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Dialysis

Water is the internal environment of the cells and extracellular matrix and thanks to its chemical properties allows to perform all processes necessary for the functioning of the body. In the aquatic environment there are all dissolved chemicals build living organisms and produced during metabolism. Water acts as a mode of transport for a variety of substances, and also supports the thermoregulation capabilities through evaporation. Water is present in the extracellular and intracellular matrix which includes the intravascular space, interstitial space, and the spaces of: gastrointestinal tract, pleural cavities, urinary tract or bones. Water derives from a supply and intracellular synthesis (so-called: metabolic water – 100 g of fat oxidation provide 108 ml of water, carbohydrates - 58 ml and proteins – 44 ml of water. There are semi-permeable selective membranes between the water spaces. Therefore, the distribution of water is uneven, and its movement is regulated at several levels. Cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (Cl^-, HCO^{3-}, SO_4^{2-}, $H_2PO_4^-$, HPO_4^{2-}) and also metabolic anions, organic acids and anionic proteins are present in water. The composition of solution in the area separated from other areas by semi-permeable membranes is governed by electro-neutrality, which assumes a balance between the sum of the concentrations of cations and anions. Sodium ion plays a fundamental role in maintaining acid-base balance, fluid and electrolyte balance and osmotic balance. Replacement of the components and possible migration of ions and water between the spaces, that take place through selective membranes, are subject to the laws of chemistry.

The aqueous solution of salt, which exerts the same osmotic pressure prevailing in the cells is referred to as physiological saline. 0.9% NaCl solution is defined as physiological saline. It is isotonic to blood plasma, so in this solution red blood cells do not undergo hemolysis.



The picture shows dialysis process – dialysis tube containing milk placed in a buffer solution, where small molecule compounds derived from milk move to.

Dialysis is the process, where small molecules dissolved in the solution pass through the semi-permeable membrane. This method is used in the laboratory for removal of unwanted small molecules from colloidal solutions. This method can be used for concentrating protein solutions.

This property was used in ancient Rome and in the Middle Ages to treat uremia related to kidney disease through hot baths, causing sweating and bloodletting.

EW Strauss and A Strauss in a book entitled: „Medical marvels : the 100 greatest advances in medicine" described the history of the introduction of dialysis to routine gynecological procedures in renal failure, as below:

„Scottish chemist Thomas Graham (1805-1869), named after the father of dialysis, began the process that led to the invention of hemodialysis. As a chemist, he used osmosis and dialysis using a semi-permeable membranes in the laboratory solely for the separation of solutes or removing water from the solutions. However, he pointed out the use of this type of techniques in medicine. The medical community was not interested in his suggestion until the time when German physiologist Adolf Fick published a quantitative description of the process of diffusion in 1855. Fifty years later, Albert Einstein presented the scientific basis of this process.

However, the first historical description of the use of this procedure for medical purposes was published in 1913. John J. Abel was performing dialysis on anesthetized animals directing their blood outside the body and tubes made of semi-permeable membranes. Eleven years later, a German physician Georg Haas conducted the first dialysis in humans, but all seven patients died as a result of allergic reactions to an agent which inhibits blood clotting - hirudin. Finally Haas applied heparin (instead of hirudin), which induced a significant fewer complications.

The first successful hemodialysis was carried out in 1954 by Willer Wolff in the Netherlands. He used a rotating drum immersed in the fluid, in order to successfully treat 67-year-old patient admitted to the hospital with acute renal failure. The woman died at age 73 due to the illness unrelated to kidney failure.

Currently, hemodialysis can be performed by patients at home, but most of them prefer to use the hemodialysis centers. Dialysis is carried out 2-3 times a week. The alternative is a successful kidney transplant. "

Osmosis

Osmosis is the spontaneous process of passage of the solvent (typically water) through a semi-permeable membrane into solution. Consequently, the pressure in the solution rises - the pressure is called osmotic pressure. Osmotic pressure depends on the number of molecules of the solute and the temperature. On the other hand, it does not depend on the: composition of the molecule, molecular weight or electric charge.

Each solution can be characterized with respect to its osmotic activity, which depends on the type of substance and results from its concentration. The measure of this activity is an osmolarity which corresponds to the product of the number of moles of solute and molecules (ions) produced during the dissociation of 1 kg of the solvent (for cells the solvent is water). All biological liquids are characterized by referred osmolarity, which can be measured and should be kept constant.

1 mmol/kg of NaCl solution as a dissociating substance shows an osmotic activity equal 2 miliosmoles, while solution of glucose (undissociating substance) of the same concentration (1 mmol/kg) – only 1 miliosmole. Hence, the above-mentioned NaCl solution is hyperosmotic relative to glucose (hypoosmotic). The glucose solution at the concentration of 2 mmol/kg will be isoosmotic relative to 1 mmol/kg NaCl solution. Changes in the osmolarity of biological fluids can be dangerous for the proper functioning of cells.