EXTREME ECMO: COMBAT, TRAUMA, TRANSPORT

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I have no disclosures

The views presented in this talk do not reflect those of the United States Military, Department of Defense or Inova Health System.
Extracorporeal Support will define the future of critical care medicine
Extracorporeal Support will direct the future care of severe heart and lung failure
• Consider early – as soon as optimal therapy failing

• Select patients carefully

• Can transport anywhere, anytime, anyplace with right team
Principles of patient selection

1. Reversible process
2. Good neurologic outcome possible
3. Ability to tolerate anticoagulation
4. Performance and functional status - age

Institutional Process:
ECMO team, Shock team
Multidisciplinary discussion
Pre-established guidelines and criteria
University Hospital Regensburg Germany – Landstuhl Collaboration

November 2007
Prototype of Small ECMO Device:
To pick up Patient on Pumpless AV Lung support
First ECMO adult patient that survived was a trauma patient
Technology advances....

- 10kg
- High or low flow
- PMP membrane
- Built in monitoring of flow pressure, temp, SVO2, hemoglobin
The ELSO Registry - Survival

Adult pulmonary  59%
Adult cardiac    42%
eCPR             29%
Three groups of patients

- Severe lung failure – VV ECMO
- Severe cardiac or cardiopulmonary failure – VA ECMO
- Cardiac arrest - eCPR
ECMO use in trauma increasing...

- Number of ECMO trauma articles – pubmed search ECMO and trauma
  - 2013- present **423** Last 5 years
  - 2007-2012 **157**
  - 2001-2006 **74**
  - 1995-2000 **72**
# Trauma Survival is better

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>n</th>
<th>Average Run Duration, d</th>
<th>Survival to Hospital Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma—total cohort</td>
<td>279</td>
<td>8.8 ± 9.5</td>
<td>61%</td>
</tr>
<tr>
<td>Trauma—respiratory support</td>
<td>247</td>
<td>9.3 ± 9.3</td>
<td>63%</td>
</tr>
<tr>
<td>ARDS, not postoperative/trauma*</td>
<td>837</td>
<td>13.0</td>
<td>54%</td>
</tr>
<tr>
<td>Acute respiratory failure, non-ARDS*</td>
<td>1408</td>
<td>11.5</td>
<td>55%</td>
</tr>
<tr>
<td>Viral pneumonia*</td>
<td>926</td>
<td>13.5</td>
<td>65%</td>
</tr>
<tr>
<td>Bacterial pneumonia*</td>
<td>1362</td>
<td>10.9</td>
<td>61%</td>
</tr>
<tr>
<td>Trauma—cardiac support</td>
<td>20</td>
<td>4.1 ± 4.5</td>
<td>50%</td>
</tr>
<tr>
<td>Adult cardiac support*</td>
<td>9025</td>
<td>6.5</td>
<td>41%</td>
</tr>
<tr>
<td>Trauma—ECPR</td>
<td>12</td>
<td>6.5 ± 16.8</td>
<td>25%</td>
</tr>
<tr>
<td>Adult ECPR*</td>
<td>2885</td>
<td>Not available</td>
<td>29%</td>
</tr>
</tbody>
</table>

*Data from ELSO.15*
Survival Rates

- Trauma Pulmonary  63%
- Adult Pulmonary   59%

- Trauma Cardiac    50%
- Adult Cardiac     41%

- The only group where trauma survival is less than non-trauma survival is eCPR
  - Trauma eCPR 25%
  - Adult eCPR 29%
Avoid ECMO in traumatic cardiac arrest

If severe shock or cardiac arrest is due to blood loss, ECMO will not work

Every guideline or rule has an exception.
ECMO works well in Trauma

• Bleeding controlled

• Same principles for other patients
  – Can run ECMO without anticoagulation for 24-72 hours or longer...

• How do we know when a good neurologic outcome is possible in patients with brain injury?
Case: Charlie - 27 year old UK Army Officer

2 months before illness
Sleeping outside - Sandstorms

Admitted to ward:
Doxycycline
2L O2 NC
CXR R infiltrates
Mild transaminitis
Low platelets

2 days later:
Increased O2 needs
Levaquin started

ANAPHYLAXIS
ICU

- Severe Respiratory Failure
  - P/F ratio 64, pH 7.01, CO2 86
  - O2 saturation 70-78% on maximal support
  - Rescue Ventilator modes ineffective

Organs down:

- Shock – distributive and cardiac – EF 30%
  - High dose norepinephrine (35 mcg/min)
  - High dose epinephrine (20 mcg/min)

LUNGS

- Shock – distributive and cardiac – EF 30%
  - High dose norepinephrine (35 mcg/min)

HEART

- High dose epinephrine (20 mcg/min)
  - Vasopression (0.4u/min)
  - Fluids + 14L crystalloids/colloids

LIVER

- Fluids + 14L crystalloids/colloids

KIDNEYS

- Liver failure – infection, shock liver
  - AST 21,000, ALT 15,000

BLOOD

- Coagulopathy
  - PT 49, PTT 48, Platelets 48

- Acute Kidney Injury – no urine output
PEEP 22, FiO2 1.0, Mean Airway pressure 34, Plateau pressure 44, Tidal volumes 500-700ml

Damaging settings required to sustain life
Failure of lung protective ventilation
Neuromuscular blockade
Prone positioning

• This is failure of optimal therapy
• Unable to meet gas exchange goals with
  TV < 6ml/kg IBW, Plateau pressure < 30, P/F < 150
• Acidosis compromising perfusion
• Not improving after 6 hours...

ECMO
pH below 6.95 for over 12 hours

Despite Bicarb ggt
Is he a candidate for Extracorporeal support?

If so, which kind?

British hospital in Afghanistan

Commander says NO ECMO!
Question: Imagine you are in a high volume ECMO center. What is the best option for this patient?

A. VA ECMO – Femoral vein to femoral artery

B. VV ECMO – femoral vein to internal jugular vein

C. Withdraw care, severe brain injury portends poor outcome

D. APRV, start CRRT, continue current supportive therapy
Resp score Estimates 40% survival
www.respscore.com

Increased mortality:
Age
Organ dysfunction
Immunocompromised
CNS dysfunction
Impaired compliance
  high PEEP, Plateau, minute vent
Cardiac arrest

Increased survival:
MV < 7 days
Prone positioning
Neuromuscular blockade
Infection related ARDS
Trauma
Asthma
RESP score for the British soldier with anaphylaxis, multi organ failure is -2; confers 30-50% survival

- High CO2
- High peak inspiratory pressures
- Bicarbonate infusion
- Non respiratory organ dysfunction

- Everyone says he is going to die, his brain injury is now severe, kinder for him to let him go?

- What do you want to do? Command, political issues...
VV ECMO

Gas exchange
And
Perfusion quickly
Improved

Fem 23F
IJ 17F
VV ECMO – Fem to IJ

On back of C17 before take off
11 days later – in Regensberg Hospital, Germany

Survived
Gentle VATS
R lung for
Hemothorax

Liver recover
After 3 weeks

Still on CRRT
4 months later - Discharged from UK hospital

What was the infection?

Hemodialysis 9 weeks

Cardiomyopathy

What about his brain?
8 months later

Hiking with his new wife in Verona, Italy

Able to run for 40 minutes – mild chest tightness

They bought a dog and named him ECMO
Patient selection for VV ECMO

- Failure of optimal therapy
  - Earlier ECMO is better
- Reversible process
  - Tolerate anticoagulation
- Good neurologic outcome possible
- If chronic organ dysfunction exists – ECMO reasonable if they are a transplant candidate
- Active bleeding – acceptable if the bleeding is reversible and not large CNS bleed
  - CNS bleed: if small, wait 6-12 hours, repeat head CT, go on ECMO without anticoagulation for 1-3 days
Evidence for VV ECMO

CESAR Trial
- Referral to an ECMO center improves outcome
- Old technology used, roller pumps, 15% MARS; not reflective of current practice
- The other older trials also not reflective of today’s technology and critical care practice

EOLIA Trial
Early VV ECMO at high volume centers versus
Early lung protective ventilation with high PEEP
- 11% reduction in mortality with ECMO p value 0.07
- higher bleeding requiring transfusion (46% ECMO v 28%)
- severe thrombocytopenia (27% ECMO v 16%)
- 28% emergency crossover rate to ECMO
- p value if include cross over patients 0.01
**Figure 2.** Kaplan–Meier Survival Estimates in the Intention-to-Treat Population during the First 60 Days of the Trial.
EOLIA Trial in Severe ARDS

Inclusion Criteria:
- P/F < 50 for 3 hours
- P/F < 80 for 6 hours
- pH < 7.25 and pCO₂ < 60 for 6 hours

Crossover Criteria:
- SaO₂ < 80% for > 6 hours
- 28% crossover with 43% survival
Indications expanding rapidly

- Hypercapnic failure (COPD, asthma, toxic overdose)
- Bridge to lung transplantation
- Pulmonary hypertension with right heart failure
- Earlier use in less severe hypoxic respiratory failure
  - Ultra lung protective ventilation
- Resuscitation of donor lungs prior to transplantation
- Bridge to early mobility

- Includes ECCO2R – low flow VV ECMO

REST, SUPERNOVA trials underway
ELSO guidelines – VV ECMO

• Relative contraindications:
  – Mechanical ventilation for 7+ days at high settings ($\text{FiO}_2 > 90\%$, $P_{\text{plat}} > 30$) – based on older data
  – Major immunosuppression
  – Recent or progressing CNS hemorrhage
  – Non recoverable co-morbidity
  – Terminal malignancy
  – “Increasing risk with increasing age”
  – Not a candidate for transplant
  – Chronic organ dysfunction
Jihye
32 yo presents for routine prenatal appointment at 32 weeks

- Ob notices her fingers are blue
- O2 saturation is 81% on RA
- Pt wants to return to work, dyspnea normal for pregnancy
- ECHO shows massive ASD
  - R to L shunt after long standing L to R shunt – Eisenmengers
  - Right heart failure, severe pulmonary hypertension
Progressive cardiopulmonary failure

- Rising O2 requirements on HFNC 50L, 90%
- Increasing pressor requirements
- Intubation carries risk for “RV suicide” and arrest

Is she a candidate for extracorporeal support?
A. Yes
B. No
Some team members say...

- She needs a heart lung transplant
- Too late to try and fix it
  - If you try and fix it heart will fail fatally
- She will lose the child...
- Call palliative care...

- Safest way is to place her on awake VA ECMO and then intubate if necessary
Planned C section on VA ECMO

- Uterine bleeding post partum – embolized
- Pulmonary hemorrhage
- Pseudomonas infection – develops resistance
- Right heart improves with venous drainage from ECMO cannula, diuresis, and treatment of pulmonary HTN
- Transitioned to VV with double lumen cannula in R IJ
O2 sats
90% tubed
65% extubated...
O₂ sats
53%...
Briefly
Mental status
Normal
Cardiac output
Hgb
65%

Goal O₂ sat > 60%

iPhone
VA ECMO

Cardiogenic Shock – inadequate tissue perfusion due to cardiac dysfunction

• Persistent hypotension:
  systolic blood pressure < 80-90 or mean arterial pressure 30 mmHg lower than baseline

• Cardiac Index reduction:
  < 1.8 L/min/m2 without support
  < 2.0 L/min/m2 with support

• Adequate or elevated filling pressures

• Evidence of end organ dysfunction
RefRACTORY CARDIOGENIC SHOCK

Shock persists despite volume administration, inotropes, vasoconstrictors, with or without IABP

Systemic hypoperfusion – cold, oliguric, altered mental status

Severe systemic hypotension

Respiratory distress due to pulmonary congestion
Cardiogenic shock

- Primary RV, LV, bivent failure – lungs working
  - Impella, Centrimag, TandemLife
- RV, LV, bivent failure with pulmonary instability
  - VA ECMO
- End organ dysfunction despite multiple pressors and ionotropes
- Use ECHO and PA catheter
VA ECMO - Indications

- 74 male POD 6 2\textsuperscript{nd} kidney transplant, cardiogenic and septic shock with multiorgan failure.
  - NSTEMI Trop 22, S/P remote CABG, EF 30\% down from 60\%.
  - Chronic immunosuppression due to transplant. Acute liver and renal failure.
  - Norepi at 300, Milrinone 0.5, neosynephrine at 250. Max doses. Lactate rising to 9. BP 60s/40s.
  - Respiratory failure O2 sat 85\% on 100\% and high PEEP.
- Transplant surgeons requesting VA ECMO

What do we decide?
A. Yes
B. No
Contraindications to VA ECMO

Absolute
- Unrecoverable heart and not a transplant or VAD candidate
- Chronic organ dysfunction (COPD, cirrhosis, renal failure)
- Compliance (financial, cognitive, psychiatric, social limitations) for further therapies if needed

Relative
- Contraindication for anticoagulation
- Advanced age
Estimate survival in VA ECMO

Save score  [www.save-score.com](http://www.save-score.com)

3846 patients

Increased mortality:
Chronic renal failure, longer MV,
Pre ECMO organ failure, cardiac arrest,
Congenital heart disease,
lower pulse pressure, lower HCO3

Increased survival:
Younger age, lower weight,
Acute myocarditis, heart transplant,
VT/VF, higher diastolic pressure, and
Lower peak inspiratory pressure

Eur Heart J. 2015
Sep 1;36(33)2246-56
Predicted Survival 35%
SAVE score For British pt -5

Eur Heart J. 2015 Sep 1;36(33):2246-56
History of Medical Air Evacuation:
Franco Prussian War 1870 – Hot Air Balloons

Historians debate if medical evacuation actually occurred?

Lam DM, Aviation, Space Environmental Med, Oct 1988
Basics of Long Range Air Transport – with right team… ECMO transport is actually easier and safer

- 6 phases, 6 procedure process
  1. ICU to ambulance
  2. Ambulance to plane
  3. Flight
  4. Plane to ambulance
  5. Ambulance to ICU
  6. Transfer care to new team
1. ICU to ambulance

56 year old civilian we started at Straub Hospital in Hawaii then flew to Iowa
2. Ambulance to plane

Conveyor belt, almost fell off at top
3. Flight – did well

Drive Console
Overheated

Ultrasound for cannula position
4. Plane to ambulance

Forklift
5. Ambulance to ICU

Had to
Reconfigure
Equipment
6. Transfer care

New circuit

Transient hypotension
Day 2 of ECMO

Cough, dyspnea,
Hypoxic, hypercarbic
13 days on ventilator
Large Right Air Leak
CO2 94, HCO 53
P/F ratio 88
Follows commands, writing to us via notepad
Prior health excellent

Michael: 23 year old Marine with Severe Respiratory Failure
Japan ➔ Hawaii ➔ Iowa
Massive bleeding in Hawaii

Right lung Bleeding

Bronch in Japan, HI

Antithrombin
Transport from Hawaii to Iowa
After 3 hours of flight; Mixed venous 48%, pulse oximetry on finger also 66%, Hgb 14.8
Pool or ocean?
After Starting Flolan - O2 and SvO2 Saturation quickly improved
38 days of ECMO, complex course at Tripler and Iowa

Coded X2 Iowa
PEA epi, shock
VF epi X2, shock X2

Prolonged hypoxia..

What about his Brain?
Video – made for non medical people
Initiation of Extracorporeal Support in Adults

- VV ECMO, VA ECMO, eCPR
  - Three different groups of patients
- Recognize failure of optimal management early
- Ensure that optimal evidence-based therapy has been achieved
- Select patients with a reasonable chance for a bridge to recovery, device, or transplant...
Extracorporeal support will define the future of the modern ICU.

Questions?
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