Indications For and Use of Two Parallel Oxygenators in an ECMO Circuit

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ECMO Support Provides

- Oxygenation
  - 400 – 579 ml/O2/min @ 7.0 lpm
  - VV cannulation 60% of cardiac output
  - VA cannulation 100% of cardiac output
- Decarboxylation
  - 2:1 sweep:blood flow @ 7 lpm = 450 ml/CO2/min
- Blood flow
  - 0 - 7.0 lpm
Indications For ECMO Support

– Murray Score $\geq$ 3
– PaO$_2$/FIO$_2$ ratio < 100 with FIO$_2$ 60% or failure to maintain SaO$_2$ > 88%
– Ventilation parameters - Pplat < 30 mmHg, TV $\leq$ 6 ml/kg, PEEP 10-22 cm H$_2$O
– Recruitment maneuvers – positioning or proning
– PaCO$_2$ retention resulting in pH $\leq$ 7.2
Oxygen Consumption

Oxygen consumption (VO2) is variable depending on age, muscle mass, infection or level of activity.

Extraction ratio VO2/DO2 of 20 – 30% is normal for oxygen consumption to delivery.

Consumption of oxygen (VO2) at rest - 1 MET (3.5 ml/kg/min).

VO2 can be as high as 35 - 40 ml/kg/min in ARDS and Sepsis.
Worsening Hypoxia

When DO2 is inadequate to meet demand, peripheral tissues switch to anaerobic metabolism and oxygen consumption decreases.

The lactic acidosis that occurs is a reasonable clinical marker of supply dependency and inadequate tissue perfusion.

Maximizing DO2 is an important part of the hemodynamic resuscitation of patients with septic shock.

The normalization of arterial lactate concentration is a reasonable goal of resuscitative ECMO efforts.

Methods to Treat Hypoxia

- Hypothermia
- Sedation, paralysis
- Increase CaO2 (transfusion, diuresis)
- Decrease patient add mixture (beta blockade)
- Increase ECMO flow
- Reduce recirculation
- Prone positioning
- Switch to venoarterial or a hybrid configuration

Montisci et al., Management of Refractory Hypoxemia During Venovenous Extracorporeal Membrane Oxygenation for ARDS ASAIO Journal 2015; 61:227–236
Worsening Hypercapnia

**Causes:**
- Ventilation/Perfusion mismatch (shunting)
- Air trapping
- Hypermetabolism
- Fluid overload
- Sepsis

**Hypercapnia effects:**
- Elevated intracranial pressure
- Pulmonary hypertension,
- Decreased myocardial contractility
- Decreased renal-blood flow
- Release of endogenous catecholamines
- Arrhythmias
Methods to Treat Hypercapnia

- Adjust lung ventilation to reduce dead space
- Decrease FIO2
- Increase minute ventilation
- Trial of inhaled pulmonary vasodilators
- Hypothermia,
- Sedation, paralysis
- Prone positioning
- Switch to venoarterial or a hybrid configuration (VV/VA)
Single Oxygenator

- Oxygenators rated to 7 liters transfer from 400 – 579 ml/O2/min
  - Quadrox-i adult (1.8 m² - 400 ml/min O2, 10 gm Hgb/100% FIO2)
  - Dideco 903 (2.0 m² - 579 ml/min O2, 10 gm Hgb/100% FIO2)
- As flow increases in an oxygenator so does internal shunting
- At 4.0 lpm a 10% shunt fraction occurs at 37 degrees Celsius
- Shunt fraction doubles at temperatures of 32 degrees Celsius

Oxygenator Performance

Quadrox-i-adult oxygenator

**O₂ Transfer**

- Graph showing the relationship between blood flow (l/min) and O₂ transfer (ml/min).

**CO₂ Transfer (37°C)**

- Graph showing the relationship between blood flow (l/min) and CO₂ transfer (ml/min) for different gas to blood flow ratios (2:1, 1:1, 0.5:1).
Indications for Parallel Oxygenators

- Increasing lactatemia and high Cv-aCO2/Da-vO2 ratio
- VCO2 > CO2 removal
  - Need for > 2:1 sweep to blood flow
  - Maintenance of lung protective strategies per ARDS.net
  - Second oxygenator increases surface area for CO2 removal
- VO2/DO2 > 40%
  - Need for increased blood flow to meet VO2 requirements
  - VV/VA cannulation or switch to VA central cannulation
- Murray Score ≥ 3
- PaO2/FIO2 ratio < 100 with FIO2 60% or failure to maintain SaO2 > 88%
- Ventilation parameters - Pplat < 30 mmHg, TV ≤ 6 ml/kg, PEEP 10-22 cm H2O
- Recruitment maneuvers – positioning or proning
- PaCO2 retention resulting in pH ≤ 7.2
Pressure and Flow Dynamics of Parallel Oxygenators

Similar Oxygenator Internal Resistance
Pressure and Flow Dynamics of Parallel Oxygenators

Differing Oxygenator Internal Resistance

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Summary

• Indications for a second oxygenator are same as initial indication for ECMO support:
  • need for oxygenation and decarboxylation with lung protective ventilation
  • VO2 and VCO2 exceed performance of a single oxygenator

• A second oxygenator will increase surface area and function for improved CO2 removal, but will not significantly increase oxygen delivery

• Need for increased blood flow for oxygen delivery, after efforts to reduce oxygen consumption, may require advanced cannulation strategies