CHAPTER – SIX

Thi-Qar University College of medicine

Dep. Of Physiology and medical physics

Year One - Lecture No. (6) Theoretical Medical physics lecture

(Academic years 2023-2024)

PRESSURE

Objectives: after the end of this lecture, the student must know:

1-What is pressure and how can it affect our various body parts and organs like skull, eye….etc

2-Principles of use of hyperbaric oxygen in the treatment of certain diseases.

Pressure

-Atmospheric pressure is due to the weight of the air in the atmosphere .
- pressure is define as the force per unit area in a gas or a liquid .
- for a solid the quantity of force per unit area is referred as stress.

P = F/A N / m^2
Or dynes/cm^2

atmospheric pressure 1= 10^5 N /m^2
1 atm= 10^5 N/m^2
The unit of pressure is Pascal (Pa)

Since we live in a sea of air with pressure 1 atm, it is easier to measure pressure relative to atmospheric pressure.

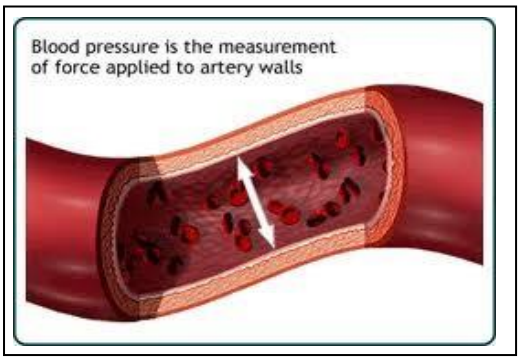
There are places in the body where the pressure are lower than atmospheric or negative for example:

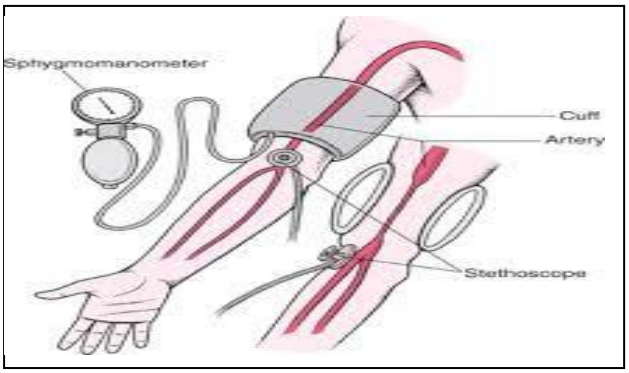
When we breath (inspire) the pressure in the lung must be lower than

atmospheric pressure or the air would not flow to the lungs.

In medicine , the unit of pressure is measured by the height of a column of mercury .

Measurement of body pressure





Pressure is a very common phenomenon in our live. eg; the doctor measures our blood pressure as a part of a physical examination.

Units: - In metric system pressure is measured in units

a. Dynes per square centimeters
b. Newton per square meter (Pascal) or (Pa)

Note: - none of the above units is in common in medicine.
The used unit is the height of a column of mercury (Hg)
The peak systolic pressure is 120mm Hg = a pressure of a liquid mercury of this height on its base.

While the atmospheric pressure = 760mm Hg

Pressure = force per unit area in a gas or liquid

For ***mercury*** $\rho=13.6\ g/cm^3$ for **water** $\rho=1\ g/cm^3$

Stress = force per unit area in a solid
1 Pa (Pascal) = 1 N/m^2

Pressure under a column of liquid: $\mathbf{P = \rho\ g\ h}$

ρ = density of the liquid
g = acceleration due to gravity
h = height of the column

In the metric system pressure is measured in dynes per square centimeter (Dy/cm^2) or Newton per square meter (N/m^2) or Pascal (Pa).

If the unit is Dy/cm^2

$P = \rho g h$ ρ = density of liquid (g/cm^3)

g=980(cm/sec^2) acceleration of gravity

h= in (cm) the height of liquid

Or **the unit is N/m^2**

$P = \rho g h$ ρ = (kg/m^3)

g= 9.8 m/sec^2

h= In (m)

Example -1-

Find the pressure of 10 m of water in Dy/cm^2 and N/m^2?

$10 \times 100 = 1000$ cm 1m=100cm. $P = \rho g h$

$=1\times980\times1000=980000=9.8\times10^5$ Dy/cm

$^2P = \rho g h$ $=1000 \times 9.8 \times10 =9.8\times10^4$ N/m^2

Example -2-:

calculate the atmospheric pressure in N/m2 and in dyne/cm2,

where ρ Hg =13.6 g/cm3 ?

1 atm =760 mm = 76 cm =0.76m

ρ Hg =13.6 g/cm3 or 13600 Kg/m3

The atmospheric pressure in N/m2 is equal **P = ρ g h =13600 Kg/m3 ×9.8m/sec2 ×0.76m** **P=101292.8 N/m2**	**The atmospheric pressure in dyne/cm2 is equal P = ρ g h =13.6 g/cm 3 ×980cm/sec2 ×76cm** **P=1012928 dyne/cm2**

Example -3-

Calculate the systolic pressure in Dy/cm^2 and N/m^2?

In systolic pressure =120 mmHg=12 cmHg

= 0.12 m Hg

$\therefore$ $P = \rho_{Hg} g h_{Hg} =13.6\times980\times12=159936=1.6\times10^5$ Dy/cm^2

$P = \rho_{Hg} g h_{Hg} =13600\times9.8\times0.12=1.6\times10^4$ N/m^2

Example – 4 –

What height of water will produce the same pressure as 120 mm Hg?

For mercury.

P (120 mmHg) = ρ g h = (13.6 g/cm3) (980 cm/sec2) (12 cm)

=1.6×105 dyne/cm2

For water:

1.6×105 dynes/cm2 = (1.0 g/cm3) (980 cm/sec2) (h cm H2O) h

=163 cmH2O

Or

PHg = Pwater

(ρ gh)Hg = (ρ gh) water

ρ Hg × hHg = ρ water × hwater

hwater = (ρ Hg × hHg) / ρ water = (13.6 ×12)/1=163 cmH2O

Note:-

1 atmosphere (atm) = 1.01×105 N/m2

1 atmosphere (atm) = 1033 cmH2O

1 atmosphere (atm) =760 mmHg

1 cmH2O =0.735 mmHg or 1mmHg = 1.36 cmH2O

- The atmospheric pressure is about 10^5 N/cm^2 (or Pa).
- When the pressure is lower than the atmospheric we call it (Negative pressure), while when it is higher than atmospheric we call it (positive pressure)
- There are many places in the body where the pressures are (Negative).

The following table lists some typical pressures in the body:

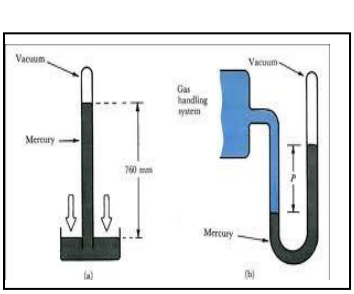
PART OF THE BODY	Typical pressure (mm Hg)
Arterial blood pressure: Maximum (systolic) Minimum (diastolic)	100-140 60-90
Venous blood pressure Great veins	3-7 < 1
Capillary blood pressure: Arterial end Venous end	30 10
Middle ear pressure	< 1
Eye pressure – aqueous humor	20
Cerebrospinal fluid pressure in brain (lying down)	5-12
Gastrointestinal pressure	10-20
Intrathoracic pressure (between lung and chest wall)	-10

Devices used to measure pressure

1- U shape tube monometer ----------used to measure either a (+ve) or (-ve)pressure.
2- Tonometer---- used to measure the eye pressure (+ve pressure only)
3- Cystometer ---- used to measure the urinary bladder .
4-Sphygmomanometer ---used to measure the blood pressure (+ve pre.)

A- **Manometer:-**This is a U-shaped tube containing a fluid that is connected to the pressure to be measured. The levels in the arms change until the difference in the levels (h) is equal to the pressure.

*This type of manometer can measure both (positive) and (negative) pressure.
*The fluid used can be
1. Mercury for high pressure measurements.
2. Water or other low density fluid (for low pressures).



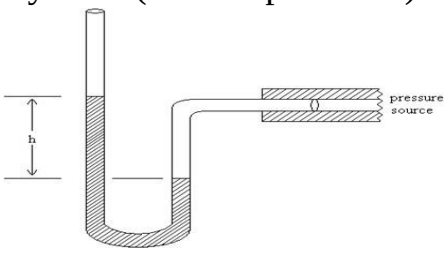


Figure: A -U tube manometer for measuring pressure which is can be expressed as the height of the fluid,

B-Sphygmomanometer -- is the clinical instrument used for measuring the blood pressure. It can be provided by one of two types of gauges.

1. Mercury gauge:-the pressure is indicated by the height of mercury inside a glass tube.
2. Aneroid type:-the pressure changes the shape of a sealed flexible container, which causes a needle to move on a dial or the value is showed as a digit.

Pressure inside the skull:-

The brain contain about ($150cm^3$) of cerebrospinal fluid "CSF" in a series of interconnected opening called "***Ventricles***"

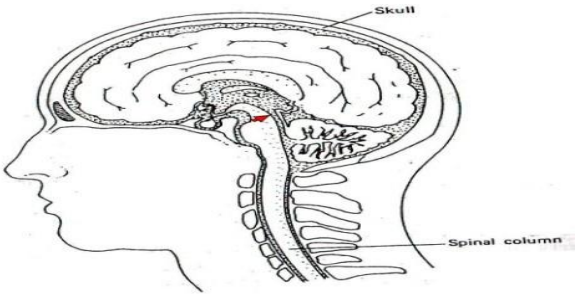
CSF is generated inside the brain and flows throw the ***ventricles*** into the spinal column and eventually into the circulatory system.

One of the ventricles the aqueduct is especially narrow. If at birth this opening is blocked for any reason ,the CSF is trapped inside the skull and increases the internal pressure, the increased pressure causes the skull to enlarge, this condition is called "Hydrocephalus"

Detection of hydrocephalus:

It is not convenient to measure the CSF pressure directly. The method to detect hydrocephalus is to measure the circumference of the skull just above the ears.

1- Normal value for the circumference of the skull of an infant is (32 to 37 cm), and a larger value may indicate hydrocephalus.
2- Transillumination: Makes use of the light-scattering properties of the rather-clear CSP inside the skull.



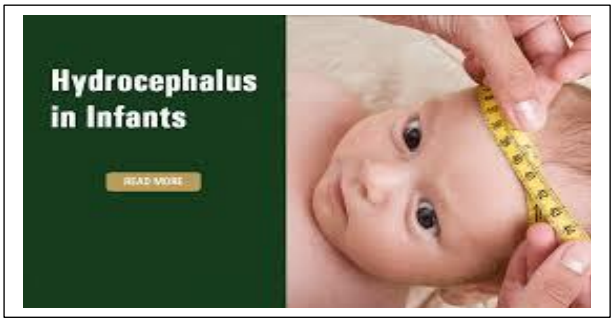


Figure: A cross-section of the brain showing the location of the cerebrospinal fluid (shaded area) and the aqueduct (arrow).

Eye Pressure:-

The clear fluids in the eye ball(aqueous and vitreous humors) are under pressures that maintain the eyeball in a fixed size and shape.(they transmit the light to the retina).

The dimensions of the eye are critical to good vision. A change of only 0.1mm in its diameter has a significant effect on the clarity of vision.

The fluid in the front of the eye, the aqueous humor, is mostly water. The eye continuously

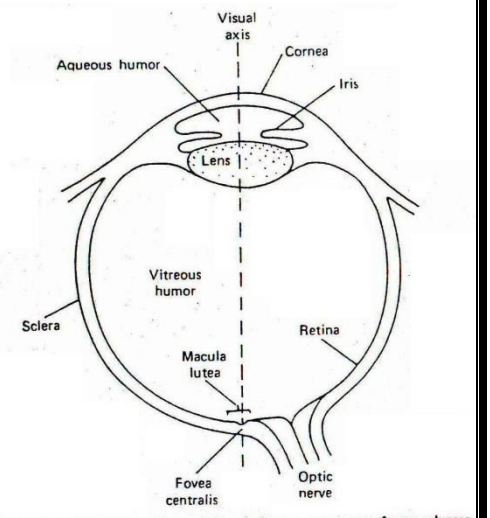


Figure. Cross-section of the left eye as seen from above.

If a partial blockage of this drain system occurs, the pressure increases and the increased pressure can restrict the blood supply to the retina and thus affect the vision. This condition called Glaucoma, produces tunnel vision in moderate cases and blindness in sever conditions.

Tonometers:-These are instruments used for measuring the amount of indentation produced by a certain force.

Pressure in the digestive system:-

Digestive tract:

□ Opening through the body
□ Over 6 m
□ Closed at the lower end and has several restrictions
□ Valves and sphincters permit unidirectional flow of food

It is (+ve) except in the esophagus part.

➢ ***Esophagus:-*** this part is coupled with pressure of respiratory system, Then esophagus pressure is (-ve) during inspiration. The intrathoracic pressure is sometimes determined by measuring the pressure in the esophagus

➢ ***Stomach:-***The pressure in it is increased because of the stretching of the stomach walls .
Eating increases the pressure in the stomach slowly due to increased volume
Air swallowed during eating increases the pressure in the stomach - burping or belching

- ***The pressure inside the stomach increase by:***

1- The accumulation of food ,then it causes the stomach wall to stretch and then the volume of the stomach increase.
2- Air swallowed during eating, air trapped in the stomach causes belching.

➢ ***Gut:-***gas (flatus) generated by the bacterial action increases the pressure, and hence it is higher the atmospheric. The pressure in the digestive system is coupled to that in the lungs through the flexible diaphragm that separates two organ systems.

Occasionally a blockage forms in the small or large intestine and a pressure build up between the blockage and the pylorus. If this pressure becomes great enough to restrict blood flow to critical organs, it can cause death. And can be solved by: **Intubation:** passing of a hollow tube through nose, stomach, and pylorus ,or**, Surgery,** chosen when the intubations don't work

●*Pressure in the skeleton:-*

This is the highest pressure that can be found in the body-for example when all the weight of the body is on one leg, such as when walking, the pressure in the knee joint may be more than 10 atmospheres!! P=F/A ----------(1)

*The surface area of a bone at the joint is greater than its area either above or below the joint. The larger area at the joint distributes the force, thus reducing the pressure. according to the equation 1.

Bone has adapted in another way to reduce pressure the finger bones are flat rather than cylindrical on the gripping side and the force is spread over a large surface this reducing tissues over the bones according to P=F/A .

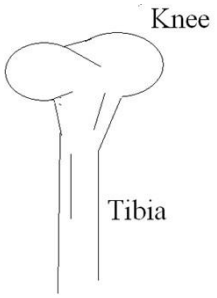


Figure: The surface area of a bone at the joint is greater than its area either above or below the joint.

Healthy bone joints ed than the best man-made bearings. The human joints system gher pressure →the better lubrication.

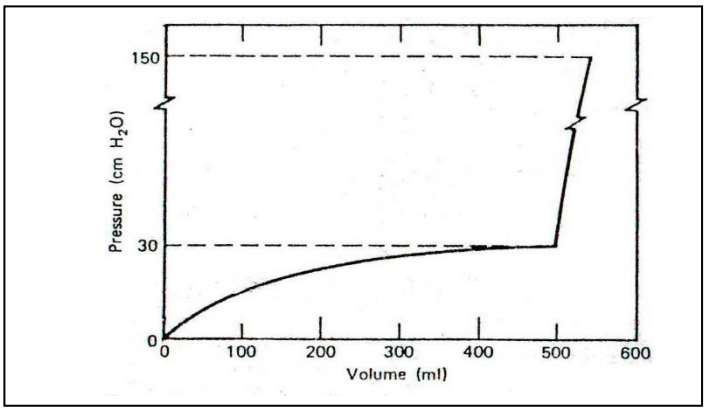
●Pressure in the urinary bladder:-

One of the most noticeable internal pressure is the pressure in the bladder this pressure is due to accumulation of the urine.

For adults, the typical maximum volume in the bladder before voiding is 500ml. At some pressure (≈30cm H_2O). The micturition reflex occurs. The resulting sizable muscular contraction in the bladder wall produces a momentary pressure up to 150cm H_2O.

- Normal voiding pressure is fairly low (20 to 40cm H_2O)
- For men who suffer from prostatic obstruction of the urinary passage it may be over 100cm H_2O

The figure below shows the typical pressure-volume curve for the bladder, which stretches as the volume increase.



Relatively slow slope of the major

Portion of the pressure-volume curve.

The bladder pressure increases during:

1- Coughing 2- Straining 3- Sitting up 4- stressful 5- Studying for exams

6- During pregnancy(During pregnancy, the weight of the fetus over the bladder increase the bladder pressure and causes frequent urination).

Measurement:

There are two methods to measure the urinary bladder pressure:

1- " In "direct" cystometry .which can be done by inserting a needle (connected to pressure sensor),through the walls of the abdomen directly into the bladder.

Note:This technique gives information on the function of the exit valves (sphincters).

2- Pressure in the bladder can be measured by passing a catheter with a pressure sensor into the bladder through the urinary passage (urethra).The catheter is connected from other side to pressure transducer.

Hyperbaric Oxygen Therapy (HOT):-

The body normally lives in an atmosphere that is about one fifth O_2 and four – fifth N_2. In some medical situations it is beneficial to increase the proportion of O_2 in order to provide more O_2 to the tissue.

1- Gas gangrene :-

The bacillus causes gas gangrene then its treated with (HOT) . That is due to bacillus cannot survive in the presence of oxygen (O_2).

2- Carbon Monoxide poisoning :-

- The red blood cells cannot carry O_2 to the tissues because the carbon monoxide fasters to the hemoglobin at the places normally used by O_2.
- Normally the amount of O_2 dissolved in the blood is about 2% of that carried on the red blood cells.
- By using the (HOT) technique , the partial pressure of O_2can be increased by a factor of 15, permitting enough O_2 to be dissolved to fill the body's need .

3- Treatment of cancer :-

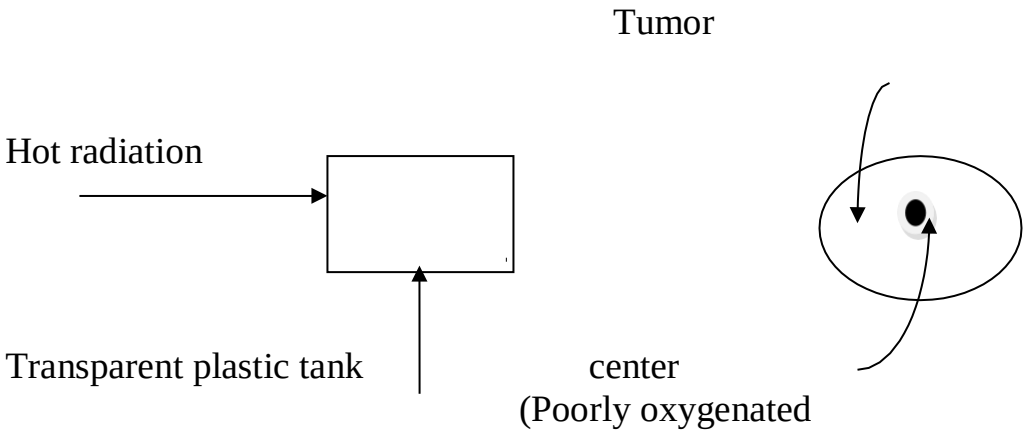
3-Treatment of cancer: The patient was placed inside a transparent plastic tank, and the radiation was beamed through the walls into the tumor. The theory was that more oxygen would make the poorly oxygenated radiation-resistant cells in the center of the tumor more susceptible to radiation damage.

Figure2: A patient receives treatment with Hyperbaric oxygen chamber

Hazard of HOT

1- The oxygen atmosphere makes fire a much greater hazard.

2- Risk of rupture of the tank due to the high pressures used



Q: If the pressure of a man is 8 cm Hg, Does the man have prostate or not?
A/: PHg= PWater

PghHg=ρghwater
The (g) is canceled from both sides
13.6x8=1xhwater
HWater=108.8 cm.so the man has prostate

Note:
▲ If hwater =100…..the man has prostate
▲ If hwater >100…..the man has prostate
▲ If hwater <100…..the man is normal