Pressure within the Body

Pressure.

Pressure is defined as the force per unit area. In a liquid the pressure at any point at rest is the same in all directions. However, the pressure in a liquid increase with depth because of the weight of the liquid above. The pressure P under a column of liquid can be calculated from the following low:

$$P = \rho\, g\, h$$

Where the:

ρ: is the density of the liquid.
g: is the acceleration due to the gravity.

h: is height of the column.

$$P = \frac{F}{A}$$

Where the:

p :is the pressure.

F: is the force.

A: is the area on contact

$$P = \frac{F \times\ distance}{A \times\ distance} = \frac{Work\ done\ (energy)}{V}$$

There are two kinds of energy:

1. Potential energy:

Potential energy is the stored energy of an object. It is the energy difference between the energy of an object in a given position and its energy at a reference position.

$$Potential\ Energy\ P.E\ =\ m\ g\ h$$

$$P = \frac{energy}{V}$$

$$= \frac{m\ g\ h}{V}$$

$$\boldsymbol{P\ =\ \rho\ g\ h}$$

2. Kinetic energy:

Kinetic energy is the work needed to accelerate a body of a given mass from rest to its stated velocity. It is the movement energy of an object.

$$Kinetic\ Energy\ K.E\ = \frac{1}{2} m v^2$$

$$P = \frac{energy}{V}$$

$$= \frac{1}{2} \frac{m\ v^2}{V} = \frac{1}{2}\ \rho v^2$$

Where v is the flow velocity.

Example: - what height of water will be produced the same pressure as 120mm Hg?

Solution:

for Hg: P=ρ g h

= $13.6g/cm^3$ x $980cm/s^2$ x (120/10) cm

P=$1.6x10^5$dyen/cm^2

for water: P=ρ g h

$1.6x10^5$=1x980xh

h= 163 cm H_2o

Note: in small unit

ρ (Hg)=$13.6g/cm^3$

ρ (H_2o) =$1g/cm^3$

g= $980cm/s^2$

in large unit

ρ (Hg)=$13600Kg/m^3$

ρ (H_2o) =$1000Kg/m^3$

g= $9.8m/s^2$

- ## Pressure Units:

The standard MKS-SI unit of pressure is a pascal (Pa), with 1Pa = 1N/m2.

- N/m^2 or $dyne/cm^2$ in metric system.
- Pascal (pa) in SI unit.
- Height of a column of mercury (Hg) usually used (mmHg).
- Height of a column of water (H2O) usually used (cmH2O).
- Torr: The pressure exerted by a column of mercury of height (1mm).
- Atm (atmospheric pressure): The pressure exerted by a column of mercury of height 76 cm.

1 atm = 760 Torr = 103 N/m^2.

○ Pressure Types :

• ***Absolute pressure (P_{abs})*** represents the combined effect of fluid pressure and Atmospheric pressure.

$$P = P_o + \rho g h$$

• ***The gauge pressure (P_{gauge})*** it is the effect of fluid alone without atmospheric pressure. Thus,

$$P - P_o = \rho g h$$

• ***Negative pressure*** is the pressure lower than atmospheric pressure.

$$P = P_o - \rho g h$$

All pressures within the body are expressed as gauge pressure. Therefore, the pressures less than atmospheric pressure are expressed as negative pressures such as in the pressure inside the lung during inspiration.

One way of directly measuring pressure is with a manometer.

○ Pressure measurement:

Many techniques have been developed for the measurement of pressure. Instruments used to measure and display pressure in an integral unit are called pressure gauges.

1. Manometer (U-shaped):

A common device use for measuring pressure in a liquid or gases, It is consists of U- tube containing a liquid (usually mercury or water), one arm of which is open to atmosphere, the other arm being connected to the vessel whose pressure we wish to measure.

2. Sphygmomanometer:

There are two types of sphygmomanometers:

A- Manual sphygmomanometers; require a stethoscope for auscultation. It is possible to obtain a basic reading through palpation alone, but this only yields the systolic pressure.

- Mercury sphygmomanometers; they show blood pressure by affecting the height of a column of mercury, which does not require recalibration. Because of their accuracy, they are often used in clinical trials of drugs and in clinical evaluations of high-risk patients, including pregnant women.
- Aneroid sphygmomanometers; (mechanical types with a dial) are in common use; they may require calibration checks, unlike mercury manometers. Aneroid sphygmomanometers are considered safer than mercury sphygmomanometers, although inexpensive ones are less accurate. A major cause of departure from calibration is mechanical jarring.

B- Digital sphygmomanometer; using oscillometric measurements and electronic calculations rather than auscultation. They may use manual or automatic inflation. These are electronic, are easy to operate without training, and can be used in noisy environments; they are not as accurate as mercury instruments. They measure systolic and diastolic pressures by oscillometric detection.

3. **Tonometer;** measure the internal pressure of the eye and tonometry is one of the principal tests for glaucoma. There are different kinds of tonometer:

A- Schiotz tonometer (impression).

B- Electronic tonometer.

C- Applanation tonometer.

D- Non-contact tonometer.

○ Blood pressure

The most common way to measure blood pressure is with a sphygmomanometer which consists of a cuff, a squeeze bulb, and a meter that measures the pressure in the cuff. Because of the pumping action of the heart, blood enters the arteries in pulses. The maximum pressure driving the blood at the peak of the pulse is called the systolic pressure. The lowest blood pressure between the pulses is called the diastolic

In a young healthy individual the systolic pressure is about 120 mmHg and the diastolic pressure is about 80 mmHg in average 100 mmHg.

- As the blood flows through the circulatory system, its initial energy, provided by the pumping action of the heart, is dissipated by two loss mechanisms:

    1. losses associated with the expansion and contraction of the arterial walls.
    2. viscous friction associated with the blood flow.

- By the time the blood reaches the capillaries, the flow is smooth and the blood pressure is only about 30 mmHg. The pressure drops still lower in the veins and is close to zero just before returning to the heart. One-way flow is assured by unidirectional valves in the veins.
- If a person is standing erect, the blood pressure in the arteries is not uniform in the various parts of the body. The average pressure in the artery located in the head, 50 cm above the heart is $P\ head = 61\ mmHg$. In the feet, 130 cm below the heart, the arterial pressure is 200 mmHg.

○ Pressure inside the Skull

The brain contains approximately 150 cm^3 of cerebrospinal fluid (CSF) in a series of interconnected openings called ventricles. One of the ventricles (the aqueduct) is especially narrow.

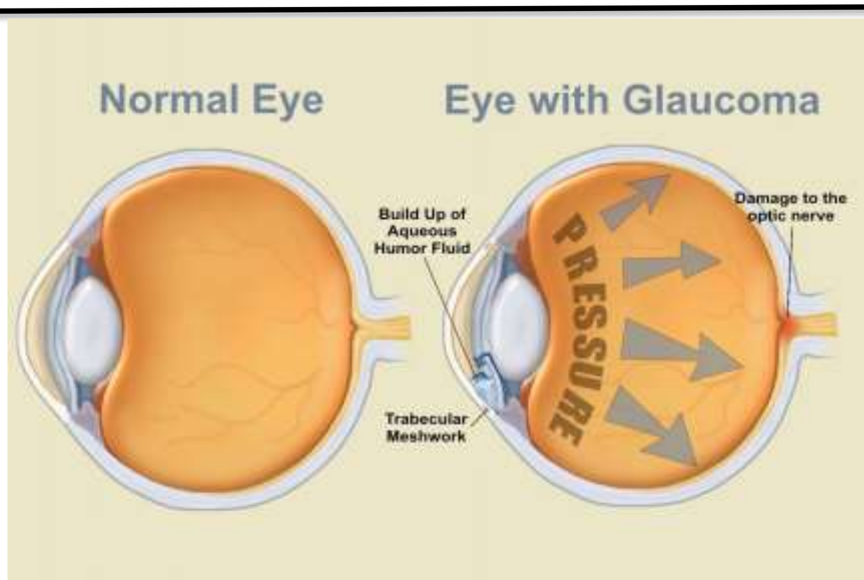
If at birth this opening is blocked, the CSF is trapped inside the skull and increases the internal pressure. This will cause the skull to enlarge. This condition called hydrocephalus. It is not convenient to measure the CSF pressure directly.

Measurement of hydrocephalus

1. *Crude method:* In this method the circumference of the skull just above the ears. Normal values of newborn infants are from 32-37 cm, and larger than this may indicate hydrocephalus.
2. *Qualitative method (transillumination):* In this method light – scattering properties is used.

○ Eye Pressure

- The clear fluids in the eye ball (aqueous and vitreous humors) that transmit the light to retina (the light sensitive part of the eye). Are under pressure and maintain the eye ball in fixed size and shape.The dimensions of the eye are critical to good vision. The pressure in normal eyes ranges from 12 to 23 mmHg. Normal eye change in diameter of the eye Only 0.1 mm



- The eye continuously produces aqueous humor and a drain system allows the surplus to escape. 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.
  a. Moderate ------------tunnel vision
  b. Sever-------------- blindness

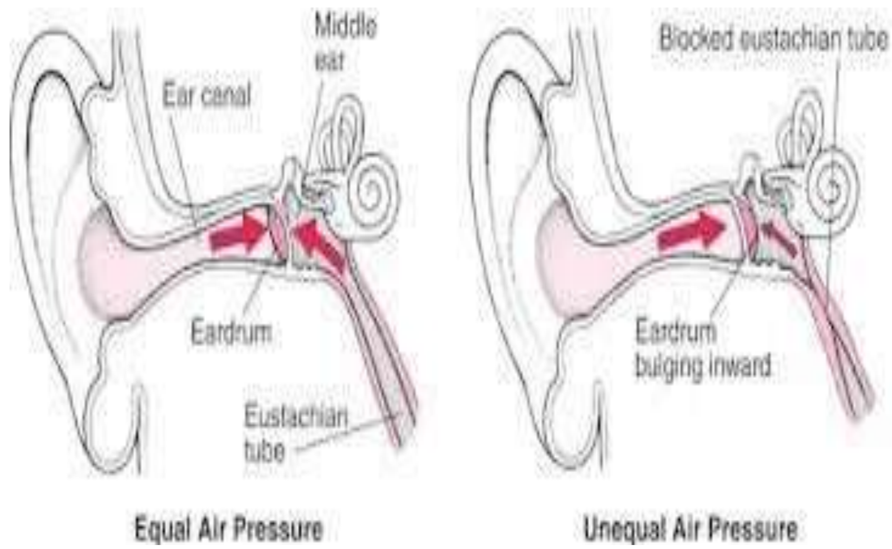
- The eye pressure is measured with several different instruments called tonometer.

○ Middle ear pressure:

- The middle ear is one of the air cavities that exist within the body. For comfort the pressure in the middle ear should be equal to the pressure to the pressure on the outside of the eardrum.
- This equalized is produced by air flowing through the Eustachian tube, which is usually closed except during swallowing, chewing, and yawning

- When diving many people has difficulty obtaining pressure equalization and feels pressure on their ears.
- (120mmHg) across the eardrum, which can occur in about 1.7 m of water, can cause damage (rupture) to the eardrum. One method of equalization used by diver is to raise the pressure in the mouth by holding the nose and trying to blow.

P middle ear=P outside eardrum



Boyle s law:

For a fixed quantity of gas at a fixed temperature the product of the absolute and volume is constant. (PV=constant)

$$P_1V_1 = P_2V_2$$

That is, if the absolute pressure is double, the volume is halved.

○ Pressure in Digestive System

Propulsive movements in this system are due to peristaltic action, with muscular contraction of the contractile ring around the gut sliding food forward.

- In most GIT the pressure is greater than atmospheric pressure and is related to volume.

- Pressure on the walls of the stomach increases during eating. The volume of the stomach of radius R increases as R^3. A more significant increase in pressure is due to air swallowed during eating. Bacterial action produces gas in the gut increases the GIT pressure. External factors such as belts, girdles, flying, and swimming affect the gut pressure.
- However, in esophagus the pressure is coupled to the intrathorasic pressure and is usually less than atmospheric.
- In general the pressure in GIT is coupled to that in the lungs through the flexible diaphragm that separate the two organ systems.

Pressure in the Urinary Bladder

One of the noticeable internal pressures is the pressure in urinary bladder due to the accumulation of urine. Bladder stretches as the volume increases.

- For adults the typical maximum volume in the bladder before voiding is 500 ml and the normal voiding pressure is fairly low (20 to 40 cm $H2O$).

- *The pressure in the bladder can be measured by two methods:*

1. Indirect cystometry: by passing a catheter with a pressure sensor in to the bladder through urethra.
2. Direct cystometry: in which the pressure is measured by means of a needle inserted through the wall of the abdomen into the bladder.

The bladder pressure increases during coughing, straining, sitting up and pregnancy also for Men who suffer from prostate obstruction of the urinary passage it may be over 100cmH_2o.

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Example: If the pressure of a man is 8 cm Hg, Does the man have prostate or not?

Solution:

$$\rho g h_{Hg} = \rho g h_{H_20}$$

The (g) is canceled from both sides

$$13.6 \times 8 = 1 \times h_{H_2O}$$

$$h_W = 108.8\ cm$$

so, the man has prostate

○ Pressure in the Skeleton

The highest pressures in the body are found in the weight-bearing bone joints. When all body weight is on one leg, such as when walking, the pressure in the knee joint may be more than 10 atm. Since pressure is the force per unit area, for a given force the pressure is reduced as the area is increased. Bone has adapted to reduce pressure. The finger bones are flat rather than cylindrical on the gripping side and the force is spread over a large surface reduces the pressure over the bones.

$$P = \frac{F}{A}.$$