

ON SOME POINTS  
IN THE  
MINUTE ANATOMY OF THE KIDNEY,  
AND  
THEIR RELATION TO THE PATHOLOGICAL  
PHENOMENON OF TUBULAR CASTS.

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SOME few years ago a fresh interest was awakened in the kidney by the announcement of the discovery of two sets of tubes in those bundles of straight tubes which compose the substance of the medullary rays of the kidney.

Observers were agreed in acknowledging the existence of these two kinds of tubes, termed from their respective courses, ascending and down-looping tubes, but the connection of the one set with the other remained a disputed matter, and Henle, to whose original investigations their discovery was due, believed them to form separate systems of channels, the one occupied, like closed gland tubes, in secreting the materials, which, after transudation through two sets of tube walls, the other set collected and discharged.

My own observations, although made many years since,

inclined me to believe that the tubes formed one continuous system, and this belief was based upon examination of fragments of urine tubes, which although obviously forming one continuous channel, differed very distinctly in diameter, calibre, and characters in different parts.

My observations were made upon the kidney of the ox, the sheep, the pig, the rabbit, and that of man; and some microscopical preparations of my own are on the table, to substantiate my views, and also to render the scheme of the real anatomical arrangement of the urine tubes easily intelligible to any one.

*Mode of Commencement and Course of:—The Tubuli Uriniferi.* To commence from below upwards. The papillary ends of the medullary cones are studded with from ten to thirty oval orifices, these open into short trunks, which, instead of mounting perpendicularly upwards, run as offshoots, or runners, at very obtuse angles from the original trunks. The short trunks, and their first angular bends, possess no *membrana propria*; the channels are simply grooved passages in the fibrous connective tissue forming the matrix of the papillæ; they measure from 0.198 to 0.099 mm. in diameter.

This arrangement offers mechanical resistance to regurgitation of fluids accumulated in the renal pelvis. The angular mains quickly divide into three or four mounting stems, and these shortly split up again into the ascending or collecting tubes proper; tubes of the third order as described by the minute anatomist.

These ascending tubes are the first which can be distinctly made out to possess a *membrana propria*; they are lined with a low sessile columnar epithelium, consisting of pale cubical cells, streaked with indistinct markings, and possessed of nearly central nuclei. The epithelium does not nearly fill up the bore of the tubes, which therefore exhibit large lumina or bores.

These ascending or collecting tubes of the third order are large tubes, and measure about 0.051 to 0.0501 mm. in diameter, at a point about 2 lines off the apex of a papilla.

They are well shown in all works which describe the minute anatomy of the kidney, and form the principal bulk of the medullary rays.

At a level some 2 lines higher as they mount towards the cortex, or, at what is called by the anatomists the cortical margin of the medullary ray, these collecting tubes, hitherto all bundled together, begin to split into branches of nearly equal size, 0.018 to 0.02, and they continue running up in bundles of three or five together; the space between the bundles being occupied by tubes presenting different characters, the down-looping tubes of Henle, which are transparent, and at parts much narrower tubes, measuring about one third their diameter, only 0.0099 mm. They are well shown in Fig. 1, made from a microscopic section cut longitudinally at the margino-medullary level.

I wish to direct attention next to the number of the down-looping tubes (well shown in Fig. 2), this drawing is made from a carmine stained specimen of great beauty. The excretory tubes, were so far washed clean of their epithelium that the down-loopers, which in this part possess no distinct epithelial linings, become apparent, and the nuclei of their endothelium afterwards stained with carmine, brought their number and arrangement into distinct relief, as also their far greater predominance at the upper or high levels of the medullary rays or cortical side of the pyramids. (It was the difficulty of throwing coloured injections so far as these down-looping tubes, which militated, in the first instance, against their discovery, and the likeness of their epithelial linings to that of blood-vessels which prevented their being recognised for what they really are, namely, continuations of urine tubes.)

Tracing the collecting tubes in their upward course, after they have entered the so-called cortical portion, in which bundles of straight and tortuous tubes alternate with each other, the collecting tubes can be seen to turn over at various different levels into the tortuous tube columns, and to become tortuous tubes, suffering two substantial changes at the same time. 1st. An alteration in calibre, for they

attain suddenly the full size of tortuous tubes proper, averaging 0.0201 in diameter; and, 2ndly, a marked difference in the characters of their cellular contents, which are far less distinctly differentiated, the individual cells being larger, more irregular shaped, and appearing nearly to fill the urine tube with finely granular cubical cells; these cubical gland-cells are admirably shown in Figs 3 and 4.

No drawing from a microscopic section will take in the whole course of an ascending collecting tube, through its first sudden tortuous enlargement, and its final gradual tapering with a down-looping prolongation, but several sections and preparations in my possession, of which I invite inspection, enable any one to follow single tubes up and down, passing into and becoming down-loopers. Figs. 3 and 4 are drawn from sections prepared by Mr. Pye, and most faithfully represent the facts of the case.

It is, however, only for a very short space that these now tortuous tubes maintain their tortuous characters, for they turn back into the straight tube bundles, and run down, as previously noticed, between the collecting tubes, as the fine transparent down-loopers, which are seen to be lined with flattened pavement epithelium, surmounted at pretty regular intervals by slightly projecting nuclei, and, indeed, resembling capillaries very closely both in size and endothelium.

The passage of such a tortuous into a straight down-looping tube is shown in Figs 3 and 4. Fig. 4 delineating the excretory or collecting tube end, and Fig. 3 the secretory or glandular tube end. As these narrow tubes retrace their passage upwards, they increase, not suddenly but gradually, in size, like carrot roots, presenting at first a distinctly imbricated columnar epithelium, then curling over again at different levels into the tortuous tube columns, and finally becoming lost as tortuous tubes proper, being filled throughout their interiors, as these always appear to be, with granular, glandular cells; each tube terminates, after many turns and windings, by a somewhat sudden, narrow neck and flask-like dilatation, which embraces a Malpighian tuft.

The tortuous tubes measure in diameter upon an average 0.0201 mm., but they vary, not inconsiderably, in size at their turns, as may be observed in fragments of them prepared by cooking in hydrochloric acid. Their main feature is the thickness and apparent solidity of their walls, and its dimly nebular aspect.

Put up as microscopical specimens it may be surmised that we see them under conditions very different to those which they present as fresh objects, derived from the perfectly fresh kidney; no bore or patent passage is then apparent in them, except when an injection fluid forced up into them discovers itself by irregular stellate figurings, marking the chinks between opposed walls, or separations between masses of granular protoplasm, in which apparently free nuclei lie imbedded.

We read in Stricker, p. 93, "That the basement, or limiting membrane, of these tubes is as clear as glass, and the degree in which the epithelial mass fills the bore of the canal, depends upon the state of the kidney at the time of death, and its mode of treatment afterwards." With this description my own original observations accord entirely.

If this account of the anatomical course of the tubuli uriniferi be accepted as correct, certain obvious inferences follow. From the size of the tubal canal at different parts of its course: nothing larger than nuclei, blood-cells, or leucocytes, could pass down from the tortuous or glandular part of the tubuli through the down-looping prolongations, so as to reach the straight collecting tubes. A cast shed from a tortuous tube, could only under circumstances of long-continued pressure *à tergo*, and extreme dilatation of the down-looping canals, reach the collecting or excretory uriniferous channels.

As a matter of fact there is no such cell lining attached to the basement walls of the upper portion, the secreting portion, of the tortuous tubes, as belongs to the lower excretory or collecting canals. By examining the Figs. 3 and 4, it must be obvious that, unless the drawing is out of scale, a single gland cell in its ordinary shape, as seen in normal

states of the glandular portions of tortuous tubes, could not squeeze itself through the channel of a down-looper. When, therefore, a cast is assumed to be derived from the profounder tissues of the kidney, and to have a relatively graver importance attaching to it, because cells are seen in its interior, an error is committed, based on ignorance of the minute anatomy of the organ.

Finely granular plasma containing fatty dottings, oil globules, and nuclei, are the derivatives and detritus which can fairly be referred to the upper portions of the tortuous tubes; since these can be often seen lodged *in situ* in their interiors in sections of kidney advanced in acute or chronic degeneration, and can without much doubt be gradually extruded so as to reach down into the lower channels, and washed from out of these; but the large gland cells massed together as desquamative casts, could not pass the narrow passage, and the synonym, desquamative nephritis, is a term which I must enter my humble protest against.

Anything resembling the epithelial lining of the large, straight, or collecting tubes shed in their entirety, akin to the desquamation of the cuticle after scarlet fever, it has never been my lot to witness, nor do the pathological appearances of the kidneys, in those who die of this acute nephritis, lend any confirmation to the hypothesis that the excretory channels are then denuded of epithelial contents. They are not found empty or collapsed, but largely swollen and blocked up. The straight collecting tubes, however, are seen oftentimes in chronic nephritis plugged or blocked with materials, which entirely correspond to those discovered in the sediment of the urine during life, and which are derived from the upper secreting gland structures.

The actual cubical columnar epithelium cells, which line the tubuli in various parts, I never yet saw in recognisable character in any renal cast; the formed objects which pass for renal cells with the ignorant, are red or white blood-cells or escaped nuclei.

Desquamative nephritis, in the sense of any desquamation of the epithelium, which, in healthy kidneys, certainly lines

the collecting and straight tubes, as a process at all, akin to the peeling of the skin which succeeds the slight serous effusion beneath the horny layer of the epidermis in the scarlatinal efflorescence, does not exist.

Our present better knowledge of the minute anatomy of the kidney, enables us to offer a less crude pathological solution of the mode of cast formations than was offered heretofore; when the assumption of some writers was, that renal inflammation led first to the shedding of the tubal epithelium, and secondly to the transudation of blood serum as a consequence of this denudation of the tubes.

Axel Key, the Swedish Professor, whose opinion upon casts and their formation is entitled to some weight, for his patient investigations into the anatomy and pathology of the kidney are known throughout Europe, allows that certain casts originate in the degeneration of renal epithelium; these elements melting down into masses more or less homogeneous or granular, but preserving no outline of their original cell forms. Certain other casts, he believes, are perverted or abnormal secretions derived from disordered functioning of the secreting cells. To these we may fairly add a third form, which consists of blood fibrine entangling more or less blood elements. For clinical purposes I should distinguish these three varieties only, calling them granular, waxy, and blood plasma casts respectively.

Casts occur in every form of renal disease in which albumen appears in the urine, although their quantity is no indicant either of the amount of albumen, or of the amount of renal degeneration.

The first value attached to the presence of casts, and to the characters of casts, by those who busied themselves most with renal disease, was very high, too high perhaps. It was supposed that being derived from the minute kidney structures, they would tell an accurate tale of the processes of disease taking place in those structures, according to their numbers and other special features.

Before even the minute anatomy of the organ, or the intricate course of the tubuli uriniferi was established, it

was pretty generally accepted that the larger casts, and those which presented most distinct cellular elements in their interiors, were derived direct from the large tortuous tubules. Still, experience taught that these large casts, with leucocytes in them, were of not very serious omen. They were furnished in greatest abundance in the re-establishment of the urinary secretion after temporary suppression in acute nephritis.

In point of fact these large casts correspond in size entirely with the diameter of the excretory canals and straight collecting tubes measuring about 0.05 mm. in diameter, and are no doubt formed in and derived wholly from them. Furthermore, they may be seen *in situ* in many pathological specimens of which I exhibit examples. The observation has been so repeatedly made that illustrative drawings are deemed unnecessary.

The next fact, clinically well ascertained, was the grave import of granular, waxy, and fat-dotted casts, as signifying changes of a chronic nature in the secretory portions of the organ. These casts too, though usually more fragmentary than those previously described, still ranged in size only from 0.01 to 0.05 mm. in diameter. Yet they were supposed to be derived from the tortuous tubes, and, indirectly, no doubt they were. But it is a different thing to be derived from a part, and to be moulded in that part. The cells which block up a tortuous tube could no more pass through a down-looper without altering their shape, than a camel could squeeze itself through the eye of a needle.

Casts are very properly thus entitled, not because the materials which compose them are necessarily cast off from some portion of the urine tubes, but because they are cast in the moulds of tubes, and form solid cylinders. One of the conditions required for their formation is the transudation of the blood plasma into the tubuli, a second is an altered state of nutrition in the renal epithelium, a third the retention of this secretion, thus abnormal, for a certain period, how long we do not know, *in situ*, in one of the collecting tube channels.

The largest casts are those found in the urine after the



suppression which succeeds the algide stage of cholera. These casts are most likely moulded in the large gathering mains near the papillary orifices.

The medium sized casts, although varying much in colour and other characters, according to the nature and duration of the renal disease, in which they are furnished, are probably all moulded in the straight collecting tubes or ascending branches of the third order.

The smallest, finest, most wavy and hyaline, so-called fibrinous casts, are probably chiefly moulded in Henle's down-looping canals.

The formation and excretion of casts are by no means simultaneous events. The more opaque, the more granular, the more dotted with delicate fat globules, they are, the longer probably has been their sojourn in the spot where they were moulded, and the greater their saturation with urinary salts; whereas, contrariwise, the finer and sharper their outline, as well as that of the cell forms entangled in them, and the more transparent their bodies, the more likely are they to have been quickly swept out of the passages in which they were formed.

The gravest forms of renal degeneration are only now and then attended by the extrusion of casts. The pale urine of low specific gravity, and very varying albumen contents, which betokens with such certainty the small cirrhotic kidney, furnishes us with few, and seldom very conclusive, forms of casts. The study of the minute anatomy of the kidneys forbids us now to expect that casts could reflect the amount of degeneration which has taken place in the upper portions or tortuous prolongations of the renal tubes, although indicating, as they certainly do, its nature. Their presence (the presence of casts) in the urine sediment only shows that the entire system of excretory tube channels is not flushed down by urinary fluid with the regularity that belongs to the secreting functions of healthy organs; and that an abnormal secretion, abiding for a longer time than it ought to, in channels, where certain conditions of heat are maintained, has gelatinized within these canals and blocked them.

Microscopic specimens in my possession give examples of granular plugging in the collecting tubes, and huge dilatation of the tortuous tubes above them, a very common event in chronic parenchymatous nephritis. The kidney some were taken from belonged to a young woman who died of this form of renal disease in the stage of advanced secondary contraction. I had carefully watched her case over a period of five years, during which she was repeatedly under my care in St. Bartholomew's Hospital.

Lastly, I will call attention to a fact of considerable interest, and which I possess specimens to illustrate, namely, the manner in which Henle's down-looping tubes, or what I shall now call communicating loops, resist fatty degeneration, and although small themselves in calibre seldom become plugged up with epithelial débris or proper fatty degeneration. They lie, as is well known, in the vascular area surrounded by the vasa recta, their nutrition is therefore provided for amply, although the tortuous tubes above them have been starved of their nutritional supplies, through parenchymatous swelling or degeneration of the Malpighian bodies. Such pluggings as we occasionally do see *in situ*, in the down-looping tubes, are generally fibrinous blood casts, and strictly of a nature which the situation of the tubes themselves would render most probable.

I must ask pardon, however, for having trespassed thus far upon the patience of the Society, and occupied its time so long with a matter of microscopical anatomy so minute. My excuse is, that the pathology of renal disease is, although much written about, and fairly well understood in its later and advanced stages, very imperfectly known, and extremely difficult to study *ab initio*.

The circulation of the blood through the kidney is a very complex matter. The intimate relation of the vasa recta or tertiary capillarisation, to Henle's looping tubes is a subject which has not received the attention which it appears to me to deserve. These looping tubes, so far as I have been able to prosecute the investigation, exist only in those classes of the animal kingdom which excrete urinary water,

their total absence, as well as that of the vasa recta in the kidneys of serpents, lends confirmation to an opinion expressed and published by me so long ago as 1865, in an article communicated to the first volume of 'St. Bartholomew's Hospital Reports,' that the down-looping tubes and vasa recta probably form the apparatus which is most instrumental in the secretion of urinary water.

If the description of the minute anatomy which I have detailed here be correct, and it is, I believe, now pretty generally accepted. It will be obvious that midway canals of smallest calibre are interposed between the secretory or tortuous, and the excretory or straight tubes. If casts or plugs collect in the tortuous tubes, their passage onwards and outwards must be slow and laborious, and to be effected only through some gradual dilatation of the narrow looping passages. Further, such casts by distending the down-looping tubes upon their passage outwards must seriously disturb or obstruct the circulation through the vasa recta.

It is only fragmentary débris and fatty globules, however, which I believe travel down from the tortuous into the excretory tubes; and I may add that even in advanced renal disease, it is remarkable how free from plugging and degeneration these down-loopers usually remain, a circumstance which could scarcely happen if much solid material ever passed through them, or except a strong current of fluid set through the walls of the capillaries by exosmosis towards the down-loopers and swept through their canals. All casts found in urine sediments derive their form from the excretory system of urine tubes. The chemistry of their substance may be vaguely described as "some colloid." Two qualities of colloid may, however, for clinical purposes be distinguished, the one derived from the upper glandular portions of the renal tubes, an abnormal secretion from its glandular cells, giving a yellow, waxy look, and highly refracting features to the cylinders formed of it; the other a fibrino or albumino-plastic colloid, essentially whiter and more transparent than the former, derived from the setting of blood plasma which has

transuded into the tubuli from the blood-vessels at a lower part of their course.

Several sub-forms or varieties of casts may be further differentiated, because different clinical significance or importance attaches to them. The more distinctly formed cell elements I perceive entangled in cast moulds, the more certainly I infer congestive blood pressure in that portion of the kidney structure, which the ground colour of the cast points out as its probable source. I cannot pretend to be able to state that a particular cell form seen in a cast has been derived from a tortuous or an excretory tube. The cell forms I can recognise are always leucocytes, white or red blood-cells. Hyaline cylinder casts, from their form and size, are pretty certainly derived direct from the down-looping tubes, and appoint obstructed circulation through the Malpighian bodies, and tortuous tubes with blood flux through the vasa recta. Lastly, the more granular a cast is, the longer generally may it be assumed to have resided in its matrix mould, and the more dotted with fat globules casts are, the more certainly do they appoint permanent obstruction to the circulation through those portions of the kidney from which the colloids which form them were derived, and permanent damage, not to the tubes only, but to the capillaries and interstitial structures of the kidney.

It is not, I believe, until some obstruction to the circulation through considerable areas exists, or until this obstruction has been maintained for some little time, that the necrosis of elements implied by fatty degeneration can take place.

To estimate the nature and extent of renal disease by the form and aspect of one or two tube casts, would be to guess in a very blind haphazard manner. Fatty casts are always ill-omened things to find; but even here the room for error in those who make their inferences from casts alone is not inconsiderable. Under such circumstances the only safe guide to a prognosis is to ascertain the functioning capacity of the remaining renal structures by estimating the amount of urea excreted per diem, and the strain of blood pressure

thrown upon the still permeable blood channels, by the diurnal amount of albumen that is being lost. Experience teaches me that it is not so much the drain of albumen which wears out the machine, as it is the blood strain, which that amount of albumen signifies, and which by induced secondary interstitial changes, slowly but surely abrogates the renal functions, and brings about the complex of secondary phenomena attendant upon deficient urinary depuration.

## DESCRIPTION OF PLATE XIII.

Minute Anatomy of the Kidney. (Dr. Reg. Southey.)

Fig. 1. Drawn from a microscopic section.  $\times 100$  diameters.

- A. Ascending collecting urine tubes.
- B. Henle's down-looping tubes.
- C. Capillary blood-vessels.

FIG. 2. Microscopical specimen shown with a low power, illustrating the number and arrangement of the down-looping tubes.

FIG. 3 A. Tortuous tube derived from a Malpighian body, tapering to join the ascending loop. *i*. Imbricated columnar epithelium.

FIG. 4 B. Tortuous tube derived from the tortuous portion of a collecting tube, suddenly narrowing into a down-looper. *C*. Cubical gland cells, with nuclei. *E*. Flattened elongated cells, with projecting nuclei of down loopers.

