Long Term Support for Respiratory Failure: VV ECMO or Oxygenated RVAD?

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Disclosure: I have no professional or financial relationship with any of the devices or technologies discussed.
THE PARACORPOREAL ARTIFICIAL LUNG: TRANSTHORACIC TOTAL SUPPORT OR PERCUTANEOUS NEAR TOTAL SUPPORT...WHICH IS BETTER?

Zwischenberger et al (2009), University of Kentucky

Ambulatory “OxyRVAD” for total right heart and respiratory support

The “OxyRVAD” is created by commercially available components consisting of “off label” use of a compact low resistance gas exchange device coupled with a right ventricular axial flow ventricular assist device...“central cannulation”

Percutaneous pump-artificial lung

Single site venous cannulation (Wang-Zwische double lumen cannula). Based on double lumen VV ECMO, the DLC is designed to be inserted from the jugular vein traversing the SVC-RA-IVC. The drainage lumen has a wide open end placed in the IVC for the lower body venous drainage and a side opening in SVC for upper body venous drainage. The infusion lumen opens towards the tricuspid valve in the RA.

Bi-caval dual lumen venovenous cannula
Requirements for long term support ...

(1) durability

(2) normalization of physiology

(2) adequate functional performance

“upright, ambulatory, and socially interactive”
| **VV** | venovenous ECMO (internal jugular and femoral vein) | **42 days** |
| **VV (DL)** | venovenous DL (right internal jugular, Avalon dual lumen) | **372 days** |
| **VA (f)** | venoarterial (femoral vein to femoral artery/retrograde) | **35 days** |
| **RA to Ao** | “walking bypass” (right atrium to ascending aorta) | **103 days** |
| **RA to PA** | “oxyRVAD” (right atrium to pulmonary artery) | **91 days** |
| **PA to LA** | “pulmonary bypass” (pulmonary artery to left atrium) | **18 days** |
| **RA to LA** | “pulmonary bypass” (right atrium to left atrium) | **14 days** |
| **VV (DL) + BAS** | venovenous right IJ double lumen catheter + atrial septostomy | **5 days** |
| **VAV (hybrid)** | RIJ dual lumen catheter with both right subclavian artery | **52 days** |
| **PECLA (central)** | pumpless extracorporeal lung assist (PA to LA) | **11 days** |
| **PECLA (peripheral)** | pumpless extracorporeal lung assist (femoral a to femoral v) | **3 days** |
| **ProTek Duo DLC** | RA to PA | **57 days** |
14 yo cystic fibrosis s/p right completion pneumonectomy

VV ECMO DLC

Cor pulmonale with PEA

... to central cannulation

ECMO day 103
68 yo scleroderma variant, elevated ANA…suprasystemic PA pressures on continuous dobutamine, lasix qtt, high flow O2. Failed vasodilator therapy x 3…non-ambulatory with syncope

To cath lab...combined atrial septostomy and right IJ dual lumen venovenous ECMO cannulation...bridge to transplant (ECMO day 4)
Use of a novel pulmonary artery cannula to provide extracorporeal membrane oxygenation as a bridge to lung transplantation

Enrique Diaz-Guzman, MD, a
Nirmal S. Sharma, MD, a Keith Wille, MD, MPH, a
and Charles W. Hoopes, MD b
The “oxyRVAD” ...

... any blood pump with an in-line oxygenator (by definition)

... hypoxia with inadequate left ventricular preload (by indication)

“We define right heart failure as a clinical syndrome due to an alteration of structure and/or function of the right heart circulatory system that leads to sub-optimal delivery of blood flow (high or low) to the pulmonary circulation and/or elevated venous pressures – at rest or with exercise.”


Our continued lack of understanding of pulmonary hypertension ... limitations of a reductionist approach to define a complex clinical syndrome based on end stage pathological observations

Chan and Loscalzo (2011) Comp Physiol 1:123-139
Etiology of Right Heart Failure

Cardiopulmonary

- Respiratory and RV Failure
- Respiratory and Biventricular Failure
  - RA-LA ECMO
  - V-A ECMO

RV Failure

- Percutaneous RVAD
- Surgical RVAD

Isolated Respiratory Failure

- V-V ECMO

Intermacs 1
Intermacs 2
Intermacs 3
Respiratory failure is not a static process ... pulmonary hypertension is a common “end stage” denominator

Compensation for pathophysiology is not equivalent to physiological support
Pulmonary hypertension in interstitial lung disease: Prevalence, prognosis and 6 min walk test

- 15% of ILD cohort
- associated with IPF
- decreased performance
- increased mortality
“The final common course in all these patients might be heralded by the onset of PH, which then drives outcomes in a similar fashion, no matter the initial cause or pattern of fibrosis … categorizing patients into one of the nine categories or subcategories of IIP might be semantic, because when PH does supervene, invariably there is a component of either UIP or NSIP, no matter the initial clinical or histopathologic presentation.”
... patients with sclerosis related PAH have relatively depressed RV function ... “during exercise, this results in ventricular-pulmonary vascular uncoupling and acute RV dilation.”


RV performance is rarely (if ever) the issue in primary pulmonary hypertension ... it can be in secondary pulmonary hypertension and hypoxic pulmonary vasoconstriction
“… arterioles or capillaries may contract or dilate so as to adjust the blood supply.”

JS Haldane
Respiration (1922, p. 427)
56 yo idiopathic pulmonary fibrosis…uncomplicated bilateral lung tx March ’08. Dec ’08 Trichosporon pneumonia, progressive SOB secondary to post-infectious obliterative bronchiolitis. Profound hypoxia with effort, non-ambulatory on high flow O2 (ICU)...listed for redo lung transplant

**Stress ECHO (exercise, supine bicycle)**

<table>
<thead>
<tr>
<th>Pre VV ECMO</th>
<th>Post VV ECMO</th>
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<tbody>
<tr>
<td>6 min 13 sec, max 10 watts</td>
<td>9min, max 50 watts</td>
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<tr>
<td>sats 84% on 8L NC with onset exercise</td>
<td>sats 87% on RA with onset exercise, 98% on 4L (Stage 3)</td>
</tr>
<tr>
<td>exercise d/c’d secondary SOB (15L O2)</td>
<td>exercise d/c’d secondary fatigue</td>
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<tr>
<td>PASP 60 + RA with peak exercise (PVTI 13)</td>
<td>PASP 41 + RA with peak exercise (PVTI 10)</td>
</tr>
<tr>
<td>R to L shunt via PFO with peak exercise</td>
<td>No shunt with peak exercise</td>
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<tr>
<td>Non ambulatory secondary to hypoxia</td>
<td>Ambulatory on treadmill</td>
</tr>
<tr>
<td>Subjective recovery time “hours”</td>
<td>Subjective recovery</td>
</tr>
</tbody>
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*More fibrinolysis, less thrombocytopenia

“Efficiency” is engineered …

“Efficacy” is dependent upon details of deployment
OxyRVADs and patient selection ...

Difficult to stratify the appropriate population most likely to benefit from oxyRVAD support and develop a communication strategy to convey disease etiology and severity
A TPR > 3 WU predicts poor performance with veno-venous ECMO support (n=5)
MCS for pre-capillary pulmonary hypertension

Primary PH
- *PECLA (PA to LA, central)
- RA to LA (central)
- **VV ECMO DLC + septostomy
- RA to PA “low flow”

Secondary PH
- “dynamic” (HPV)
  - Peripheral RA to PA (ProTEK Duo)
  - “hybrid “VV + subclavian Arterial
  - VV ECMO DLC + septostomy
  - “OxyRVAD”
- “fixed” (obstructive)
  - VA ECMO (peripheral “salvage”)
  - VA ECMO (central RA to Ao “bridge”)

Idiopathic primary pulmonary hypertension
- Hypoxic pulmonary vasoconstriction (“dynamic”)
- Obstructive (CTEPH, emboli, CWP, PVOD ...”fixed”)
- “congenital heart” (Eisenmenger’s, Fontan, PA agenesis)

* Pumpless Extra Corporeal Lung Assist

** “physiological” oxyRVAD