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PULMONARY VENTILATION

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PULMONARY VENTILATION: Pulmonary ventilation is a cyclic process, by which fresh air enters the lungs and an equal volume of leaves the lungs. It is also called minute ventilation or respiratory minute volume (RMV).

NORMAL VALUE AND CALCULATION

Normal value: Normal value of pulmonary ventilation is 6,000 mL (6 L)/minute.

Calculation: It is the product of tidal volume (TV) and the rate of respiration (RR).

It is calculated by the formula:

Pulmonary ventilation = Tidal volume × Respiratory rate

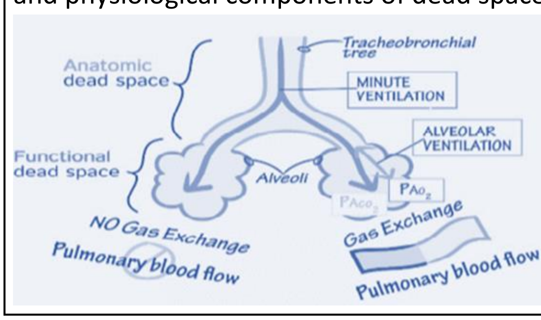
= 500 mL × 12/minute

= 6,000 mL/minute.

2) ALVEOLAR VENTILATION

Alveolar ventilation is the amount of air utilized for gaseous exchange every minute. Alveolar ventilation is different from pulmonary ventilation. In pulmonary ventilation, 6 L of air moves in and out of respiratory tract every minute. But the whole volume of air is not utilized for exchange of gases. Volume of air subjected for exchange of gases is the alveolar ventilation. Air trapped in the respiratory passage (dead space) does not take part in gaseous exchange.

Figure 1. Dead space showing anatomical and physiological components of dead space



NORMAL VALUE AND CALCULATION

Normal value: Normal value of alveolar ventilation is 4,200 mL (4.2 L)/ minute.

Calculation: It is calculated by the formula:

Alveolar ventilation = (Tidal volume – Dead space) x Respiratory rate

= (500 – 150) mL × 12/minute

= 4,200 mL (4.2 L)/minute.

3) DEAD SPACE: Dead space is classified into two types viz. Anatomical dead space and Physiological dead space (**Fig. 1**).

Anatomical Dead space: It is volume of respiratory tract from nose until terminal bronchiole.

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Physiological Dead space: It includes anatomical dead space plus two additional volumes of alveolar dead space, viz. 1) air in the alveoli, which are non-functioning. In some respiratory diseases, alveoli do not function because of dysfunction or destruction of alveolar membrane; 2) air in the alveoli, which do not receive adequate blood flow, and gaseous exchange does not take place during inadequate blood supply.

Wasted air: The dead space air normally treated as wasted air. Wasted air related to air that is not suitable for gaseous exchange.

NORMAL VALUE OF DEAD SPACE

Volume of normal dead space is 150 mL. Under normal conditions; physiological dead space = anatomical dead space. It is because, all the alveoli are Functioning and all the alveoli receive adequate blood Flow in normal conditions. Physiological dead space increases during respiratory diseases, which affect the pulmonary blood flow or the alveoli.

MEASUREMENT OF DEAD SPACE

Nitrogen washout method: Dead space is measured by single breath nitrogen washout method. The subject respires normally for few minutes. Then, he takes a sudden inhalation of pure oxygen. Oxygen replaces the air in dead space (air passage), i.e. the dead space air contains only oxygen and it pushes the other gases into alveoli. Now, the subject exhales through a nitrogen meter. Nitrogen meter shows the concentration of nitrogen in expired air continuously. First portion of expired air comes from upper part of respiratory tract or air passage, which contains only oxygen. Next portion of expired air comes from the Alveoli, which contains nitrogen. Now, the nitrogen meter Shows the nitrogen concentration, which rises sharply and reaches the plateau soon. By using data obtained from nitrogen meter, a graph is plotted. From this graph, the dead space is calculated. The graph has two areas viz. area without nitrogen and area with nitrogen. Area of the graph is measured by a planimeter or by computer. Area without nitrogen indicates dead space air **(Fig. 2).**

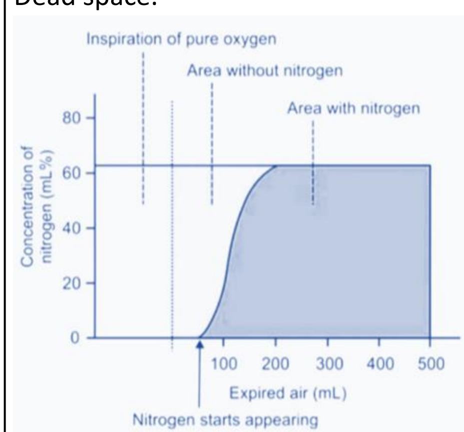
$$\textbf{Dead space} = \frac{\textbf{Area without nitrogen x volume of expired air}}{\textbf{Area with nitrogen + area without nitrogen}}$$

For example, in a subject:

1. Area with nitrogen = 70 sq. cm
2. Area without nitrogen = 30 sq. cm
3. Volume of air expired = 500 mL

$$= \frac{\text{30 sq. cm x 500 mL}}{\text{70 sq. cm+ 30 sq. cm}}$$

Figure 2: Graphical measurement of Dead space.



VENTILATION-PERFUSION RATIO

Definition: Ventilation perfusion ratio is the ratio of alveolar ventilation and the amount of blood that perfuse the alveoli. It is expressed as VA/Q. VA is alveolar ventilation and Q is the blood flow (perfusion).

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NORMAL VALUE AND CALCULATION

Normal Value: Normal value of ventilation perfusion ratio is about 0.84

Calculation

Alveolar ventilation is calculated by the formula:

Ventilation perfusion ratio = Alveolar ventilation/ Pulmonary blood flow

Alveolar ventilation = (Tidal volume – Dead space) × Respiratory rate

= (500 – 150) mL × 12/minute

= 4,200 mL/minute

Blood flow through alveoli (Pulmonary blood flow) = 5,000 mL/minute

Therefore, ventilation perfusion ratio = 4200/5000 = 0.84

SIGNIFICANCE OF VENTILATION PERFUSION RATIO

Ventilation-perfusion ratio signifies the gaseous exchange. It is affected if there is any change in alveolar ventilation or in blood flow.

a) Ventilation without perfusion = dead space
b) Perfusion without ventilation = shunt

Wasted air and wasted blood: Ventilation perfusion ratio is not perfect because of existence of two factors on either side of alveolar membrane. These factors are physiological dead space, which includes wasted air, physiological shunt, which includes wasted blood.

VARIATIONS IN VENTILATION PERFUSION RATIO

Physiological variations

1. Ratio increases, if ventilation increases without any change in blood flow
2. Ratio decreases, if blood flow increases without any change in ventilation
3. In sitting position, there is reduction in blood flow in the upper part of the lungs (zone 1) than in the lower part (zone 3). Therefore, in zone 1 of lungs Ventilation perfusion ratio increases three times. At the same time, in zone 3 of the lungs, because of increased blood flow ventilation-perfusion ratio decreases.

Pathological variations

In chronic obstructive pulmonary diseases (COPD), ventilation is affected because of obstruction and distraction of alveolar membrane. So, ventilation perfusion ratio decreases to the maximum.

Disorders of Alveolar ventilation: Alveolar hypoventilation leads to occurrence of many disorders that are collectively termed as hypoventilation syndromes. Alveolar hypoventilation is defined as insufficient ventilation results in formation of hypercapnia, which is an enhancement in the partial pressure of CO_2 as measured by arterial blood gas analysis.

Lung disorders affecting the air sacs (alveoli): An example for lung diseases affecting alveoli is pneumonia. An infection of alveoli takes place by bacteria of viruses, including corona virus that lead to

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the occurrence of covid-19, tuberculosis, pneumonia. Worse of all is caused by mycobacterium tuberculosis.

Ventilation abnormality: An example for ventilation disorders, reflected by disorders in $PaCO_2$, are alteration in Co_2 production, minute ventilation and respiratory system dead space.

Causes of lowered alveolar ventilation: Causes of central alveolar hypoventilation are drugs and central nervous disorders namely cerebrovascular accidents, neoplasms and trauma.

Pickwickiam syndrome: Obesity hypo ventilation syndrome (OHS) is also termed at Pickwickiam syndrome. Examples are triad of obesity.

Sleep disorders of breathing: Sleep disorders of respiration as well as chronic hyperaemia particularly during wakefulness in the absence of other known cause of Hyperaemia.

Lung disease or respiratory disease: An examples are asthma, cystic fibrosis, emphysema lung cancer, mesothelioma pulmonary hypertension as well as tuberculosis.

Acute respiratory distress syndrome: It takes place if fluid accumulated in the tiny elastic air sacs (alveoli) in the lungs.

Alveolar hyperventilation: Alveolar hyperventilation is observed if alveolar ventilation is enhanced out of proportion to CO2 production and arterial tension of CO2 reduces below normal range (<36 mm Hg or <4.8K Pa).

Emphysema: Normally four different stages of chronic obstructive pulmonary disease (COPD) are observed namely mild, moderate severe and very severe. The physician determines the condition of a patient dependent on results from a breathing test known as a spirometry which performs lung function by measuring how much air patient can breaths in and out as well as how quickly and easily patient can exhale

Symptoms of COPD: Frequent chest infections, enhanced breathlessness – this may occurs if exercising first and the patient may sometimes wake up at night feeling breathless, persistent Chest cough with Phlegm that does not disappear, persistent wheezing.

Hypercapnia: Elevation in the partial pressure of CO_2 above 45 mm Hg. CO_2, which is a metabolic product of various cellular processes within the body for processing carbohydrates, proteins as well as fats.

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