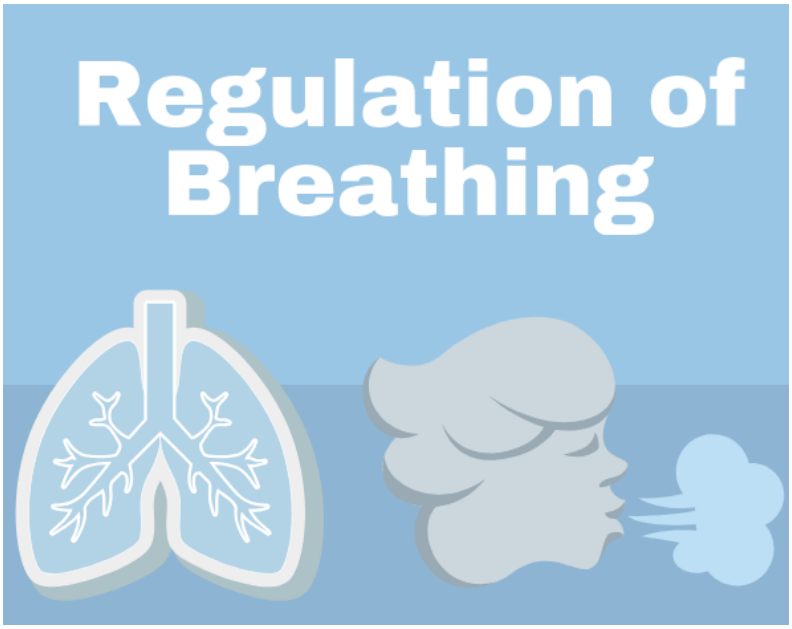


Lecture 14: Regulation Of Normal Breathing Rate

Code: RRS-209

By

Prof. Marwa Abd Elaziz Ahmed

LEARNING OBJECTIVE:

Knowledge:

- Know the neural respiratory centers and their functions.
- Know the mechanism of neural control of respiration.
- Understand the chemical control of respiration.
- Describe non chemical control of respiration.
- Know the mechanism of dyspnea.

Intellectual:

- Can detect and compare between the breathing patterns after brainstem and vagal transactions.

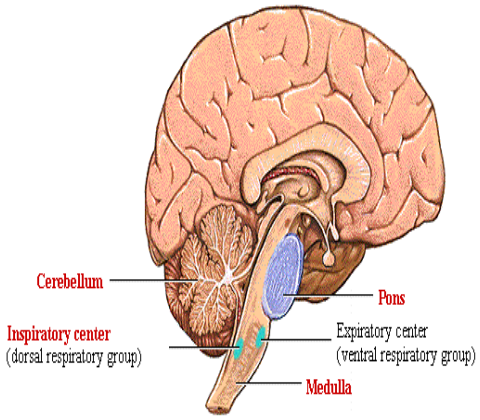
Regulation of Breathing (Respiratory rate)

- In healthy individuals, the act of breathing is ***largely automatic*** and is regulated to meet the body's requirements for O2 uptake and CO2 excretion.

Central (Nervous) Control

1- Medullary respiratory center:

There are two centers: Dorsal and Ventral respiratory centers.



I- The dorsal respiratory group (DRG):

- ✓ Present in dorsal par of the medulla.
- ✓ This is made up of exclusively inspiratory neurons.
- ✓ The DRG has a spontaneous rhythm of discharge, similar to that of breathing.
- ✓ Responsible for inspiration and determines the rhythm of breathing (normally 12–20 breaths/minute). So, it ***generates the basic rhythm of respiration.***
- ✓ Output travels via the phrenic nerve (C3–C5) and the intercostal nerves (T1‑T11) to the diaphragm and the external intercostals muscles, respectively
- ✓ Its signals are *in a ramp manner* (Inspiratory Ramp signal). This means that in normal respiration, the nervous signals transmitted to the diaphragm begins weakly and increase regularly in a ramp manner for 2 seconds. *Significance:* This is important to cause steady increase in lung volumes instead of inspiratory gasps.
- ✓ Then the signals stops and the excitation of the diaphragm is turned off for the next 3 seconds.

- ✓ Then expiration occurs by the elastic recoil of the chest wall and lungs. Then the inspiratory signal begins again for another cycle and again with expiration in between.

II-Ventral respiratory group (VRG):

- ✓ It is located in the ventral aspect of the medulla.
- ✓ It has Expiratory neurons (E) and Inspiratory neurons.
- ✓ There is reciprocal innervations between groups of inspiratory and expiratory neurons by inhibiting the other group.
- ✓ **Has no role with quiet respiration**.
- ✓ **It acts as overdrive mechanism** as it is responsible for *forced expiration,* also it is involved with *increased inspiratory effort* when high rates of pulmonary ventilation is required. (eg, during exercise).

2- Pontine Respiratory Centers:

There are two centers: Pneumotaxic and Apenustic centers.

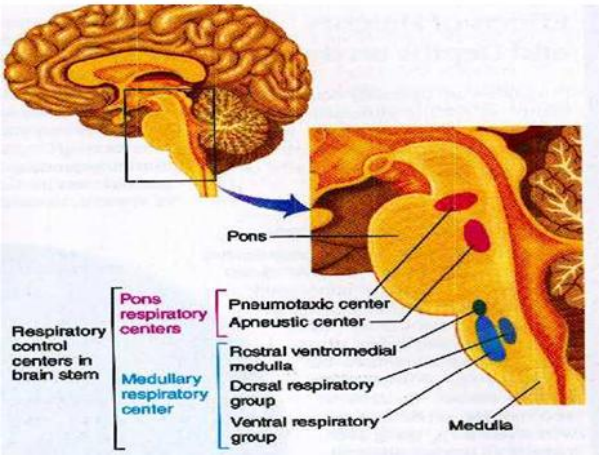
***1- Pneumotaxic center*:** Located in the upper pons.

- ✓ **It controls the "switch off" point of inspiration,** So it **inhibits inspiration.** and limits the duration of inspiration.
- ✓ It inhibits the DRG and apenuestic centers but at a *slower rate than the vagi* which control the normal breathing.
- ✓ It helps to **regulate** inspiratory volume and rate.

Think what happens regards (inspiratory rate , volume and period) when its signals increased in rate?

2-Apenuestic Center: Located in the lower third of the pons.

- ✓ It sends signals to DRG to retard the **switch off inspiration**.
- ✓ It operates with pneumotaxic center to control the depth of inspiration.
- ✓ Its function becomes significant when the pneumotaxic center is affected OR vagus nerve is sectioned.



III- Lung stretch receptors:

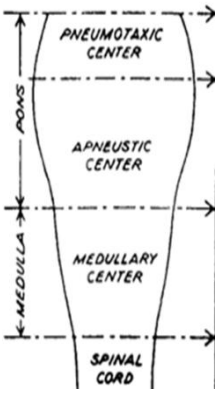
✓ Mechanoreceptors situated in the smooth muscle which makes up a large part of the walls of the trachea and bronchi, and so are stimulated by distention of the lungs and are responsible for Hering-Breuer inflation and deflation reflexes.

✓ Note, that the more the lung is inflated the greater will be the stretch of the lung

✓ ***In the Hering-Breuer inflation reflex,*** excessive inflation or stretching of the lungs during a large inspiratory effort leads to inhibition of the dorsal respiratory group and the apneustic center to promote expiration. The impulses are carried along the afferent fibers of the vagus to the RC .These impulses inhibit the apenustic and inspiratory centers leads to inhibition of inspiration. *Significance of this reflex :* ***protective in function*** as it prevents undue tension on lungs.

- ✓ ***The deflation reflex*** acts during expiration .Pulmonary stretch receptors are still active while the lungs are deflating.
- ✓ So, marked deflation of the lung stimulates the stretch receptors, which send impulses travels along the vagi to the respiratory centers (RC). This leads to stimulation of inspiration. *This reflex is responsible for shallow rapid breathing (in case of pulmonary congestion).*

think again *Think what are the breathing pattern changes that occur after brainstem and Vagal transaction?*



Chemical Control

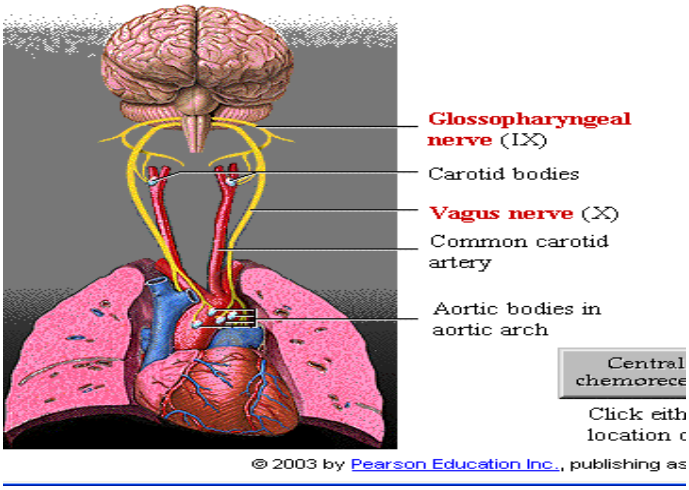
Excess CO_2 or H^+ and Lack of O_2 stimulate mainly the RC leading to increase the respiratory rate. These gases affect the RC through : *Chemoreceptors*

1- Central chemoreceptors in the medulla (bilaterally): Respond to the pH of the cerebrospinal fluid

2- Peripheral chemoreceptors in the carotid and aortic bodies:

Aortic bodies : the impulses are carried through vagus nerve.

Carotid bodies : the impulses are carried through Hering's nerve.

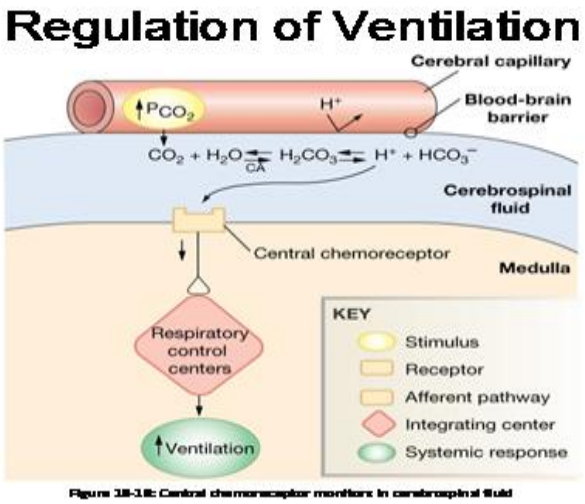


Ventilatory Response to CO2 :

The arterial PCO2 is 40mmHg. Any rise in PCO_2 as a result of tissue metabolism causes stimulation of ventilation. The CO_2 can through both central and peripheral recepetors.

Action of CO_2 on Central Chemoreceptors.

- ✓ Note that **H^+ ions (pH)** is the **1ry stimulus** of the central chemoreceptors, which is influenced by the changes in **local H^+** concentrations in CSF.
- ✓ H^+ *cannot cross the blood brain barrier*, but CO_2 can cross the blood brain barrier WHY?. CO_2 will combine with water and form **H_2C0_3** which rapidly dissociates
- ✓ **$H_2O + CO_2 \rightarrow H_2C0_3 \rightarrow HCO_3 + H^+$**
- ✓ Increased levels of **H^+** ions lowers the pH of CSF around the central chemorecptors so causing acidifying of it which leads to its stimulation.
- ✓ ***Note that***: 1- *As the H^+ passes through the blood-brain barrier with difficulty, increases in arterial H^+ does not affect the central chemoreceptors*.
- ✓ 2- *The central chemoreceptors are more sensitive to changes in* ***arterial PCO_2.***



Effects of CO_2 and H^+ ion concentrations on peripheral chemoreceptor activity:

An increase in either carbon dioxide concentration or hydrogen ion concentration also excites the peripheral chemoreceptors which send stimulatory impulses to the RC leading to hyperventilation.

The direct (central) effects of increased CO_2 and H^+ ions are so **much more powerful** than their effects mediated through the peripheral chemoreceptors (about seven times as powerful).

- ✓ The stimulatory effect of CO_2 on the peripheral chemoreceptors occurs *as much as five times as rapidly* as central stimulation, so that the peripheral chemoreceptors might be especially important in *increasing the rapidity of response to carbon dioxide at the onset of exercise.*

Ventilatory response of O_2

Has no direct effect centrally. It acts **peripherally .**

- When the oxygen concentration in the arterial blood falls below normal (= ↓ than 100mmHg), the peripheral chemoreceptors become strongly stimulated.
- ***Note that*** , the stimulatory effect of oxygen lack on ventilation is not clear when PO_2 is ranged from **100 mmHg down to 60 mmHg**, **WHY?**

Because the hypoxic stimulation of breathing is **opposed** by changes in CO_2 and $[H^+]$, because as breathing begins to be stimulated by lack of O_2, CO_2 is washed out of the blood and arterial H^+ falls as following :

a- Any increase of ventilation that occurs as a result of the stimulatory effect of decrease in PO_2 lowers the alveolar PCO_2 which will inhibit the respiration

b- When PO_2 decreases below 100 mmHg, Hb becomes less saturated with O_2. Hb becomes weaker acid so binds with H^+, this will decrease H^+ concentration in the blood which will inhibit respiration.

Hence, the lowered levels of CO2 and H inhibit breathing , producing what is sometimes called the **hypocapnic brake.**

N.B. The powerful effect of hypoxia can be demonstrated if this braking effect is prevented by adding CO 2 to the inspired air to keep its levels constant in the blood.

- *The impulse rate is particularly sensitive to changes in arterial PO_2 (below 60 mmHg) in **the range of 60 down to 30 mm Hg**, a range in which hemoglobin saturation with oxygen decreases rapidly*

Non chemical Control of Respiration

1. **Irritant receptors (nociceptors):** Located between airway epithelial cells and stimulated by noxious substances (Cough and sneezing reflex)
2. **Juxtacapillary (J) receptors:** Located close to the capillaries in the alveolar walls. Stimulation these receptors, causing rapid, shallow breathing such as during pulmonary edema.
3. **Joint and muscle receptors:** These are activated by limb movement and help to stimulate breathing early in exercise.
4. **Baroreceptors**:
   Increased ABP stimulates the baroreceptors. The baroreceptors send afferent impulses which inhibit the respiratory centers. The respiration becomes less in rate and more deep. This is associated with decreased tone of abdominal muscle which lead to decrease the venous return and COP which leads to decrease ABP toward normal.

Conscious (Control) control of breathing:

- The control of breathing described so far is **automatic and independent of the brain above the pons**. But also during conditions that require **voluntary control** of our respiratory muscles. Voluntary control is accomplished by descending pathways from the **cerebral cortex** to the motor neurons of the respiratory muscles(always bilateral)
- These conditions may be primarily respiratory, speaking, blowing, whistling;
- Also holding breath. But not for very long. as This voluntary control of respiration cannot be maintained when PCO_2 or H^+ concentration increase,and become intense.

Effect of Muscular Exercise on Respiratory rate

Muscular exercise increases the respiratory rate due to the following factors

1- Impulses from higher centers (cortex &hypothalamus), especially in emotions.

2- Increased levels of CO_2 and H^+ and decreased O_2 in arterial blood.

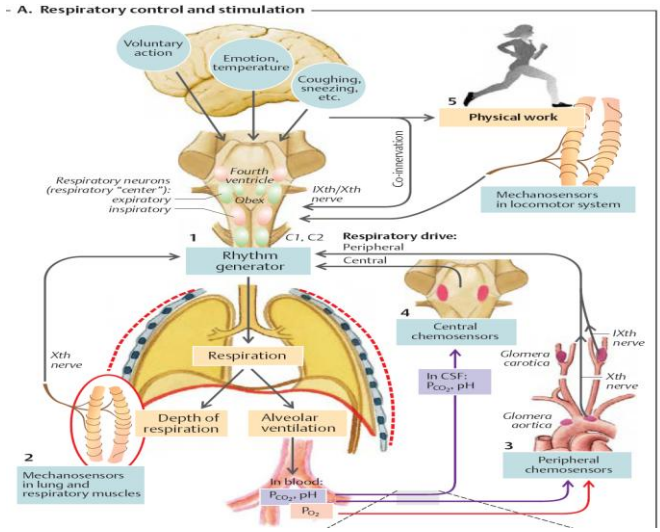
3- large amounts of lactic acid are produced during exercise that will stimulate the respiration.

4- Rise in body temperature which acts on the regulating center in hypothalamus and on the respiratory neurons directly.

5- Stimulation of Hering Breuer reflex due to increased blood in pulmonary circulation during exercise.

6- Increased venous return increases the right atrial pressure which stimulates the respiration (Harrison Reflex)

7- Impulses from propiorceptors of the limbs and exercising muscles



Dyspnea

Often The major symptom patients with lung disease complain of is dyspnea. This is usually described as **difficult breathing or air hunger** .

- It is the consciousness of the necessity of increased respiratory effort to supply the needed O_2.
- Normal Dyspneic index (DI) is above 90%. Dyspnea occurs when DI below **70%**

$$DI = \frac{MBC - RMV\ (BR)\ X\ 100}{MBC}$$

Causes :

1 –**Any disease causes increased rate of pulmonary ventilation** as in:

- Diseases causing hypoventilation with ↑ P CO_2 as - Pulmonary diseases as pneumonia, pulmonary emphysema (Diffusion impairment)
- Congestion of the lung causing stimulation of rapidly adapting receptors in the lungs causing dyspnea or shallow rapid breathing (tachpnea).

2 -Bronchial asthma: Increased the work performed by the respiratory muscles (which type of work?) .This increased effort will give the sensation of dyspnea.

3- Cardiac Dyspnea : The ↑ in right atrial pressure leading to ↑ the respiratory rate **(Harrison's reflex).**

4-Increased metabolic rate : As in hyperthyrodism and fever, so the pulmonary ventilation rate is increased and dyspnea is occurred *(State the mechanism)*

5-Neurogenic or emotional dyspnea.

Apnea

Apnea is defined as the temporary arrest of breathing, it means absence of breathing. Apnea can also be produced voluntarily, which is called breath holding or voluntary apnea.□ Apnea Time: Breath holding time is known as apnea time. It is about 40 to 60 seconds in a normal person, after a deep inspiration.

Asphyxia

□ Asphyxia is the condition characterized by combination of **hypoxia** and **hypercapnea,** due to obstruction of air passage. Axphyxia develops in conditions characterized by acute obstruction of air passage such as: 1. Strangulation .2. Hanging 3. Drowning, etc.

Cheyne-Stokes breathing

It is a periodic breathing periodic breathing characterized by rhythmic hyperpnea and apnea .It is the most common type of periodic breathing. It may be caused by physiological abnormalities in congestive heart failure,or pulmonary oedema OR instability of respiratory center.

Mechanism:

- During hyperventilation (↑ O2 & ↓CO2 in the blood) , more carbon dioxide is washed out. So, partial pressure of carbon dioxide in the blood decreases and the number of stimuli to the respiratory centers also decreases, leading to **apnea**. During apnea, carbon dioxide accumulates in the blood and the PCO2 ↑ but not to sufficient value to stimulate respiration. So O_2 Lack is the main stimulator for respiration.
- Few respiration occurs leads to ↑ O_2 and stops stimulation of breathing and apnea occurs. This process repeats itself. Each time PCO_2 is a little higher than the preceding apnea until it is about 40 mmHg to act as the normal stimulus for respiration and stops the periodic breathing.