Karbala University-College of veterinary medicine
Medical Physics-Lecture (5)

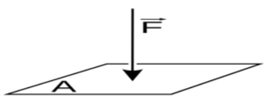
Pressure

Pressure is defined as the force per unit area in a gas or a liquid. For a solid the quantity force per unit area is referred to as stress. In the metric system the pressure is measured in dynes per square centimeter or Newton per square meter; the SI unit for the latter is the Pascal (Pa).None of these units is in commune use in medicine. The most common method of indicating pressure in medicine is by the height of a column of mercury (Hg).For example, a peak (systolic) blood pressure reading of 120 mmHg indicates that a column of mercury of this height has a pressure at its base equal to the patient's systolic blood pressure.

The pressure **P** under a column of liquid can be calculated from this formula:

$P=\rho\times g\times h$

Where ρ is the density of the liquid, **g** is the acceleration due to gravity, and **h** is the height of the column.



$p = \frac{F}{A}$ *Where p is the pressure, F is the normal force A is the area*

If we apply the following ideal gas law PV = nRT

where:

P is the pressure of the gas *V* is the volume of the gas *n* number of moles

R =8.314 $J\cdot K^{-1}\cdot mol^{-1}$

Example: What height of water will produce the same pressure as 120 mmHg?

P (120 mmHg) = ρ g h = (13.6 g/cm^3) (980 cm/sec^2) (12 cm)

$=1.6\times10^5$ dyne/cm^2

For water:

1.6×10^5 dynes/cm^2= (1.0 g/cm^3) (980 cm/sec^2) (h cm H_2O) h=163

cmH_2O

Or

$P_{Hg} = P_{water}$

$(\rho gh)_{Hg} = (\rho gh)$ water

$\rho_{Hg} \times h_{Hg} = \rho_{water} \times h_{water}$

$h_{water} = (\rho_{Hg} \times h_{Hg}) / \rho_{water}$ = (13.6

×12)/1=163 cmH_2O Note:-

1 atmosphere (atm) = 1.01×10^5 N/m^2

1 atmosphere (atm) =760 mmHg

1 atmosphere (atm) = 1033 cmH_2O

1 cmH_2O =0.735 mmHgor 1mmHg = 1.36 cmH_2O

Example: calculate the atmospheric pressure in N/m^2 and in dyne/cm^2 ,where ρ_{Hg} =13.6 g/cm^3

The atmospheric pressure in N/m^2 is equal $P = \rho g h$ =13600 Kg/m^3 ×9.8m/sec^2 ×0.76m P=101292.8 N/m^2	The atmospheric pressure in dyne/cm^2 is equal $P = \rho g h$ =13.6 g/cm^3 ×980cm/sec^2 ×76cm P=1012928 dyne/cm^2

Measurement of pressure in the body

The most common clinical instrument used in measuring pressure is the **sphygmomanometer**.

- Three types of pressure gauges are used in sphygmomanometers:

1. Mercury sphygmomanometer 2- Aneroid sphygmomanometer

3-Electronic sphygmomanometer

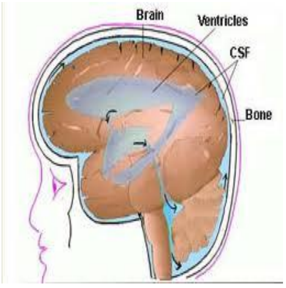
Pressure inside the skull

The brain contains approximately 150 cm^3 of cerebrospinal fluid (CSF) in a series of interconnected openings called ventricles. CSF is generated inside the brain and flows through 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 serious condition, called *hydrocephalus* (water head); it can often be corrected by surgically installing a by-pass drainage system for the CSF

Method of measurement the CSF pressuredirectly:

1-Crude method of detecting hydrocephalus is to measure the circumference of the skull just above the ears. Normal values for newborn infants are from 32-37cm, and a large value may indicate hydrocephalus.

2-Transillumination makes use of the light –scattering properties of the rather clear CSF inside the skull.



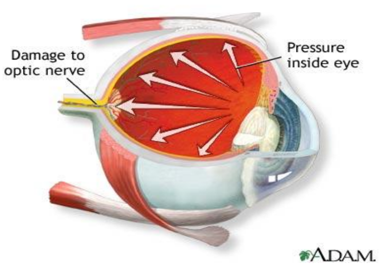
Cerebrospinal fluid in side the ventricle

Hydrocephalus

Eye pressure

The clear fluids in the eyeball (the aqueous and vitreous humors) that transmit the light to the retina (the light sensitive part of the eye), are under pressure and maintain the eyeball in a fixed size and shape .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 pressure in normal eyes ranges from 12-23 mmHg. The fluid in the front part of the eye, the aqueous humor, is mostly water. 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*, produces tunnel vision in moderate cases and blindness in severe cases.

Early physicians estimated the pressure inside the eye by "feel" as they pressed on the eye with their fingertips. Now pressure in the eye is measured with several different instruments, called *tonometers.*



Pressure in the urinary bladder

One of the most noticeable internal pressures is the pressure in the bladder due to accumulation of urine.Figure1 shows the typical pressure-volume curve for the bladder, which stretches as the volume increases. For adult, the typical maximum volume in the bladder before voiding is 500ml.At some pressure (~30 cmH2O) the micturition (gotta go) reflex occurs.

The resulting sizable muscular contraction انكماشin the bladder wall produces a momentary pressure of up to 150 cmH2O.Normal voiding pressure is fairly low (20 to 40 cmH2O), but for men who suffer from prostatic obstruction of the urinary passage it may be over 100 cmH2O.

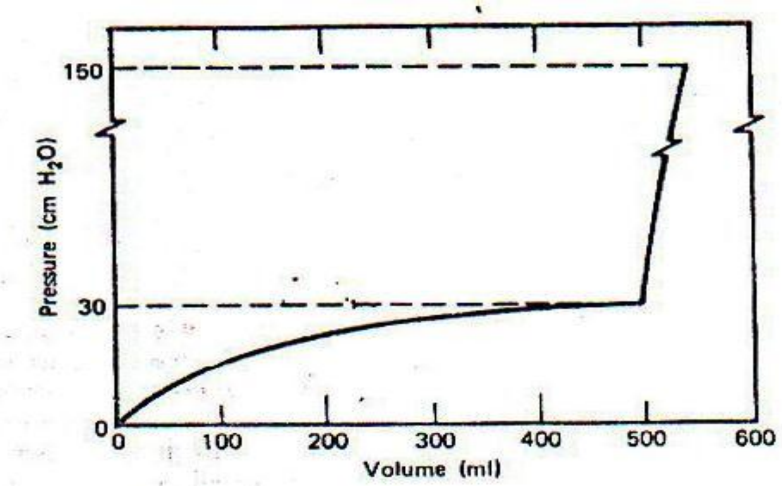


Figure1: The typical pressure-volume relationship in the urinary bladder.

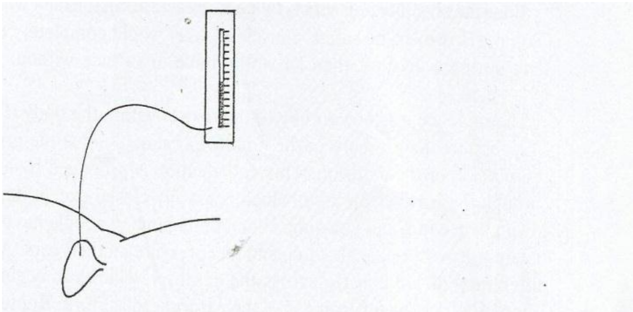
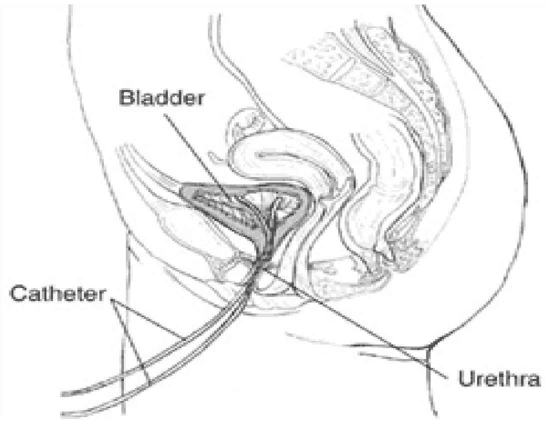


Figure 6.7. In direct cystometry a needle is passed through the wall of the abdomen directly into the bladder.



The pressure in the bladder can be measured by:

1-By passing a catheter with a pressure sensor into the bladder through the urinary passage (urethra).

2-By a needle inserted through the wall of the abdomen directly into the bladder. This technique gives information on the function of the exit valves (sphincters) that cannot be obtained with the catheter technique.

The bladder pressure increases during coughing, straining, and sitting up. During pregnancy, the weight of the fetus over the bladder increases the bladder pressure and causes frequent urination.

Pressure effects while diving (Boyle's law)

Since the body is composed primarily of solids and liquids, which are nearly incompressible, pressure changes do not greatly affect most of it. However, there are gas cavities in the body where sudden pressure changes can produce profound effects. To understand why, we must recall Boyle's law; for a fixed quantity of gas at a fixed temperature the product of the absolute pressure and volume is constant (**PV=constant**).That is, if the absolute pressure is doubled. The volume is halved.

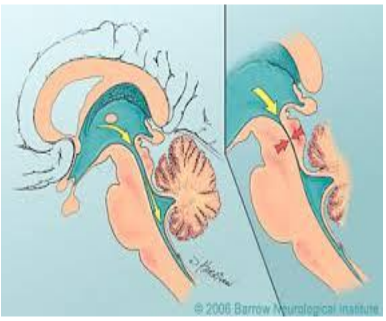
Example: What volume of air at an atmospheric pressure of 1.01×10^5 N/m^2 is needed to fill a 14.2 liter scuba tank to a pressure of 1.45×10^7 N/m^2?

$$P_1V_1=P_2V_2$$

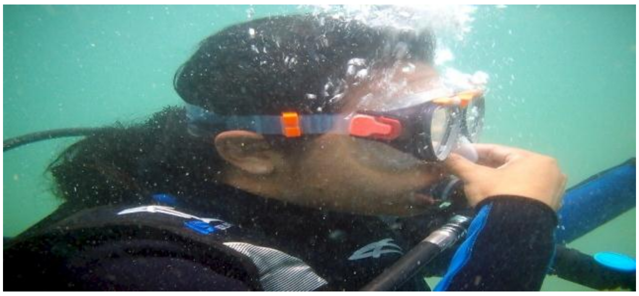
$$(1.01\times10^5)\ (V_1) = (1.45\times10^7)\ (14.2)$$

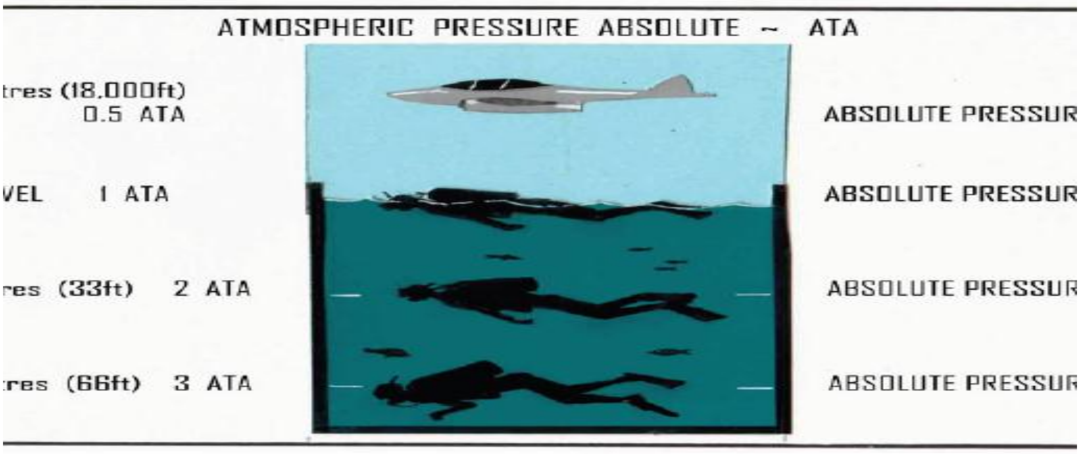
$$V_1=2\times 10^3 \text{ liters}$$

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



When diving, many people have difficulty obtaining pressure equalization and feel pressure on their ears. A pressure differential of 120 mmHg across the eardrum, which can occur in about 1.7m of water, can cause the eardrum to rupture .One method of equalization used by a diver is to raise the pressure in the mouth by holding the nose and trying to blow out.





A less serious condition is sinus squeeze. During a dive the pressure in the sinus

cavities in the skull usually equalizes with the surrounding pressure .If a diver has a cold, the sinus cavities may become closed off and not equalize, causing pain. Another pressure effect is pain during and after dives from small volumes of air trapped beneath fillings in the teeth. Eye squeeze can occur if goggles are used instead of a facemask; with a facemask the air exhaled from the lungs increases the pressure over the eyes as the descent is made.

If a scuba diver at a depth of 10m holds his breath and comes to the surface, the air volume will expand by a factor of two and thus cause a serious pressure rise in the lung. If the lungs are filled to capacity, an ascent of only 1.2m can cause serious lung damage. All scuba divers learn during training to avoid breath-holding during ascent and to exhale continuously if a rapid ascent is necessary.

The pressure in the lung at any depth is greater than the pressure in the lungs at sea level. This means that the air in the lungs is more dense underwater and that the partial pressures of all the air components are proportionately higher. The higher partial pressure of oxygen causes more oxygen molecules to be transferred into blood, and *oxygen poisoning* results if the partial pressure of oxygen gets too high. Usually oxygen poisoning occurs when the partial pressure of oxygen is about 0.8 atm (when the absolute air pressure is about 4 atmospheres), or at a depth of about 30 m.

Breathing air at a depth of 30m is also dangerous because it may result in excess nitrogen in the blood and tissues. This can produce two serious problems:

1-Nitrogen narcosis, which is an intoxication effect

2-The bends, or decompression sickness, which is an ascent problem.

While oxygen is transported primarily by chemical attachment to the red blood cells, nitrogen is dissolved in the blood and tissues. According to Henry's law (*the amount of gas that will dissolve in a liquid is proportional to the partial pressure of the gas in contact with the liquid*). Thus more nitrogen is dissolve in the blood and from there

into the tissue as a diver goes deeper since the pressure of the air and thus the partial pressure of nitrogen are increasing. When the diver ascends, the extra nitrogen in the tissue must be removed via the blood and the lungs. The removal is a slow process, and if the diver ascends too fast bubbles form in the tissues and joints.

Other problems can occur during ascent. One of the membranes that separate air and blood in the lung can burst; allowing air to go directly into the bloodstream (air embolism).Air can also become trapped under the skin around the base of the neck or in the middle of the chest. In addition, pneumothorax(lung collapse) can result if air gets between the lungs and the chest wall.

Hyperbaric oxygen therapy (HOT)

The body normally lives in an atmosphere that is about one-fifth oxygen and four-fifths nitrogen. In some medical situations it is beneficial to increase the proportion of oxygen in order to provide more oxygen to the tissues. To greatly increase the amount of oxygen, medical engineers have constructed special high pressure (hyperbaric) oxygen chambers. Some are just large enough for a patient, while others are large enough to serve as operating rooms.

Hyperbaric oxygen chamber use in

1- Gas gangrene :The bacillus that causes gas gangrene cannot survive in the presence of oxygen, almost all gas gangrene patients treated with HOT are cured without the need for amputation

2- Carbon monoxide poisoning: The red blood cell cannot carry oxygen to the tissues because the carbon monoxide fastens to the hemoglobin at the places normally used by oxygen. The presence of even a few carbon monoxide molecules on a red blood cell greatly reduces the ability of the cell to transport oxygen.

Normally the amount of oxygen dissolved in the blood is about 2% of that carried on the red blood cells. With HOT, the partial pressure of oxygen can be increased by a

factor of 15, permitting enough oxygen to be dissolved to fill the body's needs.

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.