# Physiology Team 432


9th Lecture

# Effects of Low and High Gas Pressure


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# Objectives

By the end of this lecture you should be able to:

- Describe the effects of exposure to low and high barometric pressures on the body.
- Describe the body acclimatization to low barometric pressure.
- Define decompression sickness and explain how it can be avoided.
- Understand the effects of high nitrogen pressure, and nitrogen narcosis.

# Effect of increased barometric pressure (Deep sea diving)

*Barometric pressure at sea level =760mm Hg*

- When human descend below the sea, the pressure around them increased.
- To prevent the lungs from collapse, air must be supplied also under high pressure.

The more the diver goes deeper under water the higher pressure he will be exposed to.

High pressure will compress his lungs making it difficult to "inflate"

So, for the lungs to inflate the air the diver's inhale has to equal the pressure applied to the diver's body

Ex: if the pressure applied to his body = 2 barometric, he should breath air (from the tank he's carrying) of 2 barometric

- This exposes the blood in the lungs to extremely high alveolar gas pressure (hyperbarism).
- Under certain limits these high pressures cause tremendous alterations in the physiology of the body.
- The surrounding pressure increases by 1 atmosphere for every 10 meter (33feet) of depth in seawater.
- Therefore at a depth of 31 meter (100 feet) in the ocean the diver is exposed to a pressure of 4 atmospheres.

*Hyperbarism: air under high pressure*

10 meters (below sea) → 2 atmosphere pressure

- 1 atmosphere pressure caused by the air above water
- Second atmosphere pressure by the weight of the water itself

31 meters (below sea) → 4 atmosphere pressure

- 1 atmosphere pressure caused by the air above water.
- 3 atmosphere pressure by the weight of the water itself

- These problems confront SCUBA (self-contained under water breathing apparatus).

# Effect of depth on the volume of the gases:

Is compression of gases to smaller and smaller volumes.

1L (sea level) →1/2L at 33 feet and so on

(volume of the gas compressed is <u>inversely proportional</u> to pressure)

# Effect of depth on density of gases


# Nitrogen effect at high nitrogen Pressure

Has 2 principle effects:

Nitrogen narcosis (anesthetic effect):

1

- Nitrogen like most other anesthetic gases, dissolve freely in the fats of the body including the membranes and other lipid structures of the neurons.
- This leads to alteration of the electrical conductance of the membranes, reduces their excitability and Subsequent narcosis develops.

Gas at a high pressure will change in its characteristic. And will diffuse in the body's tissue (in the brain's neural membrane) in a liquid state (liquid nitrogen), its accumulation will lead to toxicity (narcotic effect), (تأثير المخدرات).

| | |
|---|---|
| at 120 feet | • the diver lose many of his cares. (lose his focus) |
| at 150 feet | • there is a feeling of euphoria<br>• drowsiness<br>• impaired performance |
| at higher pressure | • loss of coordination<br>• finally coma might develop |

## 2 Decompression sickness (Cassion's disease)

- it is a syndrome caused by a decrease in the ambient pressure which occur in animal and men when the tissues of the body contain an excess of physically inert gas.

- During descent, the high partial pressure of nitrogen (encountered when breathing compressed air at depth) forces this poorly soluble gas into solution in body tissue particularly in fat (it has a high N2 solubility).

- On ascending, this inert gas comes out of physical solution forming a gaseous phase (bubbles), leading to symptoms and signs.

This happens when the diver beneath the sea long enough that large amounts of nitrogen have dissolved in his\her body and the diver then suddenly comes out to surface of the sea, significant quantities of nitrogen bubbles in the body fluid and can cause minor or serious damage in any part of the body, depending on the size and number of bubbles formed.

If a diver has been beneath the sea long enough that large amounts of nitrogen have dissolved in his\her body and the diver then suddenly comes back to the surface of the sea, significant quantities of nitrogen bubbles can develop in the body fluids and can cause minor or serious damage.

**During slow ascent**

N2 is slowly removed from the tissues since the partial pressure there is higher than that in the arterial blood and alveolar gas.

Nitrogen turns into a gas slowly

Ex: if the body has 1 L of nitrogen not all of it will turn into a gas at once, but in small amounts that will be e expired from the body.

If decompression is rapid Bubbles of gaseous nitrogen are released, in tissues and blood, causing the symptoms of decompression sickness (the bends or caisson disease)

# SYMPTOMS & SIGNS OF DECOMPRESSION SICKNESS (DS)

| | |
|---|---|
| mildest form of DS | • Fatigue<br>• drowsiness after decompression |
| Locally | • skin itch |
| sever symptoms may occur | • Bubbles in the tissues →Cause severe pains particularly around the joints<br>• Neurological symptoms→Include parenthesis, itching, paralysis, and inner ear disturbances |
| Thoracic pains | • Dyspnea<br>• substernal pain<br>• cyanosis<br>• cough |
| Bubbles in the coronary arteries | • May cause myocardial damage |
| Decompression sickness shock | • Capillaries become permeable to plasma and hypovolemia rapidly develop |
| Edema | • Edema may be prominent and shock is also usually complicated by pulmonary edema |

# Treatment of decompression symptoms

Rapid recompression in a pressure chamber followed by Slower decompression. This reduces the volume of the Bubbles and forces them back into solution.

In a very deep dives, the risk of decompressing sickness can be reduced if a helium-O2 mixture Is breathed during the dive.

## Helium is more desirable than nitrogen in deep dives because it has:

- ¼-1/5 the narcotic effect of nitrogen on CNS.
- 1/7 the molecular weight of nitrogen.

Only about one half as much volume of helium dissolve in the body tissues as nitrogen, and the volume that does dissolves diffuse out of the tissue during decompression several times as rapidly as nitrogen thus reducing the problem of decompression sickness

- Low density leading to decreased airway resistance of diver.

The low density of helium keeps the airway resistance for breathing at minimum, which is very important because highly compressed nitrogen is so dense that airway resistance can become extreme , sometimes making the work of breathing beyond endurance

- High diffusion through tissues
- Helium is about 1/2 as soluble as nitrogen in body fluids. This reduces the quantity of bubbles that can form in tissues when the diver is decompressed after diving

## Effects of low oxygen pressure on the body (Aviation-ascend to high altitude)

| | Barometric pressure |
|---|---|
| sea level | 760 Hg |
| 10.000 feet | 523 Hg |
| 50.000 feet | 87 Hg |
| This decrease in barometric pressure is the basic cause of all hypoxia problems in high altitude in physiology | |

## Alveolar PO2 at different altitudes

As the barometric pressure decreases, the oxygen partial pressure decreases proportionally, remaining less than 21% of the total barometric pressure.

| | PO2 |
|---|---|
| **sea level** | 159 mm Hg |
| **20.000 feet** | 40 mm Hg |
| **50.000 feet** | 18 mm Hg |

Even at high altitude $CO_2$ is continuously excreted from the Pulmonary blood into the alveoli .Also, water vaporizes into the inspired air from the respiratory surfaces.

Therefore, these two gases dilute the oxygen in the alveoli, thus reducing the oxygen concentration and therefore hypoxia develops.

# Effects of a cute hypoxia

Some of the important acute effects of hypoxia beginning at an altitude of approximately 12,000 feet are:

- Drowsiness
- lassitude
- mental and muscle fatigue
- sometimes headache
- occasionally nausea
- Sometimes euphoria.

All these progress to a stage of twitching or convulsions above 18,000.

Above 23,000 feet the un acclimatized person can enter into coma.

*un acclimatized person:*
*شخص غير متدرب على العيش في الاماكن المرتفعه*

# Acclimatization to low PO2

A person remaining at high altitudes for days, weeks or years Becomes more and more acclimatized to low PO2.

So that it causes fewer deleterious effects on the body and it becomes possible for the person to work harder without hypoxic effects or to ascend to still higher altitude.

# Principle means of acclimatization

## 1- Increase in pulmonary ventilation

The person will have hyper ventilation

Ex: if the normal ventilation 4.2 L

The ventilation will increase up to 8.4- 16 L depending on the body's need for oxygen

## 2- Increased red blood cells

Hypoxia stimulates the kidney to synthesize erythropoietin to synthesize more blood cells ,thus increase hemoglobin ($O_2$ carrier), to increase oxygen content as much as possible

## 3- Increased diffusion capacity of the lungs

A normal diffusion capacity for oxygen through the pulmonary membrane is about 21 ml/mm Hg/min this diffusion capacity ca increase as much as during exercise 40-60 ml/mm

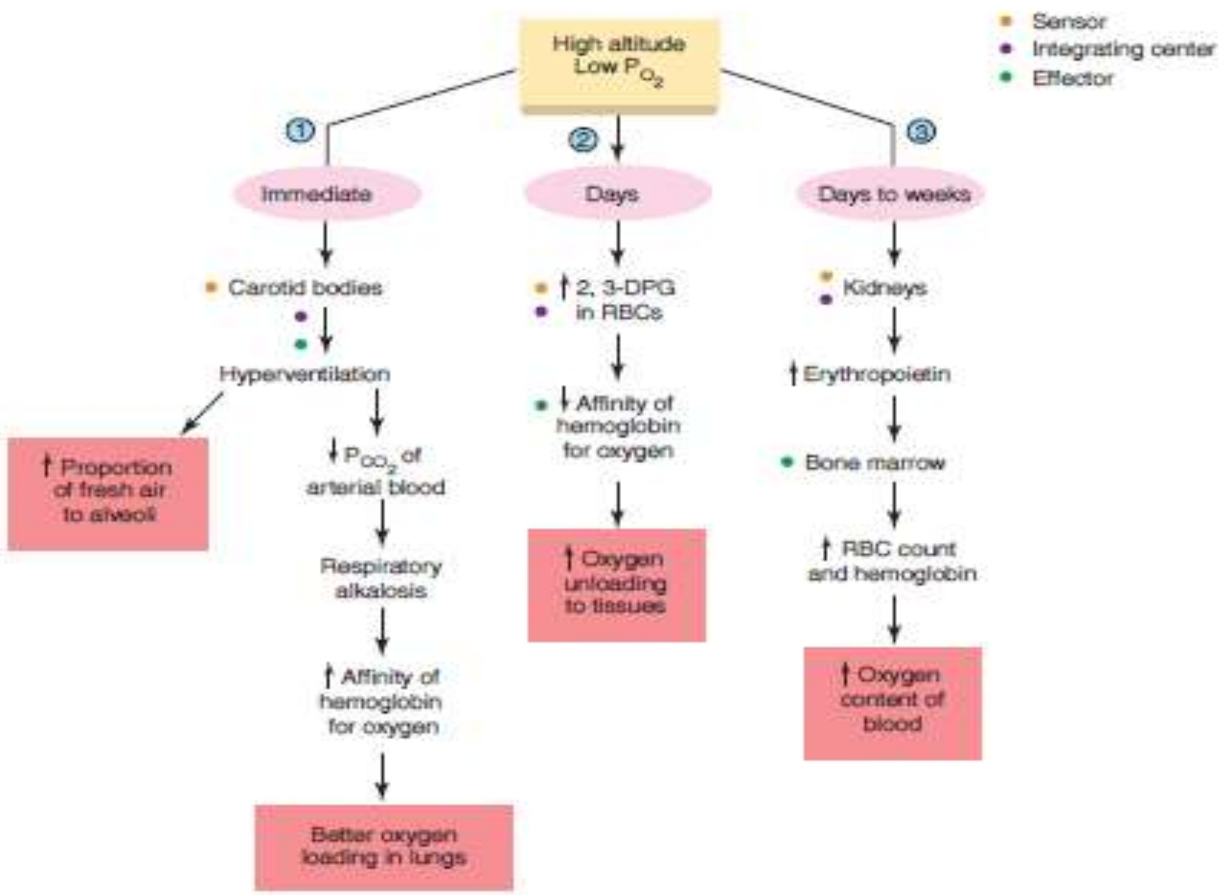
## 4- Increased vascularity of the tissues

↑ Vascularity → ↑blood flow → ↑circulation → ↑ $O_2$ transport

## 5- Increased ability of the cells oxygen despite the low $PO_2$

By increasing cellular oxidative enzymes (الانزايمات التي تساعد في استخدام الاوكسيجن)

It is presumed that the tissue cells of high acclimatized person can use oxygen more effectively than can their sea level counter parts




Immediate:

↑ Hyper ventilation → leading to a better oxygen loading.

↓pCO2 (pulmonary alkalosis)

But there is a side effect with is left shift of the oxygen hemoglobin dissociation curve

As it increase it is going to make it harder to do hyperventilation (high PH)

And eventually will lead to inhibition of respiratory ventilation

Days:

2,3-DPG will increase to solve the problem of the left shift making it right shift thus decrease the affinity of hemoglobin for oxygen and then ↑ oxygen unloading

Days to weeks:

Kidney will solve the problem of alkalosis without inhibiting hyperventilation

By synthesizing erythropoietin as we discussed earlier

And by excreting bicarbonate

The acid is hydrogen

The alkaline is bicarbonate

In the case of alkalosis it means bicarbonate is high and H2 is low so, by excreting bicarbonate is makes the body in normal PH and we no longer have alkalosis