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The Spatial Form of the Nephrons

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Abstract

The kidney excretes excess substances through urine: decomposition products of substances foreign to the metabolism and organism (medicines, nutritional supplements). The kidneys also play an important regulatory role (fluid and water balance, pH, blood pressure, hematopoiesis, bone metabolism). Our experiments analyzed the microscopic picture of kidneys of patients who died during gestational age or infancy. We found that the structural and functional unit of the kidney is the nephron. The nephrons have two important mechanisms: filtration and reabsorb. We determined the spatial form of the nephrons is rotating ellipsoid. In our opinion, the excretory apparatus should have a control associated with its own structure, which is likely to consist of neurons with hyperordonated spatial structure, called the "hypothetical secondary brain".

Key Words: Nephron, Filtration, Rotating Ellipsoid, Hypothetical Secondary Brain.

Introduction

The kidney excretes excess substances through urine: decomposition products of substances foreign to the metabolism and organism (medicines, nutritional supplements). The kidneys also play an important regulatory role [1] (fluid and water balance, pH, blood pressure, hematopoiesis [2], bone metabolism). The kidney regulates certain ions of the body (Na^+, K^+ and chlorides) and its total water content, and thus regulates the osmotic pressure of the extracellular space [3].

Table I. The quantity of the filtration and reabsorb matter

Matter	Filtration quantity	Reabsorb quantity	Excretion quantity	Proportion of reabsorb %
glucose (g/day)	180	160	0	0
bikarkonat mM/day	2160	2159	1	>>99,9
Na+ (mM/day)	25.560	25.410	150	99,4
K+ (mM/day)	756	664	92	87,8
Cl– (mM/day)	19.440	19.260	180	99,1
urea (g/day)	46,8	23,4	23,4	50
creatinine (g/day)	1,8	0	1,8	0

In addition to regulating ionic balance, the kidney also plays an important role in the excretion of metabolites resulting from metabolism. The end product of proteolysis is urea (residual nitrogen), while the end product of nucleic acid decomposition is uric acid. Creatinine is the metabolite of muscle metabolism [4]. The kidneys also play an important role in the excretion of many drugs and other foreign substances and in the elimination of red blood cell metabolites (bilirubin) in liver disease.

The Nephrogenesis

Initial signs of the final form of the kidneys are already evident on the 8th week of embryo¬nic development, i.e. they are characteristic of the early fetal period (3–5 intrauterine month). The cortex and the marrow is structured for the late fetal period, the linear ratio of the two is 1:4. In the cortex, the three zones can be clearly demarcated. The postnatal periods are next: neonates (0–1 months), infants (1–12 months) and young children (1–3 years).

Infant age is characterized primarily by morphological changes, including easily distinguishable cortical zones, well-structured lobes and lobuli, and the exclusive presence of complete renal corpuscles.

Table II. The caracteristics data of kidney

Periods	Kidney-zvolum(cm^3)	Ratio of cortex/marrow	Nefron number
Neonatals	6,5	1,37/1	300.000
Infancy	21,0	1,37/1	650.000
Little child	55,0	2/1	1000.000

Human kidney development in perinatal periods is influenced by three important parameters: periods of ontogenesis, gender and zone-based localization [5, 6]. The ontogenetic development of the kidney, in the light of the nephron number, in the perinatal periods is strongly influenced by age (ontogenetic periods), moderately influenced by the distribution based on zones, while gender has a less significant effect on nephrogenesis.

Modeling The Renal Function

According to the physiological data measured, 800 liters of blood (liquid state) flow through the kidneys daily, producing 160–180 liters of primary filtrate. The body protects the functional and structural integrity of the kidneys in the nephron so that they do not all work at the same time, but seems to "rest" some of them, and then they start working again. This alternating period of activity and rest of the nephrons probably exists to allow for a partial state of regeneration at rest. The flow rates of the primary filtrate layers in the proximal and distal tubules differ quite significantly, because the layers at the walls flow much slower than the layers inside the tubules due to the frictional force. The energy resulting from the diffe¬rences in frictional force and flow rates is converted into heat energy, and therefore the temperature difference between the layers of the flowing filtrate reaches several degrees.

Temperature differences in flowing fluids can cause cavitation. Cavitation means that the difference in the speed of flow causes the pressure to drop so much that the formation of a vapor bubble in the filtrate begins, the collapse of which can cause damage to the wall of the tubules. When the cavitation caverns are destroyed, the filtrate hits the wall of the tubule and causes a large pulse that damages the wall. It is likely that during the resting period of the nephrons, among other things, the cells that form the wall of the tubules are regenerated [7].

Vortexes are formed in any liquid when the fluid flow suddenly changes direction because the barrier acts as a vortex-forming surface. In the distal tubules, the filtrate flows in a direction opposite of 1800 to that of the proximal section of the filtrate, and therefore, in the loop of Henle, a vortex is formed in every nephron. It follows that, for the flow of a portion of the primary filtrate (in the case of the loop of Henle and the subsequent section), the flow laws of hydromechanics used for vortex fluids are applicable. A vortex flow is a flow in which the vortex vector ω is not zero at some points of the flow space. One of the characteristics of the vortex flow is the so-called vortex flux of the vortex tube (a spatial shape formed by vortex lines passing through a small closed curve). What is defined by

$$\mu = \int \omega n \, df$$

surface integral, where: ω_n is the perpendicular component of the vector ω at each point on the arbitrary smooth surface bounded by the curved fluid of the selected vortex tube. In the case of vortex thread, this integral is easy to calculate and thus μ = ω.f,

where: f is the cross-sectional area of the vortex thread. In this case μ is the so-called vorticity. The Friedmann equation resulting from the Eulerian equation of hydro¬dynamics is ideal for the theoretical description of the vortex flow of fluids:

$$\frac{\partial \omega}{\partial t} + (v.grad)\,\omega - (\omega \cdot grad)\,v + \omega \cdot div\, v =$$

$$rot\ F + \frac{1}{\rho^2} grad\ \rho \times grad\ p$$

where: v – the velocity of the fluid, ω – the vortex vector, F – the resultant of external forces acting on the mass unit, ρ – the density of the fluid, p – the pressure. This equation, in the case of external conservative forces and incompressible fluid, turns into the Helmholtz equation of:

$$\frac{\partial \omega}{\partial t} + (vgrad)\,\omega = (\omega\ grad)\,v$$

Thus, in the case of the flow of the primary filtrate both the phenomenon of cavita¬tion that may occur, as well as the phenomenon of the whirling flux at the level of the loop of Henle must be taken into account [8]. The amount of filtrate can be calculated based on the Starling principle. When a volume is filled with a solution, and is divided by a semipermeable membrane into two compart¬ments, an osmotic system is created. If both compartments are subjected to different hydrostatic pressures, filtration occurs. The amount of the filtrate (m) is calculated by using the formula:

$$m = F.(\Delta P - \Delta \pi)$$

where: F – filtration coefficient; ΔP – difference in hydrostatic pressure between the two compartments; Δπ – osmotic pressure difference between the two compartments. This is the Starling principle. If ΔPπΔπ, the filtrate flows from compartment 1 to compartment 2; ΔP <Δπ, the filtrate flows from compartment 2 to compartment 1.

When applying the Starling principle to the kidney to calculate the filtrate, certain adjustments need to be considered. Hydrostatic pressure at capillary level is given by blood pressure, whereas oncotic pressure should be used instead of osmotic pressure. Albumins are responsible for 79%, globulins are responsible for 20%, while fibrinogens are responsible for 1% of oncotic pressure. The effective filtration pressure (P_e) can be given by:

$$P_e = (P_c - P_i) - \sigma(\pi_c - \pi_i)$$

where: σε(0.75–0.95) is the rejection ratio of proteins: in case of continuous capillary. If the effective filtration pressure is positive, there is filtration, if negative, it is reabsorption. We use the Starling equation for this case:

$$m = F.[(P_c\text{-}P_i) - \sigma(\pi_c\text{-}\pi_i)]$$

The filtration coefficient depends on the capillary surface, the permeability of the wall etc., and is very different in each capillary. (It is of very small value in the brain, large in the gut, and moderate in muscle.) Endothelial cells are capable of altering the size of the pores, and thus can greatly influence the amount of material filtered.

Table. III. The pressure valour of the filtration

Surface	Blood pressure mmHg	Oncotical pressure mmHg	Intersticial pressure mmHg
Arterial	35	25	1
Venous	12	5	1

Using the values in the table, we calculate the effective pressure for both filtration and reabsorption:

filtration: $P_{es} = (35 - 1) - (25 - 5) = 14$ (mmHg)
reabsorption: $P_{es} = (12 - 1) - (25 - 5) = -9$ (mmHg)

Applying Starling's equation, the total degree of filtration is approx. 20 ml/min, 90% of which, 18 ml/min is reabsorbed, and a volume of 2 ml/min is excreted into the lymph.

Clearance is the amount of plasma that is completely cleared of a certain material by the kidney over a given time period. This virtual blood that is specific to a substance is the plasma volume [9]. The sensory part is located in the ascending thick limb of loop of Henle, and when more tubular fluid is present, the smooth muscle of the vascular wall is more tightened, causing the smooth muscle to contract and the afferent arteriole to narrow, reducing blood flow, and thus reducing glomerular filtration [10].

The spatial form of renal corpuscles

Computerized processing of linear dimensions of renal corpuscles has led to the conclusion that their spatial shape is, at first sight, a rotational ellipsoid [11]. If we intersect the rotational ellipsoid with planes parallel to the small axis, we get circles; the intersection parallel to the major axis produces ellipses of the same eccentricity; for other intersection planes, the projections will be ellipses of different eccentricities. On the basis of analytical geometry we can write the formula of the rotating ellipsoid:

$$\frac{x^2}{a^2} + \frac{y^2}{a^2} + \frac{z^2}{b^2} = 1$$

where x, y and z are spatial coordinates, and a and b are the values of the minor and major axes.

Based on the values of eccentricities and the small and large diameters of projections, we have determined the specific equations of the rotational ellipsoid for early childhood in all three cortical zones by computerized estimation methods.
In the outer zone of the cortex:

$$\frac{x^2}{74{,}4^2} + \frac{y^2}{74{,}4^2} + \frac{z^2}{124{,}0^2} = 1$$

In the middle zone of the cortex:

$$\frac{x^2}{86{,}6^2} + \frac{y^2}{86{,}6^2} + \frac{z^2}{142{,}6^2} = 1$$

In the inner zone of the cortex:

$$\frac{x^2}{111{,}6^2} + \frac{y^2}{111{,}6^2} + \frac{z^2}{161{,}2^2} = 1$$

Based on these formulas, the surface integrals can be used to determine the filtration surface of any kidney.

The volume of the renal corpuscle can be calculated by using the following formula:

$$V = \frac{4}{3} \cdot a^2 \cdot b \cdot \pi$$

This formula shows that in infancy the volume of an average renal corpuscle in the outer zone of the cortex is 8.3×10^5 µm^3, in the middle zone is 11.7×10^5 µm^3, and 14.8×10^5 µm^3 in the inner zone. These data clearly demonstrate that the size of the renal corpuscles increases significantly from the outer cortex to the marrow. This increase in volume also makes it probable that nephrogenesis starts from the outer zone of the cortex and all three germ layers are involved in nephrogenesis.

Adjustment

Nerve control: sympathetic innervation of afferent arte¬riole: vascular cross-section narrows and clearance decreases, and the volume of urine is also reduced. Angio¬tensin plays a role in hormonal regulation, which is produced by renin and has a strong vasoconstrictor role.

We assume that there is a third regulation. In severe brain injuries, it has been observed that kidney filtration and reabsorption work, and therefore it is assumed that there is a "hypothetical secondary brain" of the excretory apparatus [12].

So in our opinion, the excretory apparatus should have a control associated with its own structure, which is likely to consist of neurons with hyperordonated spatial structure, called the "hypothetical secondary brain", which performs certain control functions. This "hypothetical se¬condary brain" of the excretory apparatus, in humans, functions continuously throug¬hout their life, only so poorly controlled that it has not yet been detected and discovered by scientific research in addition to the dominant role of the central nervous system.

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