7 - Ventilation / perfusion ratio -I

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Ventilation

Gravity and the weight of the lung act on ventilation by **increasing** pleural pressure at the **base** (making it less negative) and thus **reducing the alveolar volume**.

-The lowest part of the lung in relation to gravity is called the dependent region.

In the dependent region **smaller alveolar volumes** mean the alveoli are more compliant (more distensible) and so capable of more oxygen exchange.

-The apex, though showing a higher oxygen partial pressure, ventilates less efficiently since its compliance is lower and so smaller volumes are exchanged.

Pulmonary Perfusion

The impact of gravity on pulmonary **perfusion** expresses itself as the hydrostatic pressure of the blood passing through the branches of the pulmonary artery in order to reach the apical and basal areas of the lungs, acting synergistically with the pressure developed by the **right** ventricle.

Thus at the **apex** of the lung the resulting pressure can be insufficient for developing a flow (which can be sustained only by the negative pressure generated by venous flow towards the left atrium) or even for preventing the collapse of the vascular structures surrounding the alveoli, while the **base** of the lung shows an intense flow due to the higher pressure.

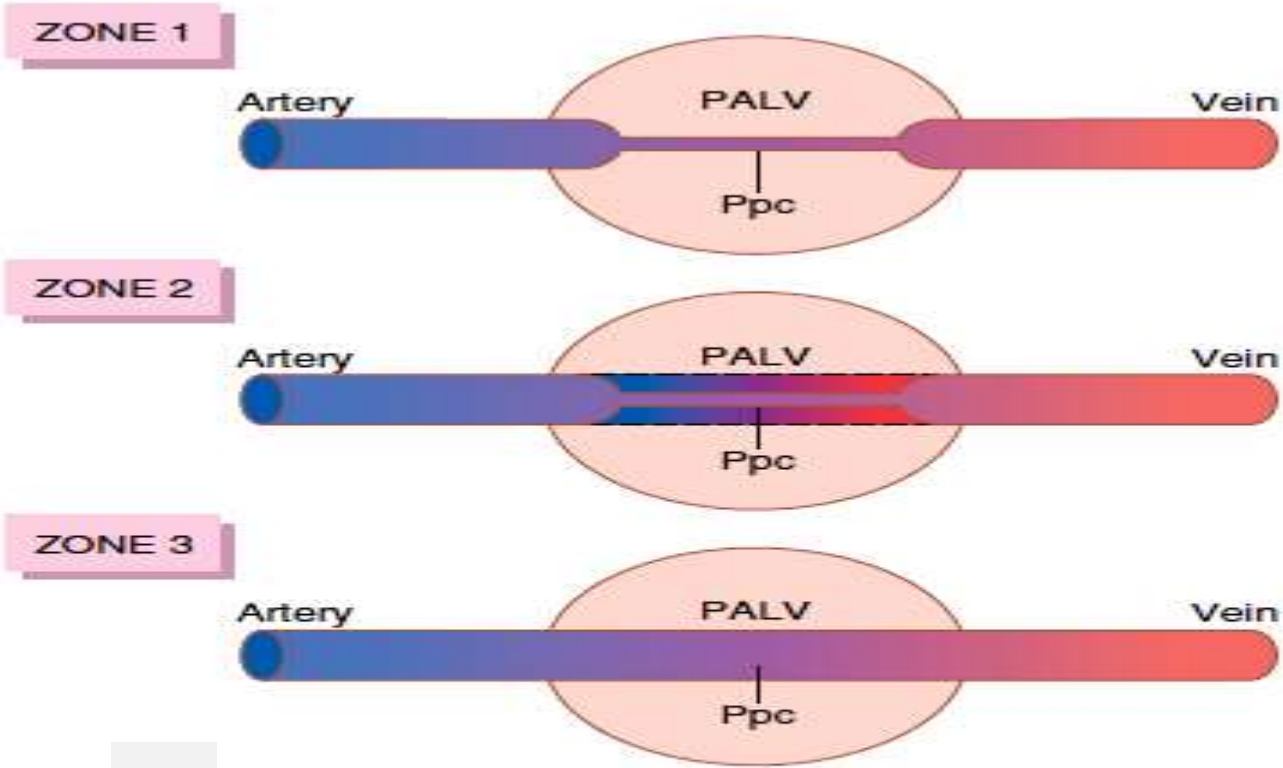
When a person is **supine**, blood flow is nearly uniform throughout the lung. When a person is **standing**, blood flow is unevenly distributed because of the effect of gravity. Blood flow is lowest at the apex of the lung (zone 1) and highest at the base of the lung (zone 3).

Zone 1 —blood flow is lowest. Alveolar pressure > arterial pressure > venous pressure.

The high alveolar pressure may compress the capillaries and reduce blood flow in zone 1. This situation can occur if arterial blood pressure is decreased as a result of hemorrhage or if alveolar pressure is increased because of positive pressure ventilation.

2. **Zone 2** —blood flow is medium. Arterial pressure > alveolar pressure > venous pressure. Moving down the lung, arterial pressure progressively increases because of gravitational effects on arterial pressure. Arterial pressure is greater than alveolar pressure in zone 2, and blood flow is driven by the difference between arterial pressure and alveolar pressure.

3. **Zone 3** —blood flow is highest. Arterial pressure > venous pressure > alveolar pressure. Moving down toward the base of the lung, arterial pressure is highest because of gravitational effects, and venous pressure finally increases to the point where it exceeds alveolar pressure. In zone 3, blood flow is driven by the difference between arterial and venous pressures, as in most vascular beds.



Figur I. Mechanics of blood flow in the three blood flow zones of the lung: *zone 1, no flow*—alveolar air pressure (*PALV*) is greater than arterial pressure; *zone 2, intermittent flow*—systolic arterial pressure rises higher than alveolar air pressure, but diastolic arterial pressure falls below alveolar air pressure; and *zone 3, continuous flow*—arterial pressure and pulmonary capillary pressure (*Ppc*) remain greater than alveolar air pressure at all times.

N.B.: *in lung apex the ventilation & perfusion decreases but the decrease in* ***perfusion*** *is* ***more****, So, ventilation/perfusion ratio is more than normal but at base this ratio is less than normal .*

-**In respiratory physiology**, the ventilation/perfusion ratio (V/Q ratio) is a ratio used to assess the efficiency and adequacy of the matching of two variables：

$\dot{V}$ – ventilation – the air that reaches the alveoli

$\dot{Q}$– perfusion – the blood that reaches the alveoli via the capillaries

The **V/Q ratio** can therefore be defined as the ratio of the amount of air reaching the alveoli per minute to the amount of blood reaching the alveoli / minute—a ratio of volumetric flow rates. These two variables, V & Q, constitute the main determinants of the blood oxygen (O2) and carbon dioxide (CO2) concentration.

The V/Q ratio can be measured with a **ventilation/perfusion scan**.

A V/Q mismatch can cause a type 1 respiratory failure.

The actual values in the lung vary depending on the position within the lung. If taken as a whole, the typical value is approximately **0.8**.

Because the **lung** is centered **vertically** around the **heart**, part of the lung is **superior** to the heart, and part is **inferior**. This has a major impact on the V/Q ratio:

Apex of lung – **higher** , Base of lung – **lower**

In a subject standing in **orthostatic** position (**upright**) the **apex** of the lung shows **higher** V/Q ratio **3.6**, while at the **base** of the lung the ratio is **lower** but nearer to the optimal value for reaching adequate blood oxygen concentrations. While both ventilation and perfusion increase going from the apex to the base, **perfusion increases to a greater degree than ventilation**, lowering the V/Q ratio at the base of the lungs **0.6**. The principal factor involved in the creation of this V/Q gradient between the apex and the base of the lung is **gravity** (this is why V/Q ratios change in positions other than the orthostatic position.

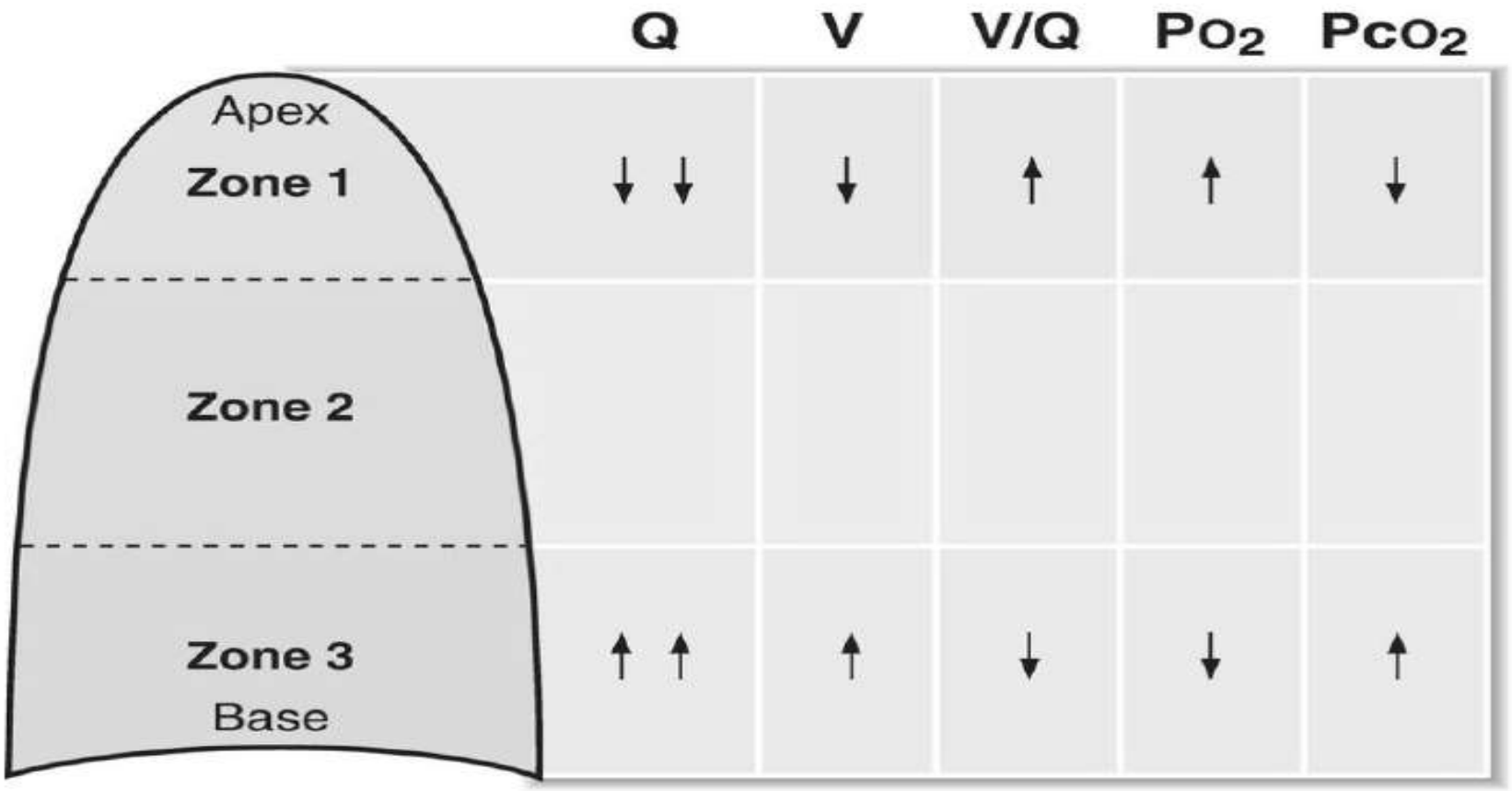
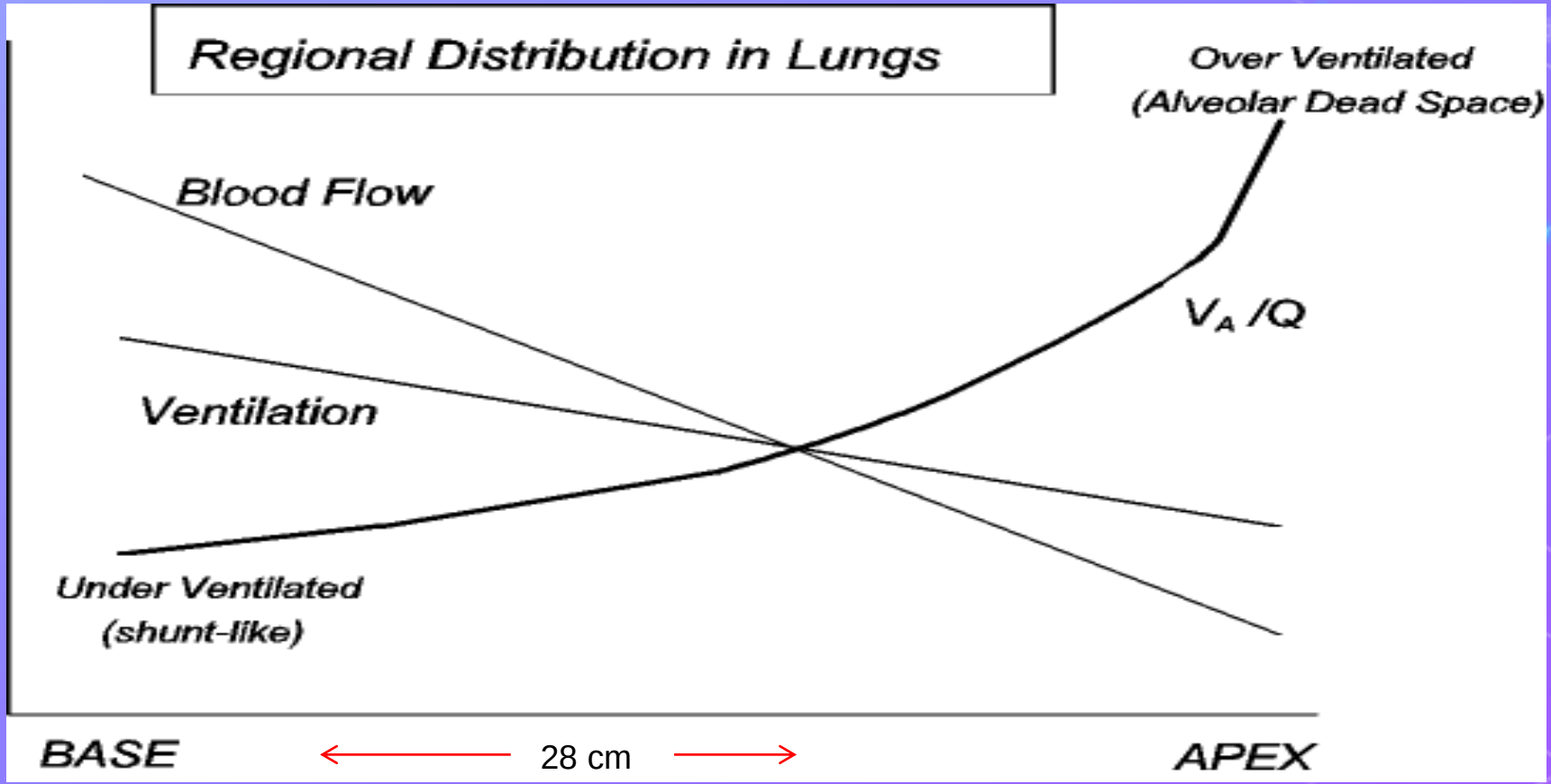


FIGURE Regional variations in the lung of perfusion (blood flow [Q]), venulation (V), V/Q, P_{O_2}, and P_{CO_2}.



Effect of gravity on the pulmonary ventilation and perfusion

Regional pulmonary blood flow: (gravity effect)

- In **upright position** the pulmonary blood flow at **base** of the lung = **5 times** as at lung **apex** and the pulmonary pressure in base is higher than at apex by **23 mmHg**.
- The pulmonary blood flow depends on either the pressure inside the capillaries and outside the capillaries (alveolar pr.). So, the lung can be classified into 3 zones according to blood flow in relation to cardiac cycle:

Zone I: No blood flow at all (alveolar pressure > **c**apillary pressure)

Zone II: Blood flow occurs only during **systolic** pressure but the diastolic pressure is less than alveolar pr.

Zone III: continuous blood flow as the blood pressure is always above alveolar pressure.

-In normal healthy lung during **standing**, there are zone II (Apex) and zone III (at base) and during **recumbent position** all lung are of zone III.

So, in cases of hypertension with more blood flow to the lung during lying down lead to severe **dyspnea**.

-**Zone I** presents abnormally if the person breaths air under **positive pressure** in which intra-alveolar pressure reaches 10 mmHg also occur in **hypovolemic shock**.

-During **muscular exercise** the pulmonary blood flow increases in all parts of the lung via opening of new capillaries especially the **apex** which has already closed capillaries during rest. Whole lung becomes **Zone III.**

As a result of the regional differences in V/Q ratio, there are corresponding differences in the efficiency of gas exchange and in the resulting pulmonary capillary PO2 and PCO2.

Regional differences for PO2 are greater than those for PCO2.

a. At the apex (higher V/Q), PO2 is highest and PCO2 is lowest because gas exchange is more efficient.

b. At the base (lower V/Q), PO2 is lowest and PCO2 is highest because gas exchange is less efficient.

Thank You