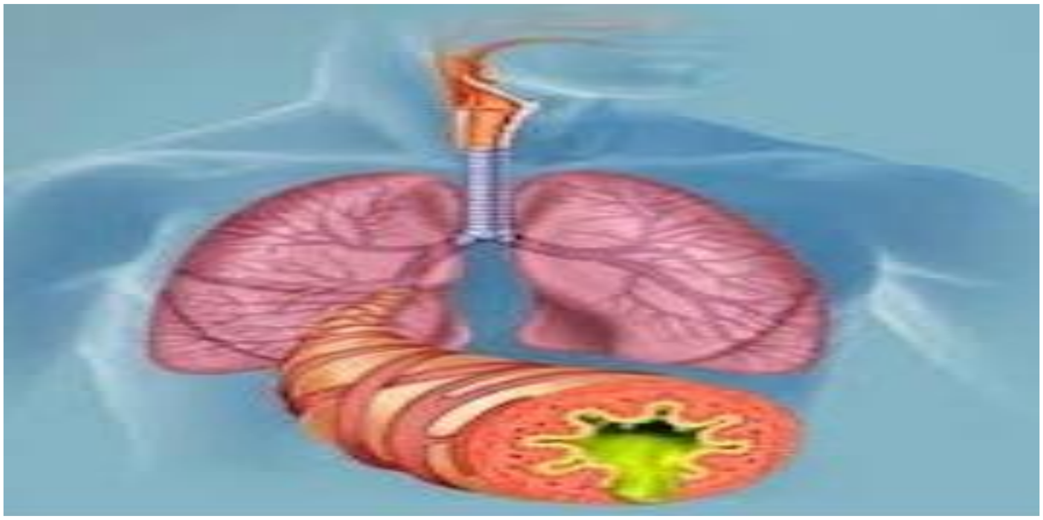


Lecture 9: Air Way Resistance and Alveolar Ventilation

BY :Prof. Marwa Abd Elaziz Ahmed

Learning Objectives:

Knowledge:

- Define airway resistance -State the relationship between airway radius and airway resistance.
- Describe the distribution of airway resistance throughout the respiratory tract the physiological factors that affect the broncho-motor tone.
- Know differences between obstructive &restrictive lung D.
- Know the physiology of asthma, emphysema.
- Know the definition of normal alveolar ventilation and its rate.
- Describe the factors affecting the dead space.
- Understand the difference between the total pulmonary ventilation and the true effective pulmonary ventilation.

Intellectual:

- Compare between obstructive &restrictive lung D.
- Explore the difference between the total pulmonary ventilation and the true effective pulmonary ventilation

Air way Resistance

- Airway resistance is the resistance offered to the passage of air through respiratory tract.
- Airway resistance only exists when air is flowing.
- Total airways resistance becomes *less during inspiration and greater during expiration.*
- As during inhalation, the airway radius of the airway expands which decreases the resistance, whereas during exhalation the air way radius is decreased, which increase resistance.
- Airways resistance is not distributed uniformly along the respiratory tract.

Sites of airways resistance:

1- Almost half the total resistance presents in the *nose, pharynx and larynx*. The vocal folds of the larynx reflexly open during inspiration, reducing resistance .

- ✓ During expiration, the vocal cords come close together forming an ‘ expiratory brake’ preventing too-rapid collapse of the lungs.

2- About 80% of the rest half, of the lower airways resistance (below) the larynx, resides in *the trachea and bronchi*.

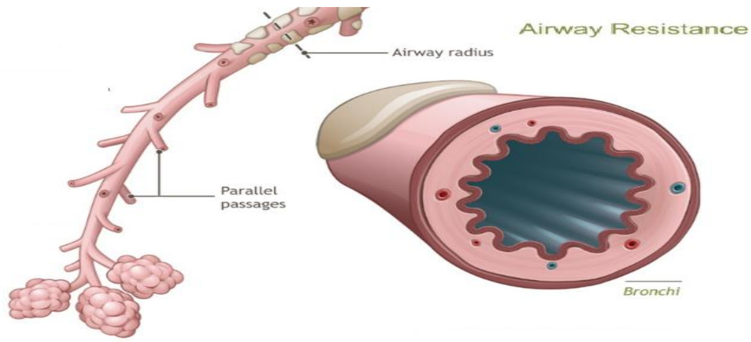
- ✓ In the respiratory system as a whole, the greatest resistance to flow actually occurs *in medium-sized airways* (fourth to eighth generation).

The factors that determine airway resistance :

They are tube length, tube radius, and the most important factor by far is the *radius of the tube*.

- Airway resistance is inversely proportional to the fourth power of the airway radii.
- So, the most important parts of the bronchial tree in physiological control of airways resistance are *the smaller bronchi and bronchioles*, as their walls contain innervated smooth muscle, which can contract to reduce their diameter**,** known as bronchomotor tone

- *While it is true that air way resistance is highest in the passages with the smallest radius, total resistance depends on the number of the parallel passages.*



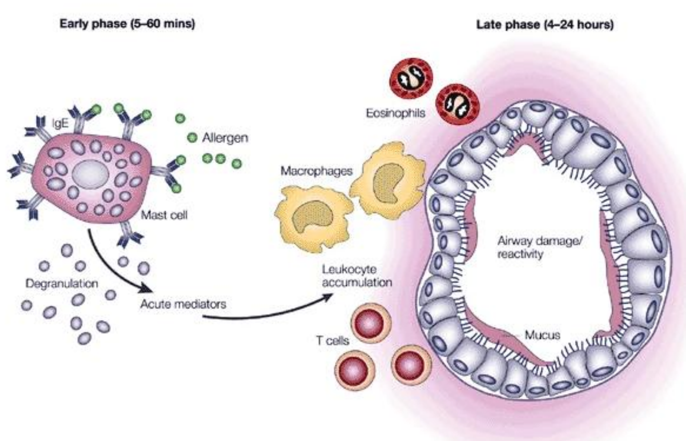
Factors Affecting The Bronchomotor Tone

1- Parasympathetic nerves. They cause contraction of smooth muscle fibers. Atropine blocks their receptors, and injections of atropine in a normal individual can reduce airways resistance by about 30%.

2-*Sympathetic nerves:* this nerve supply does *not* extend as far as the bronchial smooth muscle. Any sympathetic effects seen in the lung are due to circulating catacholamines.

3- Circulating catecholamines: the naturally occurring catecholamine **adrenaline** (epinephrine), relax smooth muscle. *They therefore form an important treatment for asthma.*

4-*Mast cell degranulation:* Allergens interact with IgE antibodies on their surface, causing them to release (within 30 s) preformed mediators, e.g. histamine, heparin, serotonin. It is now accepted that mast cell degranulation is responsible for less than 30% of the bronchoconstriction (early phase of asthma).



5-Rapidly adapting pulmonary receptors (irritant and cough receptors): Stimulation of these receptors in the airways by inhalation of particles, chemicals, or by disease provokes contraction of airways smooth muscle by a reflex mediated by **vagus nerves**. *This contraction of the airways may improve the efficiency of coughing.*

6- Slowly adapting pulmonary receptors: Their activity reduces bronchomotor tone. They are stimulated by stretching the lungs, (e.g. a large breath – a sigh)

Regional differences in ventilation

- In an upright subject, *the apices of the lungs are ventilated less efficiently than the bases*.
- This effect is gravity dependent. As these variations in ventilation arise primarily because the base of the lung undergoes a larger volume change during ventilation than the apex.
- If the subject lies on their back, posterior regions of the lung become the best ventilated.

Clinical Application

- Chronic obstructive pulmonary diseases (COPD) are diseases that interfere with movement of air through the airways.
- Asthma is a disease of the airways characterized by short term episodes of broncho-constriction (the principal feature). These can be so severe that the flow of gas along the airways is significantly reduced, leading to difficulty in breathing.
- Emphysema Involves the destruction of supporting structures in the lung, leading to the collapse of airways. Trapped air in the alveoli results in over inflation of the lungs.

Ventilation

- Ventilation is the process by which inspired gases reach the alveoli and the blood–gas barrier, and the process by which expired gases are removed from the alveoli.
- Alterations in the rate and depth of ventilation affect the composition of alveolar gas and, therefore, the composition of the gases entering the blood.

Dead Space

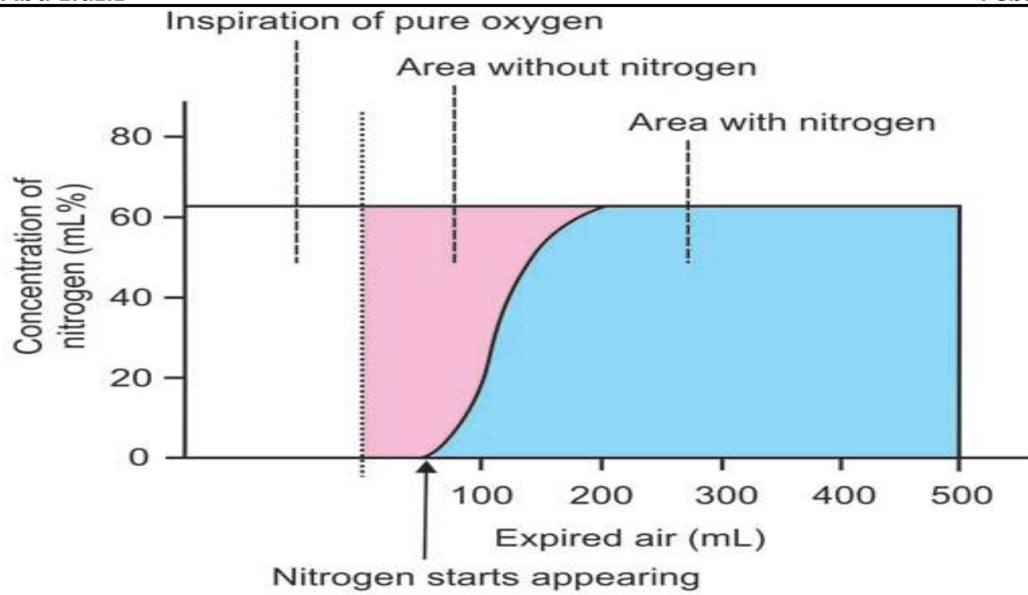
- Essentially all exchange of gas between air and blood only takes place at the alveolar surface. The conducting airways have a volume of about 150 ml.
- Because these airways do not permit gas exchange with the blood, the space

within them is termed the **anatomic dead space (*V_D*).** ***(Determine parts of V_D).***

- So, Anatomical dead space refers to the volume of the lung that doesn't undergoes gas exchange(is not alveoli)

Anatomical Dead Space:

- The conducting airways have a volume of about 150 ml.
- Because these airways do not permit gas exchange with the blood, the space within them is termed the **anatomic dead space (*V_D*).** ***(Determine parts of V_D).***
- Anatomical dead space refers to the volume of the lung that is not alveoli.
- Anatomical dead space can be measured by the nitrogen content in the expired gas from an individual inhaling 100% pure oxygen for a single breath. Initially, N2 content will be zero as gas from the non-alveolar regions is exhaled (last in, fi rst out) but, after a certain volume is exhaled, N2 will rise to 80% (the same as N2 content of alveolar gas). From this, the volume of anatomical dead space can be measured.



Alveolar Dead Space:

- In healthy subjects anatomical dead space is all the dead space there is, but as we get older or suffer from lung disease, **alveolar dead space begins to appear. By the same definition we** used for anatomical dead space:
- *Alveolar dead space* is the volume contained in alveoli which have insufficient blood supply to act as effective respiratory membranes (gas exchange)
- It is quite small in normal persons but may be very large in persons with several kinds of lung disease.

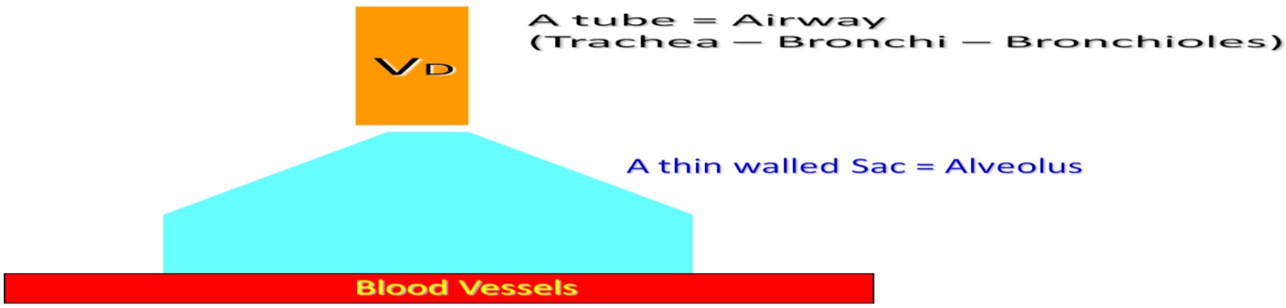
Physiological dead Space

- These two types of dead space added together make up **physiological dead space.**
- Physiological dead space is the volume of the lung that does not exchange gases with the pulmonary circulation.
- So, Physiological dead space = Anatomical dead space + Alveolar dead space

  = (zero in healthy subjects)
- In healthy individuals, these values are approximately equal. However, during lung disease, physiological dead space may be significantly increased as a result of reduced efficiency of pulmonary gas exchange.

- *Factors affecting the dead space:*

Increased	Decreased
- Sympathetic activity. -Inspiration. -Old age	-Vagal activity. -Expiration



Ventilation Rate:

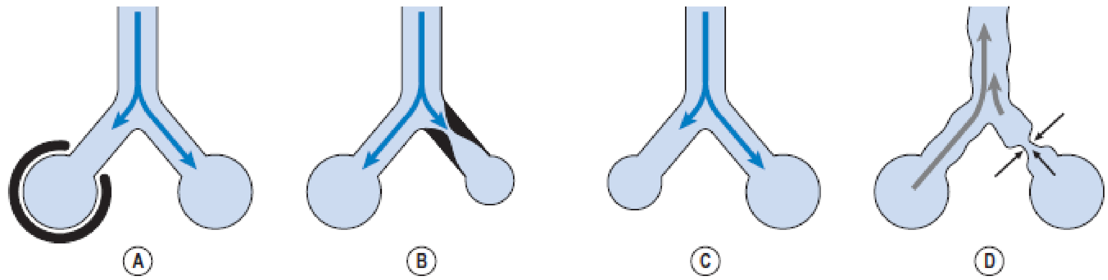
- The part of the air ventilating our lungs *is that which forms* **alveolar ventilation ,** that ventilates parts of the lung where gas exchange with the blood takes place.
- The total ventilation per minute, termed the **minute ventilation** (ml/min) ($\dot{V}E$), *is equal to the tidal volume* V_T *multiplied by the respiratory* rate:
- = Tidal volume × Respiratory rate

  (ml/breath) (breaths/min)
- The volume breathed out is approximately equal to the volume breathed in, therefore the net flow over a complete cycle is zero.

Alveolar Ventilation (effective pulm. ventilation):

- It is: The total amount of air ventilates parts of the lung where gas exchange with the blood takes place in 1 minute.
  - ***It is different from minute ventilation due to dead space.***
  - ***So, Alveolar ventilation = (VT - VD) × Breaths/min***

Some pathological changes affecting distribution of ventilation:



Restriction Obstruction Change in Compliance Airway collapse

Take Home message:

- ✓ About half airways resistance is found above the larynx, and half below.
- ✓ In the respiratory system as a whole, the greatest resistance to flow actually occurs *in medium-sized airways*
- ✓ The most variable portion of airways resistance is in the small bronchi and bronchioles whose diameter is controlled by smooth muscle bronchomotor tone.
- ✓ Dead space is that part of the airways which has insufficient blood supply or too thick walls for efficient gas exchange.
- ✓ Anatomical dead space (the conducting airways) is normal, alveolar dead space is pathological, the sum of the two is physiological dead space.

End of the lecture