Further Observations on the Glomerular Root of the Vertebrate Kidney

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With five Text-figures

INTRODUCTION

In the kidneys of a wide variety of animals the second convoluted tubule is applied to the root of the glomerulus of the same nephron (Text-fig. 1). Here the tubular cells are aggregated to form the macula densa. In these cells the Golgi element lies on the side of the nucleus opposite to that on which it lies in the rest of the tubule (McManus, 1943, 1944). The tubule is set into the angle between the afferent and efferent arterioles of the glomerulus (Text-fig. 2A). Rotation of the plane of section through 90° produces the appearance shown in Text-fig. 2B. The arteriolar cells in this region are known in a variety of species to possess granules in their cytoplasm.

These relationships become established at a very early stage in embryonic development. In the human foetus, and in every other embryo examined from fishes upwards, a segment of tubule applied to the glomerular root can be recognized as soon as there is a glomerulus supplied by two vessels destined to become the arterioles.

Since the last review of the structure of the glomerular root was written (McManus, 1942), not a great deal has been published about the problem of the role of the components of the glomerular or juxta-glomerular complex. Goormaghtigh (1944) has continued to present evidence suggesting an endocrine activity for the granular cells, and has recently (1945) described the hyperplasia of these cells in the so-called 'crush' kidney, that is, the human kidney after severe wounds in other parts of the body, especially of the limbs. The present communication describes further findings concerning the cytology and histology of the glomerular root.
Reticulin Patterns at the Glomerular Root

The distribution of reticulin has been studied by various modifications of Robb-Smith's (1937) method of floating paraffin sections on the solutions used. Foot's technique (1924) was used, as Robb-Smith recommends, as well as Divry's (1932) modification of Hortega's silver carbonate. The use of thinner sections made possible by this 'floating' routine has permitted the recognition of features that are obscured in thicker sections, and especially in thick frozen sections.

A complete basement membrane, on which the epithelial cells rest, surrounds each tubule and inter-tubular fibrils connect these membrane units with the vascular tree of the kidney. Further subdivisions of the reticulin fibrils have been described by Tello (quoted by Ramon-y-Cajal, 1933), and the development and age-changes have been discussed by Schwab (1939). These authors do not describe the arrangement of the reticulin at the glomerular root.

I find that there is always a gap in the reticulin at the glomerular root. Reticulin is totally absent between the tubule and vessels in the mouse, cat (Text-fig. 3), and rabbit, and there are multiple gaps in adult man (Text-fig. 4). The condition in the child closely resembles that in the mouse, cat, and rabbit. Thus the cytoplasm of the cells of the macula densa is only separated from that of the cells of the arterioles by the cell-membranes. The absence of any basement membrane at the glomerular root would facilitate exchange between these cells of the tubule and the arteriolar cells, which in this situation possess the specific granules.

The Composition of the Granules in the Cells of the Arterioles

Ruyter in 1925 described granules in the juxta-glomerular cells of the afferent arteriole in the mouse. Oberling saw them in man, Okkels in the frog, and
TEXT-FIG. 3. Part of a section of the kidney of a kitten. (Stained for reticulin.)

TEXT-FIG. 4. Part of a section of a normal human kidney. (Stained for reticulin.)
Goormaghtigh in the cat and rabbit (references in McManus, 1942). They have been studied by what are essentially mitochondrial methods, which are notoriously capricious. Although a few workers have subsequently recognized and studied them (Kaufmann, Donihue, and Candon), the methods for their demonstration have been unreliable, and there has consequently been delay in the general investigation of them.

The granules are perfectly shown in the mouse by the use of a cobalt-calcium-formalin fixative (McManus, 1946), followed by either sudan black or Masson’s trichrome stain. The mitochondria are well preserved and the method seems suitable for a new attack on the kidney. In the rabbit, unlike the mouse, postchroming is necessary and it is advisable to dehydrate in acetone. The same colouring methods are suitable. The human kidneys I have been able to study were not normal but ‘crush’ cases, in which the granular cells of the arterioles seem to be very numerous. As with the rabbit, postchroming is necessary but alcohol can be used for dehydration. Once again the granules can be shown with sudan black or Masson’s trichrome stain. The similarity of staining reactions suggests that the granules of the juxtaglomerular arteriolar cells of the various species are of similar chemical composition. Colouring by sudan black after fixation in the cobalt fixative and imbedding in paraffin shows that the granules consist (at least in part) of masked lipoid (perhaps lipine).
The Relation of the Granular Cells to the Renal Tubule

The distribution of masked lipoid in the kidney, especially in the mouse, but also in the rabbit and man, as shown by the cobalt-sudan-black technique and by later variants of the same method, presents features that would interest students of the kidney. The clearness with which the granules are shown is striking. The part of the afferent arteriole nearest the glomerulus seems to be composed entirely of these granular cells in the case of the mouse. Hardly less striking is the complete absence of masked lipoid in the macula densa. There is an equally strong contrast in this respect between the macula cells and the adjacent cells of the same tubule, which are rich in masked lipoid.

The facts suggest that something passes between the lumen of the tubule and the cells of the arteriole, and that this movement is accompanied by the movement of lipoids, which aggregate in the arteriolar cells. The direction of flow is suggested by the reversal of the Golgi element in the cells of the macula densa, for in this region—and in this region alone—the Golgi element lies on the side of the nucleus directed towards the base of the cell, that is, towards the side on which there is contact with the granular cells of the arteriole.

In a limited series of cases of chronic nephritis which have already been mentioned (in McManus, 1942), the tubules were not uncommonly found to be separated from the arterioles. I have now somewhat extended the investigation of these and similar cases, especially by studying the distribution of reticulin. The gap in the reticulin at the glomerular root appears often to be obliterated in some cases of chronic glomerulonephritis, but not in the cases of arteriosclerosis or malignant hypertension (Text-fig. 5) which were studied.

Summary

There is a gap in the reticulin at the glomerular root of the mammalian kidney. This gap leaves the macular segment of the second convoluted tubule in intimate contact with the arteriolar cells, which in this region contain granules consisting of or containing masked lipoid. Methods are given for the demonstration of these granules in the mouse, rabbit, and man.

The cells of the macula densa of the mouse are poor in lipoid, and there is thus a striking contrast both with the adjoining cells of the same tubule and with the adjacent arteriolar cells.
REFERENCES

——— 1946. J. Path. and Bact., 58, 93.

The original reticulin studies were done at a Canadian General Hospital, Canadian Army (England).