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Clinical paper

Impact of post-arrest care variation on hospital performance after out-of-hospital cardiac arrest



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Abstract

Background: Large variation exists for out-of-hospital-cardiac-arrest (OHCA) prehospital care, but less is known about variations in post-arrest care. We sought to evaluate variation in post-arrest care in Texas as well as factors associated with higher performing hospitals.

Methods: We analyzed data in Texas Cardiac Arrest Registry to Enhance Survival (TX-CARES), including all adult, non-traumatic OHCA from 1/1/2014 through 12/31/2020 that survived to hospital admission. We first evaluated variability in provisions of post-arrest care and outcomes. We then stratified hospitals into quartiles based on their rate of survival and evaluated the association between improving quartiles and care. Lastly, we evaluated for outliers in post-arrest care and outcomes using a mixed-effect regression model.

Results: We analyzed 7,842 OHCA admitted to 146 hospitals. We identified large variations in post-arrest care, including targeted temperature management (TTM) (IQR 7.0–51.1%), left heart catheterization (LHC) (IQ 0–25%), and percutaneous coronary intervention (PCI) (IQR 0–10.3%). Higher performing hospital quartiles were associated with higher rates of TTM (aOR 1.42, 95% CI 1.36–1.49), LHC (aOR 2.07, 95% CI 1.92–2.23), and PCI (aOR 2.02, 95% CI 1.81–2.25); but lower rates of bystander CPR (aOR 0.90, 95% CI 0.87–0.94). We identified numerous performance outlier hospitals; 39 for TTM, 34 for PCI, 9 for survival to discharge, and 24 for survival with good neurologic function.

Conclusions: Post-arrest care varied widely across Texas hospitals. Hospitals with higher rates of survival to discharge had increased rates of TTM, LHC, and PCI but not bystander CPR.

Keywords: Cardiac arrest, Out-of-Hospital Cardiac Arrest, Post-arrest care, TTM, PCI

Introduction

Out-of-hospital-cardiac arrest (OHCA) is a leading cause of death in the United States, with over 350,000 cases per year.¹ As overall survival remains low at 10.6%,² it is crucial to identify opportunities for improving care as outlined by both the National Academy of Sciences and the American Heart Association.^{3,4}

While prehospital OHCA care has improved over time,⁵ OHCA care varies widely between regions in the US, including Texas.^{6,7} Research implicates several factors as contributors to variations in

outcomes including patient characteristics,⁸ socioeconomic status of patients,⁹ arrest characteristics,¹⁰ bystander response,¹¹ amongst others.¹² The EMS agency¹³ and neighbourhood¹⁴ that the arrest occurs in are both also associated with variation in OHCA outcomes. Since variation in care can lead to outcome disparities, measuring the impact of these variations in care is important for identifying targets for quality improvement interventions,⁴ but most of OHCA care variation research focuses on prehospital care.

Hospital based, post-cardiac arrest care is another important link in the chain of survival.¹⁵ While still actively being researched, exist-

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ing studies indicate that early initiation of targeted temperature management (TTM)^{16–18} and percutaneous coronary intervention (PCI),^{19–21} are linked to improved survival, highlighting the importance of these post-arrest interventions. While literature evaluating variation in post-arrest care is sparser than that of prehospital care, recent research identified that variations in post-arrest care may also exist.²²

Given the limited research regarding variations in post-arrest care, we utilized the Cardiac Arrest Registry to Enhance Survival (CARES) registry to evaluate for variations in post-arrest care and outcomes after OHCA in Texas. We additionally evaluated the association between higher performing hospitals and characteristics of cardiac arrests and care at these hospitals.

Methods

Data source

We analyzed data from the CARES, collected in collaboration with the state affiliate, TX-CARES. CARES is a prospective, national OHCA registry coordinated by the Centers for Disease Control and the Department of Emergency Medicine at Emory University School of Medicine. CARES was created to provide local and state entities the data necessary to evaluate and improve OHCA care and outcomes. CARES includes all non-traumatic OHCA events if resuscitation was attempted and/or defibrillation was provided (by a lay person, family member, medical provider, or 911 responder). Details and methodology behind CARES has been previously described in detail.^{23–24} The University of Texas Health Science Center at Houston IRB approved the study, which the TX-CARES Data Sharing Committee approved as well.

Study population

We included data from January 1st 2014 to December 31st, 2020 for cardiac arrests reported by TX-CARES participating agencies. At the time of this analysis, 45 emergency medicine services (EMS) agencies and 146 hospitals, providing care to 10,333,529 people, were submitting data to TX-CARES. 2,119 census tracts were represented with a total population of 11,621,769 people, representing 40.1% of the Texas population. We included all non-traumatic, OHCA cases where resuscitation was attempted and the patient survived to hospital admission. We excluded patients under the age of 18 years, cardiac arrests that occurred in a healthcare facility, and cardiac arrests that were witnessed by 911 responders.

Study variables and outcomes

Patient characteristics included age, gender, and race. Cardiac arrest characteristics included witnessed arrest and initial shockable rhythm. Prehospital care characteristics included bystander CPR and bystander AED use. Post-arrest, hospital care were defined as provision of TTM (hypothermia/TTM initiated or continued in the hospital), left heart catheterization (LHC - emergency coronary angiography was performed), and PCI (if a cardiac stent was placed during this angiography). Patient outcomes were defined as survival to hospital discharge and survival with good neurological outcome, defined as a Cerebral Performance Category (CPC) of 1 or 2.

Statistical analysis

We first defined mean patient characteristics, arrest characteristics, prehospital care, and hospital care for each hospital. We then com-

pared hospital median and interquartile range for patient characteristics, arrest characteristics, prehospital care, and post-arrest care. Individual hospital cardiac arrest volumes were not reported in order to protect the anonymity of the hospitals.

We then stratified hospitals into quartiles based on patient survival to discharge rates. We then evaluated the association of decreasing quartiles (fourth to first) with cardiac arrest characteristics and care using logistic regression. We utilized univariable logistic regression for patient and arrest characteristics. For prehospital care analyses, we utilized a multivariable logistic regression, adjusting for age, gender, race, bystander witnessed, and initial shockable rhythm. For hospital care and outcome analyses, we used a multivariable logistic regression adjusted for age, gender, race, bystander witnessed, initial shockable rhythm witnessed cardiac arrest, bystander CPR, bystander AED, and sustained ROSC.

We also stratified hospitals into quartiles based on patient survival with good neurologic outcome (CPC score of 1 or 2) rates. We applied the same statistical analyses as above, but we evaluated the association between decreasing survival with good neurologic outcomes quartiles and cardiac arrest and care characteristics.

A mixed-effects regression model (Stata command `xtmelogit`) similar to our prior prehospital variation analysis⁷ was then created for each outcome of interest: TTM, PCI, LHC, survival to discharge, and survival with good CPC.⁷ We modeled outcome and hospital as random intercepts and adjusted each analysis for age, gender, race, bystander witnessed, initial shockable rhythm witnessed cardiac arrest, bystander CPR, and bystander AED use. As LHC and PCI are supplemental data elements, we excluded 23 hospitals treating 91 cardiac arrests from the analysis of LHC and PCI that had no reported LHC or PCI during the study period.

We utilized a caterpillar plot to display the adjusted outcomes for each hospital. Performance outliers were defined as hospitals with adjusted outcome rates and 95% confidence interval falling entirely above or below the overall adjusted mean.

Model fit was evaluated using goodness-of-fit test (stata command `estat gof`), and all models were found to have good fit. All statistical analyses were performed on Stata 16.1 (Statacorp, College Station, TX).

Results

The incidences of cardiac arrest per 100,000 people by year were: 2014–69.4, 2015–75.8, 2016–73.0, 2017–75.0, 2018–78.7, 2019–81.2, 2020–89.0. The number of cardiac arrests that met inclusion criteria were 7,842. The median age of participants was 60 (56–63) years and the majority of patients were male. The percentage of white patients in a quartile varied from 26.7% to 70.7%. Rates of bystander CPR ranged from 33.3% to 57.1% and rates of public bystander AED use ranged from 0% to 18.8%. The median use of TTM was 28.3% (IQR 7.0–51.1%) and the median use of PCI was 0% (IQR 0–10.3%). A median of 33.3% (IQR 24.2–46.6%) of patients survived to hospital discharge and a median of 20.0% (IQR 9.8–37.0%) survived with good CPC (Table 1).

Comparison of hospital survival performance quartiles

Stratified into survival rate quartiles, the best quartiles had a survival rate that was almost double that of the worst quartile (47.2% v 24.2%, $p < 0.05$). Better survival quartiles were associated with more white patients (aOR 1.41, 95% CI 1.35–1.47), higher witnessed

Table 1 – Mean and interquartile ranges of cardiac arrest characteristics, care, and outcomes based on mean characteristics of hospitals in Texas. (N=7842)

	25th percentile	Median	75th percentile
Age	57.0	60.4	63.0
Female gender	32.4%	38.5%	47.8%
White race	26.7%	26.7%	70.7%
Bystander Witnessed	55.4%	64.2%	71.9%
Bystander CPR	33.3%	46.2%	57.1%
Bystander AED applied*	0.0%	9.7%	18.8%
TTM	7.0%	28.3%	51.1%
LHC	0.0%	4.7%	25%
PCI	0.0%	0.0%	10.3%
Survival to Hospital Discharge	24.2%	33.3%	46.6%
Survival with good CPC	9.8%	20.0%	37.0%

* CARES only includes arrests that occurred in a public location when calculating bystander AED.

arrests (aOR 1.12, 95% CI 1.07–1.16), and initial shockable rhythm (aOR 1.13, 95% CI 1.08–1.18). Interestingly, improving survival quartiles were inversely correlated with rate of bystander CPR (aOR 0.90, 95% CI 0.87–0.94). Better survival quartiles were also associated with higher rates of TTM (aOR 1.42, 95% CI 1.36–1.49), coronary angiography (aOR 2.07, 95% CI 1.92–2.23), and PCI (aOR 2.02, 95% CI 1.81–2.25). There was no association between hospital quartile and gender or bystander AED application (Table 2).

Stratified into survival with good neurologic outcome quartiles, the survival with good neurologic outcome in the top quartile was quadruple that of the worst quartile (38.9% v 9.4%, $p < 0.05$). Better survival with good neurologic outcome quartiles were associated with more white patients (aOR 1.56, 95% CI 1.50–1.63), higher witnessed arrests (aOR 1.08, 95% CI 1.04–1.13), and higher initial shockable rhythm (aOR 1.14, 95% CI 1.09–1.19). As with the survival stratification analysis, improving survival with good neurologic outcome quar-

tiles were inversely correlated with rate of bystander CPR (aOR 0.84, 95% CI 0.80–0.87). Better survival with good neurologic outcome quartiles were also associated with higher rates of TTM (aOR 2.53, 95% CI 2.22–2.89), coronary angiography (aOR 2.30, 95% CI 2.12–2.49), and PCI (aOR 2.12, 95% CI 1.88–2.38). There was no association between hospital quartile and gender, initial shockable rhythm, or bystander AED application (Table 3).

Risk-adjusted variation in post-arrest care and outcomes

The median reliability-adjusted and risk-standardized rate of TTM was 28.1%, rate of PCI was 0.6%, rate of survival to discharge was 38.6%, and rate of survival with good CPC was 35.5%. Among hospitals, 39 were performance outliers for TTM and 34 were performance outliers for PCI (Fig. 1). Nine hospitals were performance outliers for survival to discharge and 24 were performance outliers for survival with good CPC (Fig. 2).

Discussion

In our study of Texas hospital care and outcomes variation for OHCA, we found significant inter-hospital variation in post-arrest care and outcomes after OHCA. The largest absolute variation was seen in rates of TTM (IQR 7–51.1%), though significant differences were also seen in rates of LHC and PCI (Table 2). When reliability-adjusted and risk-standardized, several hospitals were performance outliers for use of TTM, PCI, survival to hospital discharge, and survival with good CPC, representing opportunities for improving post-arrest care and outcomes. Lastly, we identified an association between improving hospital outcome quartile and rates of post-arrest care interventions for both survival and survival with good neurologic outcome, but we found an inverse relationship between improving hospital performance quartiles and bystander CPR.

Post-arrest interventions such as TTM^{16–18} and PCI^{19–21} led to improved patient outcomes after OHCA and are currently recommended in the national guidelines. However despite their benefits, many hospitals perform these important post-arrest interventions less often,^{25–26} leaving many OHCA victims without access to a crit-

Table 2 – Patient characteristics and care for out-of-hospital cardiac arrest victims stratified by hospital survival to discharge quartiles.

	Q4	Q3	Q2	Q1	Adjusted odds (95% CI)
Survival rate	474/1942 (24.4%)	558/1,751 (31.9%)	776/2,115 (36.7%)	959/2,034 (47.2%)	1.31 (1.3–1.4) ¹
Age ²	61 (50–71)	62 (52–73)	60 (50–70)	59 (47–69)	–
Female	737 (37.8%)	706 (40.3%)	778 (36.8%)	733 (36.0%)	0.97 (0.92–1.003) ³
White	626 (32.1%)	649 (37.0%)	859 (40.6%)	1,184 (58.1%)	1.41 (1.35–1.47) ³
Bystander Witnessed Arrest	1,159 (59.5%)	1,074 (61.2%)	1,336 (63.1%)	1,376 (67.6%)	1.12 (1.07–1.16) ³
Initial Shockable Rhythm	835 (29.8%)	559 (31.9%)	779 (36.8%)	761 (37.4%)	1.13 (1.08–1.18) ³
Bystander CPR	30 (42.9%)	32 (53.0%)	37 (46.5%)	37 (41.2%)	0.90 (0.87–0.94) ⁵
Bystander AED ⁴	44/404 (9.8%)	55/402 (13.7%)	78/556 (14.0%)	75/553 (13.6%)	1.02 (0.90–1.16) ⁵
TTM	489 (25.1%)	394 (22.5%)	787 (37.2%)	1,001 (49.1%)	1.42 (1.36–1.49) ¹
LHC	59 (3.0%)	19 (1.1%)	132 (6.2%)	283 (13.9%)	2.07 (1.92–2.23) ¹
PCI	59 (3.0%)	19 (1.1%)	132 (6.2%)	283 (13.9%)	2.02 (1.81–2.25) ¹

¹ Compared using multivariable logistic regression, adjusting for age, gender, race, witnessed arrest, shockable rhythm, bystander CPR, and bystander AED.

² Compared using Kruskal-Wallis, $p > 0.01$.

³ Compared using univariable logistic regression.

⁴ CARES only includes arrests that occurred in a public location when calculating bystander AED.

⁵ Compared using multivariable logistic regression, adjusting for age, gender, race, witnessed arrest and shockable rhythm.

Table 3 – Patient characteristics and care for out-of-hospital cardiac arrest victims stratified by hospital survival with good neurologic outcomes quartiles.

	Q4	Q3	Q2	Q1	Adjusted odds (95% CI)
Survival with good CPC rate	170/1,808 (9.4%)	310/2004 (15.5%)	535/2,060 (25.9%)	771/1,984 (38.9%)	1.77 (1.67–1.89)
Age ²	61 (52–72)	61 (50–71.5)	60 (50–69)	60 (47.5–70)	–
Female	717 (39.7%)	761 (38.0%)	781 (37.9%)	695 (35.0%)	0.94 (0.90–0.98)
White	527 (29.2%)	612 (30.5%)	1,046 (50.8%)	1,133 (57.1%)	1.56 (1.50–1.63)
Bystander Witnessed Arrest	1,104 (61.1%)	1,214 (60.6%)	1,311 (63.6%)	1,316 (66.3%)	1.08 (1.04–1.13)
Initial Shockable Rhythm	557 (30.8%)	604 (30.1%)	762 (37.0%)	757 (38.2%)	1.14 (1.09–1.19)
Bystander CPR	940 (52.0%)	887 (44.3%)	905 (44.0%)	857 (43.2%)	0.84 (0.80–0.87)
Bystander AED ⁴	26/394 (6.6%)	71/472 (15.0%)	74/491 (15.1%)	81/602 (13.5%)	1.12 (0.98–1.27)
TTM	348 (19.3%)	503 (25.1%)	726 (35.2%)	1,094 (55.1%)	2.53 (2.22–2.89)
LHC	39 (2.2%)	140 (7.0%)	439 (21.3%)	549 (27.7%)	2.30 (2.12–2.49)
PCI	2 (0.1%)	63 (3.1%)	193 (9.4%)	235 (11.8%)	2.12 (1.88–2.38)

¹Compared using multivariable logistic regression, adjusting for age, gender, race, witnessed arrest, shockable rhythm, bystander CPR, and bystander AED.

³Compared using univariable logistic regression.

⁵Compared using multivariable logistic regression, adjusting for age, gender, race, witnessed arrest and shockable rhythm.

² Compared using Kruskal-Wallis, $p > 0.01$.

⁴ CARES only includes arrests that occurred in a public location when calculating bystander AED.

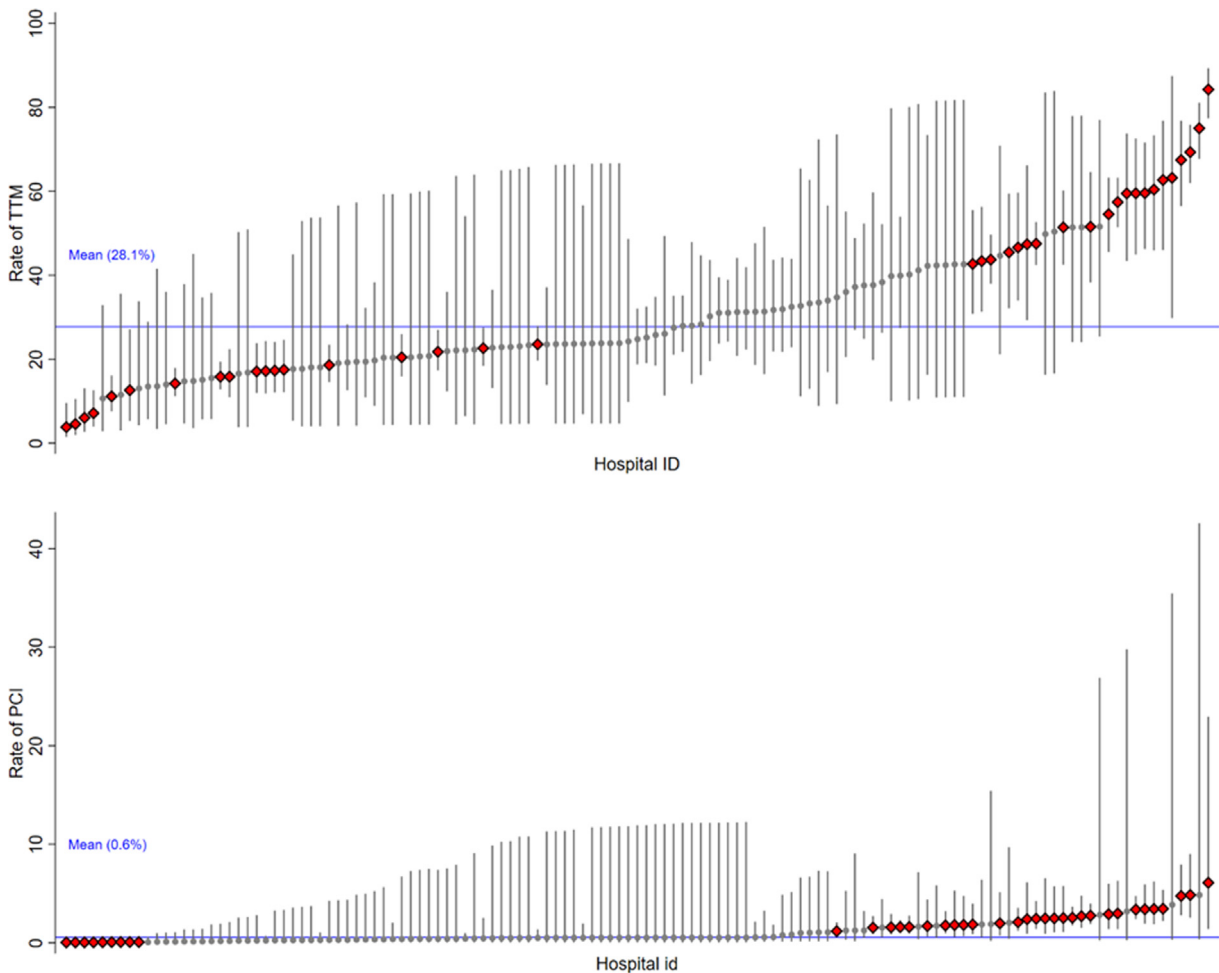


Fig. 1 – Variations in rate of TTM (top) and PCI (bottom) for each hospital; adjusted for age, gender, race, witnessed cardiac arrest, bystander CPR, and initial shockable rhythm. Red diamonds indicate communities above and below the mean, defined as hospitals with adjusted TTM or PCI rate 95% confidence interval limits falling outside of the overall community mean.

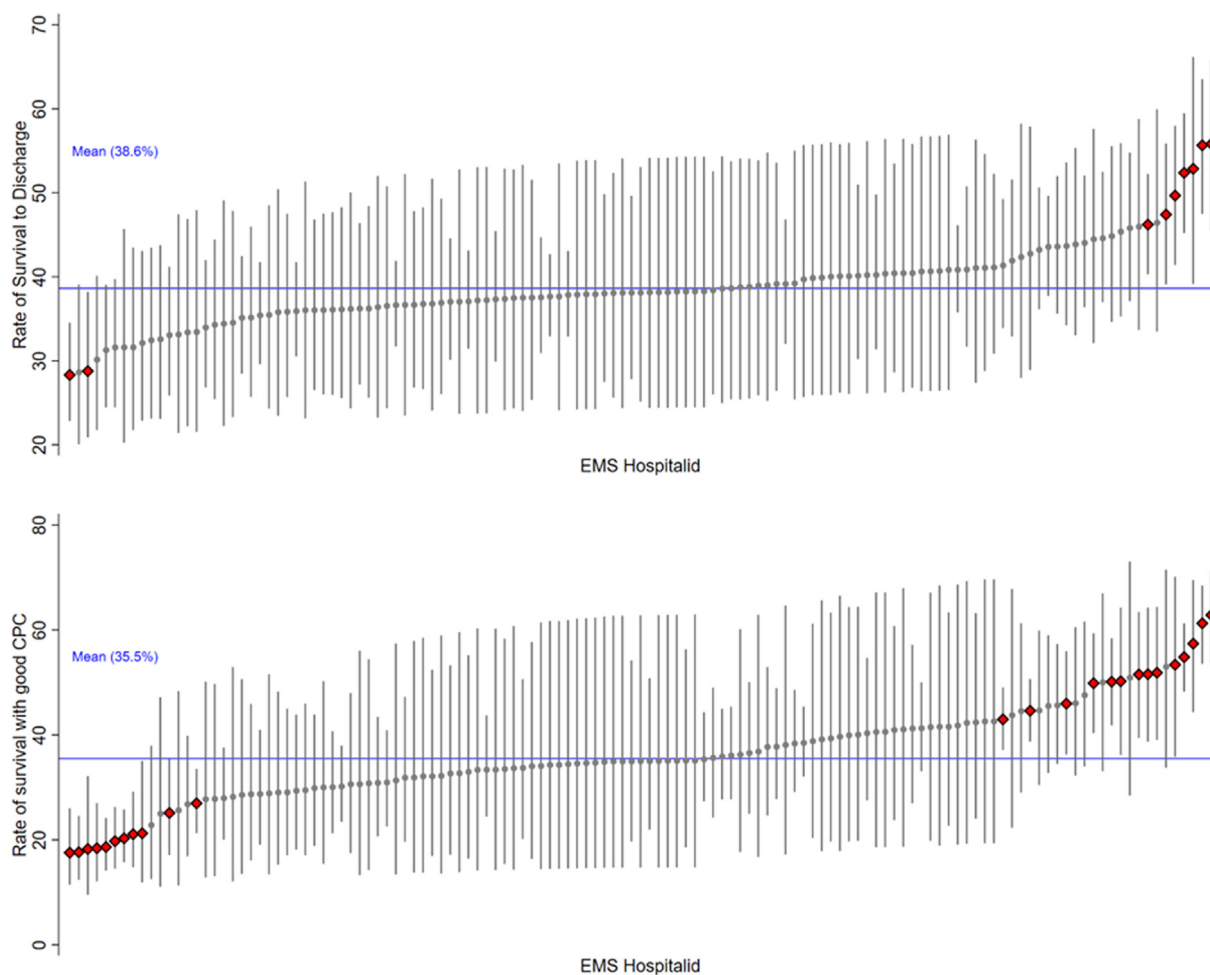


Fig. 2 – Variations in rates of survival (top) and survival with CPC score of 1 or 2 (bottom) for each hospital; adjusted for age, gender, race, witnessed cardiac arrest, bystander CPR, and initial shockable rhythm. Red diamonds indicate hospitals above and below the mean, defined as hospitals with adjusted outcome rate 95% confidence interval limits falling outside of the overall risk-adjusted mean.

ical link in the chain of survival. In Texas, we found variable use of TTM and PCI, with the lowest quartile of hospitals only performing TTM in 7% of patients and half of hospitals not reporting any PCI. Conversely, we identified 21 high performing hospitals for TTM and 26 high performing hospitals for PCI.

Due to the variations in hospital resources, the American Heart Association recommends regionalization of OHCA care.²⁷ In Arizona, statewide regionalization of OHCA care was found to be individually associated with increased survival and favorable neurological outcome.²⁸ In California, however, studies have found that few hospitals have the ability to provide a high level of OHCA care and high performing hospitals provided care for only 25% of the state's population.²⁹ While hospital resource limitations, such as the lack of a catheterization lab, might inhibit cardiac procedures such as PCI, the barriers to TTM should be less prohibitive. While recent studies have evaluated different approaches to temperature management (different temperatures, fever control rather than universal TTM),^{30,31} many studies have demonstrated the benefit of TTM.^{18,32} The most recent study of TTM2 calls in to question the broad use of TTM, finding similar survival rates between TTM and fever control (placebo) strategies. However, nearly half (46%) of

patients in the placebo group still required device cooling to maintain normothermia. Only the top quartile hospitals delivered TTM at a rate (51%) greater than the placebo group of TTM2, so nearly three quarter of hospitals in Texas deliver TTM at a rate below that of the placebo arm from TTM2. Therefore even in light of TTM2, it is likely that Texas cardiac arrest victims would benefit from interventions to increase TTM rates in Texas.

While some research finds an association between hospital volume cardiac arrest care quality, as higher volume facilities tend to provide more consistent post-arrest care and have better patient outcomes,^{22,33,34} Rea et al. failed to find this correlation.³⁵ There was only modest variation in cardiac arrest volume in our cohort with the highest performing quartile only caring for 5% more cardiac arrests than the lowest performing quartile. However, we stratified hospitals based on performance, rather than volume, in order to identify factors associated with higher performing hospitals. Interestingly, we found a negative correlation between bystander CPR and cardiac arrest outcome performance, while better hospital performance was strongly associated with post-arrest interventions: TTM, LHC, and PCI. While previous study indeed links post-arrest care to better survival, our bystander CPR findings are contrary to

prior research identifying a strong link between bystander CPR and survival.³⁶ As our analysis is focused on hospital performance rather than patient outcomes, it is difficult to interpret this result. It is possible that since we only include patients surviving to hospital admission, bystander CPR had a larger effect on survival to admission hospital than survival after admission. Additionally, the bystander CPR rate was similar between the quartiles with a minimally significant OR, so this result could be spurious and due to other reasons that are not adjusted for. Regardless, our findings highlight the importance of post-arrest care in the chain of survival.

Understanding variations in OHCA care is critical for implementing quality improvement initiatives aimed at delivering the best, most equitable care possible. While regionalization of care is an important aspect of ensuring access to resource intensive interventions, more easily implemented interventions, such as TTM, represent targets for improving cardiac arrest care at lower-resource hospitals. Future research should focus on identifying barriers to post-arrest care implementation. Additionally, states could implement similar risk adjusted models to help identify hospitals most in need of improvement interventions.

Limitations

While we included a large number of OHCA cases representing a significant portion of the population of Texas, most of the communities evaluated were in urban and suburban communities which may differ from those in rural settings. These populations were also early adopters of CARES, and they may be more invested in quality improvement and therefore more likely to provide superior care. Additionally, these quality improvement focused hospitals may be more motivated to provide post-arrest interventions, so our post-arrest intervention rates may overestimate post-arrest care rates in Texas as a whole. Evaluating an even larger portion of the state will likely show wider variations in care. Incidence of cardiac arrest in TX-CARES decreased by 25% from 2019 to 2020. We believe this may be related to the COVID-19 pandemic altering the approach of pre-hospital agencies to cardiac arrest.³⁷ It is unclear how this might impact our results, but the number of included patients that survived to hospital admission were similar between 2019 and 2020.

Hospital resources are not included in CARES, and evaluating possible confounders such as academic affiliation, availability of coronary angiography, and number of beds could not be analyzed. TTM standards vary in regards to target temperature, patient selection, time of initiation, and duration of treatment,³⁸ and these factors could not be evaluated. LHC and PCI are voluntarily reported data elements for CARES, and it is possible that better performing hospitals are more quality focused and have a better reporting rate. Hospitals that are motivated, able, and willing to report voluntary data may also dedicate more resources to cardiac arrest care and differ from hospitals not reporting voluntary elements consistently. Also, immortality bias might lead to hospitals with higher survival rates having a higher rate of patients surviving long enough to receive post-arrest interventions, exaggerating the association between post-arrest interventions and survival. However, one would expect immortality bias to have a larger effect on procedures occurring later such as PCI than those that occur earlier like TTM. While there was a greater association between survival performance and PCI (aOR 2.02) than with TTM (aOR 1.42), this was not the case for survival with good neurologic outcome performance (TTM aOR 2.53 and PCI aOR 2.12). Lastly, AED rates were quite low in our study, which could

have impacted survival. Only a quarter of patient met the CARES definition of bystander AED though, which limits our ability to compare results to other studies.

Conclusion

Rates of post-arrest interventions and patient outcomes varied widely across hospitals in Texas. OHCA hospital outcome performance was linked to post-arrest interventions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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