# Body water

The model of water (Fig1) such as the model of extracellular proteins is divided into eight main compartments: blood plasma (plasma), red blood cells (RBC), interstitial (IST)/intracellular(ICF) water of upper torso(UT), middle torso(MT) and lower torso(LT). These compartments are connected with osmotic connectors because an osmolality is the main force of transferring the water in the body. Chosen distribution of body water (41 l) between compartments is written in Table I.



Table I, Typical steady-state water volume of compartments [l]

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Plasma | RBC | UT\_IST | UT\_ICF | MT\_IST | MT\_ICF | LT\_IST | LT\_ICF |
| 3.0 | 1.6 | 2.3 | 5.0 | 5.7 | 12.5 | 3.4 | 7.5 |

Typical mean water flows between all compartments are listed in Table II as described in many studies [1-4]. In gastrointestinal tract are absorbed, in each torso is metabolically produced and also excreted by sweating or by vaporization. Flows such as hemorrhage, transfusion, intravenous drip, to peritoneum, to lungs edema are zero at normal condition. Outflow of water to urine is modeled by kidney.

Table II,Typical steady-state water flows between compartments [ml/min]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | plasma | UT | MT | LT | Total |
| from diet | 1.4 |  |  |  | -1.4 |
| through capilaries | -3.01 | 0.38 | 1.23 | 1.40 |  |
| lymph | 2.41 | -0.32 | -0.75 | -1.34 |  |
| from metabolism |  | 0.06 | 0.11 | 0.06 | -0.23 |
| evaporation |  | -0.12 | -0.59 | -0.12 | 0.83 |
| to urine | -0.8 |  |  |  | 0.8 |

## Gastro intestinal water absorption

Mean water in diet should be about 2 l/day, which is the sum of water in food and drinks. Firstly is water accumulated in gastro intestinal lumen (GILumen), where it has the mean osmolarity about 253 mosm/l. This osmolarity is composed mostly with sodium with anions (160 mosm/l), dietary fiber (43 mosm/l) and potassium with anions (50 mosm/l). Water is sucked by gastrointestinal cells, where is the mean osmolarity about 286 mosm/l called OsmBody\_CellWall in Fig1.



Because in original HumMod 1.6.1 model is the mean absorption from GILumen calculated by coefficient of osmotic gradient Absorption [ml/min] = 140 \* (0.286 [osm/l] - 0.253 [osm/l]), the pressure-gradient osmotic permeability (cond) of library membrane block has to be derived to have the same flow at the same settings. We know that the volumetric flow in this block is calculated by equation Eq1, so the recalculated parameter cond to value 0.14/(8.314\*310.15) [ml/(Pa.min)].

## Upper/Middle/Lower torso water

Flow between plasma and interstitium is determined by colloid osmolarity of extracellular proteins. Through the capillaries wall is distributed the water to or from the interstitium. Another way is the one directional lymph flow from interstitium to blood plasma [2-4], as presented in Table III. These flows can be influenced by the internal pressure in tissues caused by its volume and skin as examined by Gyuton [5] or Xie [1].

Table IV, Typycal osmolarities of substances [mosm/l]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | electrolytes | Urea | glucose | Unknown |
| ECF | 250 | 6 | 6 | 24 |
| ICF | 266 | 6 | 0 | 13 |

However the flow of water between interstitium and cells is determined by all substances. In cellular membrane the proteins osmolarity plays the minor role, because their concentration is only about 1 mosm/l. Here in extracellular space is osmolarity divided into electrolytes, urea, glucose and others solutes. And in intracellular space are electrolytes, urea and others solutes. Osmolarity in equilibrium must be the same in interstitium and in cells (typically 285 mosm/l).



## Kidney

In kidney is water delivered by blood to the glomerulus, where is blood plasma filtrated to glomerular filtrate (GFR). Most of this filtrate is reabsorbed in nephron parts: proximal tubule (PT), loop of Henle (LH), distal tubule (DT) and collecting ducts (CD) and the rest is accumulated in bladder as urine.

Table V, Typical average steady-state flows through nephron [ml/min]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GFR | to LH | to DT | to CD | to Bladder |
| 120 | 57 | 41 | 4.6 | 0.8 |



Proximal tubule:

Glomerular filtrate in glomerulus has the same pressure as blood in glomerulus and this pressure push it into nephrons. Reabsorption fraction in proximal tubule is determined only with sodium reabsorption in proximal tubule.

Loop of Henle:

Only the short coronary nephrons contains the aquaporin channels inside loop of Henle, which makes the water reabsorption fraction only 37% of sodium reabsorption fraction [6, 7].

Distal tubule:

Outflow of filtrate to collecting duct is determined by outflow of sodium, where it is dependent on ADH nephron concentration as was described in studies of Khokhar et al. and Atherton et al. [8, 9].

Collecting duct:

In collecting duct are the number of active aquaporin channels driven by ADH and it proportionally means the volumetric flow rate of reabsorbed water by collecting duct tubules [10, 11]. Changing the activity of aquaporin channels is modeled by integration of inactive channels driven by ADH concentration as simulating the process of their intracellular vesicular storage. Independently on aquaporin channels is calculated the minimal water outflow to urine, which is determined by sodium outflow to urine and medulla osmolarity.

[1] Xie S, Reed R, Bowen B, Bert J. A model of human microvascular exchange. Microvascular research 1995;49:141-62.

[2] Engeset A, Hager B, Nesheim A, Kolbenstvedt A. Studies on human peripheral lymph. I. Sampling method. Lymphology 1973;6:1-5.

[3] Eisenhoffer J, Lee S, Johnston M. Pressure-flow relationships in isolated sheep prenodal lymphatic vessels. American Journal of Physiology-Heart and Circulatory Physiology 1994;36:H938.

[4] Henriksen JH. Estimation of lymphatic conductance: A model based on protein-kinetic studies and haemodynamic measurements in patients with cirrhosis of the liver and in pigs. Scandinavian journal of clinical & laboratory investigation 1985;45:123-30.

[5] Guyton AC. Interstitial fluid pressure: II. Pressure-volume curves of interstitial space. Circulation research 1965;16:452-60.

[6] Gottschalk CW, Mylle M. Micropuncture study of the mammalian urinary concentrating mechanism: evidence for the countercurrent hypothesis. American Journal of Physiology--Legacy Content 1959;196:927-36.

[7] Nielsen S, Kwon T-H, Frøkiær J, Knepper MA. Key roles of renal aquaporins in water balance and water-balance disorders. Physiology 2000;15:136-43.

[8] Atherton J, Green R, Thomas S. Influence of lysine-vasopressin dosage on the time course of changes in renal tissue and urinary composition in the conscious rat. J Physiol (Lond) 1971;213:291-309.

[9] Khokhar A, Slater J, Forsling ML, Payne N. Effect of vasopressin on plasma volume and renin release in man. Clinical Science 1976;50:415-24.

[10] Jamison RL, Buerkert J, Lacy F, Marcus D, Henton B. A micropuncture study of collecting tubule function in rats with hereditary diabetes insipidus. Journal of Clinical Investigation 1971;50:2444.

[11] Jamison R, Lacy FB. Evidence for urinary dilution by the collecting tubule. Am J Physiol 1972;223:898-902.