Exposure to

PHYSICAL HAZARDS

Dysbarism

Prof. Ashraf Zaghloul

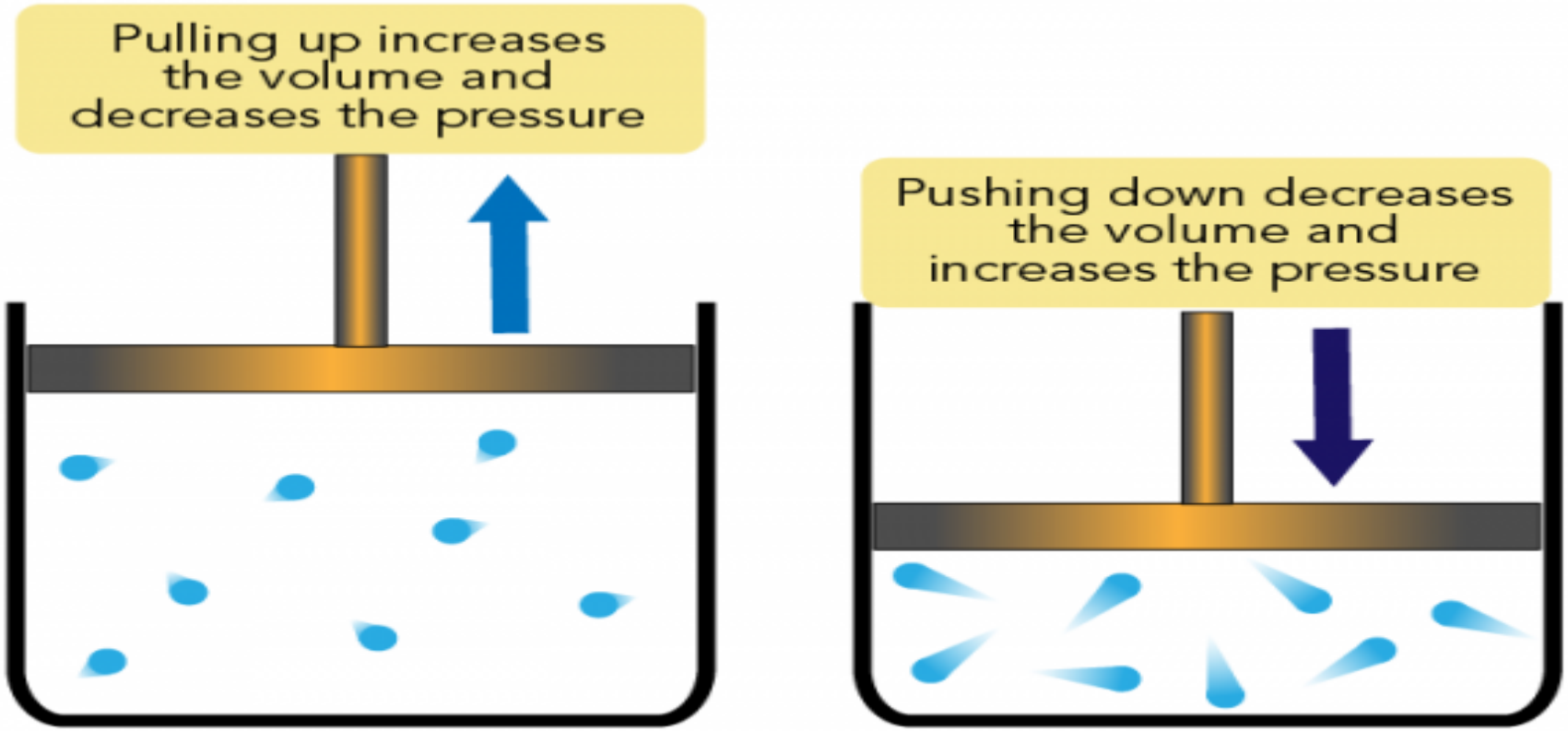
Dysbarism عسر الضغط

Robert Boyle, a chemist and physicist from the 17th century, discovered that the **volume of gas**, meaning how much space it occupies, **is related to its pressure**—and vice versa.

Boyle's Law

If you pressurize a gas, its volume contracts. If you decrease its pressure, its volume increases.

Boyle's Law


Pulling up increases the volume and decreases the pressure
Pushing down decreases the volume and increases the pressure

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Which characteristic of a fluid affects the pressure in that fluid?

Depth of the fluid and its **Density**

A fluid exerts more pressure at greater depths. Deeper in a fluid, all of the fluid above it results in more weight pressing down.

This causes greater pressure the deeper you go

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Dysbarism is the collective term used to describe the pathophysiological changes that occur when the human body is exposed to altered environmental pressure (rapid changes) and from the resulting abnormal behavior of gases in the body.

The inverse relationship between the pressure and the volume of a gas explain the change of gas volume inside the body with changes in environmental pressure.

The ambient pressure which we normally reside is defined (at sea level) as, **one atmosphere** of barometric pressure **(1 ATA** atmosphere absolute**)**

Dysbarism عسر الضغط

Pressure increases by 1 atmosphere for every 10 meters under water

*10 m = 2 ATA 20 m = 3 ATA 30 m = 4 ATA …….etc;

***The ATA is an acronym for atmospheres absolute and is defined to be one standard atmosphere of pressure at sea level.**

Hyperbaric exposures add to ambient pressure by diving under water and hypobaric exposures subtract from it by rapid ascent from sea level to 9000 m in a depressurized cabin.

The risk of dysbaric disorders can be reduced if the altered pressure to which an individual is exposed be **gradually returned** to normal according to recommended schedules.

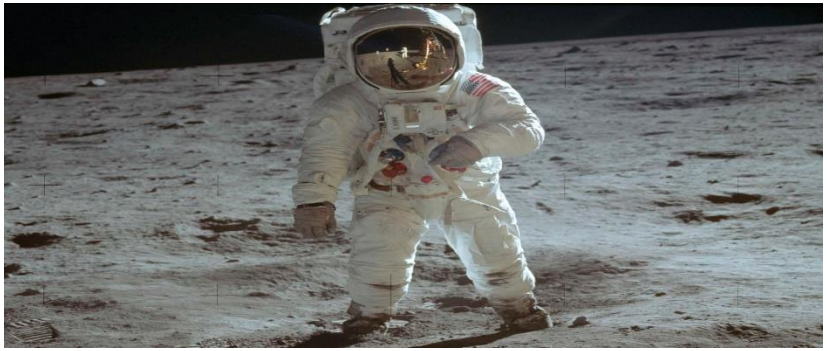
Risky Jobs to Dysbarism

Caisson Engineering

Deep sea divers

Air Force

Space Programmes



Nitrogen Narcosis (Inert Gas Narcosis)

Diving cylinders contain 20% Oxygen and 80% Nitrogen, or helium

Breathing gases for hyperbaric use have been developed to improve on the performance of ordinary air by **reducing the risk of decompression sickness, reducing the duration of decompression stops, reducing nitrogen narcosis or allowing safer deep diving**.

Nitrogen Narcosis (Inert Gas Narcosis)

- It occurs most commonly in deep diving while breathing compressed air, it also occurs with other inert gases (e.g. nitrogen because of their **Lipid Solubility** and thus the condition is called also **inert gas narcosis**.

- The resultant increase in partial pressure of inert gas (e.g. nitrogen) in compressed air generates additional nitrogen load which due to its lipid solubility and the well perfusion of brain tissue, easily saturates the brain exerting its narcotic effect.

The narcotic effect begins at depth 20 - 30m (3 - 4 ATA) causes symptoms quite similar to alcohol intoxication called (**rapture of the depth متعة, سكر الأعماق , Martini effect)** characterized by:

1. Euphoria. سعادة وانتعاش
2. Impaired judgment & intellectual functions. قدرات ذهنية
3. Incoordination of neuromuscular functions and performance.

Nitrogen Narcosis (Inert Gas Narcosis)

- **At depth of 90 meters (10 ATA)** loss of consciousness occurs & the risk of drowning accidents and death is very high if the bubbles are in the brain.

- The narcotic effect is believed to be exacerbated by: cold water /hypercarbia (↑ CO_2) / strenuous activity & fatigue & alcohol consumption

- Upon decompression during ascent **rapid and complete recovery** occurs.

High – Pressure Neurological Syndrome (HPNS)

High-pressure neurological syndrome (HPNS) is **a condition encountered in diving beyond a depth of 100 m**.

Manifestations include: euphoria, headache, tremors, myoclonus (quick, involuntary muscle jerk), sleeping disturbances, neuropsychiatric disturbances, and EEG changes.

Convulsions are seen only in experimental animals.

High – Pressure Neurological Syndrome (HPNS)

- It occurs when breathing mixtures of compressed helium, oxygen was used to allow deep dives (exceeding depth of 100 meters) while avoiding the development of nitrogen narcosis.

- The syndrome is due to the effect of **high pressure** by itself. The pathogenesis of this effect is still unclear, but it is supposed to be due to disturbances in neurotransmission:

  This will lead to N.S hyperexcitibility.

Barotrauma

The 2nd leading cause of death in divers during ascent due to pulmonary complications (they call it bubble trouble). The primary (First Leading) cause of death is drowning due to nitrogen narcosis.

Barotrauma may occur during ascent or descent whenever a gas filled space such as pulmonary alveoli, middle ear, para nasal sinuses, stomach or dental fillings, fail to equalize its internal pressure relative to changes in ambient pressure.

Barotrauma

- **Barotrauma Of Descent** (referred to as squeeze are characterized clinically by: Middle ear squeeze, para nasal and sinus squeeze, inner ear squeeze
- **Barotrauma Of Ascent** (referred to reverse squeeze) are characterized by:

Arterial Gas Embolism	**Pneumothorax**
Gastric Rupture	**Subcutaneous Emphysema**
Pneumomediastinum	**Pneumopericardium**

N.B. Prevention of barotraumas of descent can be accomplished by use of systemic or local decongestants & anti-inflammatory corticosteroids sprays.

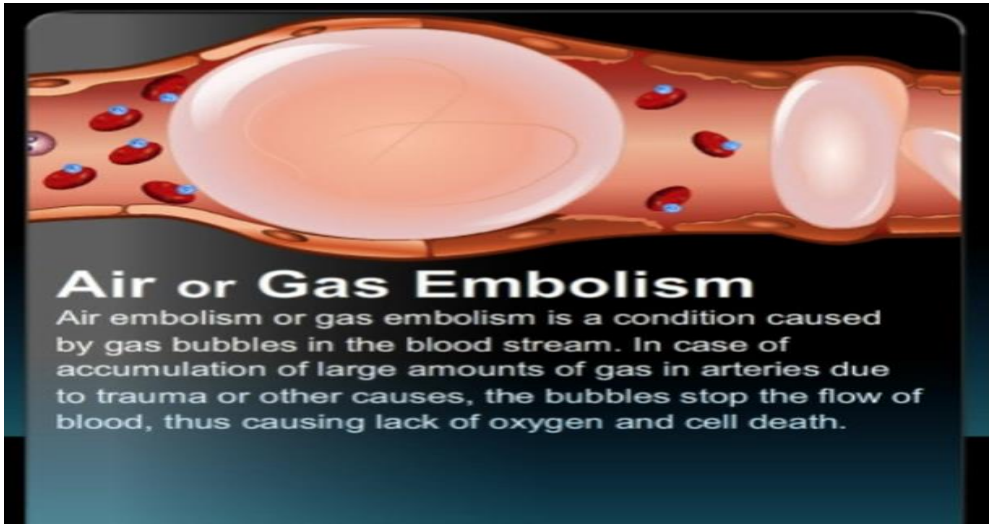
Arterial Gas Embolism (AGE)

- AGE and DCS (decompression sickness) share similar pathophysiology (formation of arterial gas bubbles and treatment (recompression).

Clinically there are two main presentation of AGE

A. Isolated central nervous system (CNS) symptoms

B. Cardiovascular collapse. (sudden effect)



Arterial Gas Embolism (AGE)

CNS symptoms

Symptoms & signs occur immediately upon surfacing.

- Brain is the most frequent target (in contrast to DCS).
- Embolization affects multiple brain arteries & this explains the diversity of neurological clinical finding which include:
- Vertigo, confusion and faintness.
- Signs rapidly progress from sensory disturbances and aphasia to hemiplegia, cortical blindness, gas in retinal arteries, convulsions & coma.

Arterial Gas Embolism (AGE)

5% of individuals **die**, **60%** **improve** within minutes after recompression, but **30%** frequently relapse انتكاس.

All individuals who have suffered AGE should permanently refrain from diving

Decompression sickness (Caisson's disease)

Acute decompression syndrome (Caisson's disease) is an acute neurological emergency in divers

It is caused due to release of nitrogen gas bubbles that impinge the blood vessels of the spinal cord and brain and result in severe neurodeficit

Decompression sickness (Caisson's disease)

- Decompression sickness (DCS) results from mechanical & physiopathologic effect of expanding gases & bubbles in blood & tissue.
- Bubbles occur intra & extravascularly and even intracellularly. The high fat content of nervous tissue combined with the low fluid solubility of N_2 may account for its vulnerability to bubble formation.
- DCS occurs upon return from **a hyperbaric** (e.g. during diver's ascent) or from **a hypobaric** exposure i.e. barotrauma of ascent (e.g. hypobaric or altitude DCS in aviators).

Decompression sickness (Caisson's disease)

When the body is exposed to an environment of higher than atmospheric gas pressure as in tunneling or diving, **it absorbs more of the inhaled gases than it does at sea level**.

N2 concentration in tissues increases particularly those of the nervous system, bone marrow and fat.

Decompression sickness (Caisson's disease)

Mechanism:

N_2 enters and leaves these tissues more slowly than O_2 & CO_2 as the surrounding pressure decrease (during **rapid** decompression), N_2 expands and will form gas bubbles because of the absence of sufficient time necessary for dissolution by diffusion from the tissues.

Because O_2 & CO_2 have greater fluid solubility & move easily between tissue compartments, then tendency for bubble formation is reduced.

Decompression sickness (Caisson's disease)

Multiple organ involvement is more frequent in **DCS** than in barotraumas of ascent.

While in the latter signs & symptoms and that of arterial gas embolism, occur sudden & immediate on surfacing; **while DCS symptoms frequently delay for 6- 48hours.**

Decompression sickness (Caisson's disease)

DCS is classified into 2 types and a late 3rd type of chronic complication of dysbaric osteonecrosis

The types (type I & II) and severity of symptoms depend on age, weight, and physical condition of the patient, the degree of physical exertion, the depth or altitude before decompression & the rate & duration of decompression.

Decompression sickness (Caisson's disease)

Type I DCS (bone and skin) has the best prognosis

Signs and Symptoms:

- **Acute pain** usually around major joints. Usually occurs either soon after decompression or delay up to 12hours after.
- Skin may show urticarial and bluish-red mottling & itching (**diver's lice**).

Type II DCS

Primarily **neurological** including spinal, vestibular, cerebral involvement & other systemic symptoms

Decompression sickness (Caisson's disease)

The typical presentation of **DCS in CNS** begins with transient back pain. Subsequently, parasthesia & hypoesthesia develop in legs.

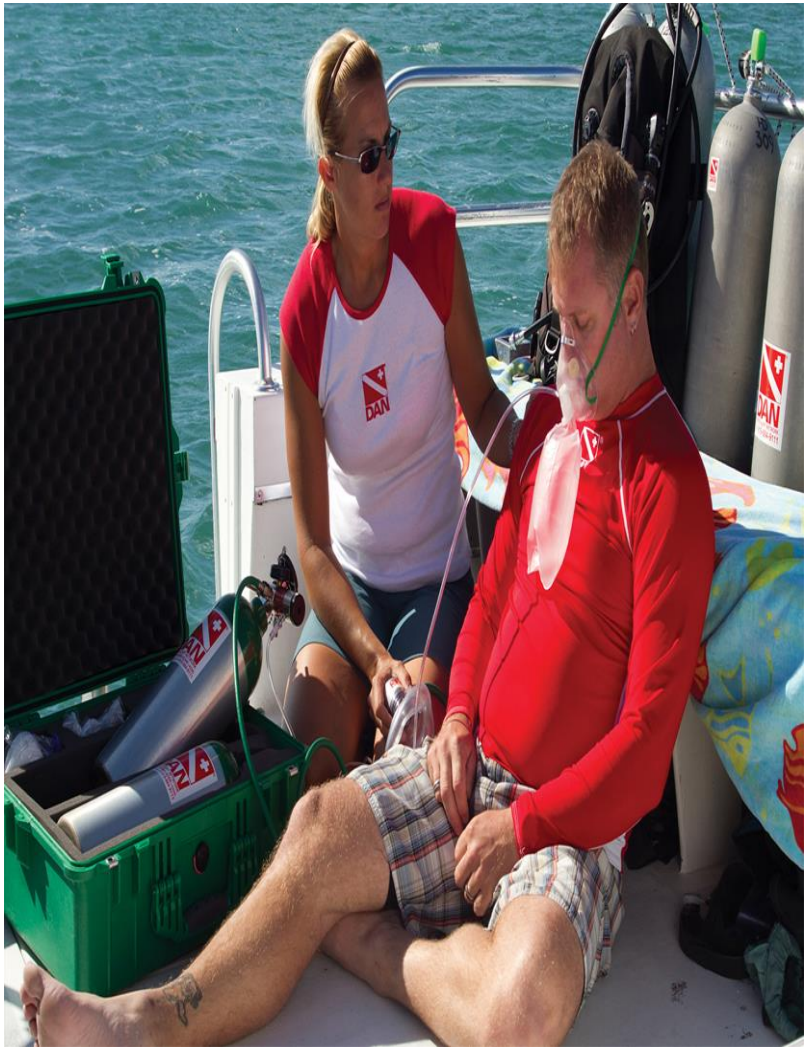
Without medical intervention this situation progress to urinary retention, paresis of lower limb and even paralysis, impaired speech, tremors & convulsions, coma.

Decompression sickness (Caisson's disease)

Pulmonary System Effects:

- **In most cases of DCS**, **No** pulmonary symptoms occur.
- The syndrome called "the chokes" by divers, develops in 2-8% of DCS patients and is characterized by paroxysmal cough, dyspnea, and sub-sternal chest pain.
- Without appropriate therapeutic intervention **(Recompression) إعادة الضغط,** this syndrome may pass to non-cardiogenic pulmonary edema, circulatory collapse & death.

Decompression sickness (Caisson's disease)



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Decompression sickness (Caisson's disease)

Inner ear effects:

- Inner ear decompression sickness occurs most common when breathing mixture is used for diving.
- Symptoms include: Vertigo, tinnitus, Hearing loss

These symptoms are similar to inner ear barotrauma of descent (squeeze) which on the contrary occur during compression and treatment is the opposite for both conditions (recompression for inner ear DCS, but not for barotrauma of descent).

Decompression sickness (Caisson's disease)

Type III DCS (Chronic dysbaric osteonecrosis):

- Chronic dysbaric osteonecrosis (aseptic necrosis) is a late and chronic complication of exposure to **hyperbaric environment** (e.g. caisson workers or divers) and rarely occur in aviators exposed to hypobaric environment (barotraumas of ascent).

- The lesions develop only in long bones and in sites where fatty bone marrow is found in mature adult.

Decompression sickness (Caisson's disease)

Chronic dysbaric osteonecrosis

Decompression sickness (Caisson's disease)

Treatment DCS cases (and barotrauma of ascent)

Rapid transport of the patient to a recompression facility is the single and most important measure and **the probability of recovery decreases with delay**.

Portable one person decompression chamber is now available for initiation of immediate treatment.

Decompression sickness (Caisson's disease)

1

The patient is placed in the hyperbaric chamber in an atmosphere of raised pressure. The pressure is then reduced at slow rate, with decompression pressures and schedules determined on the phases of the duration and pressure exposure of the incident. This accompanied by alternating 100% O_2 & air breathing or helium O_2 mixes.

Decompression sickness (Caisson's disease)

Decompression chamber

Recompression pressure causes bubbles to become smaller and breathing pure O_2 produces a gradient by which inert gas in bubbles and tissue can diffuse out of the body and thus shortens the period of decompression.

Decompression sickness (Caisson's disease)

2

Anti-coagulant **(heparin)** can be given as necessary and symptomatic treatment.