3
Missing, %	0	0	0	0	0	0	0	0	0	0	0	0

Note: Results are from eleven bivariate and multiple logistic regression analyses comparing the odds of each outcome for an individual MCA compared to all other MCAs combined. MCA = *Medical Control Authority*; HTTM = *hypothermic targeted temperature management*; OR = *odds ratio from bivariate logistic regression analysis*; AOR = *adjusted odds ratios from multiple logistic regression analysis*; CPC = *cerebral performance category*.

*$p < 0.05$.

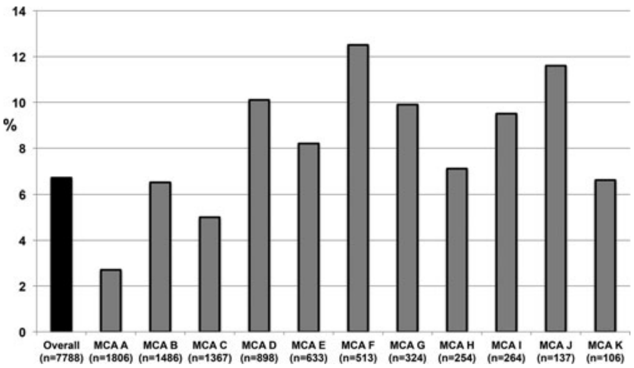

FIGURE 2. Variation in unadjusted survival with good neurologic outcome (CPC 1 or 2). Note: The black bar represents the unadjusted prevalence of survival with CPC 1 or 2 at the time of hospital discharge for the overall population and the grey bars represent the individual 11 MCAs included in the analysis. CPC = *cerebral performance category*; MCA = *Medical Control Authority*.

care within a single state. The presence of such wide variability after controlling for non-modifiable factors suggest that optimizing modifiable factors at the individual system-of-care level has the potential to improve outcomes. Previous studies have identified many modifiable factors that are independently associated or causally related to OHCA outcomes such as bystander CPR, time to initiation of CPR, dispatcher-assisted CPR, bystander AED application, time to initial defibrillation, early coronary angiography and PCI, and hypothermic targeted temperature management (16–21). Other modifiable factors that potentially impact outcomes but are more complex to implement and/or measure include EMS delivery of high-performance CPR (22), regional cardiac arrest centers as destination hospitals (23, 24), and reliable neurprognostication after ICU admission (25). While it would be ideal to optimize all modifiable parameters, a more practical approach will be to identify those most feasible and potentially impactful within an individual system of care based on available infrastructure and resources (26). Regardless of the chosen parameters, local leadership will be essential to achieve successful and sustained implementation.

STRENGTHS AND LIMITATIONS

A key strength of this analysis is that the MCA model provides a unique structure to define individual systems of care within a single U.S. state. In addition the CARES registry provides a standardized longitudinal data collection system that enables statewide and national benchmarking and supports continuous quality improvement initiatives.

There are also a number of important limitations of this analysis. This was a retrospective study limited to data available in the CARES registry from a single U.S. state. Therefore, the results may not be generalizable to other U.S. states. During the study period, CARES covered approximately 5.5 of the 9.9 million population in Michigan. Not all EMS agencies within an MCA were participating in CARES during the study period. Higher functioning EMS agencies may be more likely to participate in CARES, which may impact MCA performance in our study.

Next, not all Utstein variables were included in the risk factor adjustment. We specifically designed the risk adjustment to exclude bystander CPR and bystander AED application because they are modifiable parameters within the system of care. Ambulance response time was also not included due to the lack of consistent reporting. For example, the largest contributing MCA only reported response time data for 9% of cases. Our results do not account for patient level factors such as pre-existing comorbidities, which may vary across MCAs and impact our results. Furthermore, there are potentially other unadjusted factors that may be contributing to the variability in treatment and outcomes we observed.

Although MCAs are geographically definable, they have limited authority under Michigan law. EMS agencies may operate and participate in multiple MCAs and are under the supervision of whichever MCA the unit is in geographically at the time of service. A single MCA may supervise 30 or more agencies and communities. In highly populous areas, hospitals can be members of more than one MCA. Also, the MCA itself does not deliver care.

CONCLUSION

Clinically and statistically significant variations in system of care performance and outcomes for OHCA exist in the state of Michigan that are similar to those previously described across North America nearly a decade ago. This degree of variability when controlling for non-modifiable factors highlights the opportunity to optimize modifiable factors within local systems to improve OHCA outcomes.

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