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SPECIFICITY OF KIDNEY FUNCTION IN INFANTS AT TERM

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Annotation

The main function of the kidney is homeostasis, originally defined by Claude Bernard as maintenance of the constancy of the internal environment. The internal environment is the extracellular fluid (ECF). Homeostasis is therefore the maintenance of the volume and composition of the ECF. The main threats to the stability of the ECF are the consequences of dietary intake and the production of metabolic waste substances by the body cells. The role of the kidney in this process is to detect small changes in the volume or composition of the ECF and to adjust the volume and composition of the urine so as to offset the tendency to change (negative feedback).

Keywords: renal blood, filtration, sodium, excretion, urine, concentrating, renal failure.

A normally developed kidney in a full-term infant can usually cope well with rapidly growing functional requirements and various endogenous and exogenous stresses. But the external conditions may be severe enough to overcome the kidney's adaptive capacity. In the premature infant, the kidney may also have to work long before its maturation is complete. Below are some functions of the kidneys in infants:

Renal Blood Flow and Filtration Fraction

RBF and renal plasma flow (RPF) are impossible to measure directly in healthy human infants. The renal clearances of para-amino hippurate (PAH) and the radiocontrast material diodrast have been widely used as an estimate of RPF, based on the assumption that these compounds are almost completely (>90%) extracted from renal arterial blood on a single passage through the renal circulation. Early measurements using these methods in babies gave very low values in relation to simultaneously measured GFR, yielding an average value for filtration fraction

(GFR/RPF) of about 0.5, compared with a typical adult value of 0.2. However, in one study, the renal extraction of PAH was measured directly in infants undergoing renal vein catheterization; the results showed clearly that PAH extraction is very incomplete in early infancy, and therefore that PAH clearance seriously underestimates RPF. This is probably due to the fact that, as previously mentioned, the deeper (juxtamedullary) nephrons contribute most of the newborn infant's renal function. Postglomerular blood from this subpopulation of nephrons flows directly into the vasa recta system without perfusing the peritubular capillary plexus that supplies the proximal tubule, where PAH is extracted from the blood and secreted into the tubule lumen. When correction is made for PAH extraction, filtration fraction in infants is similar to the adult value of 0.2, indicating that RPF is about five times GFR. RBF is easily calculated from RPF and hematocrit.

Sodium Excretion

Healthy term infants are able to produce virtually Na-free urine (FENa much less than 1%). The importance of this fact is difficult to overestimate. The baby fed on her or his mother's milk has a low Na intake, in the region of 1 to 1.5 mmol/kg daily, which is close to the amount needed for growth. Virtually all of this Na must therefore be retained. Conversely, many studies have shown that the ability to excrete an Na load is less well developed than in older individuals. When this observation was first made, it was interpreted as meaning that renal function in the newborn was "immature"; however, it is unusual and unphysiologic for such an infant to be in a situation in which there is a need to excrete a salt load. In all but exceptional circumstances, the prime requirement of the neonatal kidney is conservation, not excretion, of Na.

Urinary Concentrating and Diluting Ability and Urine Flow Rate

The normal adult kidney can produce urine with an osmolality of greater than 1000 (typically 1200 to 1400) mOsm/kg H2O. The healthy newborn infant who is subjected to water deprivation for 10 to 14 hours can achieve an osmolality of only 500 to 700 mOsm/kg.23,24 This value increases gradually during the first few months and approximates the adult value by about 1 year of age. However, it was shown many years ago that, in thirsted adults, about half of the solute contributing to urinary osmolality was urea, the remainder being electrolytes. Infants, being normally in a state of marked anabolis growth), have a much lower urea production rate than adults and therefore have less need to produce highly concentrated urine in order to conserve water. if the urea production rate of infants is increased toward that of adults by means of high protein feeding or addition of urea to the diet, even young infants can concentrate their urine almost as well as adults. Here again, the casual assumption that the homeostatic needs of infants are the same as those of adults leads to incorrect interpretation of the results of tests of renal function. The capacity of the neonate to dilute urine, on the other hand, equals that of adults (minimum urine osmolality, < 50 mOsm/kg H2O). The factors determining urine flow rate (V) are the rate of generation of solute requiring urinary excretion and the capacity of the kidney to concentrate and dilute the urine with respect to plasma. Urinary solute has two main components: minerals (mostly Na, K, Cl, and P) and urea. If a healthy term infant were fed on his or her mother's milk at 150 mL/kg/day, the total potential solute content of the diet would be about 15 mOsm/kg/day. However, a large part of this content is retained and incorporated in new tissue: the actual solute load requiring excretion is in the range of 5 to 10 mOsm/kg/day. Given that the infant can concentrate urine only to about 600 mOsm/kg H2O, a solute production rate of 7.5 mOsm/kg/day necessitates a minimum urine volume of 12.5 mL/kg/day, approximately 0.5 mL/kg/hr, to avoid solute retention (i.e., uremia). This theoretical calculation agrees well with the clinical observation that, when newborn infants born at term were thirsted for 2 to 3 days after birth, their urine output was 0.3 to 0.5 mL/kg/hr.

Given that sick infants are likely to be catabolic and therefore producing more solute for excretion than healthy ones, a urine flow rate of less than 1 mL/kg/hr suggests some form of renal insufficiency and is widely accepted as a criterion for the diagnosis of oliguric renal failure. Theoretically, the maximum urine output for the same solute load, assuming a maximally dilute urine of about 40 mOsm/kg H2O, would be 375 mL/kg/day, or about 15 mL/kg/hr, although this capacity is seldom, if ever, needed in normal circumstances. Between the limiting values of 1 and 15 mL/kg/hr, V is actually determined by water intake. Healthy infants, demandfed on their mothers' milk, usually produce urine at about 3 mL/kg/hr, demonstrating that the ratio of solute to water in mature human breast milk is close to ideal for the needs of the infant.

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