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Working to Improve Cardiac Arrest Survival

Hospital Best Practices

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The aim of the **SaveMiHeart** (SMH) Hospital Workgroup is to advocate for an organized, evidence-based approach to post-resuscitation care. Without quality inpatient care and key hospital-based interventions for resuscitated patients, all of the efforts on behalf of the community, 911 dispatchers, and prehospital providers will never come to fruition. To this end, we have outlined a guide to the key components of robust hospital-based post-cardiac arrest care. We have also collected resources and protocols from hospitals across the state of Michigan, and compiled links to important guidelines, best practices, and reference materials.

The SMH Hospital Workgroup believes all post-cardiac arrest patients should be ideally cared for at a regional cardiac arrest receiving center capable of "round-the-clock" coronary revascularization, temperature management, robust critical care services, and standardized neuro-prognostication, among a myriad of other support services (Table 1).

At minimum, any hospital caring for post-cardiac arrest patients should be able to provide the following:

1) Temperature Management
2) Coronary revascularization
3) Structured, multi-modal, evidence-based neurologic prognostication with deferred withdrawal of life-sustaining therapy due to neurologic reasons for at least 72 hours

For further details or assistance in formulating a protocol to implement in your hospital, please contact SaveMiHeart.

Best Practices:

I. General considerations
   a. All patients should be cared for at a regional cardiac arrest center capable of round-the-clock coronary revascularization, temperature management, robust critical care services, and standardized neuro-prognostication. [1]

II. Temperature Management
   a. If patient is following commands, then maintain strict fever suppression. [2]
   b. If not following commands, then actively induce temperature management as soon as possible. Most patients are already mildly hypothermic; the goal temperature is 32°C - 36°C for at least 24 hours with controlled rewarming at 0.25°C - 0.5°C per hour. [3]

c. Central venous or esophageal temperature monitoring are the most accurate. Bladder temperature is limited by urine output > 0.5 mL/kg/hour. Rectal temperature lags behind during acute changes and can vary up to 1.5°C. [4]
d. If core temperature > 36°C, provide up to 30 mL/kg rapid ice-cold crystalloid infusion (2-4°C) or insert endovascular cooling device. Profound myocardial stunning and/or known profound cardiomyopathy may preclude rapid crystalloid infusions. Maintain goal temperature with surface cooling device or inserted endovascular device. [5-8]
e. Use sedatives and/or neuromuscular blockade to suppress shivering. Many sedatives result in hypotension, so consider the cardiovascular state when selecting agents. Kidney injury will prolong the effects of renally cleared drugs. [9]

III. Acute coronary revascularization
   a. The post-return of pulses EKG is less sensitive for STEMI and acute coronary syndrome. [10-13]
   b. Activate the cardiac catheterization laboratory or transfer to a capable center for STEMI or "STEMI-equivalents" (shockable initial rhythm or suspicious clinical history). [14]
   c. Maintain goal temperature throughout revascularization. [15-16]

IV. Quality intensive care to minimize secondary brain injury
   a. Ventilator Management
      i. Ventilate to normocarbia in order to optimize cerebral perfusion (goal $PaCO_2$ 35-45 mmHg). [17-18]
      ii. Avoid hyperoxia in order to minimize reperfusion/free radical injury (goal SaO2 94-98%). [19-21]
   b. Hemodynamic management
      i. The post-cardiac arrest brain often has impaired cerebrovascular auto-regulation. Use vasopressors to achieve higher mean arterial pressure in order to maintain adequate cerebral perfusion (goal mean arterial pressure at least 80 mmHg). Profound myocardial stunning may preclude this higher mean arterial pressure. [17, 22-23]
   c. Glycemic control
      i. Pursue euglycemia (goal serum glucose 140-180 mg/dL). There is no evidence to support stricter control. [24]

V. AICD placement
   a. Some, but not all, patients after surviving cardiac arrest require an AICD to be placed as a secondary prevention measure.
   b. Joint ACC/AHA guidelines recommend secondary prophylaxis in survivors of cardiac arrest due to ventricular fibrillation or ventricular tachycardia. [25]
      i. It is important to evaluate patients for the underlying cause of cardiac arrest, which may also impact the patient's family.

ii. Patients who have an AICD implanted should be counseled regarding what to expect, what to avoid, and who to call with questions. Patients who experience a shock are at risk for anxiety and other psychological concerns. Counseling and support groups have been reported as helpful, especially for the young. [26-28]

VI. Structured neurologic prognostication

a. Overview

i. Patients with more than 1-2 minutes of circulatory arrest will be initially comatose

ii. Some recover and awaken – early signs of neurologic activity after return of circulation are encouraging, but the absence does not preclude recovery

iii. Many survivors fail to awaken completely. Some meet criteria for persistent vegetative state, while others achieve a minimally conscious state. Less than 10% progress to formal brain death. [29-32]

iv. A multi-modal approach is needed for neuro-prognostication. No single exam finding or clinical test provides adequate test performance characteristics. [33]

v. A practical approach is to make an initial estimate of the probability of recovery based on clinical exam. As information is added over time from clinical progression, imaging, and neurophysiological studies, this estimate is revised up or down to advise families and proxy decision makers. Daily re-evaluation is required to determine if ongoing therapy is consistent with the patient's goals of care in light of the best estimate of probability of recovery.

vi. Patients take at least 72 hours to display the trajectory of neurologic recovery. Unless clear advance directives exist, avoid premature withdrawal of life support for poor neurologic prognosis before 72 hours. [34-35]

b. Serial physical examinations

i. Daily neurologic examinations should focus on brainstem reflexes and the best motor response.

ii. Persistent absence of bilateral pupillary light reflex and corneal response for more than 72 hours is highly predictive of permanent coma. [36-37]

iii. The motor examination is much more variable and less reliable. Motor response less than flexion at 72 hours has an unacceptably high false-positive rate for predicting poor outcome. [36-37]

iv. Myoclonus is not reliable for predicting poor outcome, and must be distinguished from status myoclonus (persistent, repetitive myoclonus). Persistent status myoclonus after 24 hours is associated with poor outcomes. [36-37]

v. Physiologic response to temperature management provides additional insight into neurologic recovery. A functioning hypothalamus will attempt to regulate body temperature and oppose cooling efforts. The presence of shivering, the amount of patient heat generation (derived from the inverse average water temperature of cooling devices), and the presence of bradycardia during periods of induced hypothermia are all favorable prognostic signs. [38-40]

c. Imaging
   i. Noncontrast CT brain assesses for intracranial hemorrhage as the etiology of cardiac arrest, which is prudent prior to anti-coagulation or fibrinolytic therapy.
   ii. Brain edema is a common sequelae of anoxic injury. Early CT provides estimates of the severity of brain edema, which is inversely associated with survival and functional outcome. [42-43]
   iii. MRI can visualize subtler changes in the brain after cardiac arrest. For patients who remain comatose for several days and have indeterminate clinical or neurophysiological testing, MRI provides additional information about the extent and regions of anoxic brain injury. Extensive cortical lesions reduce expectations and enthusiasm for long-term support. However, the anatomic complexity of the brain precludes any simple quantitative relationship between the number or size of lesions and outcome. [43-45]

d. Neurophysiology
   i. The prognostic value of EEG is limited by non-specificity of findings, and dynamic changes over time. [46-47]
   ii. The greatest utility of EEG is to detect seizures and exclude non-convulsive seizures as an etiology of coma. Seizures are diagnosed clinically in 5-20% of comatose patients after cardiac arrest, and the true incidence of non-convulsive seizures is likely higher. Termination of seizures, if possible, allows for untainted assessment of the neurologic examination. [47-48]
   iii. Certain malignant EEG patterns have strong but imperfect associations with poor outcome (generalized suppression, burst-suppression associated with generalized epileptic activity, or diffuse periodic complexes on a flat background). [49]
   iv. Seizures and other malignant EEG patterns that develop shortly after ROSC should be treated aggressively with anti-epileptic therapy.
   v. Recovery of long-latency somatosensory evoked potentials (SSEP) is associated with awakening. Conversely, absence of cortical response to the N20 evoked potential is very specific for poor neurologic outcome among patients treated with therapeutic hypothermia. However, lower body temperature may prolong the window for potential recovery of SSEP. [36-37]

e. Withdrawal of Life-Sustaining Treatment
   i. In North America, it is more common to die in the hospital after resuscitation from cardiac arrest than to receive long-term care. [50]
   ii. Among resuscitated patients from out-of-hospital cardiac arrest, ~60% die after withdrawal of life-sustaining treatments due to poor predicted neurologic prognosis. Consequently, quality of life for patients that leave the hospital is generally high. [32, 51-53]

iii. Patients take at least 72 hours to display the trajectory of neurologic recovery. Unless clear advance directives exist, avoid premature withdrawal of life support for poor neurologic prognosis before 72 hours. [34-35]
iv. For patients who survive cardiac arrest, but later progress to death or formal brain death, it is appropriate to assess candidacy to become organ donors. Outcomes for transplanted organs from this population are comparable to other donors. [54]

VII. Rehabilitation services
a. Analogous to acute stroke and traumatic brain injury, early rehabilitative services offer opportunities for continued improvements after leaving the hospital. The needs of patients and caregivers are complex and range in severity depending on the degree of brain injury. [55-57] These services include:
i. Physical Therapy & Occupational Therapy
ii. Cognitive Rehabilitation
iii. Counseling and support services

VIII. Provision of Patient/Family Resources
a. There are several national organizations with state chapters in Michigan to support survivors and families. Furthermore, the University of Michigan offers a CPR training program to family members of cardiac arrest survivors.
i. UM family CPR training program
ii. Heart Rescue Project
iii. Sudden Cardiac Arrest Association: Michigan Chapter
iv. Sudden Cardiac Arrest Foundation
v. Life After Sudden Cardiac Arrest

Sample Hospital Protocols:

Garden City Hospital
William Beaumont Hospital
University of Michigan Health System
Western Michigan University
Spectrum Health Hospitals
Monroe
Borgess Hospital
Henry Ford Hospital
Monroe Regional Hospital
Sparrow Hospital
St. John Providence Health System
St. Joseph Mercy
St. Mary's

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Proposed Clinical Services for Regionalized Cardiac Arrest Centers

Neurologic Services
Induced hypothermia
Continuous EEG monitoring
Seizure management
Neurology consultation
Neurosurgical consultation
Cerebral imaging (CT, MRI, perfusion studies)
Neurophysiological testing (evoked potentials)
Prognostication services

Critical Care Services
Ventilator management
Glucose control
Goal-directed hemodynamic management

Cardiovascular Services
Cardiac catheterization / percutaneous coronary intervention
Coronary artery bypass grafting
Intra-aortic balloon pump
Cardiovascular mechanical support devices
Extra-corporeal membranous oxygenation (ECMO)
Transplant surgery consultation
Electrophysiology consultation
ICD placement

Other Services
Physical medicine and rehabilitation consultation
Physical and occupational therapy
Social work
Organ donation
Outpatient physical and occupational therapy
Outpatient neurological rehabilitation
Outpatient psychological services

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Table: Proposed Clinical Services for Regionalized Cardiac Arrest Centers.

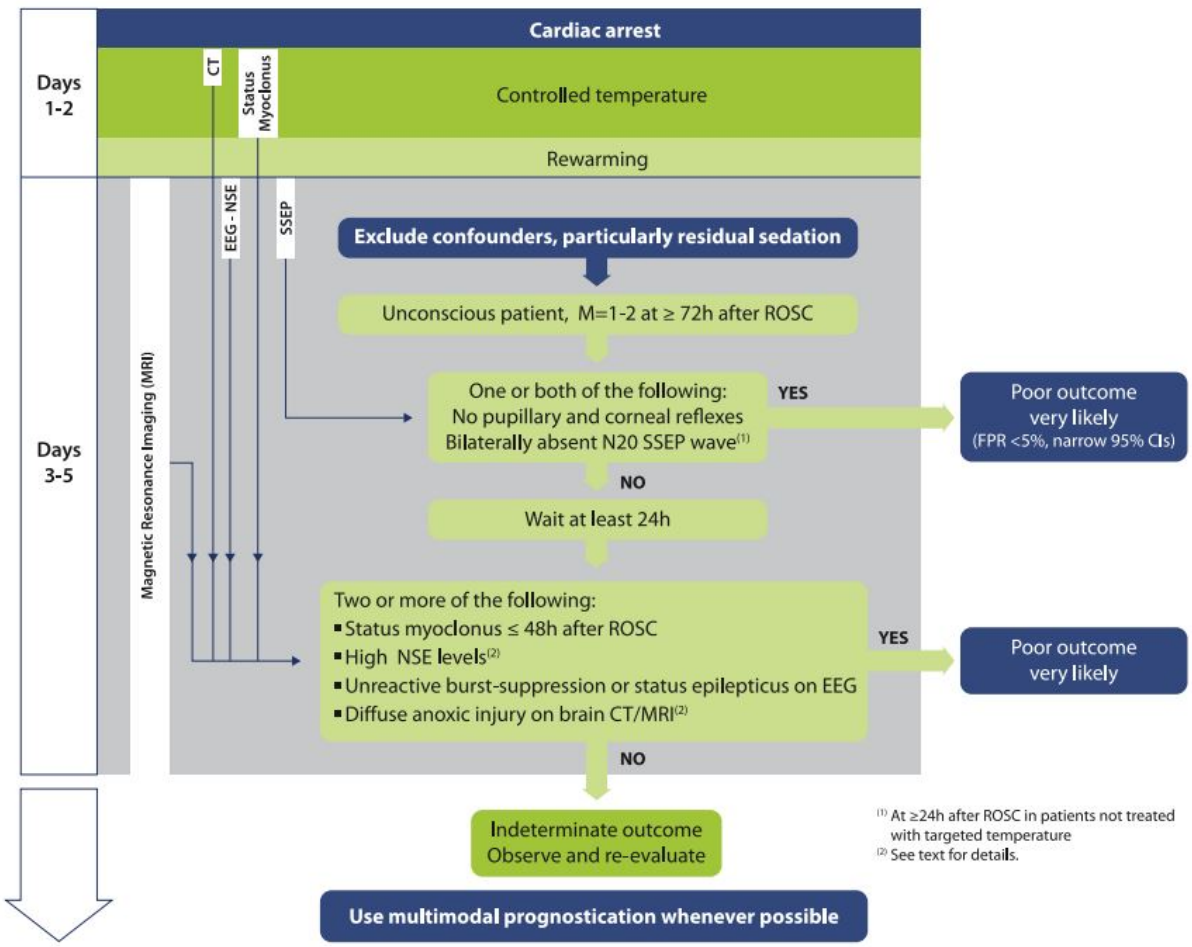

Fig. 5.2. Prognostication strategy algorithm. EEG: electroencephalography; NSE: neuron-specific enolase; SSEP: somatosensory evoked potentials; ROSC: return of spontaneous circulation; FPR: false positive rate; CI: confidence interval.

Figure: European Resuscitation Council 2015 Guidelines for neurologic prognostication after cardiac arrest.

Timing	Index	Sensitivity % [95% CI]	FPR % [95% CI]	LR+ [95% CI]	No. of patients (studies)	Quality of evidence
CPC 4–5 vs. 1–3						
At 24 h	Myoclonus	9 [7–13]	0 [0–3]	20 [1–532]	471 (2)	Moderate
	SSEPs N20 wave absent	46 [40–53]	0 [0–5]	21 [3–142]	295 (3)	Moderate
	NSE 33 μg l^{-1}	48 [42–55]	0 [0–8]	36 [2–563]	272 (1)	Moderate
At 48 h	Myoclonus	8 [5–11]	0 [0–5]	4 [0–72]	464 (2)	Low
	SSEPs N20 wave absent	46 [40–52]	0 [0–5]	11 [3–43]	328 (4)	Moderate
	NSE 33 μg l^{-1}	61 [54–68]	0 [0–8]	45 [3–709]	241 (1)	Low
	NSE 65 μg l^{-1}	62 [47–75]	0 [0–3]	129 [8–2062]	156 (1)	High
At 72 h	PLR absent	18 [15–23]	0 [0–8]	10 [1–71]	382 (2)	Low
	SSEPs N20 wave absent	46 [40–52]	0 [0–9]	18 [3–122]	293 (2)	Low
	NSE 80 μg l^{-1}	43 [29–58]	0 [0–3]	89 [6–1447]	152 (1)	High
	S-100 0.7 μg l^{-1}	42 [34–50]	0 [0–8]	30 [2–476]	207 (1)	Low
At ≤72 h	EEG voltage ≤20–21 μV	28 [23–34]	0 [0–6]	11 [1–75]	355 (2)	Low
CPC 3–5 vs. 1–2						
At 24 h	SSEPs N20 absent	37 [29–46]	0 [0–8]	27 [2–424]	159 (1)	Low

Reasonable Predictors (0% False Positive Rate & Upper Bound 95% CI < 10%): **Without** Induced Hypothermia. Sandroni C, et al. Resuscitation 2013.

Timing	Index	Sensitivity % [95% CI]	FPR % [95% CI]	LR+ [95% CI]	No. of patients with positive test (studies)	Quality of evidence
CPC 4–5 vs. 1–3						
During TH	Burst-suppression	37 [22–54]	0 [0–5]	42 [3–678]	14 (1)	Low
After RW	Burst-suppression	18 [8–34]	0 [0–5]	22 [1–379]	7 (1)	Low
Any time	SB-ESEa	42 [26–59]	0 [0–5]	49 [3–794]	16 (1)	Low
CPC 3–5 vs. 1–2						
During TH	Bilaterally absent N20	28 [22–34]	0 [0–2]	13 [5–32]	63 (4)	Moderate
During TH (at 24 h)	S-100B ≥ 0.18–0.21 mcg/L	65 [44–83]	0 [0–7]	22 [3–156]	17 (2)	Very low
After RW	Bilaterally absent N20b	42 [36–48]	0 [0–4]	15 [5–44]	109 (5)	Low
After RW	Nonreactive background	62 [53–70]	0 [0–3]	33 [7–163]	76 (3)	Low
After RW (at 48 h)	NSE ≥ 81.8 μg l−1	18 [13–25]	0 [0–2]	56 [3–909]	29 (1)	Moderate
	S-100B≥ 0.3 μg l−1	21 [9–38]	0 [0–7]	18 [1–304]	7 (1)	Very low
After RW (at 72 h)	NSE ≥ 78.9 μg l−1	48 [32–63]	0 [0–6]	52 [3–828]	21 (1)	Very low
	M ≤ 2 and no PLR and no CR	15 [7–26]	0 [0–8]	11 [1–190]	10 (1)	Very low

Reasonable Predictors (0% False Positive Rate & Upper Bound 95% CI < 10%): **With** Induced Hypothermia. Sandroni C, et al. Resuscitation 201

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Links to Guidelines, Scientific Statements, Position Papers, and Useful Materials:

Post-Cardiac Arrest Syndrome
Neumar RW, Nolan JP, Adrie C, Aibiki M, Berg RA, Böttiger BW, Callaway C, Clark RS, Geocadin RG, Jauch EC, Kern KB, Laurent I, Longstreth WT Jr, Merchant RM, Morley P, Morrison LJ, Nadkarni V, Peberdy MA, Rivers EP, Rodriguez-Nunez A, Sellke FW, Spaulding C, Sunde K, Vanden Hoek T. Post-cardiac arrest syndrome: epidemiology, pathophysiology, treatment, and prognostication. A consensus statement from the International Liaison Committee on Resuscitation (American Heart Association, Australian and New Zealand Council on Resuscitation, European Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Asia, and the Resuscitation Council of Southern Africa); the American Heart Association Emergency Cardiovascular Care Committee; the Council on Cardiovascular Surgery and Anesthesia; the Council on Cardiopulmonary, Perioperative, and Critical Care; the Council on Clinical Cardiology; and the Stroke Council. Circulation. 2008 Dec 2;118(23):2452-83.

AHA recommendations to improve survival after OHCA in the US
Neumar RW, Barnhart JM, Berg RA, Chan PS, Geocadin RG, Luepker RV, Newby LK, Sayre MR, Nichol G; American Heart Association Emergency Cardiovascular Care Committee; Council on Cardiopulmonary, Critical Care, Perioperative, and Resuscitation; Council on Clinical Cardiology; Council on Epidemiology and Prevention; Council on Quality of Care and Outcomes Research; Advocacy Coordinating Committee. Implementation strategies for improving survival after out-of-hospital cardiac arrest in the United States: consensus recommendations from the 2009 American Heart Association Cardiac Arrest Survival Summit. Circulation. 2011 Jun 21;123(24):2898-910.

Regionalized Inpatient care for OHCA
Nichol G, Aufderheide TP, Eigel B, Neumar RW, Lurie KG, Bufalino VJ, Callaway CW, Menon V, Bass RR, Abella BS, Sayre M, Dougherty CM, Racht EM, Kleinman ME, O'Connor RE, Reilly JP, Ossmann EW, Peterson E; American Heart Association Emergency Cardiovascular Care Committee; Council on Arteriosclerosis, Thrombosis, and Vascular Biology; Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation; Council on Cardiovascular Nursing; Council on Clinical Cardiology; Advocacy Committee; Council on Quality of Care and Outcomes Research. Regional systems of care for out-of-hospital cardiac arrest: A policy statement from the American Heart Association. Circulation. 2010 Feb 9;121(5):709-29.

2015 ILCOR/ECC Guidelines for post-cardiac arrest care
Callaway CW, Donnino MW, Fink EL, Geocadin RG, Golan E, Kern KB, Leary M, Meurer WJ, Peberdy MA, Thompson TM, Zimmerman JL. Part 8: **Post-Cardiac Arrest** Care: **2015** American **Heart** Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. **2015** Nov 3;132(18 Suppl 2):S465-82.

2015 AHA / ILCOR Advisory Statement on TTM

Donnino MW, Andersen LW, Berg KM, Reynolds JC, Nolan JP, Morley PT, Lang E, Cocchi MN, Xanthos T, Callaway CW, Soar J; ILCOR ALS Task Force. Circulation. 2015 Dec 22;132(25):2448-56.

Emergency Medicine Clinics of North America Review Article

Rittenberger JC, Doshi AA, Reynolds JC; Post Cardiac Arrest Service. Post-cardiac Arrest Management. Emerg Med Clin North Am. 2015 Aug;33(3):691-712.

Pittsburgh Post Cardiac Arrest Category

Rittenberger JC, Tisherman SA, Holm MB, Guyette FX, Callaway CW. An early, novel illness severity score to predict outcome after cardiac arrest. Resuscitation. 2011 Nov;82(11):1399-404.

Coppler PJ, Elmer J, Calderon L, Sabedra A, Doshi AA, Callaway CW, Rittenberger JC, Dezfulian C; Post Cardiac Arrest Service. Validation of the Pittsburgh Cardiac Arrest Category illness severity score. Resuscitation. 2015 Apr;89:86-92.

Systematic Review of Test Performance for Commonly used Predictors of Poor neurologic outcome

Sandroni C, Cavallaro F, Callaway CW, Sanna T, D'Arrigo S, Kuiper M, Della Marca G, Nolan JP. Predictors of poor neurological outcome in adult comatose survivors of cardiac arrest: a systematic review and meta-analysis. Part 1: patients not treated with therapeutic hypothermia. Resuscitation. 2013 Oct;84(10):1310-23.

Sandroni C, Cavallaro F, Callaway CW, D'Arrigo S, Sanna T, Kuiper MA, Biancone M, Della Marca G, Farcomeni A, Nolan JP. Predictors of poor neurological outcome in adult comatose survivors of cardiac arrest: a systematic review and meta-analysis. Part 2: Patients treated with therapeutic hypothermia. Resuscitation. 2013 Oct;84(10):1324-38.

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