MORPHOLOGICAL FEATURES OF DISTAL PORTIONS OF THE RENAL MEDULLA IN RODENTS LIVING IN HIGH TEMPERATURE ENVIRONMENTS

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The distal portion of the renal medulla was studied in rats and guinea pigs living at an external temperature of 36-37°, with or without access to water, and also in red-tailed gerbils caught at the end of spring and the end of summer in the region of Ashkhabad. Some animals were overheated for 1 h before sacrifice by exposure to dry air at a temperature of 45-46°.

Changes in the conditions of keeping of the laboratory animals led to changes in the distribution and content of acid mucopolysaccharides in the papilla of the renal medulla. Acid mucopolysaccharides were absent from this part of the kidney in desert rodents during the period of active life.

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Investigators have drawn attention to a link between the structure of the renal medulla in animals in closely related biological classes but differing in their habitat and their conditions of life. It has been noted that the papilla of the renal medulla is larger in animals living in hot deserts and semideserts than in related species living in wet regions, and also that this part of the kidney shows special histotopographic structural features and homeostatic reactions to exposure to high temperatures [1, 2, 5-9].

With the development of the hypothesis of a countercurrent system responsible for the concentration of urine in the mammalian renal medulla, it has been postulated that acid mucopolysaccharides present in the interstitial tissues of the renal medulla play an important role in the distal reabsorption of water. It has previously been shown that acid mucopolysaccharides form three clearly demarcated concentrations in the inner zone of the medulla, linked with the histotopography of the vessels and tubules in this area. These concentrations differ in their sensitivity to procedures stimulating or inhibiting diuresis. The mucopolysaccharides are most labile at the apex of the papilla, in the zone of the "rete mirabile" of the papilla. Stability is highest in the proximal concentration. Nowadays the state of diuresis can be judged to some extent from the histological picture of the renal medulla [3, 4].

The object of the present investigation was to study the state of the distal portion of the medulla, i.e., the papilla, of the kidney in rodents living in deserts, and also in laboratory rodents kept under high external temperature conditions.

EXPERIMENTAL METHOD

The renal medulla was investigated in red-tailed gerbils (11) caught in the desert in April and August, and in albino rats (10) and guinea pigs (10) kept in an animal house in Ashkhabad during the summer with free access to water, at a mean temperature of about 36-37°. Another 10 albino rats and 10 guinea pigs kept under the same conditions were overheated before sacrifice by exposure to dry air in a hot chamber at 45-46° for 1 h. The kidneys of another 10 albino rats kept in a mean external temperature of 36-37°, but without water, for 1-10 days also were investigated.

Blocks of the kidneys, including the papillae, were fixed in cold 10% formalin solution and embedded in paraffin wax. Serial sections cut in two mutually perpendicular projections were stained by a combined method with dialyzed iron and the PAS reaction, with a testicular hyaluronidase and amylase control and also by Mallory's method. Histological survey staining methods also were used.

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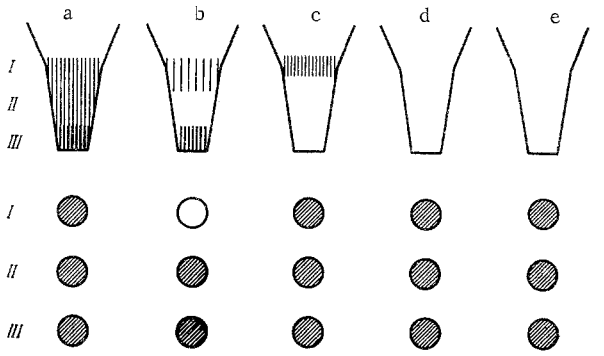

Fig. 1. Distribution of acid mucopolysaccharides (top row) and filling of capillaries (bottom row) in papilla of renal medulla in rodents living at a high external temperature. I) Proximal; II) middle; III) distal portion of papilla; a) rats kept at 36-37° with free access to water; b) similar rats but exposed for 1 h to overheating with dry air at 45-46° before sacrifice; c) rats kept at 36-37° without access to water (after 4 days); d) gerbils caught in the desert in April; e) gerbils caught in the desert in August.

EXPERIMENTAL RESULTS

It was noted that changes in the renal medulla were uniform in type in laboratory animals of different species kept under hot climatic conditions but with free access to water. Characteristic findings were a well developed zone of Hale-positive interstitial tissue occupying the whole mass of the distal portion of the medulla, wide opening (gaping) of the tubules in this layer, opening of numerous capillaries, and their filling with plasma and erythrocytes, and a high density of the boundary layer between the epithelium and interstitial tissue. Acid mucopolysaccharides covered the basement membranes so completely that the latter were almost indistinguishable. The epithelium of the collecting tubules was very high and consisted of a double layer, the cytoplasm containing large quantities of mucin-like substances. The intercellular boundaries were fairly clear, which was not found in the case of forced hydration by administration of fluid subcutaneously or by mouth.

When these animals were exposed for short periods to overheating with dry air (45-46°), a distinctive redistribution of acid mucopolysaccharides took place in the papilla: the concentration remained at the apex of the papilla and a new concentration was observed at the border between the upper and middle thirds of the papilla. In these zones dilated capillaries, congested with blood, were found whereas in the proximal part of the papilla the capillaries were empty (Fig. 1).

Paradoxical as it may seem, the animals living in hot deserts tolerated transient hyperthermia much less readily than laboratory animals. Whereas rats and guinea pigs tolerated a temperature of 45-46° relatively well, gerbils lost their balance, their normal reflexes disappeared, and they were unable to move.

In animals kept without water at a high external temperature (36-37°) acid mucopolysaccharides disappeared in the first two days from the apical and middle concentrations, while on the 8th-9th day a decrease in the amount of acid mucopolysaccharides also became apparent in the proximal concentration. Dilatation of the capillaries in the papilla increased progessively. By the 8th day they had a twisted, "corrugated" appearance and were distended with plasma, giving indistinct reactions for mucopolysaccharides. Just as in rats deprived of water and kept at a moderate temperature, in these animals changes took place in the staining properties of the interstitial tissue: in the lower portions it gave a positive PAS reaction which was not abolished by testicular hyaluronidase.

In rodents living in hot deserts, where free access to water does not exist, and the external adaptation to life at high temperatures which are observed are predominantly ecologic in character (life in deep, moist burrows, emergence on the surface only at night, and so on), the structure of the renal medulla is completely different in character. It could be described as a constantly active mechanism of intensive distal reabsorption. A closely similar pattern was observed in laboratory animals kept without water for

not less than 6 days. The characteristic features of the morphological picture were complete absence of any mucopolysaccharides in the interstitial tissue, preservation of PAS-positive basement membranes of particularly delicate structures, wide opening of numerous capillaries in the region of the apex of the papilla, a low epithelium and "bare nuclei" in the apical portions of the collecting tubules, and a high, juicy epithelium of the ducts of Bellini without visible intercellular boundaries.

The same characteristic morphological picture was observed in gerbils caught not only during the hot summer, but also in early spring. It may be considered that the state described above is one of the general adaptation characteristics possessed by the animals of this species, which are determined by the territory inhabited by it. In this case returning the largest quantity of water possible to the body from the urine (a very high degree of distal reabsorption) is an essential component of the adaptive morphological, biochemical, and ecologic characteristics enabling the animal to adapt itself to existence in a waterless desert.

This complete utilization of the bodily resources in adaptation to existence under particular extreme conditions has the effect that the animal, as was mentioned above, becomes less adaptive to a rapid change, although of short duration, in the external environment than animals inhabiting the temperate zone.

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