Technical aspects of rescue
ECLS

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Definitions

• Patient is on CPR
  – In-hospital
  – Out-of-hospital

• ECLS
  – Personnel 24/7?
  – Ready to use
    • Set-up and primed
    • Set-up, not primed
    • Not set-up
ECLS for in-hospital CPR

59 patients
>10 min CPR => ECMO
Witnessed cardiac arrest

Chen 2008
ECLS for in-hospital CPR

Probability of survival-to-discharge vs. Duration of CPR [min]

Chen 2008
study population  
$n = 46$

group 1  
cardiogenic shock  
$n = 25$

stable PCBP flow  
$n = 24$

longterm survivors  
$n = 10$

weaned from PCBP  
$n = 19$

not weaned from PCBP  
$n = 5$

major complications  
incidence 20%  

major complications  
incidence 26%  

major complications  
incidence 60%  

major complications  
none  

major complications  
incidence 22%  

major complications  
incidence 75%

longterm survivors  
$n = 3$

weaned from PCBP  
$n = 9$

not weaned from PCBP  
$n = 8$

group 2  
cardiopulmonary arrest  
$n = 21$

stable PCBP flow  
$n = 17$
Assessment of outcomes and differences between in- and out-of-hospital cardiac arrest patients treated with cardiopulmonary resuscitation using extracorporeal life support

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ABSTRACT

Aim: Cardiopulmonary resuscitation (CPR) using extracorporeal life support (ECLS) for in-hospital cardiac arrest (IHCA) patients has been assigned a low-grade recommendation in current resuscitation guidelines. This study compared the outcomes of IHCA and out-of-hospital cardiac arrest (OHCA) patients treated with ECLS.

Methods: A total of 77 patients were treated with ECLS. Baseline characteristics and outcomes were compared for 38 IHCA and 39 OHCA patients.

Results: The time interval between collapse and starting ECLS was significantly shorter after IHCA than after OHCA (25 (21-43) min versus 59 (45-65) min, p < 0.001). The weaning rate from ECLS (51% versus 35%, p = 0.03) and 30-day survival (34% versus 13%, p = 0.03) were higher for IHCA compared with OHCA patients. IHCA patients had a higher rate of favourable neurological outcome compared to OHCA patients, but the difference was not statistically significant (26% versus 10%, p = 0.07). Kaplan-Meier analysis showed improved 30-day and 1-year survival for IHCA patients treated with ECLS compared to OHCA patients.
Should We Emergently Revascularize Occluded Coronaries for Cardiac Arrest?

Rapid-Response Extracorporeal Membrane Oxygenation and Intra-Arrest Percutaneous Coronary Intervention

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Background—Extracorporeal membrane oxygenation (ECMO) and percutaneous coronary intervention (PCI) may be useful in cardiopulmonary resuscitation. However, little is known about the combination of ECMO and intra-arrest PCI. This study investigated the efficacy of rapid-response ECMO and intra-arrest PCI in patients with cardiac arrest complicated by acute coronary syndrome who were unresponsive to conventional cardiopulmonary resuscitation.

Methods and Results—This multicenter cohort study was conducted with the use of the database of ECMO in Hiroshima City, Japan. Between January 2004 and May 2011, rapid-response ECMO was performed in 86 patients with acute coronary syndrome who were unresponsive to conventional CPR. The median age of the study patients was 63 years, and 81% were male. Emergency coronary angiography was performed in 81 patients (94%), and intra-arrest PCI was performed in 61 patients (71%). The rates of return of spontaneous heartbeat, 30-day survival, and favorable neurological outcomes were 88%, 29%, and 24%, respectively. All of the patients who received intra-arrest PCI achieved return of spontaneous heartbeat. In patients who survived up to day 30, the rate of out-of-hospital cardiac arrest was lower (58% versus 28%; P=0.01), the intra-arrest PCI was higher (88% versus 70%; P=0.04), and the time interval from collapse to the initiation of ECMO was shorter (40 [25–51] versus 54 minutes [34–74 minutes]; P=0.002).

Conclusions—Rapid-response ECMO plus intra-arrest PCI is feasible and associated with improved outcomes in patients who are unresponsive to conventional cardiopulmonary resuscitation. On the basis of these findings, randomized studies of intra-arrest PCI are needed. (Circulation. 2012;126:1605-1613.)

Key Words: acute coronary syndrome ■ cardiac arrest ■ cardiopulmonary bypass ■ cardiopulmonary resuscitation ■ extracorporeal membrane oxygenation
Cannulation

• Arterial
  – Retrograde flow
  – Increased afterload

• Venous
  – Diameter depends on femoral vessel size
  – Long small catheter
    => high resistance
Arterial cannulation

Lamb 2013
NIRS for detection of limb ischemia

Lower Limb Event

Femoral Oximetry Initiated

Oximetry Drop

Placement of Distal Perfusion Cannula

Repair of Distal Perfusion Cannula

15:00 17:10 17:47 18:59

Right Leg  Left Leg

Wong 2012
Competitive flow

Batista 2013
NIRS for rapid detection of malperfusion

Systemic Event

Baseline
Trendline
Blood Transfusion

Right Forehead   Left Forehead   Right Leg   Left Leg

Wong 2012
NIRS for detection of neurological issues

Cerebral Event

- Loss of compensation
- Left Infarct Diagnosed
- Severe Cerebral Edema
- Trendline

Day 1 - 2  Day 3  Day 4  Day 5 - 6

SO2

Right Forehead  Left Forehead

Wong 2012
Intravascular volume = drainable volume
Veins are collapsible

Katz 1969
Cannula-vessel ratio
Vacuum can be tricky

- Each panel can withstand 27300 kg
- Force plastic sheet 75 kg
Cannula-vessel ratio

Assisted drainage

Flow [L/min]

Ratio Catheter - blood vessel
Table 1
Hemodynamic parameters and DFI during luxation and after repositioning.

<table>
<thead>
<tr>
<th></th>
<th>No luxation</th>
<th>Luxation</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>ISR</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>Bypass flow (l/min)</td>
<td>4.64 ± 0.38</td>
<td>0.04</td>
<td>4.72 ± 0.37</td>
</tr>
<tr>
<td>Pump speed (rpm)</td>
<td>3071 ± 142</td>
<td>7</td>
<td>3031 ± 172</td>
</tr>
<tr>
<td>DFI (ml/rotation)</td>
<td>2.4 ± 0.2</td>
<td>0.5</td>
<td>2.0 ± 0.2</td>
</tr>
<tr>
<td>$P_{pump inlet}$ (mmHg)</td>
<td>50 ± 11</td>
<td>1</td>
<td>49 ± 9</td>
</tr>
<tr>
<td>$P_{arterial line}$ (mmHg)</td>
<td>161 ± 14</td>
<td>1</td>
<td>155 ± 12</td>
</tr>
</tbody>
</table>
Hemostasis and ECMO

**Patient**
- Clotting factors
- Thrombin
- Platelets
- Endothelium

**Circuit**
- Stasis
- Shear stress
- Blood-Material
- Hemolysis

**Undefined:**
- Surgical bleeding
- Drug infusion
Monitoring hemostasis

**Cascade vs. cell-based model**


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**Cascade model**

- Hemostasis represented as two somewhat independent protein activation pathways that converge at the common final pathway and the generation of fibrin.
- The routine coagulation tests, PT and aPTT, are based on the cascade model
  - Measure how coagulation factors interact in solution
  - Determine if adequate levels of coagulation factors are present for clot formation
Intrinsic Pathway

aPTT

Factor XII/HMWK/PK

Factor XI → Factor XIa

Factor IX → Factor IXa, Factor VIIIa

Factor X → Factor Xa, Factor Va

Prothrombin → Thrombin

Monroe DM

Severe bleeding

Prolonged aPTT only

Variable bleeding

Prolonged aPTT
Monitoring hemostasis

Cascade vs. cell-based model

**Cell-based model**

- Hemostasis represented as:
  - Occurring on two cell surfaces
    - Tissue factor bearing cells
    - Platelets
  - Three overlapping phases:
    - Initiation (TF bearing cells)
    - Amplification (platelets)
    - Propagation (platelets)

- The coagulation cascades are still important, but are cell-based
  - The *extrinsic pathway* works on the surface of the tissue factor bearing cells
  - The *intrinsic pathway* works on the surface of platelets

- Routine coagulation tests do not represent the cell-based model of hemostasis.
How to optimally monitor and assess hemostatic function

- Optimal clinical management of patients on ECMO often requires information on all aspects of hemostasis, the so-called global test.
- Knowledge of the rate and amount of thrombin production can be one indication of the state of hemostasis.
- PT and aPTT only report initial generation of thrombin based on the first appearance of clot.
- However, events that occur after initial thrombin generation are also critical but are not assessed by these assays:
  - Changes in fibrin assembly, structure and mechanical properties
  - Platelet activation
  - Fibrinolysis, etc.
Visco-elastic measurements

Electronic Circuitry

Electromechanical Transducer

Tubular Probe

Cuvette

Direction of Probe Movement
Example

- Patient post surgery
- Plts: 30000/mm³
- Dialysis
- Kidney thrombosis
- aPTT: 120 s (therapeutic)
- ACT: 120 s (normal)
Heparin resistance

Ranucci 2002
ATIII and outcome

![Graph showing the relationship between AT activity (% at the arrival in the ICU) and adverse event likelihood.](image)
PARs on endothelial cells coordinate the local vascular response to injury

↑ Vascular permeability

↑ vascular permeability
↑ clotting
↑ inflammatory leukocytes

NOT DESIRABLE SYSTEMICALLY

Thrombus formation / platelet aggregation
↑ leukocyte recruitment

Landis 2008
Thrombin activates platelets

Pre-op (grade 4)  Post-op + aprotinin (grade 4)

Lavee 1992
Activation of coagulation and organ dysfunction

\( P=0.04, \rho=-0.39 \)

\( P=0.02, \rho=-0.43 \)

\( P=0.02, \rho=0.45 \)

Dixon 2005
• Haemostasis control starts with
  – Control of thrombin production
    • ATIII
    • Heparin
  – Passivation of activated platelets
    • Dipyridamole, NO
  – Monitoring fibrinolysis
    • Tranexamic acid
Extracorporeal life support following out-of-hospital refractory cardiac arrest

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Abstract

Introduction: Extracorporeal life support (ECLS) has recently shown encouraging results in the resuscitation of in-hospital (IH) refractory cardiac arrest. We assessed the use of ECLS following out-of-hospital (OH) refractory cardiac arrest.

Methods: We evaluated 51 consecutive patients who experienced witnessed OH refractory cardiac arrest and received automated chest compression and ECLS upon arrival in the hospital. Patients with preexisting severe hypothermia who experienced IH cardiac arrest were excluded. A femorofemoral ECLS was set up on admission to the hospital by a mobile cardiothoracic surgical team.

Results: Fifty-one patients were included (mean age, 42 ± 15 years). The median delays from cardiac arrest to cardiopulmonary resuscitation and ECLS were, respectively, 3 minutes (25th to 75th interquartile range, 1 to 7) and 120 minutes (25th to 75th interquartile range, 102-149). Initial rhythm was ventricular fibrillation in 32 patients (63%), asystole in 15 patients (29%) patients and pulseless rhythm in 4 patients (8%). ECLS failed in 9 patients (18%). Only two patients (4%) (95% confidence interval, 1% to 13%) were alive at day 28 with a favourable neurological outcome. There was a significant correlation (r = 0.36, P = 0.01) between blood lactate and delay between cardiac arrest and onset of ECLS, but not with arterial pH or blood potassium level. Deaths were the consequence of multiorgan failure (n = 43; 47%), brain death (n = 10; 20%) and refractory hemorrhagic shock (n = 7; 14%), and most patients (n = 46; 90%) died within 48 hours.
Conclusion

- This poor outcome suggests that the use of ECLS should be more restricted following out-of-hospital refractory cardiac arrest
- Setting up an 24/7 service is extremely expensive