

Short Communication

Age Transformations of the Kidneys Structure and Function

Aizman R.I.*¹

1. Doctor of Biological Sciences, Professor, Honored Scientist of the Russian Federation, Head of the Department of Anatomy, Physiology and Life Safety of the Novosibirsk State Pedagogical University. 630126, Vilyuiskaya, 28, Russia

*Corresponding author: Doctor of Biological Sciences, Professor, Honored Scientist of the Russian Federation, Head of the Department of Anatomy, Physiology and Life Safety of the Novosibirsk State Pedagogical University. 630126, Vilyuiskaya, 28, Russia, E-mail: aizman.roman@yandex.ru

Received: May 05, 2019; Accepted: June 14, 2019; Published: June 17, 2019

Morphological Development of the Kidneys

Budding occurs during the third week of embryo development. But the primitive nephrons formed quickly disappear without showing noticeable activity. At 7–8 weeks of development of the embryo, nephrons of the secondary kidney begin to form. Initially, they are located in the juxtamedullary zone, and after 22 weeks their formation moves into the cortex of the kidney. In this regard, in each phase of renal organogenesis, until the end of the process of nephron formation (32–34 weeks of embryonic development), there are more mature neurons in the juxtamedullary region than in the cortical one [2, 5, 6].

Electron microscopic analysis of the human fetal kidney from 5 to 36 weeks showed that a distinct epithelial differentiation sequence was observed in nephron histogenesis: first the capsule of the renal corpuscle, then the proximal tubule, the distal segment, and finally, the loop of Henle. After 5 months of intrauterine life, i.e. by the time a prematurely born child can survive under optimal conditions, more than 1/3 of the nephrons are already structurally and functionally formed, and by week 36 of embryonic development, the epithelium of human nephrons of the kidneys in some morphological, histochemical and enzymatic parameters reaches the level of adults.

Most authors believe that the formation of new nephrons continues only until birth, after which approximately 12-15 years of age mainly occurs in their maturation, but the possibility of the formation of renal bodies in the postembryonal period of up to 3–5 years is not excluded.

By the time of birth, the mass of the kidneys in children is approximately 50 g, or 1.6 g / 100 g of body weight. Their growth is most intense in the first 1.5-2 years of life, at 8–10 and 14-18 years, reaching 270 g (0,45 g / 100 g body weight) by 22-25 years. The kidneys of a newborn have a lobed structure, which usually disappears by 2-5 years. The cortex is 4 times narrower than the medulla (2 and 8 mm, respectively), whereas in adults this ratio is 1: 2 (8 and 16 mm). By 5-6 years, the innervation of the kidneys acquires a structure characteristic for adults.

Kidney microanatomy is especially well studied in newborns. During this period of life in the cortical layer there are many undifferentiated renal bodies, the glomeruli of which have a small diameter and a smaller filtering surface; glomerular vascular loops are covered with cubic and even cylindrical epithelium, which is an obstacle to the exchange between the

capillaries and the nephron capsule. Even less formed tubular apparatus. If the diameter of the renal glomeruli of newborns is 2.5 times smaller than in adults, the length of the proximal tubules is 10 times smaller.

Therefore, osmotic concentration matures later than dilution.

The basis of the low concentrating ability of the kidneys are:

- 1) the immaturity of the loop of Henle;
- 2) a positive nitrogen balance, and, therefore, a smaller amount of urea is formed;
- 3) renal insensitivity to ADH.

Therefore, when artificial feeding with cow's milk, containing more salts and proteins than female, the concentrating ability of the kidneys develops earlier than with breast feeding. However, high extrarenal water losses in young children (a relatively large skin surface with which evaporation occurs, fluid loss through breathing and through the gastrointestinal tract), as well as the absence of thirst and low concentrating ability of the kidneys make the child's water regime quite tense and contribute the development of dehydration.

The kidney of the human fetus begins to function as early as 9 weeks of embryonic development. Ultrasound determination of renal function in the fetus showed that urine production progressively increases from week 22 to week 41 - from 2.2 to 26.7 ml / h, and glomerular filtration rate (GFR) increases - from 1.8 to 2.7–4 ml / min. and fluid reabsorption from 72.3 to 78.2–89.8%. However, the excretory function of the fetus is negligible; this role is played by the placenta. The functions of the kidneys in postnatal ontogenesis develop heterochronously, in close connection with the morphological maturation of the organ, and in the newborn significantly depend on the full gestation of the child.

The prerequisite for effective kidney function is an adequate level of their blood supply. Under resting conditions in newborns, only 5% of the minute cardiac output of blood enters the kidneys, whereas in adults - 20–25%. A sharp increase in the renal blood supply is observed within 8–10 weeks after birth. Estimating the age features of the total renal blood flow, some authors indicate that by the age of 3 years it corresponds to the level of adults (689 ml / min / 1.73 m², others demonstrate an increase in the effective renal blood flow to 13-15 years (143 ± 54 ml / min / 1.73 m²).

During the transition from embryogenesis to extrauterine existence, parallel to the rapid increase in renal blood flow, a

2-3-fold increase in glomerular filtration rate is observed. This jump is not associated with an increase in the calendar age, but with a sharp increase in the load on the kidney as an excretory organ. Contradictory opinions about the change in glomerular filtration rate in postnatal ontogenesis of a person. The glomerular filtration rate in children in the first weeks after birth is 3–4 times lower (~ 22–45 ml / min) than in adults. Most authors believe that GFR reaches a level characteristic of an adult organism, between 2-3 years of life. However, there are no less convincing evidence of the increase in GFR during the entire period of ontogenesis to adolescence. GFR is usually determined by the plasma creatinine concentration (Pcr), since this substance is only filtered using various formulas. For example,

$$\text{GFR} = \frac{[140 - \text{age in years}] * \text{body weight (kg)}}{\text{plasma creatinine } (\mu\text{mol} / \text{l})}$$

For men, the resulting value should be multiplied by 1.2.

The calculated data are highly correlated with experimental results and indicate an increase in glomerular filtration rate during the development of a child. All authors give a similar age dynamics in relation to tubular fluid reabsorption — an increase in % RH₂O from 78–89% in newborns to 98–99.5% in children 13–15 years old and adults. Significant information for the assessment of renal function in ontogenesis is provided by the results of studies of the processes occurring in different segments of the nephron. One of the important parameters of the development of proximal tubules is their ability to reabsorption and secretion of substances. By the time of birth, children have an effective system of reabsorption of water, electrolytes and glucose, corresponding to the level of development of their filtration processes. At the same time, the reabsorption of amino acids is reduced, which leads to aminoaciduria. Especially pronounced loss of proline, hydroxyproline, glycine during the first month of life. This is attributed to the insufficient development of the amino acid transport system and its regulation in the cells.

A characteristic functional feature of the kidneys of newborns is the low level of secretion of organic acids and bases. The time during which maturation of the secretory capacity of the kidneys takes place is estimated differently. Some authors indicate that at the age of 6 months to 7 years, values characteristic of adults are achieved; others believe that this function becomes mature by 2.5 years of age; still others mark its maturation at the age of 4–14 years. It is believed that the cells of the proximal tubule are capable of secretion by the time of birth, but the absence of certain regulatory factors makes it difficult to perform this function effectively.

The functionality of the distal nephron segment can be judged by the degree of concentration and dilution. The kidneys of a newborn, already on the 5th day of life, are able to excrete hypo-osmotic urine in response to a water load, with the degree of dilution reaching values comparable to that of an adult kidney. However, the ability to counteract dehydration and excrete salt loads is very limited, and therefore the urine osmolality in water deprivation (water scarcity) in infants does not exceed 700 mOsm / l. Therefore, the range of fluctuations in the

osmotic concentration of urine in newborns is significantly less (50–700 mOsm / l) than in adults (50–1500 mOsm / l). Under conditions of natural mode or water deprivation, the degree of osmotic concentration and the osmolality of urine are less than in adults, up to 12–16 years. Therefore, osmotic concentration matures later than dilution.

Functional immaturity of the kidneys in early ontogenesis is especially evident during exercise: the introduction of water can cause edema, excess food - hyperazotemia, salts - salt fever, a violation of homeostatic parameters. The low ion-excretory function of the kidneys is also due to the lower filtration loading of the nephron and the increased reabsorption of ions in the tubules under the influence of the high activity of the renin-angiotensin-aldosterone system. Therefore, purification from sodium, for example, is 1/5-1/6 of the adult norm, which can lead to sodium retention in the body and the development of edema. In subsequent periods of ontogenesis, the main parameters characterizing the osmotic and ion-regulating functions of the kidneys undergo only minor changes and, as a rule, fall within the limits of the confidence intervals of normal values inherent in adults.

Thus, in conditions of relative rest of the body with a balanced diet and water consumption, most parameters of the partial functions of the kidneys do not differ from the definitive values already in the period of early childhood. However, with age there is an increase in GFR, reabsorption of fluid and electrolytes.

The most pronounced differences are detected in the interval from the neonatal period to 2-3 years. At this stage of development, the excretion of electrolytes and osmotically active substances increases significantly, the osmotic concentration index rises, probably low U/P osm. in early children reflects the nature of the food received by newborns (milk, water), and not the level of functional maturity of the kidneys.

The calculation of the total kidney function showed that by 4–5 years the integral indicator of the functions of the studied organ is approaching the adult level (Fig.), but during the course of ontogenesis it undergoes wave-like changes. The greatest intensity of development of the functions of the kidneys is observed from the neonatal period to 4-5 years, the next leap is manifested in 10-11 years, and the final stabilization of this parameter occurs in adolescence. In the periods of 7-8 and 13-15 years, a decrease in the value of the coupling coefficient (CC) between the indices of the partial functions of the kidneys is observed. This can probably be a consequence of the desynchronization of their development, as well as the result of heterochronic maturation of the kidneys and other functional systems ensuring their activity (cardiovascular, digestive, endocrine). Anyway, these periods, apparently, should be considered as critical stages in the functional development of the organ. A similar calculation of the morphological formation of the kidneys showed that it occurs more smoothly and reaches a stable level after 22 years.

In general, by the sum of morphofunctional signs, the kidneys are closest to the definitive state in 10–11 years. In adolescence, there is a decrease in the rate of development and a discrepancy between the parameters of structure and function (see Fig.). Consequently, at each stage of ontogenesis, the level

of development of the kidneys corresponds to the degree of maturation of other functional systems, the nature of the metabolism and, under conditions of balanced nutrition and water consumption, ensures that the body maintains the relative constancy of the homeostatic constants [2, 3, 4].

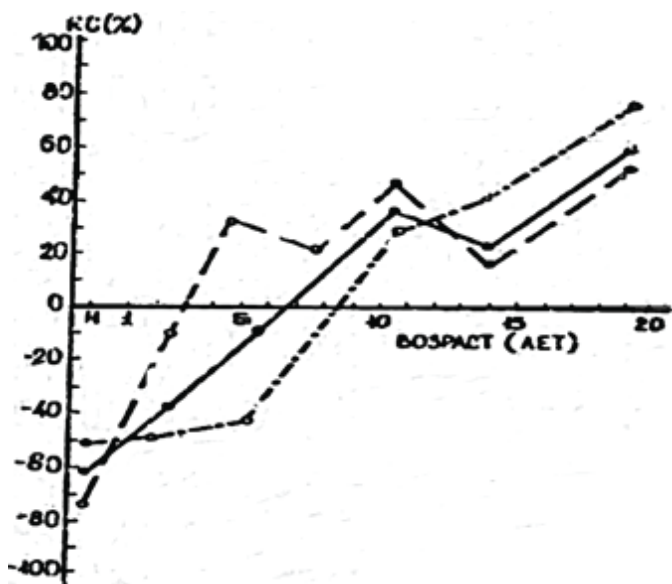


Figure 1. Integral morphofunctional characteristics of human kidneys in different periods of ontogenesis: CC - the coupling coefficient between different parameters, calculated by the method of morphokinetic synthesis; - - - CC of functional parameters; - . - CC morphological parameters; ---- - CC morphofunctional parameters.

Age features of urination

The composition of urine. The urine of newborns contains traces of protein. It depends on the increased permeability of the epithelium of the urinary glomeruli and tubules. Older children do not have urine protein. Milk sugar, glycuronic acid, hormones, enzymes (pepsin, diastasis, trypsin, maltase, uropepsin, etc.) are often found in the urine of children, but nitrogenous substances in the urine of newborns are 5 times less than in adults. The predominance of the processes of assimilation over dissimilation at an early age relieves the excretory activity of the kidneys and leads to a decrease in the excretion of not only nitrogenous substances, but also salts.

The reaction of urine in newborns is sharply acidic, becomes slightly acidic with age. The reaction of urine can vary depending on the nature of the food: when it is fed mainly meat food, many acidic metabolic products are formed in the body, respectively, and the urine becomes more acidic; when eating plant foods, the urine reaction shifts to the alkaline side.

The amount of urine. In infants, the amount of urine per 1 m² of the body surface is 2-3 times greater than that of adults, due to intensive water metabolism and a relatively large amount of water and carbohydrates in the diet of the child. The amount of urine is also influenced by the temperature and humidity of the surrounding air, clothing, and mobility of the child.

Daily diuresis (D) in children over 1 year can be calculated by the formula:

$$D \text{ (ml)} = 600 + 100 (A - 1),$$

where A is age in years.

At the age of 4-5 years, a child releases 1 liter of urine per day,

at 10 years old - about 1.5 l.

The number of urinations in a newborn 20-25 times a day, in infants up to 15 times a day, while night diuresis predominates over daytime. The number of urination in children 2-3 years 10 times, at school age 6-7 times a day. On average, a newborn excretes 10-50 ml of urine each time when urinating, a child from 1 year old 50-100 ml, at 5 years old 90-200 ml, at 10 years old 150-250 ml, at 15 years old 200-300 ml that depends on the increase in bladder capacity.

Regulation

The activity of the kidneys and urinary system is regulated by the central nervous system and hormonal factors (antidiuretic hormone, natriuretic hormone, renin-angiotensin-aldosterone system, etc.) and is in close functional relationship with other systems in the body. All links of the osmo-, volume- and ion-regulating systems reach the level of adults by 10-11 years of life, although the volume of their reserve capabilities remains even below the definitive level up to 18-21 years. In adolescence, there is a high reactivity of the osmotic and sodium regulating mechanisms, which contributes to increased diuresis, sodium retention in the body and may be a provoking factor in the development of "youthful" hypertension [2,5,6].

The process of urination and excretion of urine is influenced by emotional moments and environmental factors (air temperature, humidity, quantity and quality of food, liquids, etc.).

Bedwetting (nocturnal enuresis). In infants, there is an involuntary emission of urine in connection with the filling of the bladder and the inclusion of a reflex mechanism for stretching it. Older children, like adults, can arbitrarily delay and cause urination. This is due to the establishment of cortical, conditioned-reflex regulation of urination, the formation of which occurs by the end of 1 year of life. Usually, by the age of 2, the children have conditioned-reflex mechanisms of urinary retention, not only during the day, but also at night. However, 5-10% of older children have bedwetting (enuresis). This is facilitated by taking before bedtime a large amount of liquid (tea, coffee, milk), however, it is associated with the child's illness.

Thus, the definitive maturation of the morphology and function of the kidneys is completed on average by 22 years of age, although in the dynamics of ontogenesis there are critical periods associated with the restructuring of the structure and function of the organ.

References

1. Aizman RI. Age characteristics of the regulation of kidney function and water-salt metabolism in children. *Nephrol Dialysis*. 2003; 5:3.220.
2. Aizman RI. Development of Renal Functions and Water-Salt Metabolism. In book: *Child Developmental Physiology*. Moscow: Russian Academy of Edu. 2000; 11. 186-200.
3. Aizman RI, Panova AS, Sorokina TS, et al. Formation and Development of Scientific School on Renal Physiology and Water-Salt Metabolism in Novosibirsk. *Problems of Social Hygiene, Healthcare, and History of Medicine*. 2018; 26: 4. 247-251.
4. Aizman RI, Subotyalov MA. Formation and Development of Scientific Views about Physiology of Kidneys and Water-Balance in Novosibirsk. *MOJ Anatomy Physiol*. 2017. 4: 3. 00136.
5. Aizman RI, Velikanova LK. Peculiarities of Renal Functions. In book: *Physiology of Adolescents*. Moscow: Pedagogics. 1988. P.140-157.

6. Velikanova LK, Aizman RI. Age changes of renal functions. In book: Developmental Physiology of Child. Moscow: Pedagogics. 1983; 177-195.

To cite this article: Aizman RI. Age Transformations of the Kidneys Structure and Function. Health Educ Public Health. 2019: 2:3.

© Aizman RI. 2019.