صدقة جارية عن المغفور له بإذن الله **عمر عطية** من دفعة 2023 – كلية الطب، الجامعة الأردنية.

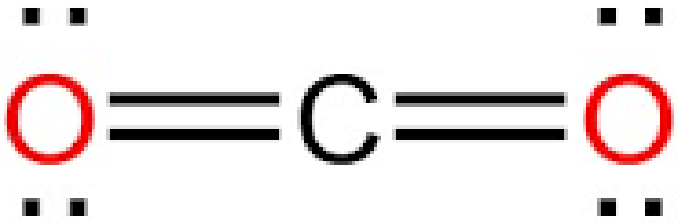
اللهم ارحمه واغفر له وأكرم نزله ووسع مدخله، لا تنسوه من دعائكم، إنا لله وإنا إليه راجعون.

#فريق_دوبامين_العلمي

Respiratory System Physiology

Comprehensive File 12

Dr. Yanal Shafagoj



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Regulation of Respiration – Recap

Note about lecture 11: The pneumotaxic center (in upper pons) has a direct suppressing effect on the apneustic center (in lower pons), in addition to its antagonizing effects.

Any control center has 3 main components: a goal, tool(s), and one or more stimuli.

The respiratory control center aims to keep the 3 ABGs (O_2, CO_2, and H^+) within physiological limits. It functions mainly by increasing or decreasing ventilation, unlike other systems that utilize more than one mechanism. The stimuli for increasing or deceasing ventilation are as follows:

- For CO_2 and H^+, an increase will stimulate increased ventilation; this corrects the acid-base balance and helps prevent acidosis. On the other hand, a decrease in any of the 2 ABGs would decrease ventilation. This means that the relation between CO_2 or H^+ (independent) and ventilation (dependent) is an increasing linear curve. We say that both CO_2 and H^+ have 2 tails, where even a subtle increase or decrease in their values counts as a stimulus for the control system.
- For O_2, the situation is different; increased arterial O2 values above 100 mmHg have no effect on the control system. Moreover, decreased values do not count as stimuli unless they become less than 60 mmHg, so we say that oxygen has a half tail since it has a partial, unidirectional control stimulus profile.

Effect of Increased Altitude on Alveolar Oxygen Tension: A Numerical Approach

When the atmospheric pressure decreases, $P_{atm}O_2$ would decrease, ultimately decreasing inspired oxygen. Alveolar PO_2 can be calculated using the following equation as discussed previously:

$$P_AO_2 = P_{inspired}O_2 - \frac{P_ACO_2}{R} = 150 - \frac{40}{0.8} = 100\ mmHg\ [at\ sea\ level]$$

Consider a higher elevation where atmospheric pressure is 500, not 760 mmHg. Humidified air total pressure is 453 (500 – 47) mmHg. Recall that PO_2 is 21% of the total pressure, which is around 95 mmHg (the normal value is 150 mmHg at sea level).

Using the same equation:

$$P_AO_2 = P_{inspired}O_2 - \frac{P_ACO_2}{R} = 95 - \frac{20}{0.8} = 70\ mmHg\ [at\ P_{atm} = 500\ mmHg]$$

Note that P_ACO_2 is less than 40 because of hyperventilation (20 was used in the lecture). In the lecture, P_aCO_2 was used in the equation, but both P_A and P_a are equal in normal situations; P_aCO_2 is used typically because it can be easily measured (as an ABG), and it represents P_ACO_2, which influences P_AO_2. R is unchanged: 0.8 for a mixed diet.

Hyper- and Hypoventilation: Additional Notes

Hyperventilation is when ventilation results in hypocapnia.

Hypoventilation is when ventilation results in hypercapnia.

Before diving, free divers hyperventilate to eliminate CO_2 rather than to increase oxygen. By reducing their CO_2 pressure to around 20 mmHg, they can remain underwater longer until CO_2 rises to approximately 50 mmHg, since they began the dive with a lower CO_2 level. This manoeuvre cannot be repeated more than about four times, because excessive reduction of CO_2 suppresses the ventilatory drive, allowing arterial oxygen to fall to critical levels before the urge to breathe occurs, leading to hypoxic coma (hypoxic loss of consciousness, sometimes called blackout in diving physiology).

Ventilation is mainly driven by CO_2 acting centrally on the medulla. The carotid bodies are primarily sensitive to hypoxemia and also respond to H^+ and CO_2, but their effect is about one-seventh the strength of the central stimulus.

In aspirin (acetylsalicylic acid) overdose, hyperventilation may occur because salicylates directly stimulate the medullary respiratory center. However, H^+ ions from the developing metabolic acidosis do not cross the blood–brain barrier easily, so the CNS is not immediately alerted to the severity of the acidosis. As toxicity worsens, severe metabolic acidosis occurs and more salicylates enters the CNS, depressing brain enzymes and leading to coma and, in severe cases, death.

In alkalosis, excessive enzyme activity can cause diaphragmatic spasm, highlighting the importance of tight regulation of H^+ levels.

At high altitude, a decrease in $P_{inspired}O_2$ can cause P_AO_2 to fall below 60, leading to increased ventilation and enhanced CO_2 elimination. In this setting, two opposing stimuli act on ventilation: hypoxia, which stimulates ventilation peripherally via the carotid bodies, and hypocapnia, which suppresses ventilation centrally.

Recall that $pH = 6.1 + \log (HCO_3^- / CO_2)$. When CO_2 decreases, HCO_3^- must also decrease to maintain a stable pH, and this occurs through renal excretion of bicarbonate in the urine. This contrasts with normal conditions, in which HCO_3^- is conserved and added to the venous side of the renal capillaries by kidney cells.

Bicarbonate is a critical buffer, as normal metabolism continuously generates acidic byproducts that must be neutralized.

In COPD, chronic elevation of CO_2 leads the kidneys to retain and generate more bicarbonate to maintain a near-normal pH. In this setting, hypoxemia becomes an important controller of ventilation, as P_aO_2 remains below 60 mmHg despite elevated CO_2 and H^+.

If such a patient is given high-concentration (pure) oxygen, maintaining P_aO_2 above 60 mmHg, the hypoxic ventilatory drive is markedly reduced, leading to diminished ventilation (apnea) and severe CO_2 retention, which can be fatal.

Therefore, **COPD patients should not be given uncontrolled pure oxygen**, but rather carefully controlled oxygen therapy.

قال **الشاطبي** وهو العلامة في علم القراءات:

وإن كان خرقٌ فادّرِكه بفضلة من الحلم وليصلحه من جاد مِقوَلًا

من مقدمة حرز الأماني ووجه التهاني المعروفة بالشاطبية.

إن أصبنا فمن الله، وإن أخطأنا فمن أنفسنا والشيطان، ملاحظاتكم مشكورة ومقدرة وهي محط اهتمام؛ وإن كان هناك خطأ "فليصلحه من جاد مِقولًا"، وسيتم تحديث الملف ورفع نسخة أخرى إن شاء الله.

شكر خاص للأستاذ الدكتور **ينال شفاقوج** على لطفه وتعاونه وإعطائه المادة حقها.

شكر خاص لأخي وزميلي **محمد المحاسنه** على جهده ورفقته الطيبة في ال12 ملفًا في هذا المساق.

في نهاية هذه الملفات ندعو الله أن ييسر لكم أمور دراستكم وتحصيلكم العلمي، آملين أن نكون قد أدينا المهمة بما يرضي الله، راجين أن يكون هذا العلم صدقة جارية عنا وعن أخينا عمر عطية – رحمه الله رحمة واسعة وألهم ذويه الصبر والسلوان، إنه ولي ذلك والقادر عليه.

لا تنسونا من صالح دعائكم

~ الفقير إلى عفو ربه، المثنى زاهي خليل