Hemodynamics and Calculations
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- Saturations
- Pressures
- Calculations
Saturations

- Mixed venous saturation
  - Saturation of venous blood returning to the heart
  - What saturation should we use?
    - Streaming
    - Sampling error
Mixed venous saturation

- Low
  - Poor cardiac output
  - Anemia
  - Systemic desaturation
- High
  - Low extraction (paralyzed, heavily sedated...)
  - Above average cardiac output
Saturations

- Systemic saturation
  - Low
    - Right to left shunting
    - Parenchymal lung disease
    - Intrapulmonary shunt
Right Heart Pressures

Right Atrium

Right Ventricle

PA
Left heart pressures

Left atrium/PCWP

Aorta

LV
Normal Values

Diagram of a normal heart with percentages and measurements:

- A = 6-12
- V = 8-15
- M = 5-10
- 15-25/5-10
- 70% (>3%)
- 70% (>8%)
- 70% (>8%)
- 70% (2-3%)
- 96%
Examples
What’s the pathology?
Example
What’s the pathology?

TRACE B

\[ P = 40 \text{ mmHg} \]
Examples
What’s the pathology?
Examples
What’s the pathology?
Examples

What’s the pathology?
Cardiac Output:

- Flow between 2 chambers can be calculated using an indicator if:
  - The indicator concentration is known for both chambers
  - The rate of addition or subtraction of the indicator is known

Indicators:
- Cold Saline (Thermodilution)
- Oxygen content (Fick)
Fick Principle

- Indicator is O2
  - O2 concentration can be measured in the PA and in the LA
  - Rate of addition/extraction of O2 = VO2
    - Estimated from age and HR norms
  - Thus Qp/Qs can be calculated

\[ Q_s = \text{Rate of O2 extraction} / \text{change in O2 content} \]

\[ Q_p = \text{Rate of O2 addition} / \text{change in O2 content} \]
What is the O2 content?

Oxygen bound to Hemoglobin

+ Dissolved Oxygen
O2 Content = (Hgb x Sat x 1.36 x 10) + 0.003(PO2)

Notes:
- 1.36ml/g = the maximal O2 capacity of Hgb
- Hgb is reported in g/dL $\rightarrow$ multiply by 10 to convert to g/L
- On RA, dissolved O2 is negligible and can be ignored
  - i.e. $70 \times 0.003 = 0.21$
O2 content simplified

O2 Content = Hgb x Sat x 13.6
Calculating Cardiac Output

\[ Qs \ (L/min) = \text{Rate of extraction/Change in content} \]

\[ Qs \ (L/min) = \frac{VO_2(ml/min/m^2)}{CaO_2(Ao)-CvO_2(MV)} \]

\[ 13.6 \times \text{Hgb} \times \text{Ao sat} \]

\[ 13.6 \times \text{Hgb} \times \text{MV sat} \]

\[ = \frac{VO_2(ml/min/m^2)}{13.6 \times \text{Hgb} \times (\text{Ao-MV Sat})} \]
Calculating Cardiac Output

\[
Q_s \ (L/\text{min}) = \frac{VO_2(\text{ml/\text{min/m}^2})}{CaO_2(Ao)-CvO_2(MV)}
\]

\[
= \frac{165\text{ml/\text{min/m}^2}}{12\text{mg/dl} \times 13.6 \times (0.96-0.72)}
\]

\[
= 4.21\text{L/\text{min/m}^2}
\]
\[ Qp:Qs = \frac{\text{VO}_2(\text{ml/min/m}^2)}{\text{CaO}_2_{(PV)} - \text{CvO}_2_{(PA)}} / \frac{\text{VO}_2(\text{ml/min/m}^2)}{\text{CaO}_2_{(Ao)} - \text{CvO}_2_{(Mv)}} \]

\[ = \frac{1}{(PV - PA \text{ sat})} \]

\[ = \frac{1}{(Ao \text{ sat} - Mv \text{ sat})} \]

\[ = \frac{(Ao \text{ sat} - Mv \text{ sat})}{(Pv \text{ sat} - Pa \text{ sat})} \]
Summary ... so far

MV Sat \rightarrow Qp \rightarrow Ao Sat \rightarrow Qs \rightarrow MV Sat
Pulmonary and Systemic Flow: Left to Right Shunt

PA Sat

Qp

MV Sat

Qs

Ao Sat
Indicator method:
- Flow can be calculated if the proximal and distal concentrations are known.

- Thus Qp is calculated using the PA sat and the PV sat.

- \[ Q_p = \frac{165 \text{ ml/min/m}^2 \times 12 \text{mg/dl} 	imes 13.6}{(0.96-0.86)} \]

  \[ = 10.1 \text{ L/min/m}^2 \]
Indicator method:
- But this number represents normal PBF + shunted PBF
- If we ignore the shunted PBF and use the MV saturation then we are calculating just the desaturated blood passing through the lungs (Qeff)

- \[ Q_{eff} = 165 \text{ml/min/m}^2 \]
  \[ 12 \text{mg/dl} \times 13.6 \times (0.96-0.72) \]
  \[ = 4.21 \text{L/min/m}^2 \]
Left to right shunt lesions

- \( Q_p = 10.1 \) (Total PBF)
- \( Q_{eff} = 4.2 \) (Desaturated PBF)

- The difference between the 2 is the amount of left to right shunt
  \[ Q_p - Q_{eff} = \text{Left to right shunt} = 10.1 - 4.2 = 5.9 \text{ l/min/m}^2 \]

- \( Q_s \) is calculated as before using the aortic sat and the mixed venous sat (ie 4.2)
Qp:Qs = \frac{10.1}{4.2} = 2.4

Remember this can be calculated with the sat data alone

\frac{(Ao \text{ sat} - Mv \text{ sat})}{(Pv \text{ sat} - Pa \text{ sat})}

\frac{(96-72)}{(96-86)} = 2.4
Right to left shunts

PA Sat

Qp

PV Sat

Qs

Ao Sat
Qp is calculated using the PA sat (72%) and the PV sat (96%)

Qp = 4.2
Right to left shunts

- Total systemic flow is calculated using the Ao sat (88%) and the Mv sat (72%)
- But this number includes the R→L shunt
- If we don’t account for the shunt and use the LA sat of 96%, we can calculate the flow of oxygenated blood to the body (Qeff)
\[ Q_s \text{ (L/min)} = \frac{165 \text{ml/min/m}^2}{12 \text{gm/dl} \times 13.6 \times (0.88 - 0.72)} \]
\[ = 6.3 \text{L/min/m}^2 \]

\[ Q_{\text{eff}} \text{ (L/min)} = \frac{165 \text{ml/min/m}^2}{12 \text{gm/dl} \times 13.6 \times (0.96 - 0.72)} \]
\[ = 4.21 \text{L/min/m}^2 \]

\[ Q_{R \rightarrow L} = 6.3 - 4.2 = 2.1 \text{L/min/m}^2 \]

Note: \( Q_{\text{eff}} = Q_{\text{ep}} = Q_{\text{es}} \)
- All use the same saturations (PV and MV)
Summary

- O₂ Content = Hgb x Sat x 13.6 (On RA)
- \( Q_s \ (L/min) = \frac{VO_2 (ml/min/m^2)}{CaO_2(Ao) - CvO_2(Mv)} \)
- \( Q_p \ (L/min) = \frac{VO_2 (ml/min/m^2)}{CaO_2(PV) - CvO_2(PA)} \)
- \( Q_{\text{eff}} = Q_{\text{ep}} = Q_{\text{es}} = \frac{VO_2 (ml/min/m^2)}{CaO_2(PV) - CvO_2(MV)} \)
- \( Q_{L-R} = Q_s - Q_{\text{eff}} \)
- \( Q_{R-L} = Q_p - Q_{\text{eff}} \)
Calculating resistance

Change in pressure = Flow x Resistance (Ohms law)

\[ \Delta P = Q \times R \]

\[
\text{(Mean PAp – Mean LAp) / Qp = PVR}
\]

\[
\text{(Mean Syst. Pressure – CVp) / Qs = SVR}
\]