Respiratory System Physiology

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The underlined headings correspond to the eight Respiratory System videos.

1. Anatomy and Mechanics

Introduction

The respiratory system carries out several homeostatic functions, including:

1. **gas exchange** between the atmosphere and the blood to provide an adequate supply of oxygen to tissues and to remove carbon dioxide (CO_2) generated in oxidative metabolism.

$$O_2 + Food = CO_2 + H_2O + ATP$$

2. **regulation of body pH** by either retaining or eliminating CO_2
3. **conversion of angiotensin I to angiotensin II** which acts to control blood pressure
4. **protection from inhaled particles**.

In the respiratory system, air flow occurs by **bulk flow** from regions of high pressure to lower pressure with the pressure differences generated by a muscular pump. Resistance to air flow is influenced primarily by the radius of the tube ($1/r^4$) through which air is flowing.

$$F = (P_1 - P_2)/R$$

The movement of fresh air into the lung (inspired) or out of the lung (exhaled) is called **ventilation**. Both the rate and size of the breath (**tidal volume**) can change in response to needs of the body.

Anatomy

The respiratory system consists of structures involved in moving air into and out of the lungs (bulk flow) and in gas exchange (diffusion).

LUNGS AND CHEST WALL act as a unit. Each lung is surrounded by a membranous sac (pleura) filled with a thin film of fluid. This intrapleural fluid serves as a lubricant so the lungs can move freely within the chest wall and "functionally connects" the lungs to the chest wall such that expansion of the chest expands the lungs.

THE CONDUCTING ZONE leads from the external environment to the gas exchange surfaces of the lungs. This zone includes a series of tubes (nasal cavity, pharynx, trachea, bronchus, and bronchioles) with small radii and small surface areas. Their total volume is about **150 ml**. Since no gas exchange occurs in the conducting zone, it is often called the **anatomical dead space**.

RESPIRATORY ZONE is the region of the lung where gas exchange occurs. The respiratory zone is much larger than the conducting zone and has a volume of about **3 L**. It consists of respiratory bronchioles, alveolar ducts and alveoli. The alveoli are small sac-like structures with very thin walls wrapped by capillaries. The 300 million alveoli provide a surface area equivalent to the size of a tennis court! Here oxygen (O_2) diffuses from the air space to the blood and carbon dioxide (CO_2) diffuses from the blood to the air space. The distance that gas has to diffuse is very short, about 0.2 microns, making the alveolus-capillary unit ideally suited for gas exchange.

TYPE I CELLS are thin epithelial cells that line about 90% of the surface area of the alveoli. Gases diffuse across the type I cells to and from the blood.

TYPE II CELLS are interspersed among the type I cells. Type II cells synthesize, secrete, and metabolize alveolar surfactant. Surfactant is a lipid-rich substance that lines the alveoli and helps keep lungs from collapsing.

ALVEOLAR MACROPHAGES are the third type of cell found in alveoli. Macrophages engulf inspired particles such as bacteria. These cells are mobile and are attracted to areas of either infection or trauma.

Pulmonary Function

BREATHING is the process of **inspiration** (air flows into the lung) and **exhalation** (air flows out of the lung).

Inspiration begins when the diaphragm and the intercostal muscles of the chest wall contract in response to neural impulses from the brain stem. Contraction of the diaphragm causes it to descend and contraction of the intercostal muscles raises the ribs; the chest cavity expands. Because the lungs are functionally connected to the chest wall by the pleural sac, the lungs also expand. This increase in lung volume reduces the air pressure in the alveolar ducts and alveoli. When the pressure in the alveoli (P_A) becomes less than the pressure at the mouth, which is ordinarily atmospheric pressure (P_{atm}), air flows in until $P_A = P_{atm}$. Atmospheric pressure (P_{atm}) is 760 mm Hg but pulmonologists designate **P_{atm} = 0 mm Hg.** All pressures are relative to P_{atm}.

Exhalation occurs when the muscles of inspiration relax. The lung returns ***passively*** to its pre-inspiratory volume due to its elastic properties. This reduction in volume raises the pressure in the lung causing air to flow out.

VENTILATION CYCLE is one inspiration and exhalation. Ventilation rate (*f*) is in the range of 10-18 breaths per min. Both the rate and depth can be changed by output from the respiratory centers in the brain stem (medulla oblongata). During heavy exercise air flow can increase 20-fold and blood flow 3-fold. To expel such increased volumes, active exhalation is required in which abdominal muscles and external intercostals muscles contract. These actions actively decrease the size of the thorax (chest cavity).