Mechanical Ventilation

Hemodynamic Monitoring

Cardiac Output

- Methods of measurement/calculation
  - 
  - 
  - 
  - 
  - 

Dye Dilution

- Need
  - Catheter in central vein or Swan-Ganz
  - Arterial catheter
  - Cardiac output computer
  - Densitometer
Dye Dilution

• Technique
  – Bolus of dye (Cardiogreen) injected while arterial blood withdrawn by a “syringe withdrawal pump” at steady rate through densitometer cuvette
  – Densitometer sends a light through blood to a photocell

Dye Dilution

• Technique
  – When dye bolus crosses light source - more light passes through sample
  – Densitometer records arrival time of dye bolus
  – Computer calculates cardiac output

Fick Equation

• Estimation

\[
\dot{Q}_T = \frac{\dot{V}O_2}{C(a - v)O_2}
\]

• Assume VO₂ stable at 250 ml/min
Thermodilution

- Most common
- Need
- 

Thermodilution

- Set-up

Thermodilution

- Procedure
  - Room temperature saline injected fast (< 3 sec.) through proximal port (RA)
  - Arrival time of temperature change detected by thermistor bead near cath tip
  - Computer calculates cardiac output
  - Do x 3 then average
Thermodilution

• Continuous measurement
  – Special swan-Ganz with thermistor
  – Heating filament on cath in RV
  – 1 to 4 sec. bursts of heat (44°C.)
  – Thermistor detects temp change
  – Computer calculates
  – Updates every 30 sec.
  – Display is average of previous 3-6 min.

Complications of BTFDC

• Pulmonary artery perforation
  – Rare
  – Can hemorrhage

Complications of BTFDC

• Pulmonary infarction
  – Cause
  •
  •
  – Precautions
  •
  •
Complications of BTFDC

- Air, blood embolus
  - Cause
  - Precautions

- Dysrhythmias
  - Cause
  - Precautions

- Pneumothorax during insertion
- Valve damage
- Infection, sepsis
- Endocarditis
- Microelectric shock
### Care of the Patient

- Limit patient to supine, < 45°, left lateral
- Do not use arms, axilla, shoulders to move patient
- Insertion site inspected & dressing changed daily
- Never flush catheter in wedge position

### Care of the Patient

- Never advance catheter in PA with balloon deflated
- Change catheter or DC after 72 hrs.
- Transducer is very fragile
- All readings taken at end-expiration when on vent
- All readings taken with transducer at RA level

### Blood Gases

\[ \text{SvO}_2, C(a - v)O_2 \]

- \( \text{SvO}_2 \) measurement can be intermittent (co-oximeter) or continuous (in vivo oximetry)
- Both method use spectrophotometry
**Spectrophotometry**

Measurement of light intensities in a specific portion of the light spectrum

2 methods of operation:
- Transmission spectrophotometry
- Reflection spectrophotometry

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**Transmission Spectrophotometry**

- Blood sample between light source & photodetector
- Light passes through
- Different wavelengths absorbed

- Reduced Hgb absorbs more light than oxyHgb
- Photodetector senses amount of light
- Transmitted to processor which converts value to mixed venous saturation

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**Reflection Spectrophotometry**

- Same principle as transmission spectr.
- Photodetector & light source on same side of blood sample
- Uses fiberoptic BTFDC catheter or forehead probes
Section 3d Monitoring 2

Fiberoptic Catheter

• 5 lumens
  – Distal port
  – Proximal port
  – Balloon lumen
  – Thermistor
  – Fiberoptic module

O₂ Transport Studies

• Various measurements & calculations can serve as excellent indicators of cardiopulmonary function
• We will look at
  – Total oxygen delivery
  – Arterial-mixed venous O₂ content
  – Oxygen consumption
  – Mixed venous saturation
  – Oxygen extraction ratio

Total Oxygen Delivery

• DO₂
  • Total amount available for tissue oxygenation
    \[ \text{CaO}_2 = (1.34 \times \text{Hgb} \times \text{SaO}_2) + (\text{PaO}_2 \times 0.003) \]
  • ml O₂/100 ml blood =
  • CaO₂ depends on
Section 3d Monitoring 2

**Total Oxygen Delivery**

\[ \text{DO}_2 = \text{CaO}_2 \times Q_T \times 10 \]

- Can see that total \( \text{DO}_2 \) also depends on cardiac output

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**C(a-v)O**

- What is between ① & ②?
  - \( \text{CaO}_2 = 20 \text{ vol}\% \)
  - \( \text{CrO}_2 = 15 \text{ vol}\% \)
  - \( \text{C(a-v)O}_2 = 5 \text{ vol}\% = 5 \text{ ml} \text{O}_2 \text{ extracted by tissues from each 100 ml blood} \)

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**Oxygen Consumption**

- \( \dot{\text{VO}}_2 \)
  \[ Q_T \times \text{C(a-v)O}_2 \times 10 \]
Section 3d Monitoring

**Point #1**

- How much oxygen was delivered in 1 minute?
- How much oxygen was consumed in 1 minute?

Normally - $O_2$ delivered $>$ $O_2$ consumed

**Point #2**

Fick Equation

$VO_2 = C(a-v)O_2 \times Q_T \times 10$

- Can see that if $VO_2$ is constant, as $Q_T \downarrow$, $C(a-v)O_2 \uparrow$

$VO_2 = C(a-v)O_2 \times Q_T \times 10$

- Normally, if:
  - met. need for $O_2 \uparrow$
  - Hgb $\downarrow$
  - $SaO_2$ $\downarrow$
  - $PaO_2$ $\downarrow$

- Body will compensate by
  - $\uparrow Q_T$ &/or
  - $\uparrow O_2$ extraction from blood $\rightarrow$ $SvO_2 \downarrow$ $\rightarrow$
Healthy body can
– ↑ O₂ up to x
– ↑ O₂ extraction → SvO₂ to
and still maintain normal amount O₂ to
tissues (providing cardiac function is OK and
tissue O₂ extraction mechanisms are OK)

However -
• If cardiac function is impaired or
  patient is critically ill
  ↓
  Only mechanism now available to
  maintain tissue oxygenation is to . . .

So . . .
• If SvO₂ monitored & it is ↓, it means
  that:
  – at least 1 of the O₂ transport components
    has been impaired (Hgb, SaO₂, PaO₂, Q₉)
    or
  – VO₂ has ↑
• Must determine which for proper Rx
Assess . . . .

- Hgb, ABGs
- If
  - Hgb OK
  - SaO₂ OK
  - PaO₂ OK
  - VO₂ constant

- A drop in SvO₂ may be 1st clinical sign!!

Mixed Venous Saturation

- Normal -
  - < 60% = onset of cardiac decompensation
  - < 50% = onset of anaerobic metabolism
  - < 30% = loss of consciousness, death is imminent

Mixed Venous Saturation

- Uses
  - Assessment of Q₁

  \[ Q_1 \downarrow \]
  \[ O_2 \text{ extraction} \uparrow \]
  \[ P\text{vO}_2, \text{SvO}_2 \downarrow \]
  \[ C(a-v)O_2 \uparrow \]
Mixed Venous Saturation

- Uses
  - Management of sepsis (septicemia)
    - massive vasodilation
    - regional pooling of blood
    - venous return, O₂, VO₂↑
    - SvO₂↓

O₂ Extraction Ratio

- = amount O₂ extracted by tissues / amount O₂ delivered (per 100 ml blood)

\[
O₂ER = \frac{\text{C(a - v)O₂}}{\text{CaO₂}}
\]
## O₂ Extraction Ratio

<table>
<thead>
<tr>
<th>Scenario</th>
<th>O₂ ER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. CaO₂ 20 vol%</td>
<td>( \text{CaO}_2 \text{ 10 vol%} )</td>
</tr>
<tr>
<td>2. ( \text{Ca} \text{(a-( \varphi ))O}_2 \ 5 \text{ vol%} )</td>
<td>( \text{Ca} \text{(a-( \varphi ))O}_2 \ 5 \text{ vol%} )</td>
</tr>
</tbody>
</table>

**Calculation:**

\[ \text{O₂ ER} = \]
Intra-Aortic Balloon Pump

• = circulatory assistance
• Valuable for patients with severe cardiogenic shock which occurs when LV cannot maintain cardiac output
• Happens when > 40% of contracting muscle mass is lost

Intra-Aortic Balloon Pump

• IAB catheter threaded through femoral artery into thoracic aorta until tip is at level of left subclavian artery
• IAB inflated & deflated by external pump with helium

IAB Pumping

• Balloon inflated during diastole
• Aortic valve is closed
• Inflation of balloon causes blood to be forced
  – Up into coronary arteries
  – Into upper extremities
  – Down into renal arteries
  – Down into lower extremities
Effect #1

IAB Pumping

- Balloon deflated just prior to systole
- Aortic valve snaps open
- Aorta contains deflated balloon & very little blood
- As LV contracts → pumps against low volume, low pressure

Effect #2
Care & Complications

- Anticoagulation therapy to ↓ clot formation around balloon & catheter
- Requires competent aortic valve
- Risk of ↓ circulation to lower extremities if arteriosclerosis
- Pressure exerted by balloon may enlarge existing aortic aneurysm

Weaning

- Balloon may be set to inflate with every heartbeat (1:1), every other beat (1:2), 1:3, 1:4, 1:6, 1:8