Karbala University-College of Dentistry
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.

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)

=1.6×10^5 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

$P_{Hg} = P_{water}$

$(\rho g h)_{Hg} = (\rho g h)_{water}$

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

$h_{water} = (\rho_{Hg} \times h_{Hg}) / \rho_{water} = (13.6 \times 12)/1 = 163\ cmH_2O$

Note:-

1 atmosphere (atm) = $1.01 \times 10^5\ N/m^2$

1 atmosphere (atm) =760 mmHg

1 atmosphere (atm) = 1033 cmH_2O

1 cmH_2O =0.735 mmHg or 1mmHg = 1.36 cmH_2O

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

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

There are two type of pressure:

Since we live in a sea of air with a pressure of 1atm, it is easier to measure pressure relative to atmospheric pressure than to measure true, or absolute pressure. Unless we indicate otherwise ,all the pressures used in this chapter are gauge pressures.

There are a number of places in the body where the pressures are lower than the atmospheric pressure or negative. For example, When we breathe in (inspire) the pressure in the lung must be somewhat lower than atmospheric pressure or the air would not flow in. The lung pressure during inspiration is typically a few centimeters of water negative. When a person drinks through a straw the pressure in his mouth must be negative by an amount equal to the height of his mouth above the level of the liquid he is drinking.

Blood pressure measured with several instruments, Sphygmomanometer, Cuff and Stethoscope (a device that magnifies the sound made by the body).

Typical pressures in the normal body

Different parts of the body	Typical pressure (mmHg)
Arterial blood pressure Maximum(systole) Minimum(diastole)	 100-140 60-90
Venous blood pressure	3-7
Great veins	<1
Middle ear pressure	20
Eye pressure-aqueous humor	20
Cerebrospinal fluid pressure in brain	5-12
Gastrointestinal pressure	10-20
pressure between lung & chest wall	~10

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 pressure directly:
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.

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 cmH_2O) the micturition (gotta go) reflex occurs.
The resulting sizable muscular contractionانكماش in the bladder wall produces a momentary pressure of up to 150 cmH_2O.Normal voiding pressure is fairly low (20 to 40 cmH_2O), but for men who suffer from prostatic obstruction of the urinary passage it may be over 100 cmH_2O.

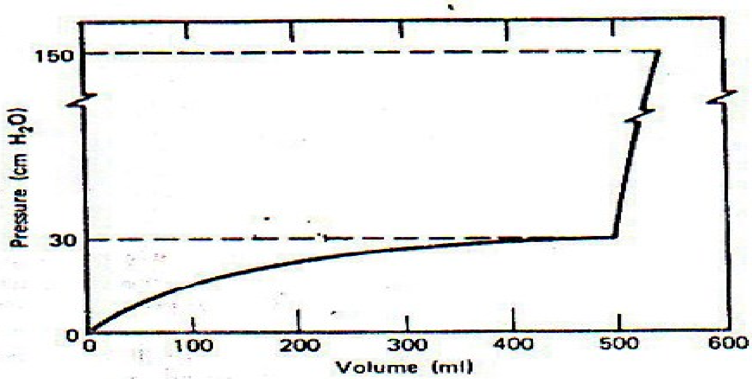

Figure1: The typical pressure-volume relationship in the urinary bladder.

The pressure in the bladder can be measured by:

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

2- 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 (Boyle's law)

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?

$$P_1V_1=P_2V_2$$

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

$$V_1=2\times10^3 \text{ liters}$$

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

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

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

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.