Commentary and concepts

The development and implementation of cardiac arrest centers

Michael W. Donnino\textsuperscript{a,\textdagger,1}, Jon C. Rittenberger\textsuperscript{b,1}, David Gaieski\textsuperscript{d,1}, Michael N. Cocchi\textsuperscript{a,1}, Brandon Giberson\textsuperscript{a,1}, Mary Ann Peberdy\textsuperscript{c,1}, Benjamin S. Abella\textsuperscript{d,1}, Bentley J. Bobrow\textsuperscript{e,1}, Clifton Callaway\textsuperscript{b,1}

\textsuperscript{a} Beth Israel Deaconess Medical Center, United States
\textsuperscript{b} University of Pittsburgh, United States
\textsuperscript{c} Virginia Commonwealth University, United States
\textsuperscript{d} University of Pennsylvania, United States
\textsuperscript{e} University of Arizona, United States

A R T I C L E  I N F O

Article history:
Received 19 November 2010
Received in revised form 22 February 2011
Accepted 14 March 2011
Available online xxx

Keywords:
Cardiac arrest center
Regionalized care
Cardiac arrest

A B S T R A C T

In the last decade, many regionalized centers for the care of post-cardiac arrest patients (cardiac arrest centers) have all independently developed with a common goal of providing multi-disciplinary and organized care plans for this patient population. The American Heart Association recently issued support for regionalized and organized comprehensive care for post-arrest patients through a position paper as well as the 2010 American Heart Association BLS/ACLS guidelines. This paper outlines the formation, structure, and implementation of four cardiac arrest centers, and also discusses a statewide model of post-arrest center care. This paper may assist other potential clinical sites that are considering or actively developing cardiac arrest centers of their own.

1. Overview

Patients with sustained return of spontaneous circulation (ROSC) after cardiac arrest exhibit a variety of specific responses to ischemia-reperfusion injury, often resulting in multi-system organ involvement requiring intervention by multiple medical specialties.\textsuperscript{1} Implementation of a comprehensive care plan for patients after cardiac arrest has been shown to lead to improved outcomes, and was recently promoted in the 2010 American Heart Association (AHA) guidelines.\textsuperscript{1–3} However, delivery of systematic care for this patient population can be problematic because of administrative, resource, and logistical barriers. Despite these facts, patients resuscitated from cardiac arrest are not routinely hospitalized at specific centers, are cared for in many different intensive care units, and often receive care from teams who encounter these patients with low frequency.\textsuperscript{4} As a result, a mismatch between patient need and delivery of resources may occur. Alternatively, care can be delivered in a comprehensive cardiac arrest center that attempts to match adequate resources and specialty skills to patient demand in an attempt to improve the overall care of this unique population.\textsuperscript{5} This paper describes the development of comprehensive cardiac arrest centers in four hospital systems and one statewide approach (Arizona) in the United States. Recognizing the increased demand for regionalized care, the overall objective of this paper is to provide a comprehensive overview and “guide” to the creation of cardiac arrest centers.

2. Center concept

Within the past several years, several tertiary care centers have developed specialized teams and “Centers” to enhance the clinical care of post-cardiac arrest patients. The provision of specialized regional centers has emerged for the management of a number of critical illnesses such as stroke and trauma.\textsuperscript{6–9} The emergence of specialized cardiac arrest centers will presumably lead to improved clinical care as well as the opportunity for increased research and education in a traditionally under-represented area of critical care.\textsuperscript{5} In order to provide other health care providers and systems with knowledge of how to approach creation of a cardiac arrest center, we have composed the following descriptive review of four established cardiac arrest centers complete with both successes and areas for improvement. In addition, we will briefly discuss a statewide model.

\textsuperscript{*} A Spanish translated version of the abstract of this article appears as Appendix in the final online version at doi:10.1016/j.resuscitation.2011.03.021.

\textsuperscript{1} Corresponding author at: Department of Emergency Medicine, Beth Israel Deaconess Medical Center, One Deaconess Road, WCC2, Boston, MA 02215, United States.

E-mail addresses: mdonnino@bidmc.harvard.edu, mdonnino@aol.com (M.W. Donnino).

For the National Post-Arrest Research Consortium (NPARC).

0300-9572/– see front matter © 2011 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.resuscitation.2011.03.021
for cardiac arrest centers that has been developed in Arizona (Tables 1 and 2).

The implementation of clinical pathways has been studied extensively for many illnesses and medical problems. Requirements for successful implementation include a well-defined patient population and general agreement among providers about core components of good clinical care for the given condition. Often a clinical pathway is implemented as an order set or a checklist that can be associated with the patient at admission or early during the hospitalization. Compliance with the pathway can then be audited as part of a continuous quality improvement (QI) activity. Outcomes and resource utilization may differ for patients who are in-compliance or out-of-compliance with the clinical pathways. A limitation of the clinical pathway model for post-cardiac arrest care is the heterogeneity of the patient population and the dynamic nature of this critical illness. After cardiopulmonary arrest, patients may manifest a broad spectrum of neurological response, ranging from rapid awakening to brain death. Likewise, the cardiovascular system may exhibit normal perfusion or the patient may have signs of intractable shock. Failure in other organ systems may manifest over the next few days leading to additional resource utilization including transfusion, prolonged ventilator support, renal replacement therapy, and surgery. Often the etiology of cardiac arrest remains undetermined for hours to days after ROSC, further complicating the treatment. Also taken into consideration must be the patient’s preexisting medical conditions, which often require a multidisciplinary approach to optimize management. For post-cardiac arrest, decisions about whether or not to implement specific therapies for each organ system are not easily reduced to an order set or checklist.

3. Founding and development of the centers

All of the centers were founded through multidisciplinary collaboration with the main participants being clinicians representing emergency medicine, cardiology, pulmonary and critical care, and neurology. Virginia Commonwealth University first established a cardiac arrest center in 2003 followed shortly thereafter by the University of Pennsylvania in 2004. Beth Israel Deaconess Medical Center and the University of Pittsburgh (UPMC-Presbyterian Hospital) began development of their centers in 2007. Therapeutic hypothermia was the initial focus for the later two centers where a comprehensive care plan eventually developed out of this single therapeutic initiative. Three of the four centers initially focused on survivors of out-of-hospital cardiac arrest but ultimately expanded to include survivors of in-hospital cardiac arrest. In addition, all centers have developed a referral

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Clinical services available at the four cardiac arrest centers.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical service</td>
<td>BIDMC</td>
</tr>
<tr>
<td>Induced hypothermia</td>
<td>Yes</td>
</tr>
<tr>
<td>Continuous EEG</td>
<td>Yes</td>
</tr>
<tr>
<td>Ventilator management strategies</td>
<td>Yes</td>
</tr>
<tr>
<td>PCI access</td>
<td>Yes</td>
</tr>
<tr>
<td>Cardiac arrest consult service</td>
<td>Yes</td>
</tr>
<tr>
<td>EP consultation (automatic/uniform)</td>
<td>Yes</td>
</tr>
<tr>
<td>Neurology consultation (automatic/uniform)</td>
<td>Yes</td>
</tr>
<tr>
<td>Neurosurgical consultation (automatic/uniform)</td>
<td>No</td>
</tr>
<tr>
<td>Social work consultation (automatic/uniform)</td>
<td>Yes</td>
</tr>
<tr>
<td>Inpatient physical and/or occupational therapy consultation (automatic/uniform)</td>
<td>Yes</td>
</tr>
<tr>
<td>Organ bank consultation (uniform approach)</td>
<td>Per hospital routine</td>
</tr>
<tr>
<td>Outpatient physical therapy (specific to patient population)</td>
<td>Not currently</td>
</tr>
<tr>
<td>Outpatient neurological rehab</td>
<td>Yes, selected patients</td>
</tr>
<tr>
<td>Outpatient psychological services</td>
<td>Not currently</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Specific clinical strategies implemented by the four centers.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIDMC</td>
<td>UPMC-Presbyterian</td>
</tr>
<tr>
<td>Goal temperature (°C)</td>
<td>33</td>
</tr>
<tr>
<td>pCO₂ goal (mmHg)</td>
<td>24</td>
</tr>
<tr>
<td>pO₂ recommendation</td>
<td>Titrate FiO₂ down when possible</td>
</tr>
<tr>
<td>Seizure Prophylaxis</td>
<td>None</td>
</tr>
<tr>
<td>PCI indications</td>
<td>STEMI and shock</td>
</tr>
<tr>
<td>Vasopressor recommendations</td>
<td>Dopamine if bradycardic from hypothermia; otherwise norepinephrine</td>
</tr>
<tr>
<td>Hemodynamic goals/protocol</td>
<td>MAP &gt; 70–80 mmHg</td>
</tr>
<tr>
<td>Head CT scan</td>
<td>Per clinician discretion (60% of cases within 24 h)</td>
</tr>
<tr>
<td>MRI</td>
<td>Discouraged during early phase</td>
</tr>
<tr>
<td>Evoked potentials</td>
<td></td>
</tr>
<tr>
<td>Time of neurologic prognostication</td>
<td>At 72 h in select pts</td>
</tr>
</tbody>
</table>

Please cite this article in press as: Donnino MW, et al. The development and implementation of cardiac arrest centers. Resuscitation (2011), doi:10.1016/j.resuscitation.2011.03.021
therefore a higher chance of a failure to initiate the pathway or driven (in part) by the greater variety of inpatient providers and when compared to out-of-hospital arrests. This disparity is likely arrests that occur in the inpatient setting remain even today.

5. Overcoming obstacles

A number of obstacles arose at each of the four centers during the establishment phase. One obstacle experienced by the majority of the developing centers was the perception by some clinicians that cardiac arrest survivors almost invariably have poor outcomes and therefore there was concern over the allocation of time and provision of resources for “futile” therapies. In several centers, groups or individuals questioned the data in support of therapeutic hypothermia. Difficulty reaching consensus about the details of the post-arrest protocol was noted by one center. In two centers, even after implementation of a “pathway”, few actually initiated the pathway in clinical practice and compliance was very poor. Finally, two centers struggled with overcoming a tendency toward “early neuroprognostication” and early withdrawal of care before there was ample time to appropriately treat the patient and later assess the potential for neurological survival.

To overcome these obstacles, centers had a variety of strategies and support systems. Support from the hospital administration of one center allowed for a “top-down” approach leading to increased hospital-wide support. Other centers developed collaborations between the directors of the cardiac intensive care unit and emergency department as a starting point. Two centers noted that individual clinicians became more supportive over time particularly when they perceived improved patient outcomes especially in terms of neurologic morbidity. The 2003 position statement from the International Liaison Committee on Resuscitation (ILCOR) and the 2005 American Heart Association statement on therapeutic hypothermia helped garner further support. Compliance with post-arrest care interventions such as therapeutic hypothermia improved significantly in three centers with the founding of a cardiac arrest consult service; the fourth center had a consult service in place from the beginning of the development of the center so it is not possible to assess the improvement percent.

Two centers note that challenges in compliance for cardiac arrests that occur in the inpatient setting remain even today when compared to out-of-hospital arrests. This disparity is likely driven (in part) by the greater variety of inpatient providers and therefore a higher chance of a failure to initiate the pathway or consult the cardiac arrest service, though this remains speculative.

The recent publication of a policy statement on the concept of regionalized care for management of post-arrest patients and the publication of the 2010 AHA guidelines with a chapter focused on post-arrest management, may mitigate obstacles for future developing centers.1,5

6. Clinical care services

Each of the cardiac arrest centers provide a series of organized clinical care services with a minimum of variation between groups. At three of the four centers, the cardiac intensive care unit (CICU) is the designated admission unit for post-arrest patients; occasionally, exception is made for various clinical reasons. The remaining center tends to manage patients with ventricular arrhythmias in the cardiac intensive care unit but those with the initial rhythm of pulseless electrical activity or asystole are typically cared for in the medical intensive care unit.

All four centers have a consult service specifically dedicated to cardiac arrest, and coverage is provided 24 h per day/7 days per week. One center provides guaranteed immediate physical presence in response to a consult, whereas the other centers provide phone consultation with the ability for physical presence in the majority of cases if necessary. At VCU, the ARCTIC attending physicians make the decision to initiate or continue therapeutic hypothermia after hospital arrival and help direct additional post-arrest care. The ARCTIC team consists of an attending, one dedicated CICU nurse practitioner, a full time nurse coordinator, and a rotating CICU fellow. The emergency department team caring for the patient stabilizes the patient and the ARCTIC team initiates or continues therapeutic hypothermia if started prior to arrival (which is usually the case) using endovascular technology. After initial stabilization, care is transferred to the CICU team which is led by one of 10 cardiologists who have all undergone intensive initial and ongoing training on post-arrest care. The nurse practitioner and coordinator provide consistency for the clinical part of the program. At the University of Pennsylvania, the cardiac arrest consult service consists of physicians and nurses trained in emergency medicine, with additional expertise in cardiac arrest and post-arrest care. The team is organized through the university’s Center for Resuscitation Science. The Post Cardiac Arrest Service at UPMC-Presbyterian hospital is a consultation service that provides 24/7 physical presence consultation and is staffed by emergency physicians with a special expertise in post-cardiac arrest care and neuroprognostication. At Beth Israel Deaconess Medical Center, the cardiac arrest consult service is currently staffed by physicians who dually practice emergency medicine and critical care medicine. All centers report excellent collaboration between the primary teams and other consultative services.

During the inpatient stay, appropriate patients in all centers receive therapeutic hypothermia for 24 h post-achievement of goal temperature. In addition, all centers provide continuous EEG monitoring for at least the first 48 h after the arrest. The timing of the initiation of EEG is variable depending on the center and is currently limited by EEG technician support. In addition to therapeutic hypothermia and EEG, the consultative services will often provide recommendations on mechanical ventilation goals as well as other post-arrest specific supports. A standing order set is provided at most centers to assist the primary admitting service in management of these patients. All centers seek to avoid early, inappropriate neuroprognostication and use multiple diagnostic adjuncts (including EEG, SSEP, MRI) in addition to the neurologic
examination to drive prognostication at approximately the 72 h time period or as clinically appropriate in some cases.10

One center (VCU) usually waits 5–7 days after the arrest before providing neuroprognostication. At discharge, one center provides a “neurological rehabilitation” program by a neurologist interested specifically in post-cardiac arrest. This is provided for patients who are generally in a cerebral performance category (CPC) class of 1–2 as opposed to those who are more profoundly debilitated. Another center evaluates patients with cognitive deficits for a traumatic brain injury rehabilitation program; others receive outpatient cardiac rehabilitation upon discharge from the hospital. One center (VCU) performs an hour long battery of neuropsychological testing at discharge and has both post discharge brain injury rehabilitation and psychological support programs for patients with deficits ranging from subtle to severe. There is also a program being developed for family members to assist in re-integration of the post arrest family member once they return home.

7. Outcomes and feedback

All four centers expressed that hospital staff and administrators view their program positively. One center was awarded a “Patient Safety Quality Improvement Award” from within their hospital system and another center received a similar award through the Society of Critical Care Medicine with the support of the hospital administration. Three centers report an increase in outside referrals specifically for cardiac arrest since the inception of the center at the respective institutions. For example, University of Pittsburgh has seen a significant increase in transfers after initiation of the center in 2007, and these cases represent the majority of patients at this center (see Fig. 1a). As another example Beth Israel Deaconess Medical Center has seen a significant increase in transfers after initiation of the center (see specific section). All four centers believe this is a necessary component in the development of a cardiac arrest center. Other models such as the one developed in Arizona (see specific section) are both community and academic-based. Three of four centers have a strong educational mission while the fourth center is currently establishing this aspect of their program. The leaders of all of the centers believe that education is an essential component to a successful center. At Penn, a week-long course, “Reinventing Resuscitation—The Future of Cardiac Arrest Care”, is offered to fourth year medical students twice a year. At the University of Pittsburgh, a small group elective, “Science of Resuscitation” is offered to fourth year medical students once per year. VCU has a dedicated Resuscitation Fellowship. Two centers (VCU/Penn) have outreach programs for the community in terms of education and support. The Center for Resuscitation Science at the University of Pennsylvania conducts a quarterly, two-day, intensive education and training institute in therapeutic hypothermia and post-arrest care, including lectures, discussion sessions, and hands-on simulation, which is attended by nurses, physicians, and other healthcare providers from around the world.

8. Research and educational mission

All four centers have a strong research mission, though only two (University of Pittsburgh and Virginia Commonwealth University) believes this is a necessary component in the development of a cardiac arrest center. Other models such as the one developed in Arizona (see specific section) are both community and academic-based. Three of four centers have a strong educational mission while the fourth center is currently establishing this aspect of their program. The leaders of all of the centers believe that education is an essential component to a successful center. At Penn, a week-long course, “Reinventing Resuscitation—The Future of Cardiac Arrest Care”, is offered to fourth year medical students twice a year. At the University of Pittsburgh, a small group elective, “Science of Resuscitation” is offered to fourth year medical students once per year. VCU has a dedicated Resuscitation Fellowship. Two centers (VCU/Penn) have outreach programs for the community in terms of education and support. The Center for Resuscitation Science at the University of Pennsylvania conducts a quarterly, two-day, intensive education and training institute in therapeutic hypothermia and post-arrest care, including lectures, discussion sessions, and hands-on simulation, which is attended by nurses, physicians, and other healthcare providers from around the world.

9. Other models

One state, Arizona, has established an entire network of hospitals classified by a governing body as “Cardiac Receiving Centers” or “Cardiac Referral Centers” after meeting minimum qualifications. The qualifications to become a receiving center include:

1) A method and protocol for therapeutic hypothermia treatment after out of hospital cardiac arrest (OHCA)
2) Primary percutaneous coronary intervention (PCI) capability
3) Capability to complete a data form following each OHCA to be sent to governing state agency
4) Evidence based termination of care protocol
5) Organ donation protocol

VCU center includes multiple hospitals and EMS systems that form an integral part of the post arrest care system. VCU provides comprehensive post-arrest management and endovascular cooling for 60–70 patients annually, approximately half of whom are referred from satellite centers and regional EMS systems.

All centers employ various modalities to track and maintain the quality of care provided by their post-arrest services. Each maintains a database of all arrests with data points including but not limited to the type of arrest, use of cardiac catheterization, therapeutic hypothermia, neurologic outcomes, and mortality. Two centers perform neuropsychological testing upon discharge and one performs three and six-month follow-up telephone calls for neurologic status testing. All systems utilize their tracking systems to continually update and improve the quality of their post-arrest pathways.

Specific quality assurance/improvement mechanisms exist at all four sites. All centers have established workgroups, which regularly review all cardiac arrest cases. Quality measures reviewed by these groups include consideration for hypothermia, achievement of hypothermia, time to goal temperature, adverse events, neurologic outcomes and mortality rates. All centers acknowledge that the post-arrest consulting physician addresses many issues surrounding quality assurance in real time. All four arrest centers keep comprehensive post cardiac arrest databases, and utilize quality data points collected to find areas for improvement.
6) Cardiopulmonary resuscitation (CPR) training for the community

A referral center must meet guidelines to emergently treat OHCA patients through stabilization methods, and arrange for transfer to a cardiac receiving center. This model allows for the establishment of quality standards across both community and academic centers and may serve as a model for more widespread implementation in the future. The data collected by the Arizona Department of Health Services can also be utilized for significant research opportunities. Currently, 34 hospitals comprise the system with upwards of 1000 post-arrest cases per year. Of note, in the state of Pennsylvania, the Department of Public Health developed statewide Advanced Life Support protocols that incorporate cardiac arrest centers by stating that post arrest patients should be transported to a cardiac arrest center, which they define as a facility that provides therapeutic hypothermia and has PCI capability, making the idea of a cardiac arrest center more attractive to local hospitals.

For quality purposes, within the matrix of 34 Resuscitation Centers in Arizona, the State Department of Health provides bi-annual data reports including total of OHCA patients seen, the percent which underwent therapeutic hypothermia, time to goal temperature, percentage of patients receiving PCI, and survival to hospital discharge stratified by presenting rhythm. Each hospital within the network also has its own internal QI program (which varies by center).

10. Conclusion

Patients who survive cardiac arrest and resuscitation are often critically ill and present significant challenges to the medical providers caring for them in the post-arrest period; these patients may benefit from being cared for in centers which have developed an expertise in treating this complex population. This paper has attempted to describe the approach of several hospitals across the United States, and may be a resource for other hospitals interested in developing their own cardiac arrest center.

Conflict of interest statement

Clifton Callaway: Grant from NIH to conduct clinical trials in cardiac arrest and trauma. Patents related to defibrillation licensed to Medtronic. Loan of equipment to conduct laboratory studies of hypothermia from Medivance.

Michael W. Donnino and Michael Cocchi: Investigator-initiated grants from the NIH, American Heart Association, and the Laerdal Medical Foundation.

Jon Rittenberger: Funding from NAEMSP/Zoll Medical EMS Resuscitation Research Fellowship, NIH KL2 funding, loaned NIRS monitors from Somanetics, and steering committee for Zoll Cool Arrest trial (no payments).

Mary Ann Peberdy: None declared.

David Gaieski: Cardiac Arrest epidemiology research support from Gaymar Industries. Loan of cooling equipment (no charge purchase orders) from Gaymar Industries and Medivance. Loan of manual compression equipment from Medtronic and Zoll.

Benjamin Abella: Research funding from NIH, American Heart Association, Doris Duke Foundation and Philips Healthcare, in-kind research support from Laerdal Medical Corporation, and speaking honoraria from Medivance Corporation.

Bently Bobrow: None declared.

Acknowledgements

We thank additional members of the National Post-Arrest Research Consortium (NPARC):

Beth Israel Deaconess Medical Center: Donna Williams RN, Shelly Calder RN, Donald Cutlip MD, Eli Gelfand MD, Justin Salciccioli, Susan Herman MD, Michael Alexander MD, Praveen Akuthota MD, Peter Zimetbaum MD.

University of Pennsylvania: Lance Becker MD, Robert Neumar MD, PhD, Daniel Kolansky MD, Barry Fuchs MD, Raina Merchant MD, Brendan G Carr MD, Gail Delfin RN, Cheryl Maguire RN, MSN, Thomas Levins RN.

University of Pittsburgh: Rene Alvarez, Alexandria Popescu, Miguel Habeych.

Virginia Commonwealth University: Joseph Ornato MD, Charlotte Roberts NP, Michelle Gossip RN, Michael Kurz MD, Harider Dhindsa MD, Renee Reid MD, Sharon Bednar, RN.

References