MORPHOLOGICAL CHANGES IN THE RENAL MEDULLA OF GUINEA PIGS CAUSED BY HYPERTHERMIA

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Considerable changes in the structure of the capillaries, interstitial tissues, and epithelium were found in the renal medulla of guinea pigs exposed to hyperthermia in a hot (34-36°) and humid chamber.

Comparative morphological and functional investigations have shown that there is a direct relationship in mammals between the available supply of water and electrolytes in the habitat of the species and the character of the function and morphology of the countercurrent concentrating system of the renal medulla [1, 5, 7]. One of us (T. L. Dubynin) has previously described corresponding morphological changes in the renal medulla of rats kept under different conditions [2-4].

The object of the present investigation was to examine the morphology of the renal medulla of guinea pigs under normal conditions and after exposure to hyperthermia. (Under natural conditions guinea pigs live in a wet climate.) Attention was concentrated on the lipids of the interstitial cells in connection with the hypothetical role of medullin, a substance which is considered to have a dilator action on capillaries. Medullin has now been isolated, its hypotensive properties have been demonstrated experimentally, and some investigators have associated (or even identified) it with lipids found in the interstitial cells of the papilla in the renal medulla of rodents [6, 8-14].

EXPERIMENTAL METHOD

Experiments were carried out on male guinea pigs weighing 430-680 g, which were exposed to a temperature of 34-36°C in a special chamber with a relative humidity of 60%. The duration of hyperthermia varied from 1 h to 18 days. In one series of experiments (18 days) the animals were subjected to stress (immobilization) for 5 h before sacrifice. The animals received food and water ad lib. They were killed by decapitation and the kidneys were fixed in cold 10% formalin solution. Serial sections were cut parallel and perpendicularly to the long axis of the papilla from blocks emberred in parafiin wax. The sections were stained by a combined method, using dialyzed iron and the PAS reaction with testicular hyaluronidase control, hematoxylin-eosin, picrofuchsin (by Van Gieson's method), and Heidenhain's method. To detect lipids in the interstitial tissue, sections cut on a freezing microtome were stained with Sudan black.

EXPERIMENTAL RESULTS

The medullary layer of the guinea pig kidney possesses certain structural features distinguishing it from the rat's renal medulla. The papillary part is relatively shorter and wider. The papilla has a well-defined network of smooth muscle, intimately connected with the epithelium covering the papillae and lining the Bellini ducts. The proximal part of the papilla contains numerous limbs of short loops of Henle, reaching at the periphery of the papilla about one fifth of its length, while in the central area it lies slightly above its visible border. The levels of the turns of the long loops of Henle occur all over the papilla, but

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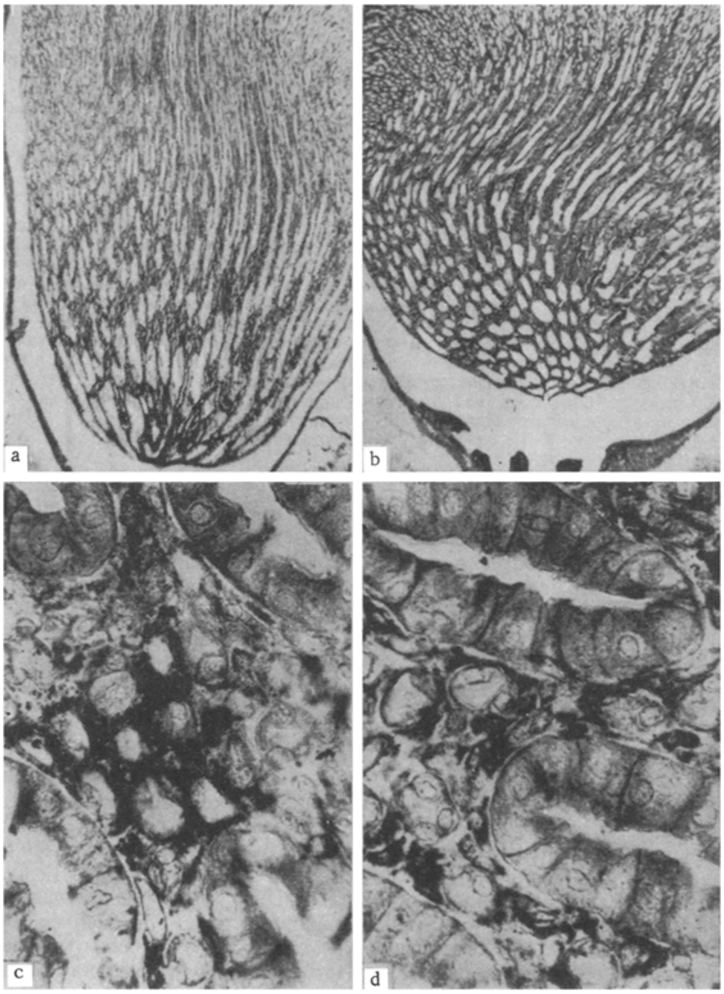

Fig. 1. Papilla of renal medulla of a guinea pig: a, c) normal; b, d) kept in the chamber 18 days with stress; a, b) acid mucopolysaccharides (stained by the Ritter–Oleson method; 120×); c, d) lipids (stained with Sudan black; 530×).

the density of their distribution increases toward the apex, where it attains 7-8 per structural unit. The center of such a structural unit is a large capillary, giving off single lateral branches. Ascending and descending thin segments of the loop of Henle lie around this capillary and are surrounded by smaller, straight capillaries with numerous lateral branches, especially well developed in the middle part of the papilla. These thin, straight vessels separate the tubules of the loops of Henle from the collecting tubules (or, in the lower parts of the papilla, from the ducts of Bellini). The renal papilla of the guinea pig has a well-developed specific interstitial tissue, rich in acid mucopolysaccharides, the content of which increases, without visible granules, toward the apex of the papilla (Fig. 1a). In the medulla of normal guinea pigs the sudanophilic granules are concentrated mainly around the nuclei of the interstitial cells and, to a lesser degree, in their processes. Collections of these granules constantly form cuffs around individual capillaries which, as a rule, are constricted (Fig. 1c). This phenomenon is observed more often in the peripheral parts of the apex of the papilla. The number of granules diminishes in a proximal direction, but they are absent in the external zone of the papilla. This boundary corresponds to the lower limit of spread of the short loops of Henle.

No changes were found in the distribution of acid mucopolysaccharides in the papilla of animals kept for a short time (from 1 to 24 h) in the chamber. With an increase in the duration of stay in the chamber, the number of open capillaries, filled with plasma and erythrocytes, increased, as also did the number of gaping lumens of the thin segments of the loops of Henle. No regular pattern of distribution of erythrocytes and plasma could be discerned. All that could be observed was that, because of intensive staining of the plasma, erythrocytes could not always be seen in the capillaries, and they were clearly visible only when they filled the lumen of a capillary. The number of lipid granules in the interstitial cells decreased toward the apex of the papilla as the length of the animals' stay in the chamber lengthened. In the late stages no cuffs of lipid granules are observed around the capillaries, whereas large numbers of granules can still be found around the cell nuclei (Fig. 1d). After long periods in the chamber, including when the animal was immobilized before sacrifice, the content of acid mucopolysaccharides in the interstitial cells was reduced. This decrease also occurred in the direction from the outer zone to the apex. It began with a gradual loss of staining properties of the cell cytoplasm with dialyzed iron. Instead, it began to stain weakly by the PAS reaction, and the result was unaffected by testicular hyaluronidase. At the latest periods of the experiment the acid mucopolysaccharides did not disappear completely, as they did in the outer zone of the papilla. Addition of the stress factor (immobilization) had no marked effect on the content of acid mucopolysaccharides in the interstitial cells. Considerable changes in the muscular system of the papilla were observed in these experiments. The papilla in these guinea pigs was greatly shortened and rounded. The muscle tissue covering it was in a sharply contracted state, as shown by the fact that the individual muscle cells were much closer together. The surface of the papilla had a faceted pattern, and in sections it had a catenary appearance. The muscular network of Bellini's ducts also was contracted, although less so, the lumen of the ducts was rounded, and their epithelium was prismatic in character. The capillaries and vasa recta were highly tortuous (Fig. 1b).

Hence, in this moisture-loving animal (guinea pig), in contrast to rats and desert rodents, the morphologically most labile portion of the papilla is not its apex, but its outer, more proximal zone, where the osmotic gradient is lower. The reason for this is evidently evolutionary factors, demanding from the animals (or, perhaps, from their ancestors living in humid regions) economy in electrolytes, rather than the preservation of water. The inconstancy of the changes in the number and distribution of lipid granules in the interstitial tissue suggests the purely local regulatory role of this capillary-dilating agent.

LITERATURE CITED

1. A. G. Ginetsinskii, The Physiological Mechanisms of Water and Mineral Balance [in Russian], Moscow–Leningrad (1964).
2. T. L. Dubynin, Arkh. Anat., No. 9, 56 (1968).
3. T. L. Dubynin, Byull. Éksperim. Biol. i Med., No. 1, 91 (1969).
4. T. L. Dubynin, Byull. Éksperim. Biol. i Med., No. 11, 105 (1969).
5. A. D. Slonim, Special Ecologic Physiology of Mammals [in Russian], Moscow–Leningrad (1962).
6. R. B. Hickler, D. P. Lauler, C. A. Saravis, et al., Canad. Med. Ass. J., 90, 280 (1964).
7. W. Kriz et al., Am. Heart J., 78, 101 (1969).
8. L. B. Lee, R. B. Hickler, C. A. Saravis, et al., Circulat. Res., 13, 359 (1963).
9. L. B. Lee, B. G. Covino, B. H. Takman, et al., Circulat. Res., 17, 57 (1965).
10. L. B. Lee, B. G. Covino, B. H. Takman, et al., Clin. Res., 13, 310 (1965).
11. H. M. Nissen, Z. Zellforsch., 83, 76 (1967).
12. H. M. Nissen, Z. Zellforsch., 85, 483 (1968).
13. L. Osvaldo and H. Latta, Anat. Rec., 151, 396 (1965).
14. L. Osvaldo and H. Latta, J. Ultrastruct. Res., 15, 589 (1966).