ExtraCorporeal Membrane Oxygenation (ECMO) for Cardiopulmonary Collapse

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Disclosures

• None
Goals

• Discuss the Basics of ECMO
  – Veno-Venous
  – Veno-Arterial

• Discuss Management

• Potential complications

• Review Outcomes of ECMO
What is ECMO?

• Therapy, not a product
• Modifications of CPB
  – Blood pump/Oxygenator
• External circulation
  – Venous blood removed
  – Blood goes through a gas exchange device (oxygenator)
    • O2 is added and CO2 is removed,
  – Oxygen rich blood is returned to the patient’s circulating blood.
Modes of ECMO Support

Veno-venous support (VV)
- Gas exchange only
- Isolated respiratory failure

Veno-arterial support (VA)
- Circulatory support
- Gas exchange
Who should be considered for ECMO?

- **REVERSIBLE** disease process
- Refractory to maximum conventional therapy
- High risk of mortality
- Absence of severe intracranial pathology – trauma/stroke
- Absence of uncontrolled bleeding/severe coagulopathy
Who should NOT be considered for ECMO?

- No
  - Unrecoverable cardiac or respiratory function and not a candidate for Transplant or VAD- no exit strategy
  - Active/Uncontrolled Malignancy
  - Neurologic injury
  - Arrest with no CPR >10 min

- Consider
  - Chronic organ dysfunction
  - Uncontrolled Coagulopathy
  - Age > 70 or BMI >35
  - Significant PVD
VenoVenous (VV) ECMO
VV ECMO

- Respiratory Support only
  - Oxygenates blood and removes CO2
  - No direct hemodynamic support
VV Cannulation
Single and Double Lumen Catheters
Recirculation

- The portion of oxygenated blood that is returning from the ECMO circuit that is immediately siphoned back into the circuit
  - SpO2 decrease, SvO2 increases

- Affected by
  - Pump Speed
  - Catheter Position
  - Cardiac Output
VenoArterial (VA) ECMO
VA ECMO

- Venoarterial
  - Cardiac and Respiratory Support
  - Blood pulled from Venous system and returned to Arterial system
  - Provides Hemodynamic Support
  - Provides O2/CO2 exchange
Why Do We Use VA ECMO?

- Post-Bypass (Cardiotomy) Support
  - Failure to wean from bypass after surgery
- Other conditions that lead to severe cardiac failure
  - Cardiomyopathy
  - Cardiogenic shock s/p MI
  - Overdose
  - Pulmonary embolism
- Post Cardiac Transplant
Cannulation Sites

Central

Peripheral
Central Cannulation
Antegrade Cannula
VA ECMO – Management

Do what you normally do in the care of any post-surgical patient!

The MAJOR difference is the ECMO machine…
Patient Management Goals

- Optimize BP, perfusion and acid/base
  - Vasopressors
  - Volume: (Fluids, platelets, FFP, Blood)

- Evaluate and correct any electrolyte abnormalities

- Evaluate and correct coagulopathy

- Maintain nutritional support
Patient Management Goals

• Optimize blood pressure, perfusion
  – Blood flow (4-6 L/min)
  – Adequate MAP (60-70mmHg)
  – Adequate SvO2 (SvO2>70%)
  – Volume: (Fluids, platelets, FFP, Blood if indicated)

• Maintain Arterial Sat >90 as measured in the right arm
VA ECMO - Cerebral Hypoxia

- VA ECMO
- Femoral cannulation
- Left ventricular ejection

Slide Courtesy of Johnathan Haft
VA ECMO - Cerebral Hypoxia

- VA ECMO
- Femoral cannulation
- Left ventricular ejection
- Respiratory failure
- Hypoxic perfusion of coronary and cerebral circulation

Slide Courtesy of Johnathan Haft
VA-V

- Combined VA and VV
- Additional inflow into RIJ
- Must regulate flow in IJ
- Does not increase oxygen delivery only changes location of delivery
Why do we check ABG in right arm???

My Right Radial ABG is my Right Brains pH, PO2, and PCO2 which is controlled by the vent if I am pulsatile!!

Anterior ECMO lflow

ECMO CIRCUIT
Manages systemic PO2 and PCO2 via FiO2 and sweep.
ECMO

Bleeding

Clotting
Bleeding

• Continuous Heparin infusion
  – ACT 180-200 if bleeding 140-160
  – Transfuse to keep:
  – Hgb > 8.5
  – If SVO2 is low, Hgb > 10
  – Thrombocytopenia (Plt > 20,000)
    • If actively bleeding, Plt > 80,000
  – INR < 2.5
    • If actively bleeding, < 1.6
  – Fibrinogen > 150
Hemolysis

- Daily plasma free hemoglobin
  - Significant hemolysis should prompt search for cause
    - Undersized arterial cannula
    - Thrombus in circuit

- Q8 hour circuit assessment for clot
Clots in Oxygenator
Left Ventricular Distension

- ECMO is partial bypass
  - Residual RV output and bronchial flow
- LV must eject to avoid pulmonary hemorrhage/thrombosis
- Maintain aortic pulsatility
- Liberal use of echo
  - LV size
  - Aortic valve opening
Thrombosis
Aortic Root/LV Thrombus

• VA ECMO via femoral artery
• Minimal LV ejection
• Stasis in aortic root
• Thrombus
• Prevention:
  – Maintain ventricular ejection
    • IABP
    • Inotropes
    • Impella as LV Vent
  – Anticoagulation
Limb Ischemia

- Occurs when femoral arterial sheath is occlusive of femoral artery
- Less likely with smaller arterial cannula
  - small cannula
    - hemolysis
    - difficulty flowing
- Antegrade perfusion
Ventilator

• Usually managed at low settings to allow lungs to rest
  • Low rate (8-10/min)
  • Long Inspiratory Time
  • Low PIP (20-25 cmH2O)
  • Low FiO2 (<30%)
  • Low PEEP (~10cmH2O)
• Careful to maintain right radial saturation >90%
• Bronchoscopcy only if needed
Renal Failure

• Urine output
  – Initially Low or None
  – $\uparrow$ Renal Blood Flow = $\uparrow$UO

• Control of Edema
  – Diuretics
  – Hemofiltration

• Early CVVH if indicated

• Goal: euvolemia
Sedation

• Daily Sedation Holidays
  – Neurological Exam
  – Avoid ‘snowing’ patient
  – Assess pupils q2hrs
  – Awake patients
Nutrition

• Require Full Caloric and Protein Support

• Initiate ASAP (w/in 24hrs of implant)
  – Monitor Blood Glucose
    • Continuous Insulin Infusion
    • Lowers risk of infection
    • Tight glycemic control
  – Bowel Regimen
Weaning from ECMO

• Assess for Readiness
• Decannulation
ECMO Weaning: What to Look For

**VV ECMO**
- Gas exchange can usually be maintained on low FiO2
- Native lungs are able to maintain ventilation when the sweep rate and FiO2 are minimal

**VA ECMO**
- BP increases
- Pulsatility returns or improves on A-Line tracing
- R radial A-line pO2 decreases
  - More blood is going through native heart, this blood is typically less oxygenated
- CVP and PA pressures increase
ECMO Weaning

- Frequent Evaluation by Team
  - “Turn-Down”
    - Adequate ACT/PTT
    - Initiation/Increase of Cardiac Infusions
    - Increase Ventilator Settings
  - Trans-esophageal Echo
- IABP
Autopsy-based thrombo-embolic events in ECMO patients
Evidence for ECMO

- Single institution
- Retrospective
- No prospective trials
- Complicated by post cardiac surgery patients
Early and late outcomes of 517 consecutive adult patients treated with extracorporeal membrane oxygenation for refractory postcardiotomy cardiogenic shock

Ardawan Julian Rastan, MD, PhD, Andreas Dege, MD, Matthias Mohr, MD, Nicolas Doll, MD, PhD, Volkmar Falk, MD, PhD, Thomas Walther, MD, PhD, and Friedrich Wilhelm Mohr, MD, PhD

(J Thorac Cardiovasc Surg 2010;139:302-311)

- 517 postcardiotomy patients
- 61% central cannulation
- Most received IABP
- 24.8% survival to discharge
- Advanced age, Euroscore, Lactate levels predictors
Clinical experience with 202 adults receiving extracorporeal membrane oxygenation for cardiac failure: Survival at five years

Nicholas G. Smedira, MD
Nader Moazami, MD
Camille M. Golding
Patrick M. McCarthy, MD
Carolyn Apperson-Hansen, MStat
Eugene H. Blackstone, MD
Delos M. Cosgrove III, MD

- 202 patients
- 107 (53%) postcardiotomy
- 38% 30 day survival
- Age > 55 predictor
- 42 Bridged to VAD
  - 60% survived to transplant
- Excellent long term survival
A 20-year experience with urgent percutaneous cardiopulmonary bypass for salvage of potential survivors of refractory cardiovascular collapse

150 patients
  – CPR in 127
26% 30 day survival
Cannulation in cath lab predictive of survival
Long term survival good

FIGURE 2. Kaplan–Meier survival in patients surviving ≥30 days. T½, Median survival.
Survival by Etiology – U. of Michigan

Survival % by Indication for ECMO

- V myocarditis
- PE
- AMI
- Post-cardiotomy
- Chronic HF
- Other

Slide Courtesy of Johnathan Haft
Sharp Memorial Experience

• Study Period - June of 1986 to March 2014

• All patients were entered into a Prospective Registry

• Retrospective Chart Review of patient data
Sharp Memorial Experience

• Inclusion criteria
  • All patients on veno-arterial ECMO at Sharp Memorial Hospital

• Exclusion Criteria:
  • OR continuations of bypass (Failure to wean post-cardiotomy)
  • Patients transferred to SMH
  • Elective Cath lab supported procedures

• Primary Endpoint Survival:
  • Long-term survival (LTS- >30 days ECMO weaned)
  • Short-term survival (<30 days, ECMO weaned)
  • Death-on-ECMO
Study Population

- Total hospital experience 290 patients to Date
  - 61 patients excluded
- Study population
  - 229 Patients
- Study Periods
  - First 18 Years - 6/1986 to 3/2004
Demographics

• First 18 years
  • 115 patients
  • 72% male
  • Age 60.5
• Primary Indication
  • Cardiac Arrest – 101
  • Cardiogenic Shock - 14
Demographics

- Last 10 years
  - 114 patients
  - 65% male
  - Age 54.8 years
- Primary Indication
  - Cardiac Arrest - 77
  - Cardiogenic Shock – 40
  - Unknown - 2
<table>
<thead>
<tr>
<th></th>
<th>First 18 Years</th>
<th>Last 10 Years</th>
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<tbody>
<tr>
<td>Expired on ECMO</td>
<td>66 (57.4%)</td>
<td>74 (64.9%)</td>
</tr>
<tr>
<td>Weaned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survive &lt;30 Days</td>
<td>24 (20.1%)</td>
<td>9 (7.9%)</td>
</tr>
<tr>
<td>Long Term Survivor</td>
<td>30 (26.1%)</td>
<td>31 (27.2%)</td>
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</tbody>
</table>
Time on Support

- Expired on ECMO
  - First 18 Years: 17.8 hours
  - Last 10 Years: 55.2 hours

- Weaned Survive <30 Days
  - First 18 Years: 26.3 hours
  - Last 10 Years: 71.5 hours

- Long Term Survivor
  - First 18 Years: 22.5 hours
  - Last 10 Years: 52.5 hours

Time (hours)
# Etiology of Shock or Cardiac Arrest

<table>
<thead>
<tr>
<th>Cause</th>
<th>First 18 years</th>
<th></th>
<th>Last 10 Years</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Patients Achieving LTS</td>
<td>%LTS</td>
<td>Total</td>
</tr>
<tr>
<td><strong>Cardiac</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coronary</td>
<td>87</td>
<td>26</td>
<td>29.9</td>
<td>82</td>
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<tr>
<td>Cardiomyopathy</td>
<td>62</td>
<td>20</td>
<td>32.3</td>
<td>67</td>
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<tr>
<td>Myocarditis</td>
<td>7</td>
<td>1</td>
<td>14.3</td>
<td>12</td>
</tr>
<tr>
<td>transplant Rejection</td>
<td>1</td>
<td>1</td>
<td>100.0</td>
<td>2</td>
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<tr>
<td>Other</td>
<td>9</td>
<td>2</td>
<td>22.2</td>
<td>1</td>
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<tr>
<td><strong>Non Cardiac</strong></td>
<td>28</td>
<td>5</td>
<td>17.9</td>
<td>25</td>
</tr>
<tr>
<td>PE</td>
<td>9</td>
<td>1</td>
<td>11.1</td>
<td>8</td>
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<tr>
<td>AFE</td>
<td>3</td>
<td>1</td>
<td>33.3</td>
<td>2</td>
</tr>
<tr>
<td>Sepsis</td>
<td>2</td>
<td>0</td>
<td>0.0</td>
<td>8</td>
</tr>
<tr>
<td>Hemorrhage/Trauma</td>
<td>6</td>
<td>2</td>
<td>33.3</td>
<td>4</td>
</tr>
<tr>
<td>other</td>
<td>8</td>
<td>1</td>
<td>12.5</td>
<td>7</td>
</tr>
</tbody>
</table>
Timing of Insertion

Number of Patients Placed on Support

- Witnessed Arrest
- No Arrest
- Unwitnessed Arrest
- Unknown

First 18 Years
Last 10 Years
Survivors

Individuals

Long Term Survivors

- Cardiac Arrest
- Shock
- Unwitnessed Arrest

First 18 Years
Last 10 Years
Survival by Location of Initiation of ECMO

% Survival

First 18 Years

Last 10 Years

Cath Lab
CCU
ED
Other/unknown
Outcome for Rhythm at Time of Cardiac Arrest

% of patients Presenting with Given Arrhythmia

<table>
<thead>
<tr>
<th>Arrhythmia</th>
<th>Long-term</th>
<th>Short-term</th>
<th>Death-on-CPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>V. Tach/V. Fib.</td>
<td>41.7</td>
<td>8.3</td>
<td>50</td>
</tr>
<tr>
<td>P.E.A.</td>
<td>28.9</td>
<td>28.9</td>
<td>47.2</td>
</tr>
<tr>
<td>Asystole</td>
<td>14.3</td>
<td>0</td>
<td>85.7</td>
</tr>
</tbody>
</table>

Outcome for Rhythm at Time of Cardiac Arrest
Overall Survival Based Upon Length of CPR

<table>
<thead>
<tr>
<th>Length of CPR</th>
<th>Long-Term</th>
<th>Short-Term</th>
<th>Death on CPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>No CPR</td>
<td>47.8</td>
<td>26.1</td>
<td>26.1</td>
</tr>
<tr>
<td>CPR &lt; 30 min</td>
<td>29.6</td>
<td>18.5</td>
<td>16.7</td>
</tr>
<tr>
<td>CPR &gt; 30 min</td>
<td>16.7</td>
<td>14.8</td>
<td>68.5</td>
</tr>
</tbody>
</table>

% of Arrested Patients
Cause of Death

- **Expired on CPS**
  - Cardiac
  - Pulmonary/CNS
  - Other

- **Short Term**
  - Cardiac
  - Pulmonary/CNS
  - Other
Complications in ECMO
Premortem unknown in 59 patients (75.6%)

Friedrich W. Mohr - Heart Center, University of Leipzig, Germany

- Pneumonia: 17.9%
- Cerebral infarction: 12.8%
- Cerebral bleeding: 6.4%
- Bowel ischemia: 2.6%
- Bowel perforation: 5.1%
- Acute pancreatitis: 3.8%

Autopsy findings:
- Pneumonia: 71.5%
- Cerebral infarction: 41.6%
- Cerebral bleeding: 20.3%
- Bowel ischemia: 50.0%
- Bowel perforation: 0%
- Acute pancreatitis: 29.7%
ER Directed ECPR

**Inclusion criteria:**

- Persistent cardiopulmonary arrest despite traditional resuscitative efforts
- Shock (SBP <70 mmHg) refractory to standard therapies

**Exclusion criteria:**

- Initial rhythm asystole
- Chest compressions not initiated within 10 min of arrest (either bystanders or EMS personnel)
- Estimated EMS transport time > 10 min
- Total arrest time > 60 min
- Suspicion of shock due to sepsis or hemorrhage
- Pre-existing severe neurological disease prior to arrest (including traumatic brain injury, stroke, or severe dementia)
Cardiac arrest or refractory shock
Meets criteria for ED ECPR: continue full ACLS resuscitation

ED ECPR Stage 1
Place femoral venous and arterial catheters

ED ECPR Stage 2
Replace femoral lines with ECLS cannulas
(venous 16F-20F; arterial 15F-19F)

ED ECPR Stage 3
Initiate cardiopulmonary bypass (ED ECPR)

Circulation established
(ROSC, RORS, or ECLS)
Manage medical and/or surgical issues

Abbreviations: ACLS, advanced cardiac life support; ECLS, extracorporeal life support; ED ECPR, emergency department extracorporeal cardiopulmonary resuscitation; RORS, resolution of refractory shock; ROSC, return of spontaneous circulation.
ER Physician Initiated ECPR
3 year experience

254 Cardiac Arrests
ER Physician initiated ECPR

254 Cardiac Arrests

177 Non-ECPR Cardiac Arrests (12% Survival to Discharge)

24 ECPR Patients

53 DNRs/Traumatic Arrests
254 Cardiac Arrests

177 Non-ECPR Cardiac Arrests (12% Survival to Discharge)

107 Patients with Arrests Lasting Less Than 30 minutes, Unwitnessed Arrests, or Unknown Durations of CPR

70 Patients with Arrests Lasting Over 30 minutes

1 Patient in Cardiogenic Shock (1 Survivor)

23 Cardiac Arrests

24 ECPR Patients

53 DNRs/Traumatic Arrests

ER Physician initiated ECPR
ER Physician initiated ECPR
3 year experience

254 Cardiac Arrests

70 Patients with Arrests Lasting Over 30 minutes
2 Survivors to Discharge (3%)

24 ECPR Patients

6 Survivors to Discharge (26.1%)
Conclusions

• Rapid initiation of extra-corporial support can be life saving
  – Biventricular
  – Pulmonary
  – Rapid initiation

• Survival rates less than 40%
Conclusions

• No survivors who presented with un-witnessed Arrest
• Poor survival if initial rhythm is asystole
• Placement in Cath lab provides survival advantage
Conclusions

• Complications of ECMO can be anticipated and should be avoided

• Less than half of patients die as a result of a cardiac failure, the rest as a result of complications