HISTOLOGICAL STRUCTURES IN THE ARTERIAL SYSTEM OF THE KIDNEY REGULATING THE INTRARENAL BLOOD FLOW

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In the normal kidney in ordinary conditions only a proportion of the nephrons function constantly, and the rest are apparently in reserve and are brought into the work of the organ when an increased functional load is placed on the kidney. However, no description has been given of the histological structures in the intrarenal arteries which could shut off the glomeruli or groups of them from the circulatory system. The only reference to the possibility that such structures may exist is found in a paper by Picard [4], who found narrowing of an arteriole at the point of its origin in serial sections of the kidneys of laboratory animals.

During studies of the vascular system of the kidneys in corrosion preparations, some authors [1, 3, 5] have observed narrowing in the initial parts of the interlobular artery and the afferent vein in the kidneys of man and animals. They regarded these constrictions as indirect evidence of the mechanism regulating the blood pressure in the system of the afferent vein. Other investigators [2], however, considered that these constrictions arise as the result of an increase of pressure during injection of the contrast material, because as they showed, it is impossible to find histological structures or changes explaining this irregularity of the lumen in the arterial wall.

When studying the kidneys of healthy rats during a general lowering of the blood pressure to 50-60 mm Hg following administration of trimetaphan by the drip method for 3-8 h, at the point of origin of the afferent artery from the interlobular artery and, less frequently, at the origin of the latter from the arcuate arteries, the author found distinctive structures which he later studied in serial sections.

EXPERIMENTAL METHOD

The kidneys of rats were fixed in 10% neutral formalin in physiological saline, or in Zenker-formol, and embedded in paraffin wax. Sections, 3 μ in thickness, were cut in series of 20-30. The sections were stained with hematoxylin-eosin, with Weigert's fuchsilin, with trichrome by Masson's method, etc. In individual series, besides staining with hematoxylin-eosin, the PAS method was used.

The first nonserial sections or short series of 4-5 sections, after fixation in Zenker-formol, were stained by Bowie's method, because the original object of the investigation was to study the juxtaglomerular apparatus in prolonged hypotensive condition; the elastic tissue is well stained by this method at the same time.

EXPERIMENTAL RESULTS

It is clear from Fig. 1a, that near the point of origin of the afferent artery from the interlobular artery, a cushion-like thickening, hemispherical in shape, is visible in the wall of the latter; the internal elastic membrane at this place is interrupted and is absent at the point corresponding to the "cushion." The point of origin of the afferent vein can be seen 2-3 sections later (Fig. 1b). On both sides of the departing arteriole two valvular structures can be seen projecting into the lumen of the interlobular artery, bounding the mouth of the afferent vein on both sides. Staining by Bowie's method, however, did not reveal the more detailed histological structure of these formations. In Fig. 1c, which is not a continuation of the two previous sections, the point of origin of the afferent vein can also be seen, but the two "cusps" of the valve are closed, and the slit-like lumen of the arteriole with an erythrocyte in it can be seen in the lower part between them. In the series of sections illustrated in Fig. 2a-d, the whole structure of the formation situated near the mouth of the afferent arteriole can be clearly seen. In Fig. 2a a cushion-like structure projecting into the lumen of the interlobular artery may be defined; the internal elastic membrane is interrupted at this point, but isolated elastic fibers, the continuation of the membrane, may be seen in the superficial parts of the "cushion." Three sections later, in Fig. 2b, the point of origin of the afferent vein can be

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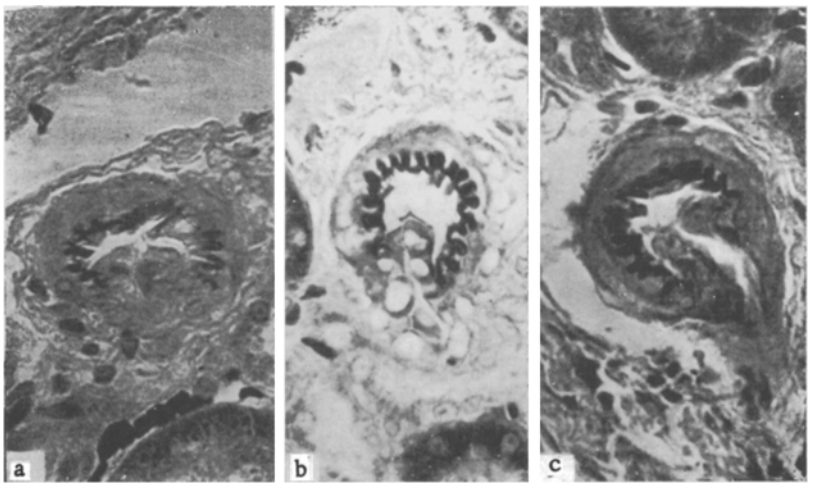

Fig. 1. Serial sections through the point of origin of the afferent artery from the interlobular. a, b, c) Sections at different levels. Bowie's stain. 500 × (explanation in text).

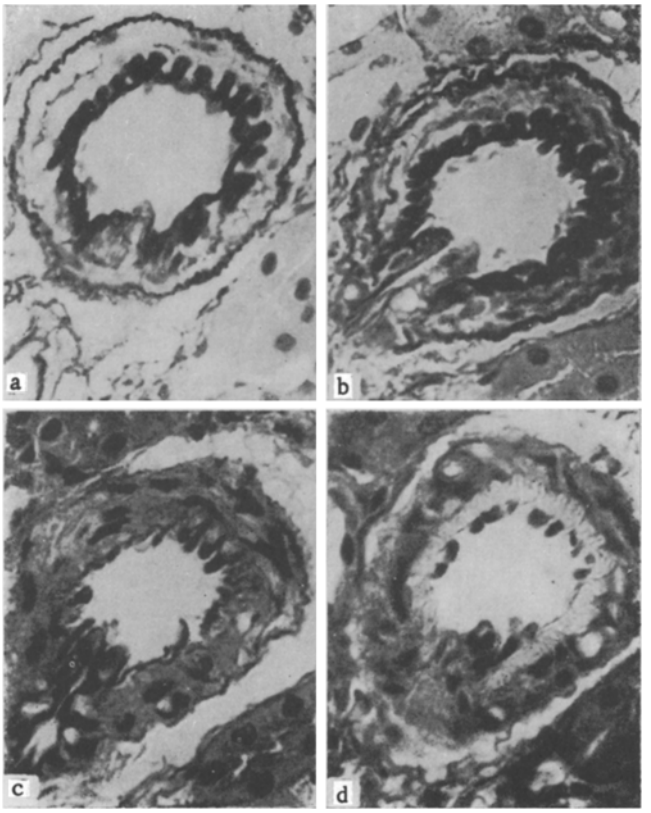

Fig. 2. Point of origin of afferent artery from the interlobular. A) Staining for elastic tissue by Masson's method; B) Weigert's stain; C, D) Masson's stain, 700 × (explanation in text).

seen: between the valves projecting into the lumen the narrow lumen of the arteriole is found. Figure 2c is the continuation of the series—the valve formations bound the mouth of the departing arteriole, their upper edges are closed, and in the thickness of the valve can be seen the nuclei of the transversely divided smooth-muscle fibers. The lumen of the afferent vein below this is slightly dilated. Finally, in Fig. 2d (the 9th serial section counting from Fig. 2a) is shown a transverse section through the interlobular artery after giving off the afferent arteriole, the

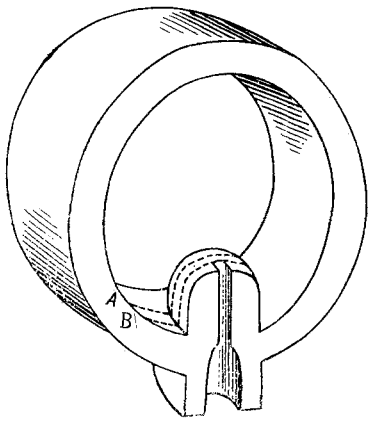

Fig. 3. Reconstruction of the point of origin of the afferent vein. Scheme (explanation in text).

lumen of which lies below and slightly to the left, outside the figure; the cusion-like thickening projecting into the lumen of the artery is again visible; the continuity of the internal elastic membrane is disturbed as in Fig. 2a.

Similar pictures were seen in other series of sections. In some series two afferent arterioles could be seen to leave the interlobular artery, and their mouths were slightly displaced relative to each other along the axis of the artery. In these cases the pictures described above were repeated regularly.

Hence, during the three-dimensional reconstruction of the pictures described above, the structure at the point of origin of the afferent vein has the appearance of a roller or press projecting into the lumen of the interlobular artery and surrounding the mouth of the afferent arteriole like a ring. Depending on the part of this ring-shaped projection through which the section passed, it appearaed sometimes as a cushion, sometimes as a valve. The elastic fibers from the internal elastic membrane entered it; single smooth-muscle fibers, arranged circularly, were also present. The picture of a cushion or valve evidently was seen when the ring-shaped press was contracted, because when the mouth of the afferent vein was open or half-open, the valves had the appearance of flat pillows.

When the valves were closed the lumen of the departing afferent vein was usually greatly constricted or absent. At the point of origin of the interlobular artery from the arcuate, similar structures were seen, but the smooth-muscle fibers in the ring-shaped press were bigger.

In Fig. 3 a schematic reconstruction is given of the point of origin of the afferent vein, based on the study of serial sections with the circular press in a contracted state. If the section passed along the line A—A, histological pictures similar to those shown in Figs. 1a, 2a, and 2d were seen, if along the line B—B, pictures similar to those in Fig. 1b and 1c, or 2b and 2c.

What is the importance of these structures? They may evidently regulate the flow of blood into individual glomeruli and may even exclude them from the circulation in normal physiological conditions. They may also play a part in regulating the secretion of renin by the juxtaglomerular cells situated in the wall of the afferent vein in the region of the hilum of the glomerulus. The function of the granular cells of the juxtaglomerular apparatus is known to be directly dependent on the pressure in the afferent vein and the tension or relaxation of the vessel wall at this point; consequently, a fall of pressure associated with closing the lumen of the afferent vein at its point of origin is stimulus for increased functional activity of the granular cells and increased secretion of renin. Finally, in pathological conditions the structures described above possibly play a role in regulating the juxtamedullary circulation described by Trueta and co-workers [7]. With the inclusion of the juxtamedullary circulation, the main mass of blood is directed through the juxtamedullary glomeruli and the venae rectae, by-passing the cortex, into the system of the renal vein. Trueta considered that this takes place either as a result of constriction of the arteries under the influence of nervous impulses or humoral factors, or by dilatation of the vessels entering the system of the juxtamedullary circulation. However, active constriction of these presses, described above, is not ruled out, and in this way the main mass of blood is deflected into the system of the juxtaglomerular vessels. It is well known that the juxtaglomerular circulation is brought into action in states connected with a sharp fall of blood pressure (shock, acute blood loss, collapse, etc.). It is possible that in these conditions the presses in the afferent arterioles are closed and the juxtaglomerular pathways of the renal circulation opened up. Exclusion of the afferent vein leads on the one hand to ischemia of the renal cortex and, on the other hand, to a decrease in tension in the vessel wall in the periglomerular portion of the afferent arteriole, where the juxtaglomerular apparatus is situated, and this in turn stimulates the secretion of renin and brings the renin-angiotensive system into play. In the kidney of most mammals the greater part of the granular cells of the juxtaglomerular apparatus are situated in the cortical glomeruli, which are excluded from the circulation in the above-mentioned conditions. Thus, closure of a large part of the afferent arterioles of the cortical glomeruli through inclusion of the renin-angiotensive system is an adaptive mechanism directed toward compensating the lowered blood pressure. It was evidently not by chance that the circular presses described above were found in conditions when the blood pressure was severely lowered by trimetaphan, i.e., in conditions of anemia of the kidneys and inclusion of the juxtamedullary circulation.

The above remarks on the possible significance of the structures discovered are purely hypothetical. This problem requires further study, both in relation to a detailed study of their fine histological structure, innervation, and topography, and also in relation to the study of their function in different physiological and pathological conditions.

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