Ventilation refresher - the regional distribution of ventilation is dependent on two main processes and one minor. The first is the most important and is the effect of gravity. As the lung has weight, the lower parts of the lung are generally more compressed and less inflated than the upper part of the lungs which leads to the more volume-dependent parts of the lung having greater compliance (compliance = inspiratory duration (and thus RR) will cause regional variation of ventilation if it is not prolonged. In patients with the commoner forms of lung disease there is usually Perfusion refresher - because pulmonary circulation operates at low pressures, it is particularly influenced by the force of gravity. This has previously covered in reference to West's zones of the lung and the waterfall analogy. A fourth zone is sometimes described where the weight of the lung reduces flow due to interstitial forces at the very based of the lung. The other factor which causes variation is due to the vascular anatomy and the pattern of branching which mathematical models show contribute significantly to the heterogeneity of flow.

Ventilation/Perfusion Ratio (V/Q) - Whilst the blood flow and ventilation to the lungs is roughly equal each usually between 4-5 litres, in different parts of the lung they are not necessarily equally matched. The effect of gravity is the most important factor for both V and Q is more significant in terms of perfusion. This leads to a scatter of V/Q ratios which is exacerbated in older subjects even in the absence of lung disease. V/Q ratios at the apex of the lungs (where ventilation is relatively greater than perfusion) has values of 3.3, at the base (where perfusion dominates) is 0.6 in normal subjects. In pathological states alveolus may receive no perfusion and thus forms part of the physiological dead space. Examples of include a pulmonary embolism, or a sudden decrease in cardiac output resulting in decreased perfusion to the apices. The V/Q ratio will approach infinity. If the alveolus receives no ventilation it represents a form of true shunt and the V/Q ratio will be 0. Compensatory mechanisms for V/Q scatter include hypoxic pulmonary vasoconstriction discussed previously.

The shunt equation is based on the assumption that the total oxygen carried by the aterial blood may be calculated by adding the oxygen contents of the blood that passes the lungs and the shunted blood. Assuming ideal gas exchange (to calculate Postcap O2 content) it is possible to create this in an equation as follows:

\[ QT \times Cao2 = (QS \times Cvo2) + (QT - QS) \times Cco2 \]

rearranged gives the shunt equation:

\[ QS \times QT = Cco2 - Cao2 \]

The Bohr equation is based on the assumption that CO2 exchange is ideal (alveolar and post capillary values are equal) therefore any difference in the expired and arterial CO2 is due to dead space.

\[ Pcco2(VT) = Paco2(VT - VD) \]

It is commonly rearranged to:

\[ \text{VT} = \frac{Paco2 + Pcco2}{Paco2} \]

The alveolar equation calculates the ideal alveolar PaCO2. It can then be used to assess the Alveolar-arterial gradient of O2. It is never equal due to V/Q mismatching. The normal value in a 20 year old patient is around 7, but this increases gradually with age, an 70 year old patient having a normal A-a gradient of 17 (the formula is 2.5 + age x 0.21). The alveolar equation needs to account for water vapour and air pressure and is therefore represented by the following equation:

\[ \text{PaCO2} = (\text{FiO2} \times \text{Patm} - \text{P}CO2) - \text{PaCO2} \]

Measurement of V/Q mismatch is problematic. The shunt equation measures venous admixture which is the amount of venous blood that is needed to add to the arterial blood to compensate for the difference between ideal and actual O2 content of the post capillary and arterial blood. In reality it consists of both V/Q mismatching and true shunting. A three compartment model aggregates the mismatch component with the true shunt component. Response to increasing FiO2 can ease out this difference. VQ Mismatch with correct however true shunt will not, especially if the shunt is >30%. Accurate measurement of V/Q relationships is possible using Multiple Inert Gas Elimination Techniques (MIGET) which uses six different gases with variable solubility to measure the V/Q ratios. This method is extremely complicated which reduces its utility but it gives a much more accurate picture than the three compartment model.

![Blood Flow Ventilation](image1)

Normal 25 year old Patient

Normal 55 year old patient

Patient with Pulmonary Embolism

Patient with Asthma