DYSBARISM & DIVING COMPLICATIONS

There are THREE relevant gas laws that apply to diving.

(1) BOYLE's LAW.

$$P_1V_1 = P_2V_2$$

- Given a constant temperature, the pressure & volume of an ideal gas are inversely related.
- ie. if pressure doubles, volume is halved.
- 1 atm = 760 mmHg = 1.013 bar = 101.3 kPa

The weight of seawater produces a change of 1 atm for each 33 ft (10m) of depth. Examples;

1. At 33ft depth = 2 atm pressure
   (1 atm for water, 1 atm for atmospheric pressure at sea level).
2. At 165ft depth = 6 atm pressure
   (1 atm per 33ft, ∴ 5 atm + 1 atm for atmospheric pressure at sea level).

Therefore, as a diver descends in a column of water, the air-containing structures will decrease.

- ie. at 33ft depth, human lungs at volume (V) at sea level will now be ½V.
- If the same diver ascends without exhaling lung volume → 2V !!
  (∴ risk of barotrauma).

(2) DALTON's LAW.

The total pressure exerted by a mixture of gases is the sum of the partial pressures of each gas.

Partial pressure of nitrogen at sea-level ≈ 600 mmHg (0.79 x 760 mmHg).

- At a depth of 99 ft ≈ (600 x 4atm = 2400 mmHg) !!

(3) HENRY's LAW.

At equilibrium, the quantity of gas in solution (in liquid) is proportional to the partial pressure of the gas.

This explains the uptake of inert gas (ie. nitrogen) into tissues when breathing compressed air at depth (intrinsic to the development of decompression sickness).

BAROTRAUMA OF DESCENT.

During descent, volume of gas in body-cavities decreases.
Most pronounced in middle ear (often fixed in descent by valsalva).

Of concern: TM rupture underwent can cause calorically-induced vertigo, subsequent panic & potential for near-drowning.

	Clinical Features	Treatment
Otic barotrauma ("ear squeeze")	Pain, fullness, vertigo, conductive hearing loss from inability to equalise middle ear pressure	Decongestants, ?antibiotics
Sinus barotrauma ("sinus squeeze")	Pain over affected sinus, possible bleeding from nose. Infraorbital nerve paraesthesia.	Decongestants, ?antibiotics
Inner ear barotrauma	Sudden onset of sensorineural hearing loss, tinnitus, severe vertigo after forced Valsalva	Head up, no nose blowing, prochlorperazine, ENT consult

BAROTRAUMA OF ASCENT.

During ascent, volume of gas in air-containing organs will expand.

Pulmonary barotrauma can occur with ascent whilst breath-holding, or with coughing & vomiting. This may cause pneumothorax or pneumomediastinum.

- Air can potentially enter pulmonary venous circulation → *cerebral arterial gas embolism (CAGE)* !!!

Any neurological sign or symptom referable to CNS circulation in the setting of barotrauma should be considered to be secondary to CAGE.

	Clinical Features	Treatment
Pulmonary barotrauma	Dyspnoea, chest pain, subcut. emphysema, PTX on CXR. Hx of rapid or uncontrolled ascent.	Pneumomediastinum: symptomatic care PTX: drainage ± immed. decompression.
Arterial gas embolism	Neurological Sx's immediately after uncontrolled/rapid ascent (or neuro Sx's w/ pulmonary barotrauma)	ABC, high-flow O2, IV hydration. Immediate recompression (hyperbaric O2)

DECOMPRESSION SICKNESS.

Results from the obstructive & inflammatory effects of inert gas bubbles in tissues & vascular system. Bubbles form when a body saturated with inert gas experiences a decrease in ambient pressure (liberating the gas from solution).

This is usually avoided by use of dive-charts or dive computer.

Bubbles may directly obstruct blood flow (leading to ischaemia) or inflammatory/thrombotic processes occur resulting in third-spacing of fluid.

Clinical Features.

Generally symptoms occur w/in minutes to several hours after surfacing.

- Flying can obviously worsening/precipitate symptoms.

Pulmonary DCS = similar to pulmonary embolism.

- large numbers of bubbles within pulmonary arteries.

Neurological DCS = similar to transverse myelitis.

- Rapidly ascending paralysis.
- Specific spinal level not often found (nor does it match spinal syndrome).
- Possible to get 'scattered lesions'.

Classification of Decompression Sickness		
Classification	**Clinical Features**	**Treatment**
Type I 'pain only' DCS	- Deep pain in joints/extremities unrelieved by movement. - Skin changes (mottling, pruritis, colour changes)	- usu. single joint, most commonly knees & shoulders - Lymphatic obstruction can occur & takes days to resolve
Type II 'serious' DCS	- Pulmonary ('chokes'); cough, haemoptysis, SOB, chest pain. - CVS collapse can occur - Neurologic; sensation of truncal constriction, ascending paralysis (rapid !) - Vestibular ('staggers'); vertigo, hearing loss, tinnitus, dysequilibrium.	Neurologic; tendency to affect lower cervical & thoracic regions Staggers: usu. after deep, long dives.
Type III combination of DCS & arterial gas embolism	- Variety of stroke symptoms, syndromes & signs.	Occurs on ascent (or immediately up surfacing). Symptoms often resolve spontaneously.

ARTERIAL GAS EMBOLISM.

Occurs when air enters the left-side of circulation (usu. from pulmonary barotrauma) and embolises distally (often to cerebral circulation).

Clinical Features.

The most dramatic effect is CAGE!!

- Variety of stroke syndromes.
- Can be large enough to completely stop cerebral circulation.
- Symptoms may resolve spontaneously (as gas bubbles enter venous circulation).

TREATMENT OF DCS & ARTERIAL GAS EMBOLISM.

Includes;

1. Administration of 100% oxygen
2. Increasing tissue perfusion w/ IV fluids
3. Rapid recompression

Some advocate for use of '*trendelenburg position + left lateral decubitus*'.

- Often already too late (particularly on dive-boats)
- Can potentiate cerebral oedema & intracranial pressure.

Recompression therapy by ***hyperbaric oxygen*** treats both DCS & air embolism.

- Decreases size of bubbles.
- High PaO2 increases inert gas washout (from bubbles & tissues).
- ↓ tissue oedema, ↑ O2 to ischaemic tissues, ↓ inflammatory cascade.

Controversy surrounds use of *lignocaine* in CAGE.