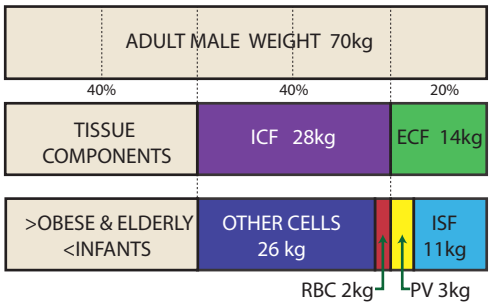
FLUIDS AND ELECTROLYTES



Distribution of body fluids The distribution of body fluids is considered from a conceptual perspective. There are two principle body fluid compartments, the intracellular compartment (ICF) which is approximately 40% of weight and the extracellular compartment (ECF) which consists of approximately 20% total weight (total body water TBW = 60%). The ECF is further subdivided into fluid which is intravascular (the plasma volume) which is about 4-5% TBW and the interstitual fluid (ISF) which is about 15-16%). The ratio of non fluid tissue components to fluid compenents varies with age, sex and body habitus. Neonates and infants have a much higher TBW (up to 80%) mostly increased extra cellular fluids. Fat tissue has substantially less water content therefore women have a slightly lower TBW, and obese people may have a markedly decreased TBW. The elderly also have decreased TBW.

Measurement of fluid compartments This is based on the conservation of mass laws. Rearranging the equation concentration = amount/volume gives the formula volume = amount/concentration. Therefore if it is possible to add a known amount of solute to a solution, which mixes evenly and completely and remains in the single compartment, then measure the resultant concentration we can apply this formula to calculate the volume. Total body water may be measured using known amounts of isotopically labelled water such as deuterium ^{2}H or tritium ^{3}H which disperses throughout the whole body and is measurable using nuclear medicine techniques. Other compartments are more difficult to measure. The ECF markers must cross capillaries easily but not cell membranes and a common example is mannitol or inulin which are large molecule that cannot cross cell membranes and therefore is excluded from the ICF. Other methods for measuring ECF involve isotopically labelled berrellium. Evans blue is a dye that binds to albumin and thus remains intravascularly (an alternative is radio iodinated serum albumin RISA). It may be measured and correcting for the RBC volume using haematocrit enables calculation of the PV. Interstitual volume is measured indirectly by the formula ECF - PV. ICF is calculated by the formula TBW - ECF. The main issue with all these methods is the assumptions involved. They often do not remain solely within a single compartment, nor do they always mix completely.

Fluid Compartment	Marker
TBW	Deuterium ^{2}H
ECF	Mannitol/Ionics ^{33}Br
Plasma	Evans Blue / RISA
RBCs	^{33}Cr labelled RBCs
Interstitual	ECF - PV
ICF	TBW - ECF

Definitions

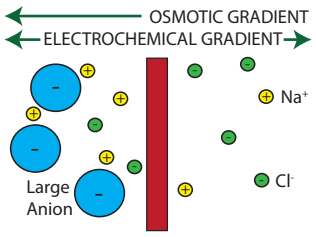
Molarity	is the number of moles of solute per kg of solvent (one mole of a substance = 6 x 10^{23} particles)
Osmosis	movement of solvent across a semipermiable membrane until the concentration of solution on both sides is equal
Osmotic Pressure	pressure required to prevent movement of solvent molecules by osmosis across a semipermiable membrane = nRT/V (ideal gas law)
Oncotic Pressure	(colloid osmotic pressure) is the compenent of total osmolality which is due to colloids MW>30000, Albumin (75%) globulin & fibrinogen
Osmol	one osmol equals 6 x 10^{23} particles regardless of the type of particle present (also the amount of substance that would depress freezing point by 1.86K - a colligative property)
Osmolality	is the number of osmols of solute per kg of solvent and is independent of temperature
Osmolarity	is the number of osmols of solute per litre of solvent and is dependent on temperature (the liquid may expand and increase volume)
Tonicity	is the effective osmolality of a solution (some of the solute may not stay in the extracellular compartment (eg urea) and is discounted)
Reflection coeff	The reflection coefficient represents the capillary permiability to albumin, with 0 being freely permiable and 1 impermiable.
Colligative prop	Are the properties that are dependent on the concentration of the particles

Osmotic pressure may be calculated using a derivation of the ideal gas law (called van't Hoffs law here). PV = nRT where Osmotic Pressure = P, V equals the volume, n = number of osmols, R is the gas constant 62.3 (using mmHg 0.082x760) and T is the temperature in Kelvins. Since the number of osmols/volume = concentration it may be expressed as P = CRT. If the concentration is 1 osmol per litre (osmolalrity = 1) then the osmotic pressure is 19300 mmHg (milliOsmols = 19.3). Therefore for every mOsmol increase in concentration gradient across the cell membrane there is a 19.3 mmHg increase in osmotic pressure. For normal plasma the osmolality is 285 mOsmol, from this we can calculate the osmotic pressure of the plasma as 19.3 x 285 = 5500 mmHg (over seven atmospheres!).

PV	= nRT	P = osmotic pressure
P	= CRT	V = volume in Litres
P	= 1(62.3)(310)	n = number of Osmols
P	= 19300 per Osmol	R = Gas constant (62.3 if using mmHg)
P	= 19.3 per mOsmol	T = Temperature in Kelvins
P	= 19.3(285)	n/V = C = Osmolarity
P	= 5500mmHg	assume osmolality is 285

Plasma oncotic pressure is the osmotic pressure exerted by the colloids which are the large non permiable particles in the intravascular space, mostly albumin and other significant protiens. They only exert about 25-30 mmHg of the total osmotic pressure (<1% of 5500) but are very important in terms of the starling forces, they are the only effective solutes exerting force to retain water in the capillaries and therefore maintaining circulating volume. The reflection coefficient represents the capillary permiability to albumin, with 0 being freely permiable and 1 impermiable. Normally it is 0.6-0.9. The more permiable the less oncotic pressure the albumin exerts in the calculation of starling forces - Filtration = capillary filtration coefficient(hydrostatic pressure difference) + reflection coefficient(colloid oncotic pressure difference).

Gibbs-Donnan effect situation created with a semipermiable membrane. Some ions (eg Na^+ and Cl^-) freely move but others (eg large anion proteins) don't. More Na^+ will exist on the side with the large anions and more Cl^- on the other side to ensure chemico-electrical equilibrium. Despite electrical equilibrium there is now osmotic disequilibrium and water will move into the intravascular side (disrupting the chemico-electrical state). The result is opposing osmotic and electo-chemical gradients. As a result of increased osmols on the intravascular side, there is an augmentation of the plasma oncotic pressure. This is also very important for the stability of the cell volume where the cell membrane is also semipermiable and intracellular proteins and organic phosphates cause a donnan effect into the cell and the extrusion of increased cations by the Na-K-ATPase pump cause a reverse donnan effect (double donnan). It makes a small contribution to the resting membrane potential.



Measurement and regulation of osmolality Osmolality is measured in the hospital setting by an osmometer which uses the colligative properties of a fluid (those dependent on the particle concentration) to calculate osmolality. This is done in two main ways, through freezing point depression or vapour point depression. Osmolarity may be estimated using the formula Osmolarity = 2(Na^+) + blood glucose + blood urea. An osmolar gap is the difference between the measured osmolality and the estimated osmolarity and is usually less than 10. This gap may be increased if there are alcohols, sugars or contrast mediums. Hyperosmolar states exist where there is raised urea, hyperglycaemia or hypernatraemia. Overall osmolality is regulated in the body by the osmol receptors in the hypothalamus which sense changes of as small as 1-2% and increase or decrease vasopressin (ADH) secretion from the posterior pituitary accordingly. At a cellular level cells manage changes in osmolality by increasing the influx of solute (usually by ions which will interfere with metabolism) and/or producing indogenic solutes which have minimal effect on metabolism. The second mechanism is particularly important in the brain which uses the idogenic molecules to draw water in to restore cellular volume. It is why the barin tolerates chronic hypo-osmolar states much better than acute hypo-osmolar states.

Lymph is the name given to interstitual fluid which enters the lymphatic system. Lymphatic capillaries are present in almost all tissues with the exception of bone, cartilage and the CNS. Up to 3L of fluid is lost per day from the ISF and if this was not recovered by the kymphatic system this would lead to hypovolaemia. This fluid travels from the blind ended lymphatic capillaries into larger lymphatics and eventually into the thoracic duct and then into junction of the subclavian and and internal jugular veins. In addition to the fluid recovery function, lymph also returns protien from the ISF, transports fat from the small intestine and performs important immunological functions such as a transport method for lymphocytes and macrophages, a transport method for antigenic material to be presented to dendritic cells and lymph nodes, and for the dissemination of cytokines. Lymph consists of the ISF (with a lower concentration of protiens than plasma), lipids from the small intestine such as fatty acids, triglycerides, chylomicrons (these lipids gives the milky composition of 'chyle'), lymphocytes and macrophages.

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