Post-Arrest Hemodynamic Management

What is the best strategy?

David F. Gaieski, MD
Assistant Professor, Department of Emergency Medicine
University of Pennsylvania School of Medicine
Director, Clinical Center for Resuscitation
Hospital of the University of Pennsylvania
June 4th, 2009
Disclosures

- Research support, consulting and honoraria from Gaymar Industries
- Research support from Inverness Medical
Outline

- Post-Resuscitation Syndrome
- Rapidly changing hemodynamics
- Hemodynamic Optimization Strategies
- Time for a care bundle?
- The Penn Experience
- Conclusions
Negovsky—Post-Resuscitation Syndrome

• The second step in resuscitation: the treatment of the ‘post-resuscitation disease’

• Post-resuscitation disease—a new nosological entity: Its reality and significance
Post-Resuscitation Disease: Mechanisms

- Ischemia
- Reperfusion
- Reactive oxygen species (ROS)
- Inflammatory cascades
- Mitochondrial dysfunction

Hypothermia

Vascular dysfunction/hypotension
Apoptosis – organ dysfunction
Cerebral edema

EGDT
Changes with stages post-arrest

- ROSC
- Resuscitation Medications
- Venous Hyperoxia
- Target T°
- Myocardial Stunning
- Sepsis-like Syndrome
- Hemodynamic recovery, increased O2 consumption
- Rewarming Begun
- Decreased CO, diuresis

Cooling Curve

- Hour:
  - 0 5 10 15 20 25 30 35 40 45 50 55 60

- Temperature:
  - 32°C to 38.5°C

- Events:
  - 34°C
  - 32°C
During era of high dose epinephrine
- Group 1: Cumulative dose < 15 mg
- Group 2: Cumulative dose > 15 mg
- "Inadvertent catecholamine toxicity represents a further complicating factor in the production of postresuscitation disease"

**Table 4—Initial, Mean, and Maximal Hemodynamic, Oxygen Transport, and Utilization Variables During the First 6 h of the Postresuscitation Period Group II is shaded**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Initial</th>
<th>Mean</th>
<th>Maximal</th>
<th>p Value</th>
<th>Initial</th>
<th>Mean</th>
<th>Maximal</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1</td>
<td>Group 2</td>
<td>p Value</td>
<td>Group 1</td>
<td>Group 2</td>
<td>p Value</td>
<td>Group 1</td>
<td>Group 2</td>
</tr>
<tr>
<td>MAP</td>
<td>93 ± 34</td>
<td>118 ± 36</td>
<td>0.02</td>
<td>103 ± 22</td>
<td>96 ± 23</td>
<td>0.47</td>
<td>131 ± 37</td>
<td>130 ± 36</td>
</tr>
<tr>
<td>CI</td>
<td>2.6 ± 1.0</td>
<td>1.7 ± 1.0</td>
<td>0.008</td>
<td>2.9 ± 0.9</td>
<td>2.1 ± 1.1</td>
<td>0.01</td>
<td>3.6 ± 1.1</td>
<td>2.7 ± 1.3</td>
</tr>
<tr>
<td>SVRI</td>
<td>2,578 ± 1,333</td>
<td>6,434 ± 4,488</td>
<td>0.001</td>
<td>3,314 ± 2,709</td>
<td>6,160 ± 5,704</td>
<td>0.18</td>
<td>4,445 ± 3,524</td>
<td>7,494 ± 5,603</td>
</tr>
<tr>
<td>SvO₂</td>
<td>87 ± 8</td>
<td>82 ± 9</td>
<td>0.10</td>
<td>70 ± 13</td>
<td>72 ± 15</td>
<td>0.63</td>
<td>86 ± 8</td>
<td>82 ± 9</td>
</tr>
<tr>
<td>OER</td>
<td>0.12 ± 0.08</td>
<td>0.17 ± 0.09</td>
<td>0.10</td>
<td>0.29 ± 0.13</td>
<td>0.27 ± 0.15</td>
<td>0.60</td>
<td>0.36 ± 0.10</td>
<td>0.40 ± 0.16</td>
</tr>
<tr>
<td>Vo₂</td>
<td>46 ± 30</td>
<td>34 ± 23</td>
<td>0.13</td>
<td>108 ± 27</td>
<td>77 ± 48</td>
<td>0.006</td>
<td>148 ± 37</td>
<td>107 ± 63</td>
</tr>
<tr>
<td>Do₂</td>
<td>406 ± 190</td>
<td>235 ± 152</td>
<td>0.002</td>
<td>408 ± 217</td>
<td>256 ± 194</td>
<td>0.01</td>
<td>541 ± 158</td>
<td>380 ± 211</td>
</tr>
</tbody>
</table>
Venous Hyperoxia

Figure 1. The phases of $SvO_2$ during and after resuscitation from cardiac arrest. This patient received 15 min of ACLS and developed ROSC after the transition phase. After a brief hypotensive episode, the patient responded to vasopressor and fluid therapy to hemodynamic stability. Venous hyperoxia was exhibited during the post-ROSC phase.

Table 1—Initial Study Variables Obtained Within the First 5 Min After Return of Spontaneous Circulation

<table>
<thead>
<tr>
<th>Variables</th>
<th>Survivors (n = 10)</th>
<th>Nonsurvivors (n = 13)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SE</td>
<td>Mean</td>
</tr>
<tr>
<td>PCWP, mm Hg</td>
<td>26.5</td>
<td>5.0</td>
<td>28.8</td>
</tr>
<tr>
<td>MAP, mm Hg</td>
<td>104</td>
<td>9.5</td>
<td>98</td>
</tr>
<tr>
<td>CI, L/min–m²</td>
<td>2.6</td>
<td>0.4</td>
<td>1.3</td>
</tr>
<tr>
<td>SVRI, dyne/s/cm²–m²</td>
<td>3,712</td>
<td>577</td>
<td>9,457</td>
</tr>
<tr>
<td>$SvO_2$, %</td>
<td>66</td>
<td>4.0</td>
<td>69</td>
</tr>
<tr>
<td>OER (CPR), %</td>
<td>71</td>
<td>12</td>
<td>76</td>
</tr>
<tr>
<td>OER (ROSC), %</td>
<td>35</td>
<td>3.6</td>
<td>35</td>
</tr>
<tr>
<td>$VO_2$, ml/min–m²</td>
<td>108</td>
<td>9.1</td>
<td>69</td>
</tr>
<tr>
<td>$DO_2$, ml/min–m²</td>
<td>344</td>
<td>49</td>
<td>218</td>
</tr>
<tr>
<td>Epinephrine, mg†</td>
<td>11</td>
<td>4.0</td>
<td>26.4</td>
</tr>
<tr>
<td>DCA, min</td>
<td>28</td>
<td>5.3</td>
<td>36</td>
</tr>
</tbody>
</table>

*CPR, during cardiopulmonary resuscitation or ACLS
†Epinephrine, dose required for ROSC (mg)
Reversible Myocardial Dysfunction

- Median time to hemodynamic instability = 6.8 hrs after OHCA
- CI and CVP were low
- It is characterized by a low CI that is reversible in most cases within 24 h, suggesting post-resuscitation myocardial dysfunction

Dobutamine reversal of myocardial dysfunction

- Prospective, controlled animal trial
- Myocardial dysfunction post-resuscitation
- Reversed by Dobutamine infusion
- Balance O2 consumption versus O2 need
- Paying back the O2 debt
- Full recovery of this postresuscitation myocardial stunning is seen by 48 h

Myocardial dysfunction after resuscitation from cardiac arrest: an example of global myocardial stunning, Kern et al, JACC 1996; 28: 232-240
Successful Cardiopulmonary Resuscitation After Cardiac Arrest as a “Sepsis-Like” Syndrome

Christophe Adrie, MD; Minou Adib-Conquy, PhD; Ivan Laurent, MD; Mehran Monchi, MD; Christophe Vinsonneau, MD; Catherine Fitting, BS; François Fraisse, MD; A. Tuan Dinh-Xuan, MD; Pierre Carli, MD; Christian Spaulding, MD; Jean-François Dhainaut, MD; Jean-Marc Cavaillon, PhD

Background—We investigated the immunoinflammatory profile of patients successfully resuscitated after cardiac arrest, representing a model of whole-body ischemia/reperfusion syndrome.

Methods and Results—Plasma cytokine, endotoxin, and ex vivo cytokine production in whole-blood assays was assessed in 61, 35, and 11 patients, respectively. On admission, high levels of plasma interleukin (IL)-6, IL-8, IL-10, and soluble tumor necrosis factor (TNF) receptor type II could discriminate between survivors and nonsurvivors. Among nonsurvivors, the initial need for a vasopressor agent was associated with higher levels of IL-1 receptor antagonist, IL-10, and IL-6 on day 1. Plasma endotoxin was detected in 46% of the analyzed patients within the 2 first days. Endotoxin-induced TNF and IL-6 productions were dramatically impaired in these patients compared with healthy control subjects, whereas an unaltered production was observed with heat-killed *Staphylococcus aureus*. In contrast, IL-1 receptor antagonist productions were enhanced in these patients compared with healthy control subjects. The productions of T-cell–derived IL-10 and interferon-γ were also impaired in these patients. Finally, using in vitro plasma exchange between healthy control subjects and patients, we demonstrated that the endotoxin-dependent hyporeactivity was an intrinsic property of patients’ leukocytes and that an immunosuppressive activity was also present in their plasma.

Conclusions—Altogether, the high levels of circulating cytokines, the presence of endotoxin in plasma, and the dysregulated production of cytokines found in these patients recall the immunological profile found in patients with sepsis. (*Circulation*. 2002;106:562-568.)

Key Words: cardiopulmonary resuscitation ■ heart arrest ■ reperfusion ■ inflammation ■ interleukins
<table>
<thead>
<tr>
<th>Cytokines and Receptors, pg/mL</th>
<th>OHCA Patients (n=61)</th>
<th>Patients With Sepsis (n=5)</th>
<th>Healthy Volunteers (n=7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNF-α</td>
<td>16 (0–30)</td>
<td>16 (0–46)</td>
<td>0 (0–0)*</td>
</tr>
<tr>
<td>sTNFRII</td>
<td>5714 (3629–8350)</td>
<td>4000 (7021–12 656)</td>
<td>1458 (1589–3617)‡</td>
</tr>
<tr>
<td>IL-1ra</td>
<td>13 972 (1947–40 319)</td>
<td>72 897 (657–94 884)</td>
<td>46 (0–111)‡</td>
</tr>
<tr>
<td>IL-6</td>
<td>177 (53–355)</td>
<td>406 (390–4901)*</td>
<td>0 (0–0)‡</td>
</tr>
<tr>
<td>IL-8</td>
<td>67 (22–183)</td>
<td>399 (76–529)</td>
<td>0 (0–0)‡</td>
</tr>
<tr>
<td>IL-10</td>
<td>122 (41–250)</td>
<td>199 (160–1003)</td>
<td>0 (0–0)‡</td>
</tr>
<tr>
<td>RANTES</td>
<td>7035 (3892–20 369)</td>
<td>2021 (583–2184)†</td>
<td>11 957 (9527–12 817)</td>
</tr>
</tbody>
</table>

Data are median (25% to 75% quartile). OHCA patients had a plasma cytokine pattern similar to that observed in patients with sepsis.

*P<0.05, †P<0.01, and ‡P<0.001 for patients with sepsis and healthy volunteers vs OHCA patients.
MAP

- MAP = [(2 \times \text{diastolic}) + \text{systolic}] / 3
- Nagao: SBP \geq 90 \text{ mmHg} (\text{MAP} > 65)
- Bernard: MAP 90 and 100 \text{ mm Hg}
- Sunde: MAP 65-70 \text{ mmHg}

What is the right answer?

What is this based upon?
Safar: Dog model of VF arrest

- Normothermic VF of 11 minutes
- Defibrillation and controlled reperfusion
- Controlled ventilation for 20 hrs; intensive care to 96 hrs
- Control group (n=8):
  - normothermic (37.5°C)
  - Normotensive
  - Hypocapnic
- Experimental group (n=8):
  - mild hypothermia (34°C) from about 10 minutes to 12 hours
  - cerebral blood flow promotion with induced moderate HTN
  - mild hemodilution
  - Normocapnia

Improved Cerebral Resuscitation From Cardiac Arrest in Dogs With Mild Hypothermia Plus Blood Flow Promotion
Dog model of VF arrest: Results

• All 16 dogs in the protocol survived
• Control group, n=8:
  – All OPC 3 (severe disability) or 4 (coma)
• Experimental group, n=8:
  – 6/8 (75%) dogs OPC 1 (normal)
  – 1/8 (12.5%) OPC 2 (moderate disability)
  – 1/8 (12.5%) OPC 3 ($P<.001$)

## Rapidly Changing Hemodynamics

<table>
<thead>
<tr>
<th>ECHO</th>
<th>Description</th>
<th>EF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Hr</td>
<td>The LV is underfilled with hyperdynamic function</td>
<td>80%</td>
</tr>
<tr>
<td>11 Hr</td>
<td>The LV is normal in size with severe global systolic dysfunction</td>
<td>15%</td>
</tr>
<tr>
<td>29 Hr</td>
<td>The LV is normal in size with normal systolic function</td>
<td>65%</td>
</tr>
</tbody>
</table>

**How should these dynamic changes be managed clinically?**
**HEART-LUNG RESuscitation**

**I FIRST AID: OXYGENATE THE BRAIN IMMEDIATELY**

- **Airway** - Tilt head back
- **Breathe** - Inflate lungs 3-5 times, maintain head tilt

*For physicians only*

**II START SPONTANEOUS CIRCULATION**

**Drugs** - Epinephrine: 1.0 mg (1.0 cc of 1:1000) I.V. or 0.3 mg INTRACARDIAC.

Sodium bicarbonate: Approximately 375-750 cc (1/2 dose in children) I.V.

**III SUPPORT RECOVERY**

- **Gauge**
- **Hypothermia**
- **Intensive Care**

*Evaluate and treat cause of arrest*

Start within 30 minutes if no sign of CNS recovery

**Support Ventilation:** Tracheotomy, prolonged controlled ventilation, gastric tube as necessary

**Support Circulation**

**Control Convulsions**

**Monitor**

---

Peter Safar:
Journal of the Iowa Medical Society,
November, 1964

**ABCs**
Historically, evidence for and against Hemodynamic Optimization Strategies

• Shoemaker:
  – Pre-operative hemodynamic optimization of high-risk cardiac surgery patients
  – RESULTS:
    • Normal MAP, CVP, UOP: Mortality 33%
    • Supranormal $DO_2$, $VO_2$, CI: Mortality 4%

•Gattinoni:
  – ICU enrollment
  – Normal CI vs. Supranormal CI vs. SvO$_2$ Optimization
  – RESULTS:
    • No difference in mortality at ICU discharge and at 6 months

• Rivers:
  – ED enrollment of severe sepsis, septic shock patients
  – Algorithmic care optimizing CVP, MAP, ScvO2
  – RESULTS:
    • 16% absolute mortality reduction
The influence of early hemodynamic optimization on biomarker patterns of severe sepsis and septic shock*

Emanuel P. Rivers, MD, MPH; James A. Kruse, MD; Gordon Jacobsen, MS; Kant Shah, MD; Manisha Loomba, MD; Ronny Otero, MD; Ed W. Childs, MD

*CRIT CARE MED. 2007
Delivery vs. Consumption

\[ \text{VO}_2 \quad \text{O2 debt} \]

Supply dependent

Supply independent

\[ \text{DO}_2 \]

Must be repaid post-resuscitation
AHA Post-Arrest Recommendations

2005 AHA guidelines recommend hemodynamic optimization of patients post-arrest:

- Invasive monitoring
- Titrate volume infusion to CVP
- Titrate vasoactive, inotropic, and vasodilator drugs as needed to support blood pressure, cardiac index, and systemic perfusion
Are people applying these concepts to post-arrest patients?

- Is anyone doing this?
- Literature survey looking for studies using a goal-directed hemodynamic optimization strategy post-arrest
- Inclusion criteria:
  - a clearly defined intervention consisting of a structured cardiovascular resuscitation protocol
  - a control group that received standard of care therapy
- NO studies found where the AHA recommendations were being followed

Jones, Trceziak, Shapiro: Resuscitation, 2007
Post resuscitation care
Time for a care bundle?

• Editorial examining whether it is time for a care bundle for systematic delivery of post-resuscitation care

• Proposed bundle elements include:
  – Therapeutic hypothermia
  – Early percutaneous coronary intervention
  – Hemodynamic optimization
  – Other adjuncts to intensive care

• Question—Do bundles improve care?

• For example, surviving sepsis campaign’s bundles:
  – Do we believe the evidence for each component?
  – Are bundles revised with changing evidence?
  – Is the evidence objectively analyzed?

This study was not included because there is no control group.

However, there is a clearly defined hemodynamic resuscitation strategy:
- SBP $\geq$ 90 mmHg
- CI $\geq$ 2.2L/min/m$^2$
- Systemic O$_2$ Delivery $\geq$ 520mL/min/m$^2$
- Oxygen Extraction Ratio between 20-30
- Hemoglobin $\geq$ 12 g/dL

Nagao et al, CardioCerebral Resuscitation
JACC 2000; 36: 776-83
Bernard’s Landmark Trial

- What hemodynamic strategy was pursued?
- “The mean arterial blood pressure was maintained between 90 and 100 mm Hg by infusion of epinephrine or nitroglycerin, as indicated.”
- “After the admission of the patient to the intensive care unit, a pulmonary-artery catheter was inserted, and hemodynamic data were obtained 1 to 3, 6, 12, 18, and 24 hours after arrival at the hospital.”

Treatment of comatose survivors…
Bernard SA et al. NEJM. 2002; 346: 557-563
## Table 2. Physiological and Hemodynamic Values.*

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>TREATMENT GROUP</th>
<th>ADMISSION TO ED</th>
<th>ADMISSION TO ICU</th>
<th>6 HR</th>
<th>12 HR</th>
<th>18 HR</th>
<th>24 HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td></td>
<td>43</td>
<td>39</td>
<td>39</td>
<td>39</td>
<td>39</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Hypothermia</td>
<td>34</td>
<td>33</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Normothermia</td>
<td>34</td>
<td>33</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>31</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hypothermia</td>
<td>35.0±1.18</td>
<td>33.3±0.98†</td>
<td>32.7±1.19†</td>
<td>33.1±0.89†</td>
<td>36.0±1.24†</td>
<td>37.4±0.85†</td>
</tr>
<tr>
<td></td>
<td>Normothermia</td>
<td>35.5±0.90</td>
<td>36.0±0.76†</td>
<td>37.1±0.75</td>
<td>37.4±0.58†</td>
<td>37.3±0.56†</td>
<td>37.3±0.59†</td>
</tr>
<tr>
<td></td>
<td>P value‡</td>
<td>0.02</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.60</td>
</tr>
<tr>
<td>Mean arterial blood pressure</td>
<td></td>
<td>90.4±18.89</td>
<td>108.7±20.89†</td>
<td>97.0±14.92</td>
<td>89.5±13.16</td>
<td>88.8±9.17</td>
<td>89.1±12.9</td>
</tr>
<tr>
<td>(mm Hg)</td>
<td>Hypothermia</td>
<td>87.2±21.46</td>
<td>94.4±18.80</td>
<td>92.2±13.00</td>
<td>90.8±14.16</td>
<td>91.3±12.96</td>
<td>92.1±11.76</td>
</tr>
<tr>
<td></td>
<td>Normothermia</td>
<td>0.51</td>
<td>0.02</td>
<td>0.16</td>
<td>0.82†</td>
<td>0.38</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>P value‡</td>
<td>0.51</td>
<td>0.02</td>
<td>0.16</td>
<td>0.82†</td>
<td>0.38</td>
<td>0.24</td>
</tr>
<tr>
<td>Pulse (per minute)</td>
<td></td>
<td>97±22.5</td>
<td>82±21.6§</td>
<td>72±17.1§</td>
<td>70±17.6</td>
<td>80±18.2§</td>
<td>89±17.9†</td>
</tr>
<tr>
<td></td>
<td>Hypothermia</td>
<td>105±30.4</td>
<td>100±17.0</td>
<td>100±21.9</td>
<td>94±17.9</td>
<td>97±16.8</td>
<td>99±15.5</td>
</tr>
<tr>
<td></td>
<td>Normothermia</td>
<td>0.18</td>
<td>0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>P value‡</td>
<td>0.18</td>
<td>0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.02</td>
</tr>
<tr>
<td>Cardiac index (liters/min/m²</td>
<td></td>
<td>2.0</td>
<td>2.1</td>
<td>2.4</td>
<td>2.9</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>of body-surface area)¶</td>
<td>Hypothermia</td>
<td>(1.2–4.4)</td>
<td>(0.9–4.2)</td>
<td>(0.8–4.9)</td>
<td>(1.5–7.3)§</td>
<td>(1.6–6.8)§</td>
<td>(1.6–6.8)§</td>
</tr>
<tr>
<td></td>
<td>Normothermia</td>
<td>2.6</td>
<td>2.7</td>
<td>3.2</td>
<td>3.3</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>P value‡</td>
<td>(1.4–5.5)</td>
<td>(1.4–6.1)</td>
<td>(1.2–6.1)</td>
<td>(1.5–5.8)</td>
<td>(1.8–5.7)</td>
<td>(1.8–5.7)</td>
</tr>
<tr>
<td>Systemic vascular resistance</td>
<td></td>
<td>2213</td>
<td>1808</td>
<td>1564</td>
<td>1198</td>
<td>987</td>
<td>581</td>
</tr>
<tr>
<td>(dyn·sec·cm⁻²)¶</td>
<td>Hypothermia</td>
<td>(599–4645)</td>
<td>(836–4531)</td>
<td>(439–4280)</td>
<td>(402–2833)§</td>
<td>(551–2500)§</td>
<td>(551–2500)§</td>
</tr>
<tr>
<td></td>
<td>Normothermia</td>
<td>1356</td>
<td>1278.5</td>
<td>1056</td>
<td>964</td>
<td>1072</td>
<td>1072</td>
</tr>
</tbody>
</table>
Studies that employ some of a hemodynamic optimization protocol

- Since the publication of Bernard and HACA studies several implementation studies have incorporated components of hemodynamic optimization:
  - Oddo et al, CCM, 2006
    - MAP: 90-100 mm Hg
    - Early PCI
    - IABP
    - PA Catheter
  - Sunde et al, Resuscitation, 2007
Table 4
Cardiac index and systemic vascular resistance index (SVRI) during the first 32 h in the intensive care unit (ICU).

<table>
<thead>
<tr>
<th></th>
<th>Cardiac index (l/min/m²)</th>
<th>SVRI (dyn s/cm²/m²)</th>
<th>Central venous oxygen saturation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At 4 h in ICU*</td>
<td>2.1 (1.1–3.8) (n = 22)</td>
<td>1990 (1260–4200)</td>
<td>69 (56–85)</td>
</tr>
<tr>
<td>At 8 h in ICU*</td>
<td>2.2 (1.6–4.2) (n = 23)</td>
<td>2100 (800–3300)</td>
<td>76 (57–85)</td>
</tr>
<tr>
<td>At 12 h in ICU*</td>
<td>2.3 (1.0–3.6) (n = 25)</td>
<td>1785 (1163–4975)</td>
<td>75.5 (63–87)</td>
</tr>
<tr>
<td>At 16 h in ICU*</td>
<td>2.6 (1.1–4.3) (n = 27)</td>
<td>1650 (645–3520)</td>
<td>77 (61–83)</td>
</tr>
<tr>
<td>At 20 h in ICU*</td>
<td>2.6 (1.8–3.9) (n = 27)</td>
<td>1540 (980–3110)</td>
<td>77 (65–86)</td>
</tr>
<tr>
<td>At 24 h in ICU*</td>
<td>2.8 (1.7–5.5) (n = 28)</td>
<td>1500 (580–2810)</td>
<td>75 (63–85)</td>
</tr>
<tr>
<td>At 28 h in ICU*</td>
<td>3.15 (2.0–5.4) (n = 26)</td>
<td>1400 (860–2660)</td>
<td>79.5 (65–88)</td>
</tr>
<tr>
<td>At 32 h in ICU*</td>
<td>3.3 (2.2–5.7) (n = 24)</td>
<td>1250 (740–1860)</td>
<td>74 (55–85)</td>
</tr>
</tbody>
</table>

*Median values (minimum–maximum).
How do we apply this knowledge and a hemodynamic optimization strategy to patients who have ROSC after OHCA?
Aspects of Post-Resuscitation Care Bundle

- STEMI $\rightarrow$ Early PCI
- Therapeutic Hypothermia
- Early Hemodynamic Optimization
- Hyperglycemia $\rightarrow$ Glucose Management Protocol
- ALI/ARDS $\rightarrow$ Low Stretch Protocol
- Antibiotic, GI, DVT Prophylaxis
- Assessment for Relative Adrenal Insufficiency or HPA Dysfunction
Post-Cardiac Arrest Early Goal-Directed Therapy

Who selects this?
- Unarrested patient with:
  - Pulseless < 60 min
  - GCS Motor score < 6
  - Not DNR or DNI status
  - NPO for > 6 hours
- If pregnant consult Obstetrical
- Notify ICN Coordinator for ICU bed and EEG fellow for EEG

Getting Started
- STAT ECG, echocardiogram, and cardiology consult
- STAT head CT
- Insert arterial pressure monitoring line in radial or femoral artery
- Initiate therapeutic hypothermia if indicated (after arterial line)
- Insert fentanyl, IVF in escalation or internal med

< 80
- MAP

> 80
- CVP > 8

< 80
- MAP

> 100
- CVP > 8

80-100
- Consider lower goal if ACS, CHF, Shock

ScvO2 = 65%

Yes
- If evidence of shock is present:
  - Optimize CVP if not already done (up to 20)
  - Transfuse PRBC’s if hemoglobin ≤ 10 mg/dl
  - Dobutamine if not already initiated
  - Consider PA Cath if CVP>15 or escalating vasoressors

No
- ScvO2 ≤ 65% w/ shock?

Yes
- Re-evaluate to achieve goal
- Consider IABP

No
- MAP, CVP, ScvO2 goals achieved
- Monitor serial lactate to rule out inadequate organ perfusion

* ACS=Acute coronary syndrome

Updated 5/16/06
Early goal-directed hemodynamic optimization combined with therapeutic hypothermia in comatose survivors of out-of-hospital cardiac arrest

• Feasibility study
• Hypothesis
  “We can implement early goal-directed hemodynamic optimization while inducing TH w/o negatively impacting on time to target T”
• Analyzed first 18 patients since start of TH
• Versus 18 historic controls from 2001-2005
• Examined differences in
  – Volume resuscitation
  – Vasoactive drug use
  – Mortality
  – Good neurologic outcomes

Gaieski et al. Resuscitation, 2009; 80: 418-424
## GDR Endpoints Over Time

<table>
<thead>
<tr>
<th>Resuscitation End-Point (hr)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVP ≥ 8 ≤ 20 mmHg</td>
<td>77.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>81.3</td>
</tr>
<tr>
<td>MAP 80-100 mmHg</td>
<td>50.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>83.3</td>
</tr>
<tr>
<td>ScvO2 &gt; 65</td>
<td>83.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>93.8</td>
</tr>
<tr>
<td>Target Temp 32-34°C</td>
<td>5.6</td>
<td>11.1</td>
<td>44.4</td>
<td>55.6</td>
<td>61.1</td>
<td>66.7</td>
<td>77.8</td>
</tr>
</tbody>
</table>

- **Intravenous Fluid Boluses**
- **Vasoactive Medications**
- **Inotropic Agents and Blood**
- **4°C Chilled Saline; Cooling Wraps**
<table>
<thead>
<tr>
<th></th>
<th>MAP</th>
<th>CVP</th>
<th>ScvO2</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour</td>
<td>84</td>
<td>6</td>
<td>78</td>
<td>3800</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3300+</td>
</tr>
<tr>
<td>ED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 hours</td>
<td>75</td>
<td>17</td>
<td>87</td>
<td>5550</td>
<td>1400</td>
</tr>
<tr>
<td>12 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4130+</td>
</tr>
<tr>
<td>Balance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hours</td>
<td>96</td>
<td>7</td>
<td>87</td>
<td>13546</td>
<td>6410</td>
</tr>
<tr>
<td>24 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7136+</td>
</tr>
<tr>
<td>Balance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

20 yo male, witnessed arrest, no bystander CPR
asystole first rhythm on monitor
ED ongoing CPR, ROSC @ minute 21
Dobutamine started @ hour 12
<table>
<thead>
<tr>
<th>ECHO</th>
<th>Description</th>
<th>EF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Hr</td>
<td>The LV is normal in size with moderate global systolic dysfunction</td>
<td>40-45%</td>
</tr>
<tr>
<td>12 Hr</td>
<td>The LV is mildly dilated with moderate global systolic dysfunction</td>
<td>40%</td>
</tr>
<tr>
<td>32 Hr</td>
<td>The LV is normal in size with normal systolic function</td>
<td>60%</td>
</tr>
</tbody>
</table>
HUP Data

Survival to discharge

- Normothermia: 22%
- Hypothermia: 51%

87% Neurologically intact

Bernard’s pilot study 26% vs 49%
Conclusions

- Multiple studies demonstrate that treatment of Post-Resuscitation Syndrome improves outcomes
- Implementation of Early Hemodynamic Optimization Strategy in the ED while inducing therapeutic hypothermia is feasible
- Further understanding of post-arrest hemodynamic changes is needed
- Optimal Post-Resuscitation Bundle not yet defined
Center for Resuscitation Science

Lance Becker
Bob Neumar
Vinay Nadkami
Dave Gaieski
Munish Goyal
Raina Merchant
Ben Abella
Roger Band
Brendan Carr
Bob Berg

www.skypic.com