



University of Colorado Hospital

UNIVERSITY OF COLORADO HEALTH

Extracorporeal Membrane Oxygenation Program

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 ≥ 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

Oxygen Consumption

Oxygen consumption (VO_2) is variable depending on age, muscle mass, infection or level of activity

Extraction ratio VO_2/DO_2 of 20 – 30% is normal for oxygen consumption to delivery

Consumption of oxygen (VO_2) at rest - 1 MET(3.5 ml/kg/min)

VO_2 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)



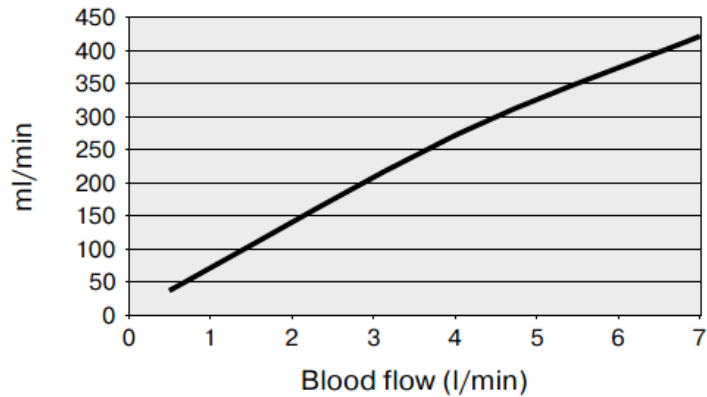
Single Oxygenator

- 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 Celcius
- Shunt fraction doubles at temperatures of 32 degrees Celcius

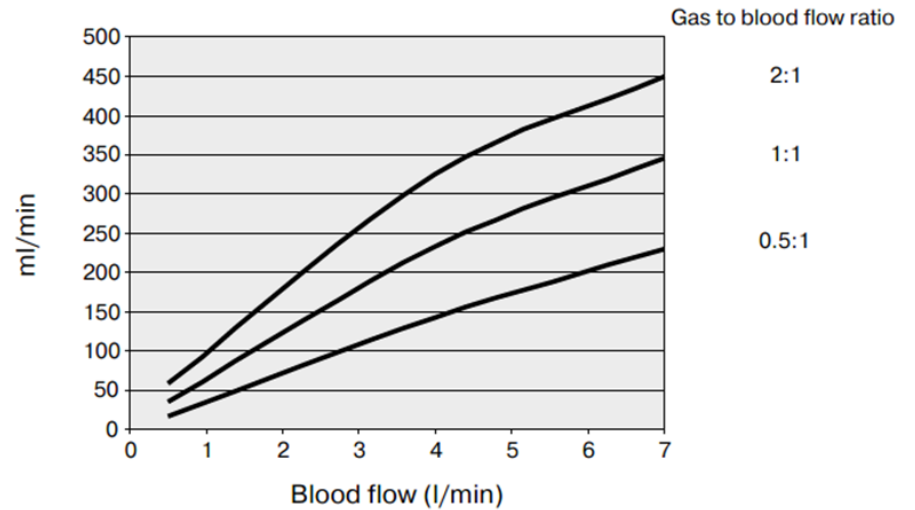
Oxygenator Performance

Quadrox-i-adult oxygenator

O₂ TRANSFER

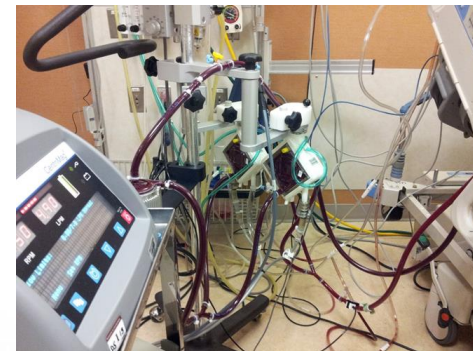


CO₂ TRANSFER (37°C)



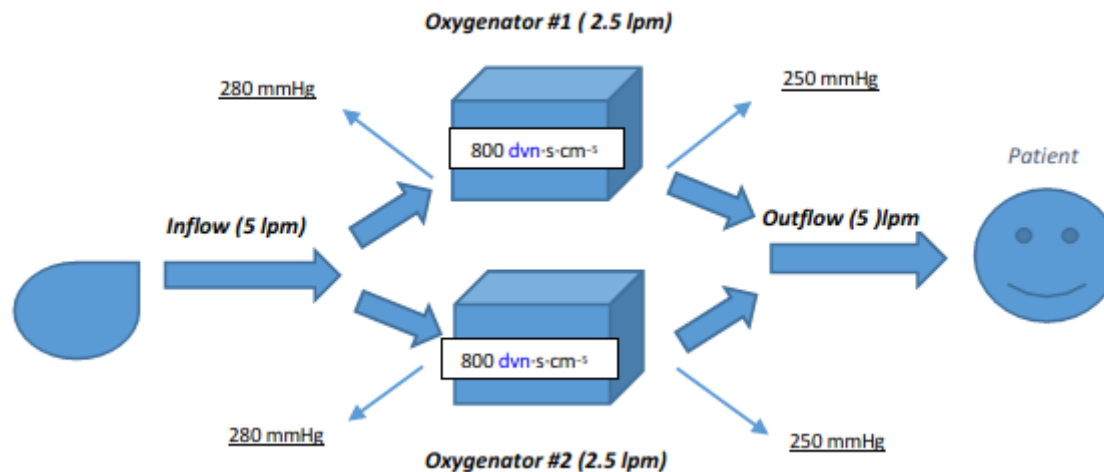
Indications for Parallel Oxygenators

- 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



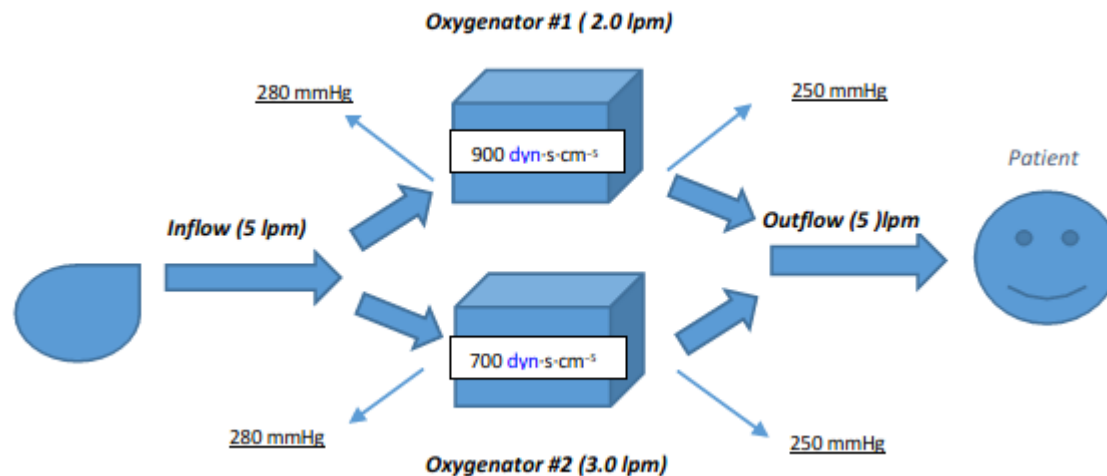
Pressure and Flow Dynamics of Parallel Oxygenators

Similar Oxygenator Internal Resistance



Pressure and Flow Dynamics of Parallel Oxygenators

Differing Oxygenator Internal Resistance



Summary

- Indications for a second oxygenator are same as initial indication for ECMO support:
 - need for oxygenation and decarboxylation with lung protective ventilation
 - VO_2 and VCO_2 exceed performance of a single oxygenator
- A second oxygenator will increase surface area and function for improved CO_2 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

