Regionalization of postcardiac arrest care

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Purpose of review

To discuss the concept and implementation of regionalized postcardiac arrest care.

Recent findings

American Heart Association guidelines call for therapeutic hypothermia in patients who have return of spontaneous circulation but remain comatose after out-of-hospital cardiac arrest due to ventricular fibrillation. The real and perceived technical challenges of inducing, maintaining, and monitoring postarrest patients who have received induced hypothermia have limited its widespread use. In addition, recent data suggest that emergency primary coronary intervention may benefit those victims of out-of-hospital cardiac arrest with return of spontaneous circulation. However, most community hospitals lack consistent 24-h a day emergency percutaneous coronary intervention capability. Therefore, despite showing efficacy in clinical trials, these therapies remain underutilized in clinical practice, thus limiting their widespread use. The concept of regionalized specialty care has been used successfully for other time-sensitive illnesses such as major trauma and acute stroke. Evidence extrapolated from the trauma and stroke literature suggests that such a system of care would be well tolerated, feasible, and would improve outcomes after out-of-hospital cardiac arrest.

Summary

It is feasible to implement a large system of care in which eligible postcardiac patients are triaged to centers capable of delivering standardized, state-of-the art postarrest care. Further research is warranted to determine the optimal design of such a system of care.

Keywords

cardiac arrest, cardiocerebral resuscitation, percutaneous coronary intervention, postarrest care, therapeutic hypothermia, ventricular fibrillation

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Introduction

For many decades, it was believed that the survival from out-of-hospital cardiac arrest (OHCA) was based solely on interventions occurring in the prehospital setting [1,2]. Even after the restoration of spontaneous circulation (ROSC), a sense of futility frequently thwarts aggressive in-hospital postresuscitation care for comatose postcardiac arrest patients [3–6]. Recent evidence, however, suggests that neurologically meaningful survival is significantly improved by in-hospital postresuscitation care despite persistent coma after arrest [7–9]. The American Heart Association (AHA) recently published a consensus statement on guidelines for postcardiac care including implementation and barriers to implementation [10••]. Currently, in the United States, a majority of medical centers that receive 9-1-1 emergency patients do not consistently provide specialized postarrest cardiac care [11]. Subsequently, consideration has been given to bypassing local hospitals en route to regional cardiac arrest centers (CACs) equipped and staffed to provide specialized postarrest care [12,13]. This article focuses on the question of whether transporting patients to specialized CACs improves survival.

Postarrest physiology

Negovsky [14] described postresuscitation disease as a specific multiorgan pathophysiologic state in patients who are resuscitated following cardiac arrest. Patients who have ROSC following a cardiac arrest often have a clinical syndrome affecting cardiovascular, neurologic, pulmonary, renal, and metabolic systems.

Myocardial dysfunction after resuscitation from cardiac arrest has been described in both animal and clinical studies [15–18]. The myocardial stunning or dysfunction was related to the overall time required for resuscitation and included systolic and diastolic dysfunction. Left ventricular wall motion is globally depressed, resulting in a decreased ejection fraction that frequently improves in the first 24–72 h after arrest.

The quality of in-hospital monitoring and care following resuscitation from OHCA is vital in optimizing the chances for survival and good neurologic outcome. Because cardiovascular status will be affected by myocardial dysfunction in most postarrest patients, pressor support for maintaining adequate systemic perfusion may be required for the first 24–72 h until myocardial dysfunction reverses [19].

Therapeutic hypothermia

Two randomized controlled trials have demonstrated substantial improvement in survival and neurologic outcome when victims of witnessed prehospital ventricular fibrillation receive therapeutic hypothermia [20,21]. Subsequent meta-analyses, systematic reviews, and case controlled clinical series have given additional support to the positive improvement in outcome from this comparatively simple and inexpensive procedure in patients with ROSC who remain comatose after cardiac arrest [22–25]. In response, several consensus statements on postresuscitation care have supported the use of therapeutic hypothermia [10••,19]. Despite these two randomized controlled trials along with the endorsement of the AHA and the International Liaison Committee on Resuscitation, therapeutic hypothermia is used in only a small minority of patients who are comatose after cardiac arrest [11]. This was true in Arizona where a survey of hospitals revealed that less than 5% of all hospitals in the state had a protocol to perform therapeutic hypothermia [26].

Although therapeutic hypothermia is gradually gaining acceptance and making its way into community practice, patients who would benefit from therapeutic hypothermia right now are not receiving the therapy. This situation greatly concerned our group and gave us a keen sense of urgency to change our system. We believed that as a state, we could provide optimal postresuscitation care to more than only a fraction of patients.

Rationale for percutaneous coronary intervention

The use of coronary angiography and percutaneous coronary intervention (PCI) following cardiac arrest has been reported in patients with postresuscitation electrocardiographic evidence of ST elevation [27–39]. Acute coronary intervention following resuscitation had shown improved survival compared with historical controls [27–39]. Such a strategy has also improved neurologically intact survival compared with prior more conservative approaches [27–39]. A recent editorial, summarizing the results of early catheterization and PCI after cardiac arrest, showed that from 13 clinical reports involving 744 patients, 62% survived to discharge after resuscitation, with 82% of those survivors having good neurological function. Even more impressive, if both therapeutic hypothermia and early PCI were performed early in the postresuscitation period, survival rates of 78% were seen, with 81% of survivors having good neurological function. This combination seems to hold real promise for postresuscitation care.

Rationale for regionalization of postarrest care

Sunde *et al.* [40] reported marked improvement when prehospital ROSC patients subsequently received bundled postresuscitation care. In their study, favorable neurological survival occurred in 56% of patients during the intervention period compared with only 26% during the control period [40]. The odds ratio (OR) for good outcome was 3.6 for those receiving specialized postresuscitation care. Lurie [41] initiated a comprehensive cardiac arrest 'Resuscitation Center' with an intentional, standardized approach to postresuscitation care in a rural city in Minnesota. In the 12 months following inception of the program, 63% of 26 patients with witnessed ventricular fibrillation were discharged in good neurologic condition. This represented a 131% relative increase in survival among ROSC patients who arrived at the hospital in coma [41].

The overarching concept, as first described by Lurie [41], is to transport eligible patients to specialty centers with the appropriate level of care as soon as possible. Simply, 'getting the right patients to the right place in the right time'. This concept evolved from the development of trauma systems: integrating out-of-hospital guidelines, communication, capabilities, levels of care, trauma registries, uniform clinical practice guidelines, and practice inside level 1 trauma centers across the United States. Additionally, patient outcomes are improved at trauma centers when critically injured patients receive care by nursing and ancillary staff accustomed to caring for critically injured patients. Our belief is that an integrated system approach would also benefit cardiac arrest victims requiring intensive and specialized care.

Another potentially important benefit of the CAC model is the built-in continuous quality improvement of the team, including a requisite review of protocols and pathways along with the care given to critical patients in a structured multidisciplinary format. Such a system would also be capable of rapidly assessing new therapies, which can be systematically evaluated within the construct of a uniform-based protocol system of care. Limiting the number of medical centers receiving OHCA patients would also greatly help streamline and allow for more rigorous and in-depth data collection.

With the premise that 'time is muscle', recent large-scale efforts have also been aimed at providing rapid prehospital diagnosis and triage of patients with ST-elevation

myocardial infarction (STEMI), including prehospital 12-lead ECG acquisition and transportation of patients to a medical facility capable of around-the-clock emergent coronary reperfusion. Whereas a system performance measure for STEMI is time from accessing 9-1-1 to reperfusion, a system performance measure for OHCA would be the percentage of neurologically intact survivors in each jurisdiction.

Components of a cardiac arrest center

The Arizona CAC Consortium met in late 2007 and developed initial components of a CAC. These primary criteria were meant to be a starting point from which to build and expand in the future.

The most fundamental of the criteria was a commitment to full participation with data collection and submission by each CAC. Each CAC was required to submit 6 months of baseline OHCA data prior to designation. Next, an institutional therapeutic hypothermia protocol and a methodology for therapeutic hypothermia were required. Additionally, each CAC was required to demonstrate 24/7 PCI capability, and the CAC Consortium recommended that each postarrest patient should be considered for emergent PCI. The Consortium also advocated that each CAC should use an evidence-based guideline for prognostication of futility. Hospitals were encouraged to have a protocol for organ procurement when efforts are deemed futile. Lastly, the CAC Consortium suggested that each CAC have a public outreach program to teach bystander cardiopulmonary resuscitation (CPR) in their communities.

Is it safe to delay transport to a cardiac arrest center?

In an attempt to answer this key question, Spaite *et al.* [42] carried out an analysis of the Arizona statewide OHCA database. On review of 1177 OHCAs that occurred prior to emergency medical service (EMS) arrival, 253 patients (21.5%) achieved ROSC and remained comatose, making them theoretically eligible for transport to specialized care. Overall, 70 patients (70/1177; 5.9%) survived, including 43 (43/253; 17.0%) comatose ROSC patients. Mean transport interval (time from on scene to arrival at hospital) for the study group was 6.9 min [95% confidence interval (CI) 6.7–7.1). Logistic regression revealed factors that were independently associated with survival: witnessed arrest, bystander CPR, method of CPR, initial rhythm of ventricular fibrillation, and shorter EMS response time interval. Importantly, there was no significant association between transport interval and outcome in either the overall study group (OR 1.2, 95% CI 0.77–1.8) or in the comatose, ROSC subgroup (OR 0.94, 95% CI 0.51–1.8). Spaite *et al.* [42] concluded that survival was not significantly impacted by transport interval and suggested that a modest increase in transport interval from bypassing the closest hospital en route to specialized care would be safe. This same analysis has recently been done for the significantly larger Ontario Prehospital Advanced Life Support Study database with similar findings. (D.W. Spaite, unpublished observation).

Cardiocerebral resuscitation

Cardiocerebral resuscitation (CCR) represents a bundle of specific therapies designed to enhance myocardial and cerebral blood flow during cardiopulmonary arrest by emphasizing chest compressions over ventilations. The heart is 'primed' with chest compressions prior to and immediately after defibrillation attempts. Implementation of CCR in Arizona and Wisconsin improved outcomes compared with those treated with standard guidelines. The subgroup of patients with bystander-witnessed collapse and ventricular fibrillation on EMS arrival especially benefited. This may be because patients in this group have adequate oxygen reserves at the time of arrest and decreased requirement for immediate positive-pressure ventilation. Beyond the specific EMS interventions, CCR includes therapeutic hypothermia for all comatose postarrest victims (regardless of presenting rhythm) and consideration for early PCI regardless of initial electrocardiographic findings.

Arizona Cardiac Arrest Center Consortium experience

In December 2007, the Arizona Department of Health Services (ADHS) and the Sarver Heart Center Resuscitation group embarked on a program of designating hospitals as CACs on the basis of their ability to administer therapeutic hypothermia, perform 24/7 PCI, report accurate data, utilize an evidence-based termination of resuscitation protocol, have a protocol for organ procurement, and train their community in bystander CPR. We did not dictate how the therapeutic hypothermia should be induced or whether it must be done in the emergency department or ICU settings. Currently, there are insufficient data to make strong recommendations regarding the method or timing of therapeutic hypothermia induction. Our hope is that by collecting accurate data on the various therapeutic hypothermia methods and protocols, we may be able to formulate conclusions as to the optimal method and timing of inducing hypothermia.

The foremost goal of this program was for a majority of OHCA victims in Arizona to receive standardized, guideline-based postcardiac arrest care. We had evidence prior to implementation that, as in most places in the United States, this was not being done in Arizona [26].

Figure 1 Cardiac arrest center data form

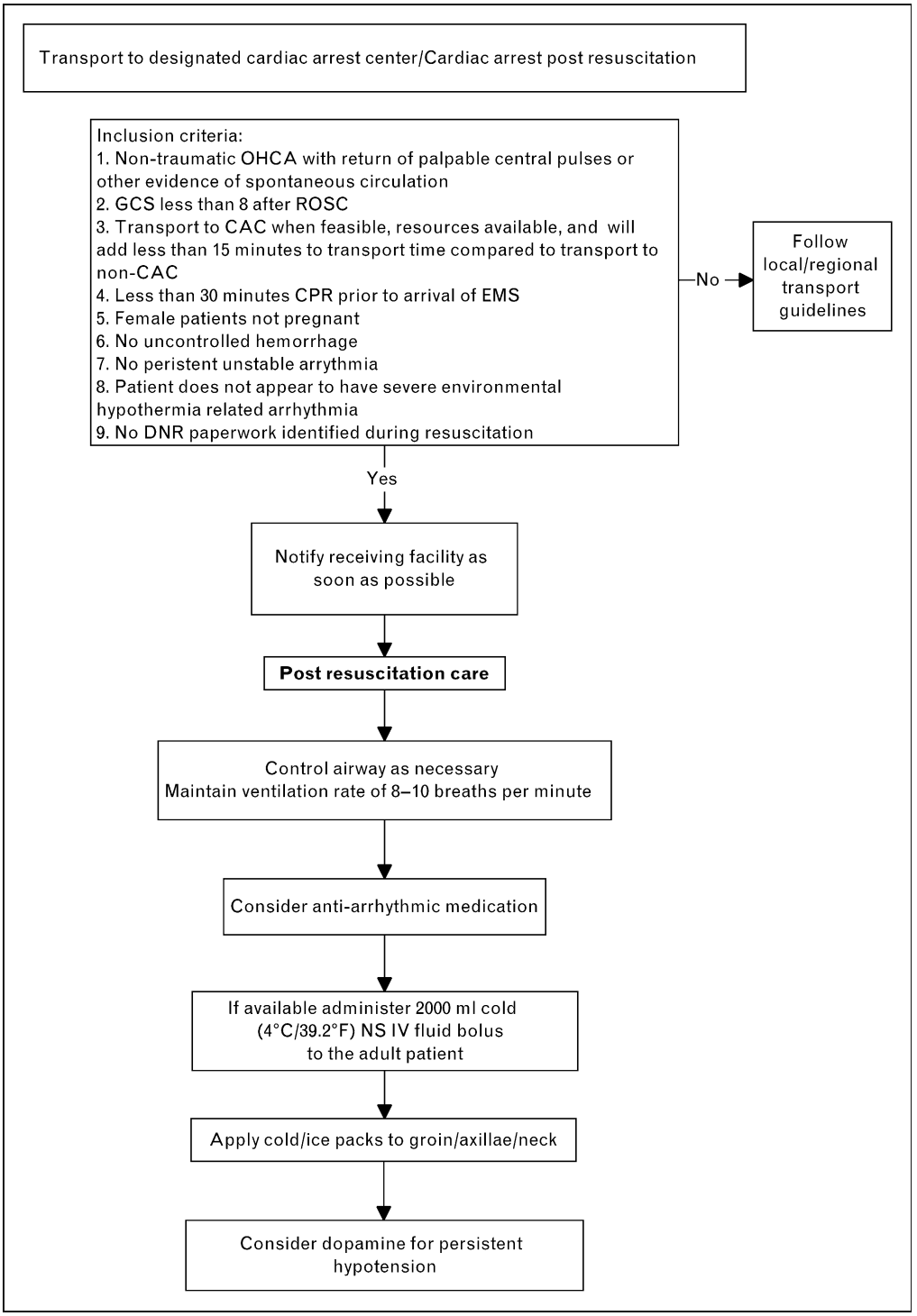
SHARE cardiac arrest center printable data form

Hospital:		Transporting agency:		
Patient name (Last):		(First):	DOB:	Gender M☐ F☐
Date of incident:	Time of collapse:	Time arrive ED:	Intubated? Yes☐ No☐	
On arrival ED: Pulse:	BP:	Spont. RR:	Cardiac rhythm:	
Eligible for therapeutic hypothermia? Yes☐ No☐ If No, why not? ☐ >60 minutes of CPR prior to ED arrival ☐ Regained consciousness ☐ No return of spontaneous circulation/lost spontaneous circulation ☐ Other:				
Therapeutic hypothermia was initiated in the: Field☐ ED☐ ICU☐				
What method of therapeutic hypothermia was used? Where? (check all that apply)				
Ice ☐ Prehospital ☐ ED ☐ ICU	**Cold IV fluids** ☐ Prehospital ☐ ED ☐ ICU	**Cooling blanket** ☐ Prehospital ☐ ED ☐ ICU	**Intravascular catheter** ☐ Prehospital ☐ ED ☐ ICU	**External cooling** ☐ Prehospital ☐ ED ☐ ICU
Other method:				
Did patient receive vasopressor agent? Yes☐ No☐ If Yes, which agent(s)				
Neurological assessment: GCS upon arrival in the emergency department:				
Time elements: Time of ROSC: Time cooling started: Date: Time to cath lab: Date:		Time arrive ICU: Date: Time target temp reached: Date: Time warming started: Date:		
If care terminated: Date: Time: Where?		Why? ☐ No response to treatment ☐ Life support discontinued		
Adverse events as inpatient: None☐ Infection☐ Bleeding☐ DVT☐ Hyperkalemia☐ other:				
OUTCOME: Discharged alive☐ Death☐ Date of D/C or death:				
Cerebral performance category (CPC) score on discharge (circle): 1 2 3 4 5 (see CPC scale attached)				
Organ donation? Yes☐ No☐		Did patient receive ICD on discharge? Yes☐ No☐		
Suspected cause of initial cardiac arrest:		STEMI? Yes☐ No☐		
Any additional notes/comments:				

The Arizona CAC Program was initiated with key stakeholders (hospitals, critical care medicine, emergency medicine, cardiology, nursing and community leaders, hospital administrators, and prehospital providers). A website (www.azshare.gov) was utilized to relay program concepts along with detailed system and protocol information to interested hospitals. Those hospitals meeting the above criteria and showing interest were given targeted live presentations. ADHS staff were available to help review hospital protocols and answer questions regarding the program goals and implementation. Unlike some specialty center certifications, there was no fee for Arizona hospitals to join the Arizona CAC Consortium.

Hospitals were required to provide 6 months of baseline OHCA data along with a letter of intent from their administration agreeing to participate and continue to submit data to a Health Insurance Portability and Accountability Act exempt secure database used for system-wide OHCA quality improvement (Fig. 1). In addition, the State EMS Council developed and approved a prehospital protocol. This established protocol allowed EMS personnel to bypass the nearest

Figure 2 Prehospital resuscitation bypass protocol



CAC, cardiac arrest center; CPR, cardiopulmonary resuscitation; DNR, do not resuscitate; EMS, emergency medical service; GCS, Glasgow coma scale; OHCA, out-of-hospital cardiac arrest; ROSC, restoration of spontaneous circulation.

local hospitals to transport eligible patients (comatose, ROSC patients) to CACs, with a maximum transport interval not to exceed 15 min (Fig. 2). This time limit, although somewhat arbitrary, was arrived at after analysis of statewide OHCA transport interval data [42]. Prehospital providers are encouraged to transport eligible post-arrest OHCA patients to CACs when resources make this feasible. Arizona has vast geographical regions, many

with rural communities. As such, aeromedical services are an integral component of the CAC Consortium. It is our hope that data from this system of care will not only improve survival but also help shed light on key resuscitation questions such as how to optimize cooling, emergent PCI, and other interventions.

The CAC Consortium continues to evolve and expand. By the end of 2008, 19 hospitals had applied for CAC designation, met the requisite criteria, and had been formally designated as a CAC [43]. Since its inception, we have refined and added criteria to our model, and the number of designated CACs continues to increase. While we are accumulating system data, early analysis of therapeutic hypothermia utilization and patient outcomes appear favorable [43].

Conclusion

Regionalized postcardiac arrest care appears to significantly improve the utilization of guideline-based therapies, particularly therapeutic hypothermia. We believe that this system enhancement will improve the chance for a good neurological outcome after an OHCA. Implementing a CAC system of care is feasible and may become the preferred model of postarrest care for the future. Although it has taken our trauma colleagues three decades to pave the initial path for regionalized care, we should use their experience for creating an accelerated roadmap for cardiac arrest care.

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Papers of particular interest, published within the annual period of review, have been highlighted as:

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- •• of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 270).

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