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The impact of hospital experience with out-of-hospital cardiac arrest patients on post cardiac arrest care[☆]

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ABSTRACT

Objective: Patient volume as a surrogate for institutional experience has been associated with quality of care indicators for a variety of illnesses. We evaluated the association between hospital experience with comatose out-of-hospital cardiac arrest (OHCA) patients and important care processes.

Methods: This was a population-based, retrospective cohort study using data from 37 hospitals in Southern Ontario from 2007 to 2013. We included adults with atraumatic OHCA who were comatose on emergency department arrival and survived at least 6 h. We excluded patients with a Do-Not-Resuscitate order or severe bleeding within 6 h of hospital arrival. Multi-level logistic regression models estimated the association between average annual hospital volume of OHCA patients and outcomes. The primary outcome was successful targeted temperature management (TTM) and secondary outcomes included TTM initiation, premature withdrawal of life-sustaining therapy, and survival with good neurologic function.

Results: Our analysis included 2723 patients. For every increase of 10 in the average annual volume of eligible patients, the adjusted odds increased by 30% for successful TTM (OR 1.29, 95% CI 1.03–1.62) and by 38% for initiating TTM (OR 1.38, 95% CI 1.11–1.72). No significant association between patient volume and other secondary outcomes was observed.

Conclusions: Patients arriving at hospitals with more experience treating comatose post cardiac arrest patients are more likely to have TTM initiated and to successfully reach target temperature. Our findings have implications for regional systems of care and knowledge translation efforts aiming to improve quality of care for this patient population.

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Introduction

Out-of-hospital cardiac arrest (OHCA) is an important public health concern, with an annual incidence rate of 95 per 100,000 and mortality of approximately 90% in North America.[1] The high in-hospital mortality of resuscitated patients[2,3] is attributable to post-cardiac arrest syndrome.[4] Brain injury accounts for the majority of deaths after cardiac arrest, but multi-organ dysfunction and post-resuscitative shock are common.[5]

There are several features of post-cardiac arrest care that have been emphasized in treatment guidelines.[6] Targeted temperature management (TTM) and the avoidance of premature withdrawal of life-sustaining therapy on the basis of neuroprognostication are recommended processes that could be feasibly implemented regardless of individual hospital facilities.[4,7] Yet, these best practices are not universally implemented for eligible patients.[8] Significant variability in survival between hospitals has been reported by several studies from various regions around the world.[9–12]

Regionalized systems of post-cardiac arrest care wherein patients are directly transported to specialized, high volume, cardiac arrest care centres have been implemented in the US and around the globe.[7,13–18] The volume–quality relationship has been studied extensively in other complex medical emergencies such as myocardial infarction,[19] stroke,[20] and trauma,[21] but there is a relative paucity of data to examine the question of whether diversion of post cardiac arrest patients to higher volume specialty centres is advisable. Our primary objective was to evaluate the relationship between hospital experience with post-cardiac arrest patients and the use of TTM. Our secondary objectives were to evaluate the relationship between hospital experience with post cardiac arrest patients and (1) the occurrence of premature withdrawal of life-sustaining therapy on the basis of neuroprognosis and (2) neurologically intact survival.

Methods

Design and setting

This was a population-based retrospective cohort study of consecutive out-of-hospital cardiac arrest cases conducted with data from 37 hospitals within the Toronto Regional RescuNet (http://www.emergencymedicine.utoronto.ca/research/ptmr/CS/ROC/rescunet.htm). The Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board approved the study.

Data sources

We used data from the Rescu Epistry which is a population-based database capturing consecutive out-of-hospital cardiac arrest events occurring within the Toronto Regional RescuNET. The Rescu Epistry database is a composite of two precursors; the Toronto Epistry-Cardiac Arrest database of the Resuscitation Outcomes Consortium and the Strategies for Post Arrest Care (SPARC) database, the methodologies of which have been described elsewhere.[22–25] Rescu Epistry captures all patients with cardiac arrests or trauma for which there was a 911 response occurring in the City of Toronto and 6 adjacent regions with a total population of 6.6 million.

Study population

Patients who were treated for OHCA and delivered to a participating hospital in a comatose state with sustained return of spontaneous circulation (ROSC) between September 1, 2007 and December 31, 2013 were considered for inclusion in the study. Patients were excluded if they had a Do-Not-Resuscitate (DNR) order identified in the prehospital setting, were less than 18 years old, or suffered a cardiac arrest with an obvious non-cardiac cause identified by paramedics or in-hospital staff. Additionally, patients were excluded if any of the following occurred within six hours of emergency department arrival: A DNR order, withdrawal of life sustaining therapy, intracranial bleeding, severe bleeding, or death.

Outcome measures

The primary outcome was successful TTM, defined as achieving a core body temperature of ≤34 °C within 6 h of hospital arrival. Secondary outcomes included having cooling initiated, the proportion of patients who had life-sustaining therapy withdrawn within 72 h of emergency department arrival on the basis of neuroprognostication among those patients at risk for premature withdrawal of life-sustaining therapy and survival to hospital discharge with good neurologic function (defined as having a Cerebral Performance Category (CPC) score of 1 or 2). Patients who died within 72 h of first emergency department arrival despite full and aggressive intensive care and those who had life-sustaining therapy withdrawn after meeting criteria for brain death were not considered "at risk" for the premature withdrawal outcome and were excluded from these calculations. For all patients who died in hospital, mode of death was categorized as one of the following: death despite full medical care (the subject was unstable with continued life support impossible), death after meeting brain death criteria,[26] death after withdrawal of life sustaining therapy on the basis of neuroprognostication, and death after withdrawal of life sustaining therapy for reasons other than neuroprognostication (e.g., family/patient wishes, pre-exiting DNR, poor pre-morbid function, pre-existing terminal status, etc.).

Those patients who were alive but had a missing CPC score were classified as "poor neurologic function" by convention (CPC score of 3 or 4).[27]

Statistical analyses

For the purposes of our descriptive analysis only, institutions were categorized by average annual volume of patients eligible for TTM as: low (less than 15 patients per year), moderate (between 15 and 25 patients per year), and high (greater than 25 patients per year). These categories were determined taking into consideration what would be considered a meaningful difference in volume based on consensus among the investigators, while maintaining a sufficient number of hospitals and patients in each category for analysis. Patients were stratified by hospital volume category based on the hospital at which treatment was first received.

Variables were compared across volume categories using χ^2 and *t*-tests as appropriate, adjusting for the clustered nature of the data within hospitals. A *p*-value <0.05 was considered significant.

Several multi-level logistic regression models were built to assess the relationship between each outcome and average annual hospital volume of eligible OHCA patients (Proc GLMMIX, SAS v 9.4, Cary, NC, 2013). Multivariate multi-level regression models were constructed for each of the outcomes of interest adjusting for covariates. Covariates at the patient level included sex, age, initial rhythm, bystander witnessed arrest, EMS witnessed arrest, location of arrest (public versus private), bystander resuscitation (any CPR or AED use), bystander CPR, bystander AED use, EMS response time interval, ROSC in the field, ROSC at emergency department arrival, and whether the patient was admitted to a hospital in the active phase of the SPARC TTM trial (NCT00683683).[25] SPARC TTM was a step-wedge randomized controlled study which involved active and passive knowledge translation interventions aimed at increasing the number of eligible patients who received TTM.

Hospital-level covariates included the average number of post cardiac arrest patients eligible for TTM per year, number of beds, teaching status (academic health science centre as designated by the Ontario Ministry of Health and Long Term Care), and whether or not the hospital was a percutaneous coronary intervention (PCI) centre. For cases involving hospital transfer, patients were assigned to the first hospital at which they were treated. A sensitivity analysis was conducted where patients were assigned to the final treating hospital. Bed number and teaching status were obtained from the Ontario Ministry of Health and Long Term Care, and PCI centres were identified from a report from the Cardiac Care Network of Ontario.[28]

A quantity called the median odds ratio (MOR) was used to understand total variability in a given outcome at the hospital level and the variability in a given outcome in different hospitals not explained by covariates included in the regression models. The MOR is defined as the median of the set of odds ratios that obtained by repeatedly comparing two patients in the sample with identical patient-level characteristics from two randomly chosen, different hospitals. This procedure generates a distribution of odds ratios when repeated many times. The median of this distribution is the median odds ratio. In this analysis, the MOR demonstrates the extent to which the individual probability of a given outcome (e.g., successful TTM) is determined by hospital. The MORs derived from empty models (without co-variates included) quantify the total hospital level variability for each outcome. The MORs derived from the full models quantify the hospital level variability that is not explained by modeled covariates. MORs can be directly compared to ORs for patient-level characteristics, i.e., the MOR being of greater magnitude than the ORs of most patient-level characteristics suggests that unexplained between-hospital variability is more important than patient-level characteristics for understanding successful TTM rates.

For the clinical process outcomes including successful TTM and cooling initiated, the change in estimate approach[29,30] was used in model building to assess any potential confounders between hospital volume and the clinical process outcomes. For patient outcomes such as life-sustaining therapy withdrawn on the basis of neuroprognostication and survival to hospital discharge with good neurologic function, all variables with a $p < 0.10$ or felt to be clinically significant based on published evidence were included in the final models.

The relationships between hospital volume and the outcomes were assessed by modeling volume as a continuous variable, as a categorical variable using the categories defined in the descriptive analysis, and as a fractional polynomial using a standard algorithm to select the best fit term.[31] Model fit was assessed using Akaike Information Criteria (AIC). For each outcome the model with volume as a continuous variable has the lowest AIC value and it was assessed that the relationship between the exposure and the log odds of successful TTM was approximately linear through a LOWESS curve, therefore the continuous volume models were used for the analysis.

Results

From September 2007 to December 2013, there were 2723 patients eligible for post-cardiac arrest processes of care included in the study (Fig. 1). Characteristics of included patients and hospitals are presented in Table 1.

Hospitals that received a higher volume of eligible post-cardiac arrest patients tended to have higher bed numbers, be academic centres, and be PCI centres. Hospital volume categories only differed at the patient-level in terms of TTM process outcomes. For these process outcomes, patients at high volume hospitals had

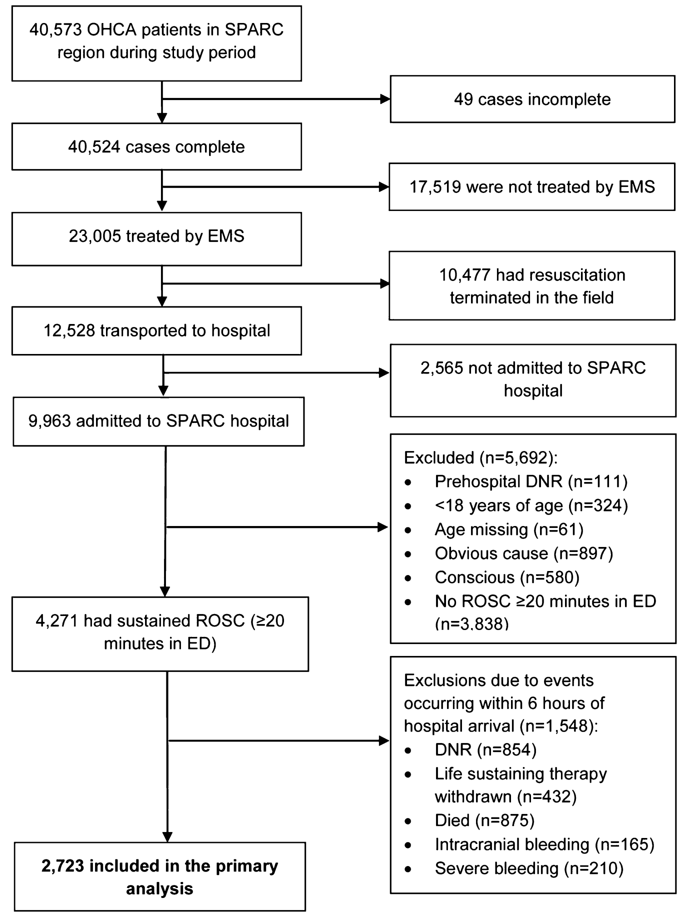

Fig. 1. A consort diagram outlining selection of patients included in our analysis. OHCA = out-of-hospital-cardiac-arrest, EMS = emergency medical services, SPARC = Strategies for Post Arrest Care Network, DNR = Do-Not-Resuscitate, ROSC = return of spontaneous circulation.

cooling initiated more often than in low volume hospitals (80% versus 64%, respectively) and had successful TTM more often than patients at low volume hospitals (38% versus 26%, respectively).

We observed marked variability in outcomes across hospitals. For example, across all volume categories, the primary outcome of successful TTM ranged from 0% to 61% with a median of 27% [IQR 16–38%] (Fig. 2). In addition, cooling ever initiated ranged from 25% to 88% with a median of 67% [IQR: 54–79%], and premature withdrawal of life sustaining therapy on the basis of neuroprognostication ranged from 0% and 18% with a median of 3% [IQR 0–6%].

Multilevel logistic regression modeling demonstrated a statistically significant association between average annual hospital volume of eligible OHCA patients and both cooling outcomes; successful TTM and cooling initiated. These associations remained statistically significant after adjusting for potential confounders. For each 10-unit increase in annual volume of patients, the adjusted odds for successful TTM increased by 29% (OR 1.29, 95% CI 1.03–1.62). For each 10-unit increase in annual volume of patients, the adjusted odds for cooling initiated increased by 38% (OR 1.38, 95% CI 1.11–1.72). We did not observe a statistically significant association between hospital experience (i.e., unit increase in average annual hospital volume) and withdrawal of life-sustaining therapy on the basis of neuroprognostication within 72 h of hospital arrival (OR 1.10, 95% CI 0.81–1.51) (Table 2) or survival to hospital discharge and (OR 0.87, 95% CI 0.74–1.02) (Table 3).

Table 1
Patient and hospital characteristics.

	Overall (N = 2723)	Low (<15 eligible TTM/year) (N = 721)	Moderate (15–25 eligible TTM/year) (N = 1024)	High (>25 eligible TTM/year) (N = 978)
Patient level data				
Age, years (mean)	65 (±16)	65 (±15)	65 (±16)	64 (±16)
Male	1868 (69%)	510 (71%)	684 (67%)	674 (69%)
Bystander witnessed arrest	1588 (58%)	428 (59%)	591 (58%)	569 (58%)
EMS witnessed arrest	430 (16%)	97 (13%)	185 (18%)	148 (15%)
Shockable initial rhythm	1379 (51%)	382 (53%)	492 (48%)	505 (52%)
Public location	694 (25%)	205 (28%)	242 (24%)	247 (25%)
Bystander resuscitation	1145 (42%)	340 (47%)	406 (40%)	399 (41%)
Bystander CPR	1135 (42%)	339 (47%)	402 (39%)	394 (40%)
Bystander AED	123 (5%)	39 (5%)	42 (4%)	42 (4%)
EMS response time, seconds (mean)	375 (±156)	391 (±187)	379 (±152)	360 (±135)
ROSC in the field	2371 (87%)	633 (88%)	893 (87%)	845 (86%)
Emergency department status				
Pulse present	2114 (78%)	570 (79%)	787 (77%)	757 (77%)
Ongoing resuscitation	585 (21%)	144 (20%)	228 (22%)	213 (22%)
Unknown	24 (1%)	7 (1%)	9 (1%)	8 (1%)
Intervention: group in SPARC trial	1770 (65%)	436 (60%)	666 (65%)	668 (68%)
Successful TTM*	895 (33%)	184 (26%)	342 (33%)	369 (38%)
Cooling initiated	1918 (70%)	460 (64%)	678 (66%)	780 (80%)
Life sustaining therapy withdrawn on the basis of premature neuroprognostication	120/1571 (8%)	27/454 (6%)	47/591 (8%)	46/526 (9%)
Angiography	728 (27%)	199 (28%)	264 (26%)	265 (27%)
EP consult	192 (7%)	51 (7%)	67 (7%)	74 (8%)
ICD placement	253 (9%)	72 (10%)	83 (8%)	98 (10%)
Survival with good neurologic function	828 (30%)	244 (34%)	297 (29%)	287 (29%)
Hospital level data				
Hospitals	37	22	9	6
Patients eligible for TTM/year (mean)	13.8 (±10.8)	6.1 (±4.4)	21.3 (±2.5)	30.6 (±7.5)
Hospital beds (median)	393	231	444	843
Academic hospital	11 (30%)	5 (23%)	3 (33%)	3 (50%)
PCI center	7 (19%)	2 (9%)	3 (33%)	2 (33%)

TTM = targeted temperature management, EMS = emergency medical services, CPR = cardiopulmonary resuscitation, AED = automated external defibrillator, ROSC = return of spontaneous circulation, SPARC = Strategies for Post Arrest Care, EP = electrophysiology, PCI = percutaneous coronary intervention.

* $p < 0.05$ Rao–Scott chi-square test.

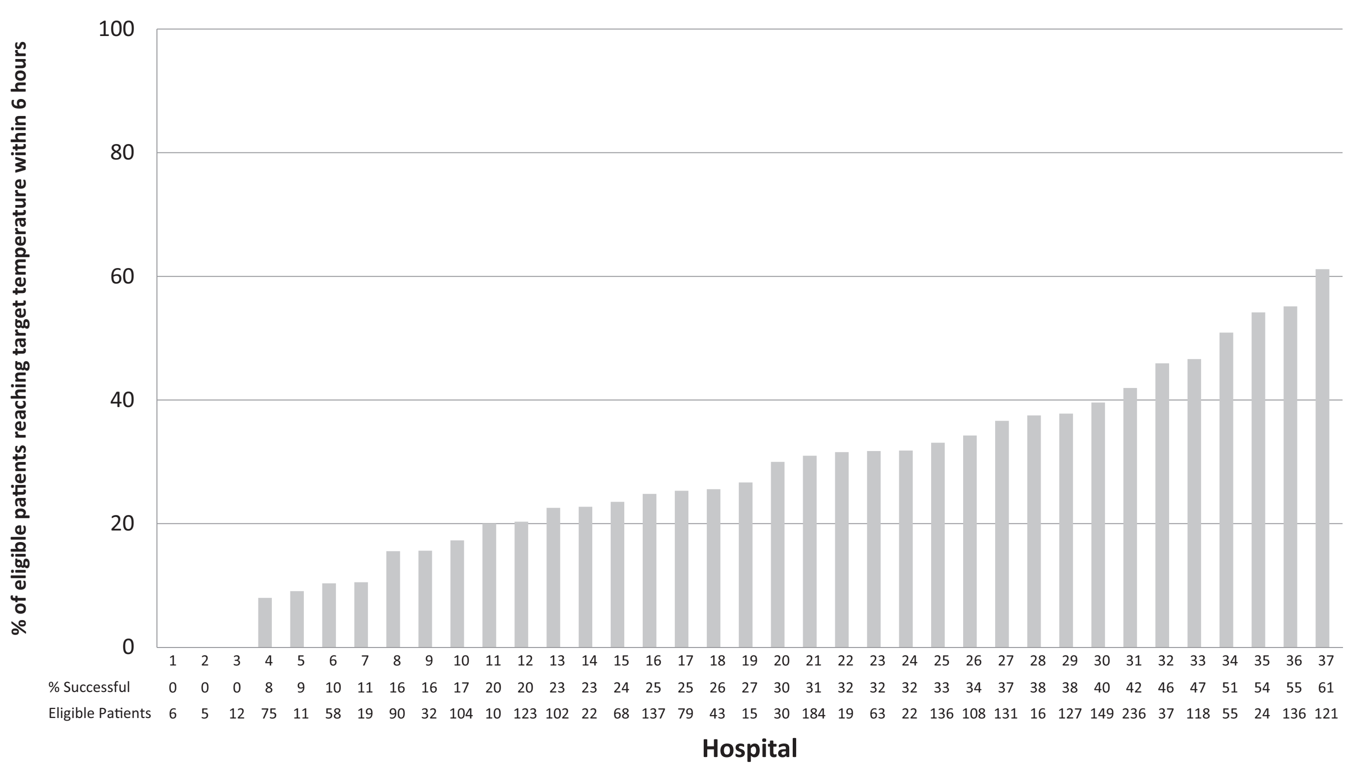

Fig. 2. Variability in proportion of eligible patients with successful targeted temperature management across participating hospitals.

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Table 2
Multilevel model for premature withdrawal of life sustaining therapy on the basis of neuroprognostication (N = 1571).

	Odds ratio	95% CI	*p*
Average annual volume of patients eligible for TTM	1.10	0.80–1.52	0.53
Age	1.04	1.02–1.05	<0.01
Male	1.00	0.66–1.53	0.99
EMS witnessed	0.30	0.16–0.58	<0.01
Bystander CPR	0.65	0.42–0.99	0.05
ROSC in the field	0.45	0.26–0.79	<0.01
Shockable initial rhythm	0.23	0.14–0.38	<0.01

TTM = targeted temperature management, EMS = emergency medical services, CPR = cardiopulmonary resuscitation, ROSC = return of spontaneous circulation.

Table 3
Multilevel model for survival with good neurologic function (N = 2723).

	Odds ratio	95% CI	*p*
Average annual volume of patients eligible for TTM	0.87	0.74–1.02	0.08
Age	0.96	0.96–0.97	<0.01
Male	1.09	0.87–1.37	0.45
Bystander witnessed	1.61	1.25–2.06	<0.01
EMS witnessed	3.69	2.60–5.26	<0.01
Bystander CPR	0.99	0.80–1.25	0.99
AED use	1.55	0.99–2.43	0.05
ROSC in the field	4.02	2.77–5.83	<0.01
Public location	1.36	1.08–1.72	<0.01
EMS response time	0.99	0.98–0.99	<0.01
Shockable initial rhythm	4.65	3.66–5.92	<0.01

TTM = targeted temperature management, EMS = emergency medical services, CPR = cardiopulmonary resuscitation, ED = automated external defibrillator, ROSC = return of spontaneous circulation.
TTM = targeted temperature management, EMS = emergency medical services, CPR = cardiopulmonary resuscitation, AED = automated external defibrillator, ROSC = return of spontaneous circulation, SPARC = Strategies for Post Arrest Care, EP = electrophysiology, PCI = percutaneous coronary intervention.

We calculated a median odds ratio from the empty model (which only included hospital as an explanatory variable) to characterize variability in the primary outcome at the hospital level. The median odds for successful TTM were 1.83 times higher if the same patient was assigned to a randomly selected hospital with higher propensity for the outcome, indicating a substantial amount of variability across hospitals. The median odds ratios for the secondary outcomes of cooling initiated, premature withdrawal of life sustaining therapy on the basis of neuroprognostication, and survival with good neurologic function were 1.92, 1.97, and 1.52, respectively. Median odds ratios derived from the full models were very similar indicating substantial variability in these outcomes at the hospital level even after adjusting for cardiac arrest volume and other co-variates.

The sensitivity analysis assigning patients to the final treating hospital as opposed to the first receiving hospital demonstrated a slightly stronger impact of volume on whether a patient achieved successful TTM. For each 10-unit increase in annual volume of patients in the treating hospitals, the adjusted odds ratio was 1.38 (95% CI 1.12–1.72).

Discussion

In this multicenter, population-based retrospective cohort, we observed that the initiation of TTM and the occurrence of reaching target core temperature were highly variable across hospitals and more likely to occur at hospitals receiving higher volumes of post cardiac arrest patients eligible for TTM. We did not observe an association between hospital experience and early withdrawal of life-sustaining therapy or survival.

Although there is controversy over the optimal target temperature within the range of 32–36 °C,[32] and uncertainty about the relationship between time-to-temperature-target and outcomes, our finding of an association between hospital experience and successful TTM is important because TTM remains a critical aspect of post cardiac arrest care emphasized in current guidelines.[33–35] Understanding the association between hospital experience with post cardiac arrest patients and quality of care in this population is important when planning regional systems of care and knowledge translation efforts to optimize care for this patient population.

We noted marked variability in the proportion of eligible patients who had TTM initiated and reached target temperature across hospitals (0–61%, Fig. 2). This heterogeneity in clinical practice could be due to variable uncertainty in best practices among clinicians, hospital-based implementation barriers, influence of hospital champions and practice traditions for cardiac arrest patients that differ from hospital to hospital.

We observed that most patients do not achieve target temperature within 6 h of emergency department arrival. This is true even in experienced, high volume centres where only 38% of eligible patients are successfully cooled and achieve target temperature within 6 h after emergency department arrival (Table 1). Post cardiac arrest care is challenging and the process of TTM is complex. Prior work has identified barriers to successful TTM including lack of comfort with the procedure, lack of expertise, lack of equipment and poor collaboration between treating services in the hospital (e.g., emergency, intensive care, cardiology).[8,36,37] Providers working within hospitals receiving fewer post cardiac arrest patients are likely to have more difficulty in developing comfort, proficiency and expertise in caring for these complex patients. This likely includes proficiency with temperature management procedures which can be challenging.[8] Although still facing significant barriers to consistent successful TTM, larger volume centers may have more comfort in dealing with complex and critically ill patients in general and this may translate into improved process outcomes for this specific subset of cardiac arrest patients. Although this was not captured in our data, larger centers with higher patient volumes may also have other resources available such as technology and additional staffing to facilitate successful cooling. In recent analysis of hospitals within the ROC network, Stub et al. observed an association between "hospital performance score" and survival with good neurologic function.[38] The hospital performance score was a composite statistic assigned to each hospital based on several guideline-recommended post cardiac arrest treatments such as TTM, coronary angiography and avoidance of premature withdrawal of life-sustaining therapy. These authors observed an association between higher hospital performance scores and improved outcomes. Hospitals with higher volumes of out of hospital cardiac arrest patients tended to have higher performance scores.

The median odds ratios calculated in our analysis suggest that experience with cardiac arrest patients may not be the only hospital-level factor driving variability in care processes. Future work should aim to explore other factors such as individual provider characteristics, institutional culture, neighborhood socioeconomic status, hospital design, and equipment availability that may be associated with post cardiac arrest care quality.

Our study did not demonstrate a significant association between increased hospital experience with post cardiac arrest patients and likelihood of neurologically intact survival. Previous investigations measuring this association have provided mixed results. An investigation from the Cardiac arrest Registry to Enhance Survival (CARES) found no association between increasing hospital volume and improved survival.[39] In an Australian study, some hospital characteristics were associated with improved clinical outcomes, but there was no independent association between hospital

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volume and survival.[40] In contrast, a study from the Resuscitation Outcomes Consortium (ROC) in the US and Canada demonstrated reduced mortality for post-cardiac arrest patients treated at hospitals who received greater than 40 cardiac arrest patients per year versus those that received less than 40 patients per year, however this association was not evident after adjusting for several hospital- and patient-level factors known to be associated with survival.[41] Carr et al. observed reduced in-hospital mortality for post cardiac arrest patients admitted to US ICUs who treated more cardiac arrest patients.[42]

Although modeling premature withdrawal of life sustaining therapy on the basis of neuroprognostication did not demonstrate statistically significant association with post cardiac arrest patient volume, it yielded some interesting secondary findings. Being younger, having an EMS witnessed arrest, bystander CPR, ROSC in the field, and having a shockable initial rhythm all tended to protect against early withdrawal of care. Perhaps these factors were associated with optimism for a good outcome among care providers making decisions around withdrawal of life-sustaining therapy.

Our study has several limitations. Due to the observational design of our study the associations observed cannot establish causal relationships between hospital volumes and outcomes. The study relied on hospital records data and some important details about the patient or clinical care may not have been documented. We did not include other important aspects of post arrest critical care such as hemodynamic optimization, ventilator management, and coronary angiography in our analysis, but instead focused on the key aspects of TTM and decisions around withdrawal of life sustaining therapy. Our definition of successful TTM on the basis of achieving target temperature within 6 h was not based on any strong evidence that this was the optimal time-to-target, but rather, on the basis of data from positive clinical trials available when we designed our study[43] and expert opinion.

Conclusions

Comatose patients after out-of-hospital cardiac arrest arriving at hospitals with more institutional experience in treating this population are more likely to receive successful targeted temperature management when compared with hospitals having less experience. There is no clear association between hospital experience and premature withdrawal of life-sustaining therapy or survival to hospital discharge. Future research should identify other hospital-level factors contributing to the observed variability in processes and outcomes so that regional systems of care for post-cardiac arrest patients can be optimized.

Conflict of interest statement

No potential conflicts of interest have been declared by any of the authors apart from the funding sources identified in Acknowledgments section.

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