Conflicts of interest

None relevant

I have permission to use the photos used in this presentation
Objectives

• Appreciate spectrum of cardiorespiratory failure and ECLS therapies

• Understand mechanisms behind harlequin syndrome

• Discuss techniques to recognize and disrupt upper body hypoxia on VA ECMO
Spectrum of cardiorespiratory failure

- Predominant respiratory failure
- Predominant cardiac failure
- Combined cardiorespiratory failure
  - cardiac >> respiratory
  - respiratory >> cardiac
Conventional therapy

- Mechanical ventilation +/- adjuncts
- Vasoactive agents and IABC
- Renal replacement
- Other supportive ICU care
Conventional therapies can fail
Expanding use of ECLS

- Extracorporeal respiratory support
- Mechanical circulatory support (MCS)
- Advanced ECLS providing both respiratory and circulatory support
Extracorporeal respiratory support

• More straightforward

• VV ECMO or ECCO2R

• Cardiac function often improves after VV ECMO

• Small group needs additional MCS
MCS far more complex

- It's all about choosing the
  Right perfusion strategy
  Right time
  Right patient
The Grey Scale of MCS

• Acute Heart Failure
  – IABP
  – VA ECMO
  – Temporary LVAD/ BiVAD +/-oxygenator
  – Percutaneous VAD’s

• Chronic Heart Failure
  – LVAD/ RVAD
  – Total Artificial Heart
Adult MCS Pathways

Nature of Heart Failure
- Chronic
- Acute

Presentation
- Symptomatic
- Cardiogenic shock
- CPR

MCS Option
- VAD
  - Long Term
- pVAD/ECMO
  - Short Term

Destination
- Bridge to Transplant
- Recovery (+/- medical therapy)
- Destination
Spectrum of Acute MCS therapies

A  IABP

B  Impella

C  TandemHeart

D  ECMO
Is there a perfect MCS strategy

• NO
• All available options have risks/benefits
• Tailored to patient
• Often Incremental
• Fem-Fem VA ECMO a good starting point for most patients
Femoro- femoral VA ECMO
<table>
<thead>
<tr>
<th></th>
<th>Total Patients</th>
<th>Survived ECLS</th>
<th>Survived to DC or Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neonatal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>28,723</td>
<td>24,155</td>
<td>21,274 74%</td>
</tr>
<tr>
<td>Cardiac</td>
<td>6,269</td>
<td>3,885</td>
<td>2,599 41%</td>
</tr>
<tr>
<td>ECPR</td>
<td>1,254</td>
<td>806</td>
<td>514 41%</td>
</tr>
<tr>
<td><strong>Pediatric</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>7,210</td>
<td>4,787</td>
<td>4,155 58%</td>
</tr>
<tr>
<td>Cardiac</td>
<td>8,021</td>
<td>5,341</td>
<td>4,067 51%</td>
</tr>
<tr>
<td>ECPR</td>
<td>2,788</td>
<td>1,532</td>
<td>1,144 41%</td>
</tr>
<tr>
<td><strong>Adult</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>9,102</td>
<td>5,989</td>
<td>5,254 58%</td>
</tr>
<tr>
<td>Cardiac</td>
<td>7,850</td>
<td>4,394</td>
<td>3,233 41%</td>
</tr>
<tr>
<td>ECPR</td>
<td>2,379</td>
<td>948</td>
<td>707 30%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>73,596</td>
<td>51,837</td>
<td>42,947 58%</td>
</tr>
</tbody>
</table>
Results. Mean VA-ECMO support was $9.9 \pm 19$ days (range, 2 to 24 days). Cardiac recovery with ECMO weaning was achieved in 43 patients (75.5%), major complications were observed in 40 patients (70.1%), and survival to hospital discharge occurred in 41 patients (71.9%). After hospital discharge (median follow-up, 15 months) there were 2 late deaths. The 5-year actual survival was $65.2\% \pm 7.9\%$, with recurrent self-recovering myocarditis observed in 2 patients (at 6 and 12 months from the first AFM event), and 1 heart transplantation.

Table 4. Multivariate Analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\beta$</th>
<th>SE</th>
<th>Exp ($\beta$)</th>
<th>$p$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH before ECMO implantation</td>
<td>-14.251</td>
<td>7.148</td>
<td>.000</td>
<td>0.046</td>
</tr>
<tr>
<td>Lactate normalization, hours from ECMO implantation</td>
<td>0.029</td>
<td>0.012</td>
<td>1.029</td>
<td>0.013</td>
</tr>
<tr>
<td>Cardiac recovery</td>
<td>5.288</td>
<td>1.769</td>
<td>197.930</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Venoarterial Extracorporeal Membrane Oxygenation for Acute Fulminant Myocarditis in Adult Patients: A 5-Year Multi-Institutional Experience

VA ECMO: major challenges

- Maintaining LV ejection
- Preventing upper body hypoxia
- Distal limb perfusion
Peripheral VA ECMO: considerations

- Only an adjunct to native heart
- ↑LV after load and ↓LV ejection
- Pulmonary reserve and upper body hypoxia

Attempts to ↑ LV ejection worsen upper body hypoxaemia in setting of ↓pulmonary function
Pulmonary reserve and peripheral VA ECMO

- Normal
- Marginal
- Can get worse subsequently: pulmonary edema, haemorrhage, infection etc

Do marginal lungs matter if heart is not ejecting well?
Cardiac reserve and peripheral VA ECMO

• Can get better or worse
• Consequences depend on pulmonary reserve and LV distension and need for venting
If lungs good, Double thumbs up!!
If not, bit of a problem

Fem–fem VA ECMO
16 y old, pneumonia, septic shock

Day 1 SOFA score = 17
16 y old, pneumonia, septic shock

- Presenting in extremis
- Severe cardiac failure, but not critically hypoxic
- Urgent fem-fem VA ECMO
- Over next 2 days heart gets better, lungs get worse -> differential hypoxia
- Changed to VV ECMO
- Weaned off VV ECMO after 44 days
Understanding differential hypoxia
Peripheral VA ECMO and systemic oxygenation

Minimal LV ejection +/- bad lungs = retrograde perfusion from ECMO = less risk of upper body hypoxia

Some LV ejection + bad lungs = upper body hypoxia
fem–fem VA ECMO and harlequin

- Differential venous oxygen return
  \[ \text{SVC Sao2} \ll \text{IVC Sao2} \]

- Lower body perfused with ECMO and upper body from native cardiac ejection

Two circuits
Two independent circuits

**UPPER BODY**

- SVC
- Lungs
- LV

**LOWER BODY**

- IVC
- Oxygenator
- ECMO pump
Note drainage cannula in IVC

RA drainage much better and preferred

*†Mattias Lindfors, *‡Björn Frenckner, §Ulrik Sartipy, ¶**Anna Bjällmark, and *†***Michael Broomé

Artificial Organs 2016, 00(00):00–00
Superior vena cava drainage improves upper body oxygenation during veno-arterial extracorporeal membrane oxygenation in sheep

Xiaotong Hou\textsuperscript{1,2*}, Xiaofang Yang\textsuperscript{1,2}, Zhongtao Du\textsuperscript{1,2}, Jialin Xing\textsuperscript{1,2}, Hui Li\textsuperscript{2,3}, Chunjing Jiang\textsuperscript{1,2}, Jinhong Wang\textsuperscript{1,2}, Zhichen Xing\textsuperscript{1,2}, Shanglei Li\textsuperscript{1}, Xiaokui Li\textsuperscript{4}, Feng Yang\textsuperscript{1,2}, Hong Wang\textsuperscript{1,2} and Hui Zeng\textsuperscript{5,6*}
Anesthesia, intubation, mechanical ventilation, and IVC-FA canulation (control)

Blood gas

IVC-FA circulation (IVC-FA+mechanical ventilation: n=18)

15 min Blood gas

Discontinue ventilation to make respiratory failure

IVC-FA (divided into 3 groups)

15 min Blood gas

SVC-FA (n=6)  IVC-CA (n=6)  FA-IV (n=6)

15 min Blood gas
Is IVC-FA really a good option?

Table 1 The difference of oxygen saturation between IVC-FA and other approaches of cannulation

<table>
<thead>
<tr>
<th></th>
<th>SVC-FA</th>
<th>IVC-CA</th>
<th>FA-IJV</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVC</td>
<td>30.9 ± 0.5</td>
<td>39.6 ± 1.7*</td>
<td>46.4 ± 1.4*</td>
</tr>
<tr>
<td>PA</td>
<td>40.2 ± 1.4</td>
<td>38.3 ± 1.2</td>
<td>22.0 ± 0.4*#</td>
</tr>
<tr>
<td>Aorta</td>
<td>40.3 ± 0.9</td>
<td>63.9 ± 1.3*</td>
<td>22.1 ± 0.6*#</td>
</tr>
<tr>
<td>IVC</td>
<td>−1.3 ± 0.9</td>
<td>−18.8 ± 1.8*</td>
<td>−7.6 ± 0.7*#</td>
</tr>
</tbody>
</table>
Retrograde flow on IVC-FA VAECMO

Figure 3 Aorta angiography in IVC-FA. (a) The diagram of aorta angiography. (b) Representative photos in the early stage of angiography. (c) Representative photos in the intermediate stage of angiography. (d) Representative photos in the late stage of angiography. The black arrow shows the contrast medium, which could only reach the diaphragm level. IVC-FA: inferior vena cava through the femoral vein and a return cannula was inserted into the femoral artery.
SVC-FA vs. IVC-FA

IVC-FA: contrast from IVC doesn’t reach RA

SVC-FA: contrast from SVC doesn’t reach RA
Harlequin avoidable

• Optimal RA drainage from start

• Careful monitoring

• Optimal medical management

• Timely change of ECLS configurations
Monitoring for differential hypoxia

- Spo2/Pao2 both radial arteries, esp. R radial
- Neuro monitoring, NIRS, Bto2
- Jugular oximetry
- PA catheter -> SVO2
- Pre oxygenator sao2/pao2 poor predictors
Disrupting differential hypoxia
Medical measures

- Optimise mechanical ventilation, add inhaled nitric oxide / prostacyclin
- Minimise O2 consumption: sedation, paralysis, hypothermia
- Haemoglobin ~100
- Reduce inotropy if possible
- Modulate HR if native CO relatively high
- ↑ECMO blood flows transiently
Harlequin: problem or positive sign?

- Bad news is lungs are bad
- Good news is heart is ejecting

Is the heart good enough to wean from VA ECMO
Perfusion strategies

- Change to VV ECMO ± inotropes, IAB/ pVAD
- Advance IVC cannula to RA/SVC
- VAV : Return oxygenated blood to RA
- VVA: additional SVC drainage cannula
- Upper body arterial return: subclavian
- Central VA ECMO
- LVAD/BiVAD configurations with oxygenator in circuit
Change to VV

- Tricky as heart not fully recovered
- Turn down for assessment may precipitate upper body hypoxia crisis due to ↑LV ejection
- Much safer to have another venous cannula in before turn down: if heart good change to VV if not to VAV
- If heart not fully recovered – pVAD one short term option
Push IVC cannula into SVC

- Safety concerns
- Dual lumen catheters often limit flows and ↑hemolysis
- Not recommended as first line option
VAV ECMO

Return on left and right side of circulation

Increases respiratory support

Decreases cardiac support

Modulating return flows on both sides can be tricky

L. Christian Napp¹ · Christian Kühn² · Marius M. Hoepel³ · Jens Vogel-Clausen⁴ · Axel Haverich⁵ · Andreas Schäfer⁶ · Johann Bauersachs⁷

Clin Res Cardiol (2016) 105:283–296
VVA ECMO

Better RV unloading

Draining hypoxic SVC blood for oxygenation

Dual lumen cannula an option but flows limited

L. Christian Napp¹ · Christian Kühn² · Marius M. Hoepel³ · Jens Vogel-Clausen⁴ · Axel Haverich⁵ · Andreas Schäfer⁶ · Johann Bauерsachs⁷

Clin Res Cardiol (2016) 105:283–296
Subclavian /axillary/carotid return

Cannulation not always possible

Differential flows UL oedema
Central VA ECMO

More relevant to paediatrics

Invasive procedure in sick patients

Allows for LV venting if need be

Bleeding risks
LVAD /RVAD/ BiVAD with oxygenator in circuit
ECMO circuit as temp VAD

A: Fem – Fem VA
B: Fem-Fem VA + LV apex vent
C: LVAD Fem return
D: LVAD Subclavian return

Shekar et al. Critical Care 2014, 18:219
http://ccforum.com/content/18/2/219
ECMO circuit as temp BiVAD

- 1 pump
- 2 pumps
+/- Oxygentorar

Shekar et al. Critical Care 2014, 18:219
http://ccforum.com/content/18/2/219
Other Alternatives

Combining pVADs (Impella or Tandem Heart) with VV ECMO
- costs
- short term use and arterial complications
- Hemolysis
Summary

• Harlequin syndrome a real problem esp. with fem-fem VA ECMO
• Draining just IVC/SVC suboptimal
• RA drainage and optimal medical management minimizes risks
• Early recognition and timely change of ECLS configurations critical
APELSO Gold Coast, Australia, October 2017

The 3rd Conference of Asia-Pacific Extra-Corporeal Life Support Organization

ECMO ....and Beyond

www.apelso2017.com

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Adult Intensive Care Services, The Prince Charles Hospital
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| Gunma University | Texas Heart Institute |
| Institut Jantung Negara |  |
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