The Role of the Cath Lab in the Treatment of Cardiac Arrest

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Tucson, Arizona
Potential Conflicts of Interest.

I am a member of two separate Science Advisory Boards:
- PhysioControl
- Zoll Medical

Karl B. Kern, MD
The Role of the Cath Lab in the Treatment of Cardiac Arrest

- Post Resuscitated Cardiac Arrest Patient
- Cardiac Arrest in the Cath Lab
- Refractory Cardiac Arrest Patient
Coronary Angiography in the Resuscitated Patient

- 1990’s
  - Can be Done!

- “Safe” and “Helpful”
  - 70% post CA pts with CAD
  - ECG findings/Peri-Arrest Hx not very helpful to identify those with an acutely occluded coronary\n
Spaulding et al. NEJM 1997;336:1629
Current Outcomes From OOH CA

Number of Patients

100 pts

Δ = 60%

40 pts

Δ = 75%

10 pts

Δ = 30%

7 pts

Largest drop off occurs in hospital, where 75% of those initially resuscitated die.
Can Anything Be Done About these Post Resuscitation Deaths?

What’s the Role of the Cath Lab?
Control period (1996-98)
68 patients admitted to ED

10 excluded
died before
ICU admission

58 patients admitted to ICU

18 (31%) patients survived
9 CPC 1
6 CPC 2
2 CPC 3
1 CPC 4

15 (26%) patients with
one-year survival

Intervention period (2003-2005)
69 patients admitted to ED

8 excluded
died before
ICU admission

61 patients admitted to ICU

34 (56%) patients survived
31 CPC 1
3 CPC 2

34 (56%) patients with
one-year survival
Early Cardiac Catheterization and PCI After Resuscitation from Cardiac Arrest

- Who should go to the Cath Lab?
- When should they go?
- Does it Really Improve Outcome?
## Survival Post Cardiac Arrest After Early PCI

<table>
<thead>
<tr>
<th>Author/Date (19 studies)</th>
<th>Surv to DC</th>
<th>Good Neuro among Surv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kahn 1995</td>
<td>6/11</td>
<td>4/6</td>
</tr>
<tr>
<td>Spaulding 1997</td>
<td>32/84</td>
<td>30/32</td>
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<tr>
<td>Lin 1998</td>
<td>9/10</td>
<td>NA</td>
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<tr>
<td>Bulut 2000</td>
<td>4/10</td>
<td>NA</td>
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<tr>
<td>McCollough 2002</td>
<td>22/54</td>
<td>14/22</td>
</tr>
<tr>
<td>Borger van der Berg 2003</td>
<td>39/42</td>
<td>NA</td>
</tr>
<tr>
<td>Keelan 2003</td>
<td>11/15</td>
<td>9/11</td>
</tr>
<tr>
<td>Bendz 2004</td>
<td>29/40</td>
<td>NA</td>
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<tr>
<td>Quintero-Moran 2006</td>
<td>18/27</td>
<td>NA</td>
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<tr>
<td>Gorjup 2007</td>
<td>90/135</td>
<td>72/90</td>
</tr>
<tr>
<td>Garot 2007</td>
<td>102/186</td>
<td>88/102</td>
</tr>
<tr>
<td>Richling 2007</td>
<td>24/46</td>
<td>22/24</td>
</tr>
<tr>
<td>Markusohn 2007</td>
<td>19/25</td>
<td>17/19</td>
</tr>
<tr>
<td>Werling 2007</td>
<td>9/13</td>
<td>NA</td>
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<td>Pleskot 2008</td>
<td>14/20</td>
<td>11/14</td>
</tr>
<tr>
<td>Hosmane 2009</td>
<td>63/98</td>
<td>58/63</td>
</tr>
<tr>
<td>Anyfantakis 2009</td>
<td>35/72</td>
<td>33/35</td>
</tr>
<tr>
<td>Reynolds 2009</td>
<td>52/96</td>
<td>NA</td>
</tr>
<tr>
<td>Lettieri 2009</td>
<td>77/99</td>
<td>67/77</td>
</tr>
</tbody>
</table>

**Totals:** n= **1,083 pts**  655/1083 (60%)  425/495 (86%)*

- Includes both conscious and comatose pts upon arrival at the cath lab

**Non-randomized Case Series**

**Summary (Not Meta-analysis)**

**No MTH**
What If Emergent PCI is combined with Therapeutic Hypothermia Post Cardiac Arrest?
## Survival Post Cardiac Arrest After Early PCI & MTH

### Author/Date (25 studies)

<table>
<thead>
<tr>
<th>Study</th>
<th>Surv to DC</th>
<th>Good Neuro among Surv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hovdenes 2007</td>
<td>41/50</td>
<td>34/41</td>
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<td>Richling 2007</td>
<td>24/46</td>
<td>22/24</td>
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<tr>
<td>Knafelj 2007</td>
<td>30/40</td>
<td>22/30</td>
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<td>Wolfrum 2008</td>
<td>12/16</td>
<td>11/12</td>
</tr>
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<td>Peels 2008</td>
<td>22/44</td>
<td>NA</td>
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<tr>
<td>Schefold 2009</td>
<td>NA</td>
<td>19/31</td>
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<tr>
<td>Reynolds 2009</td>
<td>52/96</td>
<td>NA</td>
</tr>
<tr>
<td>Nielsen 2009</td>
<td>303/479</td>
<td>278/303</td>
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<tr>
<td>Batista 2010</td>
<td>8/20</td>
<td>6/8</td>
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<td>Dumas 2010</td>
<td>171/435</td>
<td>160/171</td>
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<tr>
<td>Koeth 2010</td>
<td>114/143</td>
<td>NA</td>
</tr>
<tr>
<td>Stub 2011</td>
<td>52/81</td>
<td>46/52</td>
</tr>
<tr>
<td>Laish-Farkash 2011</td>
<td>69/110</td>
<td>59/69</td>
</tr>
<tr>
<td>Tomte 2011</td>
<td>140/252</td>
<td>132/140</td>
</tr>
<tr>
<td>Radsel 2011</td>
<td>154/212</td>
<td>128/154</td>
</tr>
<tr>
<td>Mooney 2011</td>
<td>78/140</td>
<td>72/78</td>
</tr>
<tr>
<td>Cronier 2011</td>
<td>60/111</td>
<td>54/60</td>
</tr>
<tr>
<td>Grasner 2011</td>
<td>143/183</td>
<td>118/143</td>
</tr>
<tr>
<td>Bro-Jeppesen 2012</td>
<td>129/198</td>
<td>127/129</td>
</tr>
<tr>
<td>Zanuttini 2012</td>
<td>29/48</td>
<td>NA</td>
</tr>
<tr>
<td>Liu 2012</td>
<td>36/81</td>
<td>NA</td>
</tr>
<tr>
<td>Nanjayya 2012</td>
<td>18/35</td>
<td>14/18</td>
</tr>
<tr>
<td>Strote 2012</td>
<td>44/61</td>
<td>34/44</td>
</tr>
<tr>
<td>Waldo 2013</td>
<td>57/84</td>
<td>NA</td>
</tr>
<tr>
<td>Callaway 2014</td>
<td>495/765</td>
<td>413/495</td>
</tr>
</tbody>
</table>

**Totals:** n = 3,640 pts  
2235/3640 (61%)  
1727/1978 (87%)#
44 Clinical Cohort Studies

- 4,723 patients
- 61% survival to Hosp DC
- 87% of survivors have good neurological function

Nearly “60/90” Club
Who Should Go to the Cath Lab Post Resuscitation?

Patients resuscitated from OHCA Associated with a STEMI

Patients resuscitated from OHCA Without ST Elevation
<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>All medical and paramedical personnel caring for a patient with suspected myocardial infarction must have access to defibrillation equipment and be trained in cardiac life support.</td>
<td>I</td>
<td>C</td>
<td>-</td>
</tr>
<tr>
<td>It is recommended to initiate ECG monitoring at the point of FMC in all patients with suspected myocardial infarction.</td>
<td>I</td>
<td>C</td>
<td>-</td>
</tr>
<tr>
<td>Therapeutic hypothermia is indicated early after resuscitation of cardiac arrest patients who are comatose or in deep sedation.</td>
<td>I</td>
<td>B</td>
<td>34–36</td>
</tr>
<tr>
<td>Immediate angiography with a view to primary PCI is recommended in patients with resuscitated cardiac arrest whose ECG shows STEMI.</td>
<td>I</td>
<td>B</td>
<td>31–33</td>
</tr>
<tr>
<td>Immediate angiography with a view to primary PCI should be considered in survivors of cardiac arrest without diagnostic ECG ST-segment elevation but with a high suspicion of ongoing infarction.</td>
<td>IIa</td>
<td>B</td>
<td>31, 33</td>
</tr>
</tbody>
</table>
Therapeutic hypothermia should be started as soon as possible in comatose patients with STEMI and out-of-hospital cardiac arrest caused by VF or pulseless VT, including patients who undergo primary PCI.

Immediate angiography and PCI when indicated should be performed in resuscitated out-of-hospital cardiac arrest patients whose initial ECG shows STEMI.
Who Should Go to the Cath Lab Post Resuscitation?

Patients resuscitated from OHCA Associated with a STEMI

Patients resuscitated from OHCA Without ST Elevation
This Man Was Dead.

He Isn’t Anymore.

How Science Is Bringing More Heart-Attack Victims Back To Life

Brian Duffield, patient of Dr. Kern’s at the University of Arizona Sarver Heart Center treated with all three aspects of Cardiocerebral Resuscitation
Initial EKG in Emergency Department
Post Resuscitation from OOH VFCA
Clinical Data for Those without ST Elevation Post Resuscitation
INTCAR-Cardiology
Cardiac Arrest Registry
754 Cardiac Arrest Patients

- 172 PEA
- 120 Asystole
- 435 VT/VFib
- 27 Unknown Initial Rhythm

156 STEMI

10 No TH, or missing STEMI info

269 Patients with VT/VFib and no STEMI

147 No Early CC

122 Early CC

41 Late CC

106 No CC

82 No PCI

40 PCI

25 No PCI

16 PCI

Hollenbeck (Kern). Resuscitation 2014;
Culprit Lesion Found in Pts without ST Elevation

- Early Cath: 32% (39/122)
- Late Cath: 39% (16/41)

Ave = 34%
p = 0.54
Acute Culprit Vessel Occlusion Found in Pts without ST Elevation

- Early Cath: 82% (32/39)
- Late Cath: 75% (12/16)

$p = 0.38$
Survival to DC Among Pts without ST Elevation

- Early Cath: 66% (80/122)
- No Early Cath: 49% (71/147)

p = 0.017
No ST Elevation but Acutely Occluded Coronary at Angiography Post Arrest

<table>
<thead>
<tr>
<th>Study</th>
<th>Count/Total</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>Spaulding 1997</td>
<td>9/85</td>
<td>11%</td>
</tr>
<tr>
<td>Anyfantakis 2009</td>
<td>8/44</td>
<td>17%</td>
</tr>
<tr>
<td>Radsel 2011</td>
<td>20/54</td>
<td>36%</td>
</tr>
<tr>
<td>Gupta 2014</td>
<td>891/2775</td>
<td>32%</td>
</tr>
<tr>
<td>Hollenbeck 2014</td>
<td>44/163</td>
<td>27%</td>
</tr>
<tr>
<td><strong>SUMMARY:</strong></td>
<td><strong>972/3121</strong></td>
<td><strong>31%</strong></td>
</tr>
</tbody>
</table>
What Proportion is Enough?

1:1?
1:2?
1:3?
1:4?
1:5?

Is 1:3 Enough?
Because that’s what it is!
Early Cardiac Catheterization and PCI After Resuscitation from Cardiac Arrest

- Who should go to the Cath Lab?
- When should they go?
- Does it Really Improve Outcome?
What’s the Real Purpose of Catheterization Post Arrest?

- Salvage Myocardium
  - Preserve LV Function
  - Prevent Recurrent Cardiac Arrest

- Improve Favorable Long-Term Survival
  - Neurologically-intact survival!
What Accomplishes That Best?

Early Emergent Catheterization and PCI

Or

Late “Elective” Catheterization and PCI
After Neurological Status is Known
If reperfusion is to be done... should be done early

Δ = 159%;

• <90 min mortality rate 2.9%
• >150 min mortality rate 7.5%
What Do You Find with Early Coronary Angiography Among Resuscitated Cardiac Arrest Patients?
Culprit Vessel Identified

- n = 417

Culprit Vessel

- n = 222

- LAD: 47%
- LCX: 20%
- RCA: 33%

p < 0.001
Culprit Vessel Occluded

- 85% Occluded
- 15% Not Occluded
Culprit Vessel Occluded

- Occluded: 7%
- Not Occl: 93%

STEMI
- Occluded: 31%
- Not Occl: 69%
Early Cardiac Catheterization and PCI After Resuscitation from Cardiac Arrest

- Who should go to the Cath Lab?
- When should they go?
- Does it Really Improve Outcome?
The Data in 2014

- No randomized, controlled studies (yet)

- Lots of cohort: “Before and After” evidence
  - Nearly 5,000 patients in literature
  - Very consistent:
    - 60% survival to discharge
    - 87% of survivors have good neuro function
If an OOH CA victim is fortunate enough to be resuscitated…

They deserve the best chance for a good long-term outcome, including not only independent neurological functioning but also preserved left ventricular function.
The Role of the Cath Lab in the Treatment of Cardiac Arrest

- Post Resuscitated Cardiac Arrest Patient
- Cardiac Arrest in the Cath Lab
- Refractory Cardiac Arrest Patient
Cardiac Arrest in the Cath Lab

- Cardiac Arrest in Cath Lab:
  - 1.3% with PCI, but increases with co-morbidities
    - 6X if pt in Shock; 10X if pt is moribund

- Rhythm:
  - VT/VF = 64%
  - Brady = 32%
  - PEA = 4%

- Not Benign: 60% dead within 24 hours!
Coronary Angiogram During Manual Chest Compressions

2013;369:1047-1054
Manual Chest Compressions in the Cath Lab

- **Difficult to Perform:**
  - Limited space at the cath table
  - Over reaching or stretching
  - Table itself unstable in the “working” position
  - May require lengthy periods of compressions

- **Extensive radiation exposure to the rescuer**
  - Hands in the beam, overall exposure high
Mechanical CPR:
Better Alternative to Manual CPR in the Cath Lab
Mechanical CPR During PCI

- **Positives:**
  - Uninterrupted CC- No fatigue or changing rescuers
  - No hands in beam (radiation exposure)
  - Less crowded at the cath table
  - Better compressions

- **Challenges:**
  - Limited views due to the mechanical device
    - Piston (LUCAS)
    - Hardware in the baseboard (AutoPulse)
New AHA 2010 Guidelines on resuscitation in the cath lab

The Problem:

“Although high-quality chest compressions improve the chance of successful resuscitation and survival, it is difficult to perform effective, high-quality chest compressions during PCI. “

AHA Page S849: Part 12. Cardiac arrest in special circumstances
2010 AHA class IIa recommendation for mechanical CPR during PCI

The solution:

‘Mechanical chest compression devices have been used successfully in an animal model and adult humans to provide maintenance of circulation in cardiac arrest while continuing a percutaneous coronary procedure. It is reasonable to use mechanical CPR during PCI (Class IIa, LOE C). “

AHA Page S849: Part 12. Cardiac arrest in special circumstances
“The mood in the cath lab was calm at all times despite the ongoing VF. This is quite contrary to what usually happens in such situations when manual compressions are used.”—Dr. Olivecrona, Lund, Sweden
LUCAS is designed with the cath lab in mind.

A radiotranslucent Back Plate in carbon fibre.
LUCAS allows for most projections
Enables life-saving PCI during CPR
Mechanical CPR in the Cardiac Catheterization Laboratory

- N = 43 pts
  - All suffered CA in the CCL
  - 5 had spontaneous myocardial rupture with their MI
    - All of these five died
  - 38 had PCI or pericardiocentesis during LUCAS CPR

Wagner et al. Resuscitation 2010;81:383-387
<table>
<thead>
<tr>
<th>Rhythm</th>
<th>n</th>
<th>Survival</th>
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<tbody>
<tr>
<td>VF</td>
<td>6</td>
<td>4 (67%)</td>
</tr>
<tr>
<td>PEA</td>
<td>28</td>
<td>3 (11%)</td>
</tr>
<tr>
<td>Asystole</td>
<td>9</td>
<td>5 (56%)</td>
</tr>
</tbody>
</table>

Wagner et al. Resuscitation 2010;81:383-387
A Structured Approach for Treatment of Prolonged Cardiac Arrest Cases in the Coronary Catheterization Laboratory Using Mechanical Chest Compressions

Henrik Wagner1*, Malin Rundgren2, Bjarne Madsen Hardig3, Karl B Kern4, David Zughalt1, Jan Harnek1, Matthias Götberg1 and Goran K Olivecrona1

Wagner et al., Int J Cardiovasc Res 2013, 2:4
http://dx.doi.org/10.4172/2324-8602.1000135
Important Key Concepts

- If the patient has a shock resistant VF, continue MCC and precede with PCI in order to open the occlusion, rather than continue with further defibrillation attempts while the culprit coronary vessel remains occluded.

- Optimize physiological parameters

- If systolic ABP is below 70 mmHg, rule out cardiac tamponade, reposition the LUCAS-device, consider change in ventilation rate, or administer inotropic/vasoactive medications.
The Role of the Cath Lab in the Treatment of Cardiac Arrest

- Post Resuscitated Cardiac Arrest Patient
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- Refractory Cardiac Arrest Patient
Refractory Cardiac Arrest Patient

- **In-patients**
  - Mechanical CPR
  - Circulatory Support Pumps

- **Out-patients**
  - Combination of Mechanical CPR plus Circulatory Pumps to transport to Cath Lab for PCI plus Therapeutic Hypothermia

To facilitate PCI
2 cases

- One refractory VFCA in ED, other VFCA at home, then PEA
- Both converted to AutoPulse CPR

BP during AutoPulse CPR is 170/110 mmHg
<table>
<thead>
<tr>
<th>Case:</th>
<th>#1</th>
<th>#2</th>
</tr>
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<tbody>
<tr>
<td>First Med Contact to Balloon time</td>
<td>110 min</td>
<td>122 min</td>
</tr>
<tr>
<td>Door to Balloon time</td>
<td>NA</td>
<td>69 min</td>
</tr>
<tr>
<td>Survival with Good Neuro</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
In-Hospital Experience

- Mechanical CPR: Larsen et al

TIMI 3 flow seen in 4/6 pts during LUCAS CPR
In-Hospital Experience

- ECMO: Chen et al.

Figure 3: Kaplan-Meier plot of the survival curves in the extracorporeal CPR-M and conventional CPR-M groups for 1 year

Chen et al. 2008;372:554-61
In-Hospital Experience

- ECMO: Chen et al.

Figure 1: Relation between CPR duration and the survival rate to discharge
ECPR=extracorporeal CPR, CCPR=conventional CPR.

Chen et al. 2008;372:554-61
Out-of-Hospital Experience: PCPB

Nagao et al.

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>N</td>
<td>32</td>
<td>50</td>
<td>171</td>
</tr>
<tr>
<td>Surv/Good Neuro</td>
<td>5%</td>
<td>18%</td>
<td>12%*</td>
</tr>
</tbody>
</table>

* as high as 20% if:
- Collapse to CPB <56 min
- CPB to 34°C <22 min
PCI for Refractory VFCA: What’s Next?

➢ Pre-Hosp ECMO Initiation
   • Germany-2013
   • France-2013

➢ Ongoing Trials or Programs:
   • (Mech CPR, ECMO, HT, and Early PCI)
     – CHEER Trial (Australia)
     – Prague OHCA Study (Czech Republic)
     – Pavement-to-PCI Pathway (Edinburgh, Scotland)
CHEER Trial-S. Bernard

- Phase 1 trial (NCT01186614)
- n=24
- Unsuccessful Resusc after 20 min
- Intervention: Mech (L) CPR in field, ECMO in field then PCI/TH at admission
- Primary endpt: Survival to DC
- Secondary endpt: Neuro fx at DC
Prague OHCA Study

- Randomized Trial
  - Standard CPR vs
  - Mech CPR (L) with IntraNasal-TH in field & ECMO/PCI at Cath Lab
- n=200-400
- Unsuccessful ACLS for at least 5 min
- Primary endpt: 6 mo survival with good neuro
- Secondary endpt: 30 day neuro and cardiac recovery
Edinburgh

“Pavement-to-PCI Pathway”

The Resuscitation Research Group is working closely with the Cardiology and Intensive Care teams at Edinburgh Royal Infirmary and has established a ‘Pavement-to-PCI’ pathway. This allows select out-of-hospital cardiac arrest patients to be transported directly to the cathlab with on-going mechanical CPR. We look forward to reporting on the impact of this novel pathway soon!
Summary:
The Role of the Cath Lab in the Rx of Refractory CA

- Feasible
  - Advances:
    - Mechanical CPR & Circulatory Assist Devices
- Patient Selection is Key
- Realistic Expectations:
  - Some cases expected 80% mortality, but 100% without it
- Large Resource Commitment