By Adam Hollingworth

Respiratory Equations

Partial Pressure of Gas

- Partial pressure of gas = concentration x total pressure
  - Eg dry air had 20.93% O_2
  - @ sea level pressure = 760mmHg ∴ Po2 @ sea level = 20.93/100 x760 = 159mmHg
- When air inhaled it is warmed & moistened
  - Water vapour pressure = 47mmHg ⇒ total dry gas pressure = 760 – 47 = 713
  - ∴ P_IO_2 inspired air = 20.93/100 x 713 = 149mmHg

Alveolar Gas Equation

- Allows relationship between fall in PO2 & rise in PCO2 which occurs in hypovent can be calculated

$$P_AO_2 = P_IO_2 - \frac{PACO_2}{R} + F$$

F= small correction factor (~2mmHg)
R = respiratory quotient (~0.8)
↳determined by CO2 prodction/O2 consumption
↳ie metabolism of tissues in steady state
P_IO_2 = composition of inspired gas

Fick Principle

- = application of Law of Conservation of Matter
- uptake (or output) of a substance by a tissue must be equal to difference between amount entering tissue (flow x arterial concentration) and the amount leaving the tissue (flow x venous concentration)
- rearrangement of the formula:

flow = uptake / A – V concentration difference)

$$\text{Blood flow/min} = \frac{\text{O2 consumption/min}}{\text{Conc of O2 in pulmon artery} - \text{Conc O2 in pulmon vein}}$$

Eg cardiac output:

$$CO = \frac{\text{250mls O2/min}}{\text{200mls O2}_{\text{(art o2 content)}} - \text{150mls O2/l}_{\text{(mixed venous o2 content)}}}$$

= 250/50
= 5 L/min

O2 flux or Delivery

Do2 = CaO2 x CO

Measurement of VQ Mismatch

- In practise use alveolar-arterial PO2 difference
- Need to calculate predicted P_AO_2 & use alveolar gas equation:

$$P_AO_2 = P_I02 - \frac{P_ACO_2}{R} + F$$

- Measured arterial PCO2 used for P_ACO_2
- P_IO_2 = inspired alveolar PO2

- Then A-a difference = P_Ao_2 (predicted) – P_aO_2 (measured)
- Should be <10

- Eg pt breathing air at sea level has
  - Inspired Po2 149mmHg
  - a measured PaO2 of 50mHg
  - measured PaCO2 of 60mmHg

$$149 - \frac{60}{0.8} = 74 \text{ mmHg predicted PaO2}$$

∴ 74 – 50 = 24mmHg A-a difference
↳high ∴ VQ difference

- R = 0.8
- F is ignored as so small

Mechanics of Breathing

Boyles Law

- PV = K
- Pressure x volume is constant (at a constant temp)

Compliance

- Change: Δvolume / Δ pressure

Surface Tension

Laplace's Law: $\frac{4T}{r}$ or $\frac{2T}{r}$

T = surface tension
R = radius

↳when only one surface is involved
ie liquid lined alveoli need to change law:

Reynold number:

$$Ra = \frac{2rvd}{n}$$

D = density
V = average velocity
R = radius
N = viscotity

Poiseuille Law

$$R = \frac{8nl}{\pi r^4}$$

R = resistance
r = radius
N = viscocity
L = length

- double length ⇒ double resistance
- half radius ⇒ x16 ↑ resistance
- viscocity & not density effects pressure-flow relationship

Bohr's Method

- Calculates physiologic dead space

$$\frac{\text{Volume of Dead Space } (V_D)}{\text{Volume of Tidal Volume } (V_T)} = \frac{\text{Alveolar Expired CO2 } (PA_{CO2}) - \text{ Mixed Expired PCO2 } (PE_{CO2})}{Pa_{CO2}}$$

Shunt Equation

Qs = shunt flow
Qt = CO
Cc'O2 = O2 content of end capillary blood,
CaO2 = arterial blood O2 content
C vO2 = <u>mixed</u> venous blood content.
Qt-Qs = flow through the lungs

$$\frac{Qs}{Qt} = \frac{(C_{c'}O2 - C_aO2)}{(C_{c'}O2 - C_vO2)}$$

Diffusion Capacity of Lung

- Diffusion capacity of lung for CO = Volume of CO transferred (ml/min) / Alveolar Partial pressure of CO (mmHg)

$$D_L = \frac{VCO}{P_{Aco}}$$

Pulmonary Vascular Resistance

- vascular resistance = $\frac{\text{input pressure} - \text{output pressure}}{\text{blood flow}}$

Water Balance in Lungs

net fluid out = $(Pc - Pi) - o(\pi c - \pi i) \times k$

Pc = capillary hydrostatic pressure
Pi = interstitial pressure
O = reflection coefficient ie effectiveness of capillary in preventing proteins across it
πc = osmotic force of blood
πi = osmotic force of interstitum

Hypoventilation

- alveolar ventilation and PCO2 relationship:

$$PCO2 = \frac{\text{CO2 production}}{\text{Alveolar Ventilation}} \times \text{constant}$$

O2 Saturation

- O2 saturation of Hb = percentage of available binding sites which have O2 attached
  ↳calculated by

$$\frac{\text{O2 combined with Hb}}{\text{O2 capacity}} \times 100$$

O2 Capacity

- O2 capacity = 20.8ml O2/100ml blood in norm Hb ie 15g/100ml
  ↳∴ if anaemia of 10g/100ml capacity would be 20.8 x 10/15 = 13.9

O2 Concentration of Blood

Oxygen concentration of blood: (ml O2/100ml blood)

$$= (1.39 \times Hb \times \frac{SpO2}{100}) + 0.003\ PO_2$$

Hb – gm/100ml
Po2 mmHg

Bicarbonate

- bicarbonate formed by

$$CO2 + H20 \underset{\text{Carbonic anhydrase}}{\leftrightarrow} H2CO3 \leftrightarrow H^+ + HCO3^-$$

pH

- pH resulting from solution of CO2 in blood & dissociation of carbonic acid given by Henderson-Hasselbalch equation:

$$H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

or

$$pH = pK + \log \frac{HCO_3^-}{0.03PCO_2}$$

pK value = 6.1

- bicarbonate concentration determined by kidney
- PCO2 by lung