11/8/2023

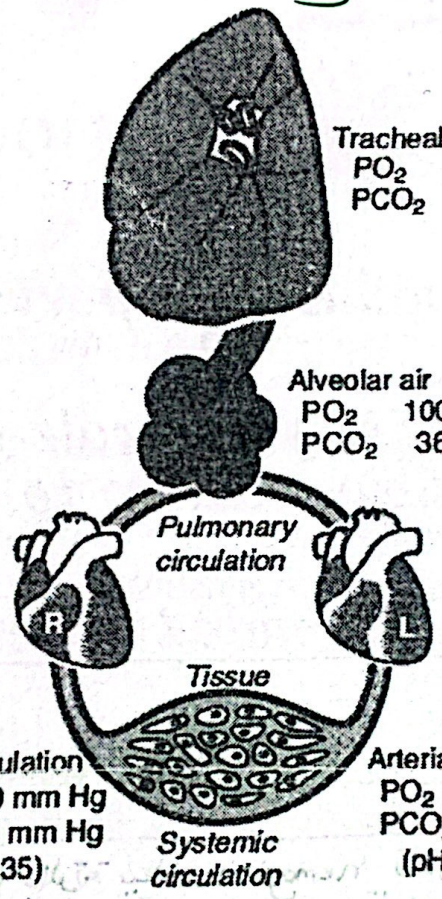
* CO_2 خروجه أسرع بـ 20 مرة من دخول O_2

Oxygen and gas exchange
Oxygen and carbon dioxide

- The role of oxygen in metabolism is crucial to all life. In cell mitochondria, electron pairs from the oxidation of NADH and FADH2, are transferred to molecular oxygen
- For adequate tissue oxygenation, the following seven conditions are necessary:
  1. available atmospheric oxygen (الناس اللي بيكونوا داخل حريق)
  2. adequate ventilation (asthma , COPD)
  3. gas exchange between the lung and arterial blood (infections , edema)
  4. Loading of O2 onto hemoglobin (acidosis)
  5. adequate hemoglobin (anemia)
  6. adequate transport (cardiac output), and (cardiac proplemes)
  7. release of O2 to the tissue. (smoking)

- Any disturbances in these conditions can result in poor tissue oxygenation

* هاي الرسمة بتعطيني indication كيف بعمل process العينة .



- في الهواء الخارجي =

= exchange in kindney

= in vein.

= in artery

* اذا أخذت عينة من artery وتركتها معرضة للهواء رح يذوب O_2 بالعينة و CO_2 يطلع على شكل غاز فبصير عندي error بالعينة .

1

Oxygen and carbon dioxide

- Factors that can influence the amount of O2, that moves through the alveoli into the blood and then to the tissue include:

1. **Destruction of the alveoli:** the normal surface area of the alveoli is as big as tennis court. When the surface area is destroyed to a critical low value by diseases such as emphysema

= ∝1 antitrepsin (elastase enzyme تحمك) / elastine ⇒ give elasticity to lungs / elastase بيصير عندي infection بالرئة بيخرب elastine بالرئة.

2. **Pulmonary edema:** Gas diffuses from the alveoli to the capillary through a small space. With pulmonary edema, fluid leaks into the space, increasing the distance between the alveoli and capillary walls

مثلاً لو حدا عنده أمراض بالقلب وصار عنده edema بالرئة بتجي alveoli جلحي.

3. **Airway blockage.** Airways can be blocked, as in asthma and bronchitis , COPD

4. **Inadequate blood supply:** As in pulmonary embolism, pulmonary hypertension or a failing heart not enough blood is being carded away to the tissue where it is needed.

أكثر اشي بتعرضوله الدخنين .

5. **Diffusion of CO2 and O2.** Because O2 diffuses 20 times slower than CO2, it is more sensitive to problems with diffusion. This type of hypoxemia is generally treated with supplemental O2. 60% or higher O2 concentrations must be used with caution because it can be toxic to lungs

emphysema ⇒ ∝1 antitrepsin deficiency.

- Diffusion of CO_2 and O_2 :

= حكينا انه CO_2 بصيرله diffusion أسرع من O_2 ب 20 مرة .

عشان هيك ممكن نواجه مشاكل بالـ diffusion لـ O_2 .

= مثلاً في حالة hypoxemia بصير لازم أعطي supplemental O_2 (بس!!)

لازم ننتبه لما نعطي O_2 بتركيز 60% أو أعلى ... ليش ؟!!

↲ زي ما في حالة نقص O_2 الدماغ بيعطي إشارة من Respiratory Center عشان يزيد ventilation .

↲ كمان لما نزيد O_2 بالجسم بشكل مفاجئ الدماغ بيعطي إشارة من Respiratory center عشان يقلل ventilation فيقل Respiratory rate عنده .

• في هاي الحالة بنسميها Oxygen toxicity .

Oxygen transport

- Most O2 in arterial blood is transported to the tissue by hemoglobin.
- Each adult hemoglobin (A1) molecule can combine to four molecules of O2. reversibly with up to four molecules of O2
- The actual amount of O2 loaded depends on:
  1. The availability of O2
  2. The concentration and type(s) of hemoglobin present — عند anemia ، نوع hemoglobin
  3. The presence of interfering substances, such as (CO) — - التدخين ، - منطقة ملوثة
  4. The pH (لما تقل PH بالرئة بيظل hemoglobin قادر يحمل O_2 للخلايا ، لما تزيد بالرئة قادر يحمل release لـ O_2 للخلايا)
  5. The temperature of the blood — يتبخر O_2 عشان kinetic energy بتزيد
  6. The levels of PCO2 and 2,3- DPG. — هاي النقطة لا تحرطو فيها لأني أنا بحربط.

عند الناس اللي في المناطق المرتفعة بكون الـ PO_2 قليل ، 2,3-DPG بيزيد عندهم عشان يساعد على سرعة تحميل وتنزيل O_2 من وإلى الخلايا .

11/8/2023

Oxygen transport

* هاد نفس اللي مشروح عند Oxygen toxicity.

- With adequate atmospheric and alveolar O2 available and with normal diffusion of O2 to the arterial blood, more than 95% of the "functional" hemoglobin will bind O2.
  - Functional hemoglobin: النسبة الطبيعية للـ O2 بال
- Increasing the availability of O2 to the blood further saturates the hemoglobin. However, once the hemoglobin is 100% saturated, an increase in O2 to the alveoli serves only to increase the concentration of dissolved O2 (dO2) in the arterial blood. This offers minimal increase in oxygen delivery.

- Prolonged administration of high concentration of O2 may cause oxygen toxicity and in some cases, decreased ventilation that leads to hypercarbia

= احنا بالعادة عنا أربع أنواع hemoglobin بس الناس اللي مش عايشين بمكان ملوث أو مش مدخنين أو ما بيتعرضو للدخان بكون عندهم فقط أول نوعين .

Oxygen transport

- Normally blood hemoglobin exists in one of four conditions:
  - Oxyhemoglobin (O2Hb), which is O2 reversibly bound to hemoglobin. (4 O_2 عليه)
    له هاد اللي بيحمل الأكسجين
  - deoxyhemoglobin (HHb; reduced hemoglobin), which is hemoglobin not bound to O2 but capable of forming a bond when O2 is available
    له مش محمل بالأكسجين ونسبته ضئيلة جداً (0.5-1.5%)

  هدول النوعين موجودين بشكل طبيعي .
  - Carboxyhemoglobin (COHb), Which is hemoglobin bound to CO. Binding of CO to Hb is reversible but is greater than 200 times as strong as that of O2
    له الـ affinity للـ O_2 كتير عالية فلو بيحمل O_2 ما بيقدر ينزله للخلايا . (عالفاضي)
  - Methemoglobin (MetHb), which is hemoglobin unable to bind O2, because iron (Fe) is in an oxidized rather than reduced state. The Fe +3 can be reduced by the enzyme methemoglobin reductase, which is found in RBC's
    له بصير لما يتعرض الواحد لـ oxidants يأكسد Fe^{+2} لـ Fe^{+3} وتقل ارتباطه بالـ O_2 .
    له أو لما يكون في defect في methhemoglobin enzyme بيأكسد Fe^{+2} لـ Fe^{+3} .
- Co-oximeter are used to determine the relative concentrations (relative to the total hemoglobin) of each of these species of hemoglobin.

methhemoglobin reductase ⟹ Ferric (Fe^{+3}) convert ⟹ (Fe^{+2}) Ferrous

له هاد لشكل اللي لازم يرتبط بـ hemoglobin .

Assessing a patient oxygen status

- Four parameters used to assess a patient's oxygen status are:
  - Oxygen saturation (SO2)
  - Measured fractional (percent) oxyhemoglobin (FO2Hb);
  - Transcutaneous pulse oximetry (SpO2) assessments and
  - The amount of O2 dissolved in plasma (PO2)

- Oxygen saturation (SO2) represents the ratio of O2 that is bound to the hemoglobin compared with the total amount of hemoglobin capable of binding O2

$$SO_2 = \frac{cO_2Hb}{(cO_2Hb + cHHb)} \times 100$$

Oxygen saturation (SO2)

Oxygen saturation (SO2)

- Software included with the blood gas instruments can calculate SO2 from pO2, pH and temperature of the sample.
- These calculated results can differ from those determined by direct measurement due to the assumption that only adult hemoglobin is preser and the oxyhemoglobin dissociation curve has a specific shape and locatio
- These algorithms for the calculation do not account for the other hemoglobin species, such as COHb and MetHb
- So calculated SO2 should not be used to assess oxygenation status

Fractional oxyhemoglobin

⇒ بقسيم كلهم وبطلع نسبة OHb بسيطة.

- Fractional (or percent) oxyhemoglobin (FO2Hb) is the ratio of the conc. of oxyhemoglobin to the conc. of total hemoglobin (ctHb)

$$FO_2Hb = \frac{cO_2Hb}{ctHb} = \frac{cO_2Hb}{cO_2Hb + cHHb + dysHb}$$

- Where the dysHb represents hemoglobin derivatives, such as COHb, that can't reversibly bind with O2 but are still part of the "total" hemoglobin measurement.

- These two terms SO2 and FO2Hb, can be confused because as the numeric values for SO2 are close to those of FO2Hb (differ in smokers and if dyshemoglobins are present)

Partial pressure of oxygen dissolved in plasma

- Partial pressure of oxygen dissolved in plasma (pO2) accounts for little of the body's O2 stores.

- Noninvasive measurement are attained with pulse oximetry (SpO2). These devices pass light of two or more wavelength through the tissues of the toe, finger or ear. (light يمرق منها طبقة الجلد رقيقة جدًا)

- The pulse oximeter differentiate between the absorption of light as a result of O2Hb and dysHb in the capillary bed and calculates O2Hb saturation. Because SpO2 does not measure COHb or any other dysHb, it overestimates oxygenation when one or more are present.

- The accuracy of pulse oximetry can be compromised by many factors, including diminished pulse as a result of poor perfusion and severe anemia.

- The maximum amount of O2 that can be carried by hemoglobin in a
- given quantity of blood is the hemoglobin oxygen (binding) capacity The molecular weight of tetramer hemoglobin is 64,458 g/mol.
- One mole of a perfect gas occupies 22,414 mL. Therefore, each gram of hemoglobin carries 1.39 mL of O2

$$\frac{22{,}414\ \text{mL/mol}_4}{64{,}458\ \text{g/mol}} = 1.39\ \text{mL/g}$$

⟹ 1g كمية الأكسجين في hemoglobin.

- When the total hemoglobin (tHb) is 15 g/dL and the hemoglobin is 100% saturated with O2, the O2 capacity is:

$$15\ \text{g/100 mL} \times 1.39\ \text{mL/g} = 20.8\ \text{mL O}_2\text{/100 mL of blood}$$

⟹ كمية الأكسجين كاملة بالدم لشخص ما عنده anemia.

Oxygen content

- Oxygen content is the total O2 in blood and is the sum of the O2 bound to hemoglobi (O2Hb) and the amount dissolved in the plasma (pO2)

- Because pO2 and pCO2 are only indices of gas-exchange efficiency in the lungs, they not reveal the content of either gas in the blood.

- If the pO2 is 100 mmHg, 0.3 ml of O2 will be dissolved in every 100 ml of blood plasr

- The amount of dissolved O2 is usually not clinically significant. However, with low tH at hyperbolic conditions, it may become a significant source of O2 to the tissue. Nor 98-99% of the available hemoglobin is saturated with O2.

- Assuming a tHb of 15 g/dL, the O2 content for every 100 mL of blood plasma becor

$$0.3\ \text{mL} + (20.8\ \text{mL} \times 0.97) = 20.5\ \text{mL}$$

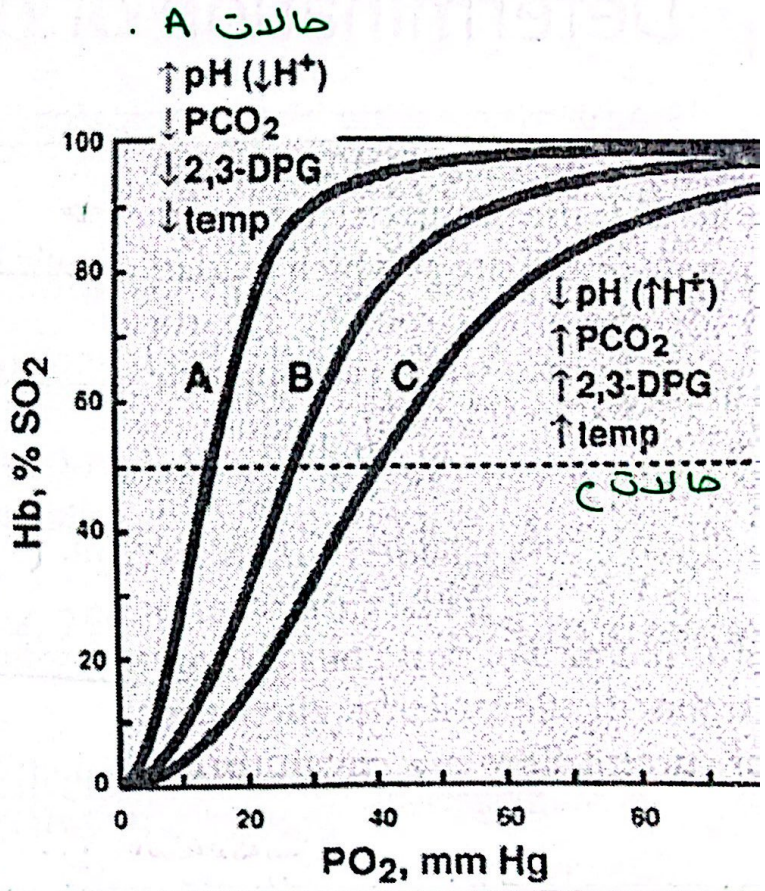
Hemoglobin-oxygen dissociation

- 2,3-DPG levels increase in patients with extremely low hemoglobin values and as an adaptation to high altitude.

A ⇒ decrase affinity to O_2
لمعناها بيي كمية O_2 أكبر عشان أحصل على نفس مقدار saturation

B ⇒ normal affinity to O_2

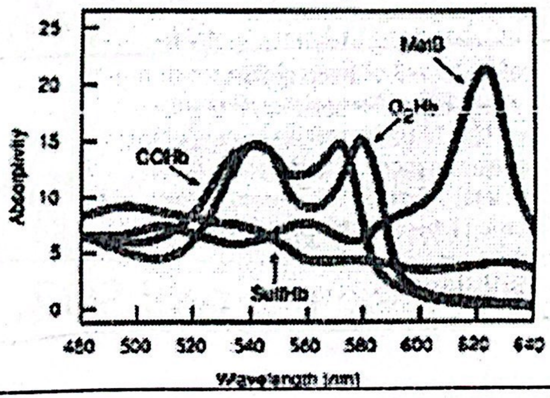
C ⇒ increase affinity to O_2.
لمعناها بيي كمية O_2 أقل عشان أحصل على نفس مقدار saturation.



Measurement

Spectrophotometric (Co-oximeter) Determination of oxygen saturation

- The actual determination of oxyhemoglobin (O2HB) can be determined spectrophotometrically using co-oximeter designed to directly measure the various hemoglobin species.
- The number of hemoglobin species measured will depend on the number and specific wavelength incorporated into the instrumentation. For example, two wavelength instrument systems can measure only two hemoglobin species (O2Hb and HHb), which are expressed as a fraction or percentage of the total hemoglobin.



بقيس كل أنواع hemoglobin =
وبيحسب fractional

Spectrophotometric (Co-oximeters) Determination of oxygen saturation

- As with any spectrophotometric measurement, potential sources of errors exist, includir
  1. Faulty calibration of the instrument
  2. Spectral-interfering substances → مادة بالدم إلعانس دماء
- The patient's ventilation status should be stabilized before blood sample collection
- An appropriate waiting period before the sample is redrawn should follow changes in supple or mechanical ventilation
- All blood samples should be collected under anaerobic conditions and mixed immediately with or other appropriate anticoagulant. (عشان ما يذوب O_2 بالدم سه الجو ويطلع من CO_2 من العينة.) (pseudo high oxygen)
- If the blood gas analysis is not being done on the same sample, EDTA can be used as an anticoagu
- All samples should be analyzed promptly to avoid changes in saturation resulting from the use of ox by metabolizing cells'

* لازم أحلل العينة بسرعة عشان ما يقل الـ O2 بسبب استهلاكه من الخلايا الكرات البيضاء في الدم فيصير حالة pseudo low oxygen .

* لقيس الفرق بين Current بين two electrods .

Blood gas analyzers (pH, pCO2 and pO2)

- Blood gas analyzers (macroelectrochemical or microelectrochemical sensors) as sensing devices
- The pO2 measurement is amperometric (current flow) related to the amount of O2 being reduced at the cathode
- The PCO2 and pH measurement are potentiometric (change in voltage)
- The blood gas analyzer can calculate several additional parameters, bicarbonate, total CO2, base excess and SO2.

Measurement of pO2

- The primary source of error for pO2 measurement is associated with the buildup of protein material on the surface of the membrane (retards diffusion of O2)
  - pseudo low
- Bacterial contamination within the measuring chamber, although uncommon, will consume O2 and cause low and drifting values

pseudo low بستهلك ; كبيرين فلما كانت الأخراض معقدة رح يطلع عندي

- It is important not to expose the sample to the room air when collecting, transporting and making O2 measurement.
  - pseudo high.
- Contamination of the sample with room air (pO2, 150 mmHg) can result in significant error
- Even after the sample is drawn, sample should by analyzed immediately as leukocytes continue to metabolize O2 leading to low PO2 values
  - Pseudo low

Measurement of pO2

- Cutaneous measurement for pO2 also are possible using transcutaneous (TC) electrodes placed directly on the skin.
- Measurement depends on oxygen diffusing from the capillary bed through the tissue to the electrode. Although most commonly used with neonates and infants
- Skin thickness and tissue perfusion with arterial blood can significantly affect the results.
- Heating the electrode placed on the skin can enhance diffusion of the O2 to the electrode, however, burns can result unless the electrodes are moved regularly.

Measurement of pH and pCO2

- Two electrodes (the measuring electrode responsive to the ion of interest and the reference electrode) are needed and voltmeter, which measures the potential difference between the two electrodes.

لـه بقارن reference مع Sample عن طريق فرق الجهد بينهم .

- The potential difference is related to the concentration of the ion of interest.

- To measure pH, a glass membrane sensitive to H+ is placed around an internal Ag-AgCl electrode to form a measuring electrode

- The potential that develops at the glass membrane as a result of H+ from the unknown solution diffusing into the membrane's surface is proportional to the difference in [H+] between the unknown sample and the buffer solution inside the electrode

تراكم الـ protins بيعمل عندي error .

pCO2

- An outer semipermeable membrane that allows CO2 to diffuse into a layer of electrolyte, usually bicarbonate buffer, covers the glass pH electrode. The CO2 that diffuses across the membrane reacts with the buffer, forming carbonic acid, which then dissociates into bicarbonate plus H+

- The change in the activity of the H+ is measured by the pH electrode and related to pCO2

- As with the other electrodes, the buildup of protein material on the membrane will affect diffusion and cause errors, pCO2 electrodes are the slowest to respond because of the chemical reaction that must be completed. Other error sources include erroneous calibration caused by incorrect or contaminated calibration materials

Specimen

- Arterial blood specimen is an excellent reference
- Peripheral venous samples can be used if pulmonary function or O2 transport is not being assessed (the source of the specimen must be clearly identified)
- Depending on the patient, capillary blood may need to be used to measure pH and pCO2
- Although the correlation with arterial blood is good for pH and pCO2, capillary pO2 values even with warming of the skin before drawing the sample, do not correlate well with the arterial pO2 values as result of sample exposure to room air
- Sources of error in the collection and handling of blood gas specimens include the collection device, form and concentration of heparin, speed of syringe filling, maintenance of the anaerobic environment, mixing of the sample to ensure dissolution and distribution of the heparin anticoagulant, and transport and storage time before analysis

Interpretation of results

- Laboratory professionals need certain knowledge, attitude and skills for obtaining and analyzing specimens for pH and blood gases.
- Simple evaluation of the data may reveal an instrument problem (possible bubble in the sample chamber or fibrin plug)
- A possible sample handling problem (PO_2 out of line with previous results and current inspired FiO_2 levels)
- The application of knowledge saves time. The ability to correlate da quickly reduces turnaround time and prevents mistakes.