The Role of the Cardiac Cath Lab Following Cardiac Arrest

Ajay J. Kirtane, MD, SM

Columbia University Medical Center
The Cardiovascular Research Foundation
Conflict of Interest Disclosure

- Ajay J. Kirtane
  - Consultant/Honoraria/Lecture Fees from Medtronic CardioVascular, Abbott Vascular, Boston Scientific, St. Jude Medical, Medicines Company
  - Advisor to Medtronic CardioVascular
Level of Evidence for Primary PCI Following Resuscitated Cardiac Arrest

- Virtually all randomized trials of primary PCI have excluded patients with cardiac arrest
- The majority of data is therefore observational
- Observational studies of cardiac arrest are typically small, and patient selection (especially for invasive procedures) plays a large role in outcomes
The Spectrum of CAD

Death
MI
Risk

Stable
1-2VD
3VD
LM
ACS
STEMI
The Spectrum of CAD

- Stable 1-2VD
- 3VD
- LM
- ACS
- STEMI
The Pathophysiology of AMI

Ruptured plaque with luminal and intraplaque occlusive thrombus
23 Randomized Trials of PCI vs. Lysis

N = 7,739

Event rate

Death

Death (excl shock)

23 Randomized Trials of PCI vs. Lysis

N = 7,739

Event rate

- Reinfarction: 6.8% (P<0.0001)
- Hemorrhagic stroke: 1.0% (P<0.0001)
- Total stroke: 2.0% (p=0.0002)

The RIKS-HIA Registry

Consecutive pts admitted in 75 of 78 hospitals with CCUs in Sweden (N=26,206 STEMIs)

Unadjusted Cumulative Mortality

- In-Hospital Thrombolysis: 15.9%
- Pre-hospital Thrombolysis: 10.3%
- Primary PCI: 7.6%

Days

Cumulative Mortality, %

# at Risk
- In Hospital TL: 14260, 12322, 12100, 11931
- Prehospital TL: 2736, 2491, 2460, 2442
- Primary PCI: 6030, 5661, 5607, 5555

Stenestrand U et al. JAMA 2006;296:1749-56
SHOCK Trial

302 pts with cardiogenic shock within 36° of AMI & ST↑/new LBBB randomized to emergency revasc. (n=152) or initial medical care (n=150)

Hochman J et al. NEJM
Primary PCI: Impact of Total Ischemic Time

N=1791 STEMI pts
5.8% 1 year mortality
Quadratic regression

Y = 2.86 (+1.46) + 0.0045X + 0.000043X^2
p < 0.001

RR for 1-year mortality for each 30 minute delay of 1.08 [1.01 to 1.15], p = 0.041

Impact of Patient Risk on the Relationship Between DBT and Mortality

2300 pts undergoing primary PCI (Moses Cone)

High risk = Killip class 3/4, age >70 years, or anterior infarction

Brodie BR et al. JACC 2006;47:289–95

Cardiac Survival %

Years

Door-to-Balloon Time (hrs)

0-1.4

1.5-1.9

2.0-2.9

≥3.0

p<0.0001

p=0.54

High Risk Patients
(n=1,307)

Low Risk Patients
(n=993)
NRMI: Multivariate Adjusted Impact of Incremental PCI Delay Stratified by Age, MI Location and Presentation Delay


192,509 pts at 645 hospitals
Distal Protection and Thrombectomy in AMI

Macroscopic embolic debris can be retrieved from >75% of cases
AMI: Attempts to Decrease Infarct Size

*Have been mostly met with frustration*

The concept of reducing embolic load

![Bar chart showing infarct size (% LV) with data from different studies.](chart.png)

- **Emerald (n=501)**
  - Distal protection (GuardWire Plus)
  - Stone GW et al. *JAMA* 2005
  - Infarct size: 16.2%
  - Control (N=208): P=0.26

- **AIMI (n=480)**
  - Active thrombectomy (AngioJet)
  - Ali A et al. *JACC* 2006
  - Infarct size: 9.8%
  - Distal protection or thrombectomy: P=0.018

- **Kaltoft et al (n=225)**
  - Passive thrombus aspiration (Rescue)
  - Kaltoft A et al. *JAMA* 2005
  - Infarct size: 7.5%
  - Distal protection or thrombectomy: P=0.004
RCA Occlusion (Inferior STEMI)
Direct Stent Implantation
Final Angiogram
The Spectrum of CAD

Stable
1-2VD

3VD

LM

ACS

STEMI

Death
MI
Risk
### Meta-analysis of Conservative vs. Invasive Strategies in ACS

9,212 randomized pts in 7 trials

<table>
<thead>
<tr>
<th>Source</th>
<th>Routine invasive</th>
<th>Selective invasive</th>
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<tbody>
<tr>
<td>TIMI IIIB</td>
<td>86/740 (11.6)</td>
<td>101/733 (13.8)</td>
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<tr>
<td>VANQWISH</td>
<td>152/462 (32.9)</td>
<td>139/458 (30.3)</td>
</tr>
<tr>
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<td>16/111 (14.4)</td>
<td>11/90 (12.2)</td>
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<td>127/1222 (10.4)</td>
<td>174/1235 (14.1)</td>
</tr>
<tr>
<td>TACTICS</td>
<td>81/1114 (7.3)</td>
<td>105/1106 (9.5)</td>
</tr>
<tr>
<td>VINO</td>
<td>4/64 (6.3)</td>
<td>15/67 (22.4)</td>
</tr>
<tr>
<td>RITA</td>
<td>95/895 (10.6)</td>
<td>118/915 (12.9)</td>
</tr>
<tr>
<td>Total</td>
<td>561/4608 (12.2)</td>
<td>663/4604 (14.4)</td>
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Meta-analysis of Conservative vs. Invasive Strategies in ACS
9,212 randomized pts in 7 trials

Composite death or MI from rand to latest FU

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OR, 0.82
[0.72-0.93]
P<0.001
Optimal Strategy for ACS

9 Randomized Trials
N=10,412

VANQWISH
ICTUS
MATE
TIMI IIIB

RITA-3
VINO
TRUCS
TACTICS-TIMI 18
FRISC II

Conservative (N=920)  N=2874
Invasive (N=6618)

c/o Chris Cannon
Design, Eligibility Criteria and Protocol

UA or NSTEMI
2 of 3 Criteria: Age > 60, ischemic ECG or biomarker AND suitable for revascularization

RANDOMIZE*  *Randomization ratio 1:1, 1:2 or 2:1

Early Invasive
Cardiac Cath as soon as possible (<24 h)

Delayed Invasive
Cardiac Cath >36 hrs

Follow-up 180 days

Mehta et al, NEJM 2009
Primary Outcome
Death, MI, or Stroke

Death/MI/Stroke at 180 days

Cumulative Hazard

No. at Risk
Delayed: 1438, 1328, 1269, 1254, 1234, 1229, 1211
Early: 1593, 1484, 1413, 1398, 1391, 1382, 1363

HR 0.85
95% CI 0.68-1.06
P = 0.15

Mehta et al, NEJM 2009
## Pre-specified Subgroups

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N</th>
<th>Early</th>
<th>Delayed</th>
<th>HR (95% CI)</th>
<th>Interaction p-Value</th>
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<tbody>
<tr>
<td>Overall</td>
<td>3031</td>
<td>9.7</td>
<td>11.4</td>
<td>0.85 ( 0.68 - 1.06 )</td>
<td></td>
</tr>
<tr>
<td>Age &lt; 65</td>
<td>1293</td>
<td>6.5</td>
<td>6.5</td>
<td>0.98 ( 0.64 - 1.52 )</td>
<td></td>
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<tr>
<td>Age &gt;=65</td>
<td>1736</td>
<td>12.3</td>
<td>14.8</td>
<td>0.83 ( 0.64 - 1.07 )</td>
<td>0.463</td>
</tr>
<tr>
<td>Female</td>
<td>1052</td>
<td>9.7</td>
<td>12.3</td>
<td>0.77 ( 0.54 - 1.12 )</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1976</td>
<td>9.8</td>
<td>10.9</td>
<td>0.89 ( 0.68 - 1.18 )</td>
<td>0.540</td>
</tr>
<tr>
<td>No ST deviation</td>
<td>1523</td>
<td>7.6</td>
<td>8.7</td>
<td>0.88 ( 0.62 - 1.26 )</td>
<td></td>
</tr>
<tr>
<td>ST deviation</td>
<td>1508</td>
<td>11.7</td>
<td>14.3</td>
<td>0.81 ( 0.61 - 1.07 )</td>
<td>0.722</td>
</tr>
<tr>
<td>No elevated marker</td>
<td>668</td>
<td>10.5</td>
<td>10.5</td>
<td>1.00 ( 0.62 - 1.60 )</td>
<td></td>
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<tr>
<td>Elevated marker</td>
<td>2363</td>
<td>9.5</td>
<td>11.7</td>
<td>0.81 ( 0.63 - 1.04 )</td>
<td>0.423</td>
</tr>
<tr>
<td>GRACE 0-140</td>
<td>2070</td>
<td>7.7</td>
<td>6.7</td>
<td>1.14 ( 0.82 - 1.58 )</td>
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</tr>
<tr>
<td>GRACE &gt;=141</td>
<td>961</td>
<td>14.1</td>
<td>21.6</td>
<td>0.65 ( 0.48 - 0.88 )</td>
<td>0.0097</td>
</tr>
</tbody>
</table>

Mehta et al, NEJM 2009

Preliminary Results as of Nov 7, 2008
Secondary Outcome
Death, MI, Stroke, RFI or Rep Intervention

Death/MI/RI/Stroke/Rep Intervention at 180 days

Cumulative Hazard

HR 0.84
95% CI 0.71-0.99
P=0.039

No. at Risk

Delayed 1438 1250 1166 1150 1128 1118 1097
Early 1593 1400 1321 1304 1287 1276 1256

Mehta et al, NEJM 2009
The Spectrum of CAD

Death
MI
Risk

Stable
1-2VD
3VD
LM
ACS
STEMI
There is a Wide-Range of Morbidity/Mortality among “Stable Angina” Patients

Hachamovitch et al, Circulation 2003;107:2900-07

5.4% cardiac mortality in 1.9 years - Is this “stable” angina?
Mitigated Gradient with Revascularization

Cardiac Death Rate

Medical Rx
Revasc

P < .0001

Rates of Death or MI by Residual Ischemia on 6-18m MPS

Revascularization: The Bottom Line

- Revascularization improves prognosis (hard clinical endpoints) in:
  - STEMI (time-dependent)
  - NSTACS (moderately time-dependent)
  - Stable CAD with high ischemic burden (less time-dependent)

- Prompt revascularization therefore has the potential to improve outcomes in appropriately selected patients with cardiac arrest!!
Etiologies of Cardiac Arrest

- **Coronary Heart Disease (>65%)**
  - Coronary Occlusion (frequent on autopsy)
  - Arrhythmia
  - Pump Dysfunction

- **Structural Heart Disease (10%)**
  - Valvular Disease
  - HOCM
  - Coronary Anomalies

- **Other:** Takotsubo, Primary Arrhythmias, etc

- **Non-cardiac / metabolic abnormalities (30%)?**
Diagnoses in 72 Pts with Cardiac Arrest Undergoing Routine Catheterization

PCI performed in one-third of patients

Anyfantakis et al, Am Heart J 2009
Use and Utility of Angiography after In-Hospital VF Arrest

- Of 110 patients with confirmed VF-arrest at a major US academic hospital, only 30 (27%) received angiography within 1 day of the arrest
  - Less than half had STEMI or new LBBB
  - More than half underwent PCI
- Performance of angiography has been associated with increased survival (but this association is quite confounded)

Merchant et al, Resuscitation 2008
Werling et al, Resuscitation 2007
A Case for Immediate Angiography for Survivors of Out-of-Hospital Arrest

- 85 (selected) patients with no obvious non-cardiac cause of arrest
- Coronary occlusions seen in 48% of pts
- Clinically significant CAD in 71% of pts
- Mean LVEF 34%
- 38% Survival; predictors were:
  - No need for inotropes on transport
  - Successful angioplasty
  - Shorter time from arrest to presentation

Spaulding et al, NEJM 2007
Problems with the Diagnosis of Ischemic CAD in Arrest Patients

- Often abnormal in post-arrest setting
- Often Difficult to Obtain
- Too Long To Wait!
Diagnostic Dilemmas in Cardiac Arrest

Immediate post-arrest EKG
Diagnostic Dilemmas in Cardiac Arrest

After ventilation/sodium bicarbonate (3 min later)
Diagnostic Dilemmas in Cardiac Arrest

35 minutes after initial EKG
Diagnostic Dilemmas in Cardiac Arrest

4 hours post-arrest

[ECG diagram showing various cardiac rhythms and waveforms]
Diagnostic Dilemmas in Cardiac Arrest

The next morning (12 hours post-arrest)
Ability of 12-lead EKG to Diagnose STEMI after Resuscitated Arrest

<table>
<thead>
<tr>
<th></th>
<th>MI at Discharge</th>
<th>No MI at Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST Elevation on Admission EKG</td>
<td>37</td>
<td>3</td>
</tr>
<tr>
<td>No ST Elevation on EKG</td>
<td>11</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>48</td>
<td>27</td>
</tr>
</tbody>
</table>

Out of hospital EKG: PPV 88% and NPV 69%
Sensitivity 77% and Specificity 83%
Summary of PCI Outcomes Data

- Studies of primary PCI for STEMI after resuscitated cardiac arrest:
  - 7 studies, 458 patients; successful PCI in 89%
  - 66% survival, 58% neuro recovery
  - Lower survival / recovery in comatose patients
- PCI also performed in 34 patients undergoing active resuscitation
  - 88% success, 41% survival

PCI for STEMI after Resuscitation

All patients with STEMI (n=2393)

No cardiac arrest
n=2257 (94.3%)

Primary PCI 65%
TIMI 2/3 93%
Survival 94.8%

Resuscitated cardiac arrest
n=135 (5.7%)

Primary PCI 98%
TIMI 2/3 94%
Survival 100%

Conscious
n=49 (36%)

Primary PCI 70%
TIMI 2/3 82%
Survival 51%

Comatose
n=86 (64%)

Gorjup et al, Resuscitation 2007
### Correlates of 6-Month Survival in STEMI Patients With Cardiac Arrest

**186 PCI patients; overall survival 54%**

<table>
<thead>
<tr>
<th></th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time from Arrest to 1st Responder (per min)</td>
<td>0.67</td>
<td>0.54-0.84</td>
</tr>
<tr>
<td>ROSC time (per 10 min)</td>
<td>0.43</td>
<td>0.25-0.66</td>
</tr>
<tr>
<td>Absence of Shock</td>
<td>12.66</td>
<td>3.39-47.62</td>
</tr>
<tr>
<td>Absence of Diabetes</td>
<td>7.30</td>
<td>1.80-29.41</td>
</tr>
<tr>
<td>Absence of prior PCI</td>
<td>10.99</td>
<td>1.65-71.43</td>
</tr>
</tbody>
</table>

Garot et al, Circulation 2007
Outcomes in STEMI Patients with Cardiac Arrest (n=98)

![Graph showing outcomes for different levels of response: Alert (n=25), Minimally Responsive (n=14), Unresponsive (n=59).]

Hosmane et al, JACC 2009
Correlates of Death in STEMI Patients Following Cardiac Arrest (n=98)

<table>
<thead>
<tr>
<th></th>
<th>OR</th>
<th>95% CI</th>
<th>p</th>
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<tbody>
<tr>
<td><strong>Neurologic Status</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Alert</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Min Responsive</td>
<td>2.1</td>
<td>0.1-68.1</td>
<td>0.69</td>
</tr>
<tr>
<td>Unresponsive</td>
<td>47.8</td>
<td>3.3-549.1</td>
<td>0.004</td>
</tr>
<tr>
<td><strong>ROSC time (per 10 min)</strong></td>
<td>2.8</td>
<td>1.5-5.7</td>
<td>0.002</td>
</tr>
<tr>
<td>Age (per 5-yr)</td>
<td>1.3</td>
<td>1.1-1.7</td>
<td>0.009</td>
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<tr>
<td>Female Gender</td>
<td>5.9</td>
<td>1.2-30.1</td>
<td>0.034</td>
</tr>
</tbody>
</table>

Patients arresting in ED had better survival and neurologic recovery than out-of-hospital arrest patients

Hosmane et al, JACC 2009
Combining Hypothermia and PCI for Cardiac Arrest Patients with STEMI

- Can be accomplished with minimal increases in door-balloon times
- Requires regimented protocols and buy-in / cooperation between ED, Cath Lab, ICU units / staff
- No differences in in-hospital complications with a trend toward improved outcomes (vs. historical controls in 3 published studies)

Wolfrum et al, Crit Care Med 2008
Knafelj et al, Resuscitation 2007
Sunde et al, Resuscitation 2007
“COOL-IT” Outcomes

Alive at hospital discharge with favourable neurological recovery

Abbott Northwestern Hospital  53/96  55.2%

- Survival by initial rhythm
  - VF/VT:  47/75  62.6%
  - PEA/Asystole:  5/19  26.3%

- Survival by diagnosis
  - Other:  20/46  43.5%
  - STEMI:  33/50  66.0%

Mooney, TCT 2008
CPC Comparison
Pre and Post Cool-It program

% of patients

CPC 1  CPC 2  CPC 3  Death

Pre n=38  Post n=40

Mooney, TCT 2008
COOL-MI – A Negative Trial

- Preliminary data has suggested that systemic cooling has the potential to reduce infarct size (animal models of ischemia/reperfusion)
- **Endovascular cooling to 33º for 3 hrs was tested in a 357 patient randomized trial**
- 94% of patients tolerated the cooling
- No difference in SPECT-measured infarct size, possible trends in anterior infarction

O’Neill et al, TCT 2003
What About Fibrinolytic Therapy (post-TROICA)?

- Riskier to implement many successful hemodynamic diagnostic / therapeutic maneuvers after lytics are given
- Worries about use in cardiac arrest patients (particularly prolonged CPR)
- In a non-randomized study of 147 STEMI patients with VF arrest (101 treated with fibrinolysis and 47 treated with primary PCI), there were similar outcomes with both strategies, which is reassuring

PCI During Cardiac Arrest

- Gas-driven sternal compression device with suction cup (LUCAS)
- PCI feasible in 13 pts with arrest or severe hypotension / bradycardia; mean BP 81/34 mmHg

Larsen et al, Resuscitation 2007
PCI Using Hemodynamic Support

Impella 2.5 Device during LMCA Dissection
Cardiac Cath Lab ≠ Always a Stent!!!

- **Distinction between diagnostic and interventional cath procedures**

- **Diagnostic:**
  - Hemodynamic evaluation
    - Right heart catheterization / shunt evaluation
    - Left heart catheterization
    - Simultaneous LV/PCWP, LV/RV
  - Left ventriculography (ability to identify structural defects)
  - Coronary angiography
  - Aortography
Cardiac Cath Lab ≠ Always a Stent!!

- Interventional Procedures:
  - Percutaneous coronary intervention
  - IABP, hemodynamic support
    - TandemHeart
    - Impella
  - Pressor/Vasodilator titration
  - Temporary pacemaker (Ventricular, CS/Ventricular)
  - Pericardiocentesis
  - Pulmonary Embolectomy
  - Rapid access to other subspecialties
    - EP, CHF Team, CT Surgery
Summary

• A significant proportion of patients with cardiac arrest (especially VT/VF) have coronary occlusion or significant coronary artery disease

• There are clear data supporting primary PCI for STEMI (acute coronary occlusion), a major cause of VT/VF

• Cardiac catheterization has other benefits, including making a diagnosis / further triage / hemodynamic support
An early invasive strategy is preferred for patients with non-ST-elevation acute coronary syndromes, but the timing may be less urgent.

Patients with significant “stable ischemic CAD” can benefit from revascularization, typically on an urgent / elective basis.

The key question is whether all (or selected) cardiac arrest patients should undergo emergent angiography and/or PCI if indicated.
Conclusions

- Integrated systems of care are being implemented with success for patients with STEMI (primary PCI) as well as for cardiac arrest patients (hypothermia protocols)
- The overlap between these two areas is significant, and it makes sense to coordinate efforts
- Angiography / catheterization is likely underutilized in arrest patients and ought to be considered 1st line care for VT/VF