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Routes of Absorption in Hydronephrosis: Experimentation with Dyes in the Totally Obstructed Ureter.[1]

By DUNCAN M. MORISON, F.R.C.S.Ed.

ABSTRACT.—In hydronephrosis the contents of the renal pelvis are constantly being changed. The exact mode of the interchange is still obscure. With the hope of obtaining some evidence of this absorption, a series of experiments has been carried out, introducing dyes at various periods in total hydronephrosis.

The findings of previous experimental work on the subject are conflicting. Two views are held; one, that absorption occurs solely through the tubular system, and the other, that there is a direct outflow from the renal pelvis into the venous system.

In the present work only such an amount of dye was introduced in each instance as to be well within the pelvic capacity of the type of kidney (rabbit). The factor of positive pressure forcing the dye into abnormal channels was thus reduced to a minimum.

Two groups of experiments were undertaken. In Group I, the dye was introduced at the outset of the hydronephrosis, and in Group II the dye was introduced at varying periods in the course of an established hydronephrosis.

The results obtained would indicate that in total hydronephrosis there are two routes of absorption from the renal pelvis, i.e., lymphatic and tubular. At the outset of complete ureteral obstruction there ensues for the first two or three days an active lymphatic absorption from the walls of the renal pelvis and ureter. After about the third day, tubular absorption commences and continues more actively than the lymphatic. If, however, dye is not introduced till the third day of a hydronephrosis, there is rapid tubular absorption but no lymphatic absorption. With longer periods of hydronephrosis the dye is drawn up the tubule system as far as the convoluted tubules. The further absorption of dye into the general system has not yet been obtained.

It is known that in hydronephrosis[2] the contents of the renal pelvis are constantly being changed. The exact mode of the interchange is as yet not apparent. To permit of a continuation of renal secretion, even though that secretion is admittedly progressively modified, there must be some process of reabsorption going on from the totally obstructed sac of the renal pelvis. With the hope of obtaining some evidence of this reabsorption, a series of experiments has been carried out, introducing dyes at various periods in hydronephrosis.

The findings of previous experimental work on the routes of reabsorption in total or closed hydronephrosis are conflicting. Burns and Swartz, working on dogs, were able "to demonstrate conclusively that a path of absorption is by way of the tubules and through the glomeruli into the blood-stream." Hinman and Lee Brown claim that the route is not through the tubules, but by fine venules directly into the venous system. This mechanism they term "pyelovenous backflow." Bird and Moise have more recently obtained results which do not, in their opinion, support the idea of "pyelovenous backflow.

In the work that has been done, the factor of "pelvic capacity" appears to have received little attention. Dye media have been injected into the renal pelvis in amounts far in excess of the total capacity of the respective type of kidney, and at pressures fully capable of producing trauma and forcing the dye into abnormal channels. Further, results drawn from autopsy material cannot correctly be compared with those derived from investigations on the living animal. To try and obviate these apparent discrepancies in the present work and to simulate more closely the natural process, only such an amount of dye was introduced in each instance as to be well

1 From the Department of Surgical Research, University of Edinburgh.

2 For convenience and simplicity, the term hydronephrosis is used to embrace the condition, from the induction of complete ureteral obstruction onwards.

within the pelvic capacity of that kidney. It was decided to observe the effects of dye reabsorption in two separate groups of experiments, the dye being introduced in Group I at the outset of a hydronephrosis and in Group II at varying periods in the course of an established hydronephrosis.

Experimental Procedure.

Animals employed.—Eighty-two rabbits, two dogs.

Dyes used.—Berlin blue, 2 per cent. in normal salt solution; collosal argentum, 1 per cent.; india ink (Pelican), 5 per cent. to 50 per cent. in normal salt solution.

Operation.—Throughout the series the lower end of the left ureter was selected as the site of total obstruction. Access was gained by a mid-line suprapubic incision.

In *Group I* dye was introduced into the renal pelvis through a fine ureteral catheter (No. 4 Ch.) passed up from the lower end of the ureter.

On withdrawal of the catheter the ureter was ligated, care being taken to prevent any spilling of the dye. The usual amount of dye introduced was 0·4 c.c. The rabbits averaged from $3\frac{1}{2}$ to $4\frac{1}{2}$ lb. in weight.

In *Group II* the lower end of the ureter had previously been ligated and left for a varying period. The contents of the renal pelvis were aspirated, the amount measured, then half that quantity in dye introduced, the ureter being again ligated with the usual precautions.

The procedure thus aimed at having the dye lying passively in the renal pelvis, and obviating, as far as possible, the factor of positive pressure forcing it into abnormal channels.

In *Group I* the process of dye absorption was observed after periods varying from thirty minutes to hours, days and weeks.

In *Group II* observations were made from a period of thirty minutes' hydronephrosis, followed by thirty minutes with dye, to equal periods of each, ranging from hours to days and weeks. Several series were also carried through of unequal periods of each, i.e., 1 day hydronephrosis, with 2, 3, 4, etc., days of dye; 1, 2, 3, etc., weeks of hydronephrosis, with 1, 2, 3, etc., days of dye.

At the conclusion of a prescribed time the animal was killed and the right kidney, spleen, and portion of the liver removed and fixed *in situ*. The left kidney and ureter were left *in situ* and subjected to Jore's fixing solution, usually for twenty-four hours, before being carefully resected and submitted for a further fixing. The ureter was then divided at the pelvo-ureteral junction, longitudinally incised, and pinned out for clearing. Thick, serial frozen sections were taken of the left kidney and cleared. Ordinary paraffin sections were made of the right kidney, liver and spleen. These were stained with eosin only. The superficial layer of the posterior abdominal wall was also removed and cleared for the purpose of studying the lymphatics.

Findings.

Group I.—Dye introduced simultaneously with the production of hydronephrosis.—In this group of experiments, the first evidence of dye absorption is by the lymphatics of the renal pelvis and ureter. It commences early (in one instance within thirty minutes) and continues as the sole route of absorption for about three to four days. In the renal pelvis the primary site of absorption, is at the angle where the walls of the calyx margin fuse with the expanded base of the pyramid. Later, the walls of the pelvis, as far as the pelvo-ureteral junction, show definite presence of dye. The walls of the ureter show patchy dye absorption at first in the lower portions and later in the upper third. There is a zone, roughly corresponding to the junction of the upper and middle thirds of the ureter, which rarely shows any trace of dye. From about the third day onwards, in addition to this lymphatic absorption, dye may be noted ascending the main collecting tubules at the papilla, and ultimately reaching

the convoluted tubules in the cortex corticis. This degree of tubular absorption has been observed before the seventh day. From the walls of the renal pelvis and upper portion of the ureter, the particles of dye are apparently conveyed by lymphatic channels, which pass posterior to the renal vein, and deposited in an elongated gland lying just below the union of the vein to the inferior vena cava.

In this group accordingly, the outstanding feature is the initial active rôle played by the lymphatics of the ureter and renal pelvis, followed later by the renal tubules. As the hydronephrosis progresses the contained dye would appear to be more actively absorbed by the tubules.

Group II.—Hydronephrosis established previous to the introduction of dye.—With a hydronephrosis of three days' duration and dye for one day, no evidence of any lymphatic absorption could be found. There was, however, a marked dye absorption up the collecting tubule system and into the secondary convoluted tubules situated in the cortex corticis. The tubule systems continue the absortion and after about the fourth day are accompanied by a slight degree of lymphatic absorption in the lower portions of the ureter. As periods lengthen the lymphatics appear to become as active as the tubules.

The findings in this group suggest that even a short period of pre-existing back pressure favours rapid tubular absorption, and that the lymphatics play a late and secondary rôle.

Both groups of experiments show that there are two main routes of absorption from the totally obstructed renal pelvis, i.e., lymphatic, and tubular.

Lymphatic Routes.

Renal Pelvis.—As evidenced by the presence of dye particles, the pelvic epithelium presents numerous intercellular spaces which connect by fine channels to a deeper system in the muscular coats and adventitia ; this in turn becomes segregated into larger vessels which accompany the interlobar veins and, passing along behind the main renal vein, communicate with the lumbar glands. As previously stated, the most active lymphatic absorption occurs at the angle where the walls of the calyx margin fuse with the expanded base of the pyramid.

Ureter.—Since the lower end of the ureter was ligatured in all the experiments, the route of lymphatic flow in the lower third of the ureter could not be determined. There was usually a patchy area of dye absorption in the lower middle third zone. In this area the dye particles appeared to lie for the most part in fine channels running at right angles to the long axis of the ureter. Although no definite channels could be seen, it is possible that the lymphatic plexus draining this segment of the ureter, passes into channels which accompany the ureteric branches of the ovarian or spermatic vessels to reach the lumbar glands. In the upper third, the patches of dye absorption appeared to connect up with vessels running towards the renal pelvis.

Tubular Route.

It is to be noted that in all the experiments performed, no dye entered the tubule system till after a preliminary period of back pressure had been established. Once, however, this factor was present, the dye appeared to rapidly ascend the collecting tubules and reach the convoluted tubule systems situated in the cortex corticis. In the earlier phases of hydronephrosis it is interesting to note that the convoluted tubules which take up the dye, are those associated with the most peripheral layer of glomeruli in the cortex. As the condition advances, dye is observed in the tubule systems of the more deeply situated glomeruli. The extent to which dye reaches within the tubules is variable. The secondary convoluted portion is that which presents usually the most copious dye absorption. Occasionally the loops of Henlé are clearly defined. The primary convoluted tubules are difficult to differentiate, but may in some instances show absorption. No obvious dye particles have been

seen in Bowman's capsule. Paraffin sections show dye not only within the lumina, but also lying in and between the cells of the convoluted tubules.

The process of dye absorption is not evenly distributed throughout the kidney. Groups of tubule systems here and there appear to be picked out leaving others completely free of dye. Contrary to the findings of previous writers, no marked predilection for the poles of the kidney has been noted.

With the exception of two instances which will be referred to later, no definite evidence of a further absorption into the systemic system was observed, despite careful inspection of the sections taken from the liver, spleen, and right kidney of the animals used throughout Groups I and II. In many instances dark granules of a yellowish colour were seen in the liver, and spleen. These occurred even when india ink was used as the dye medium. It may be possible that they represent the dye in an altered form. It is difficult, however, to account for any change in the case of carbon particles.

The two exceptions above-mentioned occurred when the pelvic capacity had been inadvertently over-estimated, and a slight excess of dye introduced. In both instances, extravasation occurred from the renal pelvis at the angle where the walls of the calyx margin fuse with the expanded base of the pyramid, and are in intimate association with the interlobar vessels. From this site, the dye had invaded the venous system, and was disseminated. The liver, spleen, and opposite kidney in both cases showed obvious presence of dye. These two accidents apparently illustrate the condition described by Hinman and Lee Brown as "pyelovenous backflow."

Throughout the investigation, the sequence of the changes observed, in each group of experiments, remained practically constant. The rate and degree with which the changes occurred showed, however, marked variation in some instances. In setting down these observations, accordingly, an average has been deduced regarding the time factor. In several of the experiments conducted under Group I the findings tended to resemble those usually obtained in Group II. The explanation which offers itself is that in these animals a mild degree of back pressure may have already existed at the time of operation.

Discussion.

Throughout the present investigation care was taken to obviate, as far as possible, the factor of positive pressure forcing the dye into any abnormal channels. The action of the lymphatics can be readily appreciated, but the part taken by the tubular system is difficult of explanation. Why is there an initial period of delay before the dye begins to ascend the tubules? Is it due to some natural valve-like action at the tip of the renal papilla? Longitudinal sections of the normal rabbit's kidney show that the epithelium covering the sides of the pyramid is cuboidal in type, and arranged in a single layer. As the tip of the papilla is approached this layer becomes elaborated, till around the mouths of the papillary ducts it is fully 5 to 8 cells in depth, and papillary in type. With sudden raising of the intrapelvic pressure as produced by total ureteral obstruction, it may be that this redundant epithelial layer becomes sufficiently compressed so as to lie in apposition over the papillary duct channels, and thus prevent any regurgitation of the pelvic contents. With continued pelvic distention, there is a radial and outward pull on the papilla which would tend to stretch the epithelial layer and remove its obstructing influence from the mouths of the papillary ducts, thus allowing a patent communication with the pelvic contents. Should the initial delay be accounted for by some such mechanism, there yet remains an explanation regarding the ascent of the dye into the renal tubules. Despite the fact that a certain amount of urinary secretion continues to pass down the collecting tubules, yet the dye apparently passes up against stream. Considering the greatly modified process in hydronephrosis, it is obvious that the rate of secretion must be extremely slow. Further, to allow of fluid entering a closed sac which is already full, some of the existing contents

must be removed to make room. It is apparently during this gradual process of compensatory withdrawal that the suspended dye particles are carried up the lumen of the tubules. In the mechanism of renal secretion, the inference is gaining ground that the action of the convoluted tubules as well as of the loops of Henlé, is to reabsorb much of the filtrate issuing from the glomeruli. Should a given glomerulus be so embarrassed as to be unable to furnish its usual quantity of filtrate, then its own tubule system, still capable of good absorption activity, would be left with a margin of absorptive power. It is conceivable that this margin of absorptive power could draw fluids from associated portions of the tubule system, i.e. collecting tubules, especially if a state of fluid continuity existed in the lumen of the system.

In hydronephrosis, it has been shown that the peripheral layer of glomeruli is the first to suffer from pressure atrophy. In consequence the amount of filtrate coming from these glomeruli is progressively lessened, and if their associated tubules are still actively functioning they must be continuing to absorb. As in hydronephrosis the condition is one of fluid continuity throughout the lumen of the renal pelvis and the subdivisions of the tubular system, one would expect that if any absorption were occurring it would be by the tubules of the embarrassed glomeruli. By introducing fine granular dyes into the contents of the renal pelvis, suggestive evidence has been obtained that it is this acquired altered absorption exerted by the peripheral layer of tubules which steadily draws the dye from the pelvis, up the collecting tubules, and into the cells of the convoluted tubules. With advancing periods of hydronephrosis, and pressure atrophy proceeding from the periphery inwards, one finds that this action is taken up by the successive layers of convoluted tubules.

Conclusions.

From the foregoing study it would appear that in total hydronephrosis there are two routes of absorption from the renal pelvis, the lymphatic and the tubular. At the outset of complete ureteral obstruction, there ensues for the first two or three days, a purely lymphatic absorption from the walls of the renal pelvis and ureter. After about the third day, tubular absorption commences and continues more actively than the lymphatic. The convoluted tubules of the most peripheral glomeruli are the first to take on this function, and as pressure atrophy progressively supervenes, the more subjacent layers continue the process of reabsorption. In thus absorbing dye media, the cells of the convoluted tubules may be demonstrating a slightly altered normal function. If so, their action would tend to favour the "filtration and reabsorption" theory of renal secretion.

The routes from this absorption into the general system have not yet been identified.

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Discussion.—Mr. J. Swift Joly (President) said that in this interesting and important paper the author had gone far beyond the consideration of mere hydronephrosis; he had gone into fundamental principles, and had traversed what could be regarded as a great part of renal pathology.

Mr. F. G. Jeans asked Mr. Morison what was his explanation of the anuria, following sudden relief of bladder tension, in cases of enlarged prostate.

Mr. Winsbury White said that he had been greatly interested to see these convincing details of the experimental evidence that a re-absorption took place by way of the tubules. A good deal of clinical evidence suggested that some absorption went on. He had no recollection of a case of hydronephrosis, with a long history, in which there had not been some very definite signs of ill-health. That, he assumed, was due to re-absorption, and the

experimental evidence now adduced seemed to bear out his assumption. Again, if one examined microscopically the renal parenchyma of old-standing cases of hydronephrosis, there was always to be found this marked dilatation of the tubules.

Another point in which he was much interested was the site of junction of the base of the pyramid with the renal calyx. It would be remembered that there was a venous plexus there, and that was the site at which, according to Hinman, the pyelovenous backflow occurred. He was once carrying out experiments on autopsy kidneys in the post-mortem room, and what he had found drew his attention to this phenomenon in a striking way, though at the time he did not understand it. He was injecting liquefied gelatine up the ureter and into the pelvis, and he continued the pressure until there occurred a sudden rupture inside the kidney, and, to his surprise, he saw the renal vein full of liquid gelatine. He hardened the specimen and opened it and found that there was gelatine throughout the venous system of the kidney, and that rupture had occurred at the bases of several pyramids. He understood what had happened after he read Hinman's work. He took it that in what Mr. Morison called his accidental experiment, when rupture occurred, the same thing happened. He (Mr. White) repeated these experiments on several other occasions, and he found that by continuing the pressure he could always get a rupture in the same part of the kidney, and if the force was not relaxed the fluid would be found making its appearance at the hilum, thence spreading out on the surface of the kidney beneath its true capsule, and he thought this might possibly happen during pyelography if undue pressure were applied; in certain pyelograms one saw a diffuse opacity, which might be explained in that way.

Mr. JOCELYN SWAN said that he could discuss Mr. Morison's excellent piece of experimental work rather from the clinical than from the experimental aspect, particularly as to the relationship that the experimental evidence which Mr. Morison had now brought forward might have to the treatment in dealing with cases of renal infection. With regard to the common infection of the kidney by means of the *Bacillus coli* and other organisms, in which there was frequently some dilatation of the renal pelvis, this work suggested that the organisms could find their way into the renal tubules as easily as the particles of the dye which Mr. Morison had shown. If this were the case, it surely pointed to the superiority of medicinal treatment of these cases over-mechanical irrigation of the renal pelvis with disinfecting solutions, and perhaps it explained some of the failures following treatment by these means. The presence of organisms in the tubules of the kidney, and particularly in the cortical portion, would probably explain some of the more severe general symptoms associated with renal infections.

Again, in those cases in which a calculus was present in the renal pelvis, there was not only a certain amount of back pressure in the renal tissues, but, as was well known, many of these cases were infected. Was one, therefore, to be content to remove the calculus and think that by so doing the patient was going to be cured? or ought one, in the light of this evidence, to be more careful to treat the co-existing infection of the kidney after the removal of the calculus? In other words, should one suture the pelvis after a pyelolithotomy, or should one drain the kidney in all cases after the removal of a stone? Another question with regard to the clinical side was prompted by the two instances which Mr. Morison had shown and had described as "accidents," namely, whether solution under pressure had forced its way through the renal substance as far as the capsule of the kidney, a point of great importance in the technique of pyelography which should not be performed under an anæsthetic as no undue pressure should be used. Any anæsthetic necessary for carrying out pyelographic examination should be a local or parasacral anæsthetic.

Mr. KENNETH WALKER said he was himself particularly interested in the question of lymphatic spread; at one time he had done some work on that subject. In recent years, however, he had come to the conclusion that the lymphatics were not so important as he thought they were fifteen years ago. He would like to know whether Mr. Morison paid any attention to the capsule of the kidney in the cases showing an early lymphatic absorption of the dye. In his (the speaker's) own experiments with animals, he found that the capsule was of extreme importance. On placing dyes in the lower parts of the urinary tract, without any obstruction, he found that particles of the dyes wandered up in a surprising way, and distributed themselves throughout the whole of the urinary tract, and almost invariably he found dye in the capsule of the kidney. When one was using carbon and carmine particles, and when the particles were few and far between, it was easy to make mistakes: but in Mr. Morison's experiments, where more concentrated dyes were used it would not be difficult to see whether there was any

dye in the capsule of the kidney. It was known that there was a connexion between the lymphatics of the renal cortex and those of the capsule.

Mr. G. E. NELIGAN said that in all the experiments which Mr. Morison had described, the ureter was ligated. He (the speaker) used to be taught that if the ureter were completely ligated, in the majority of cases atrophy of the kidney would follow. Had Mr. Morison found that in every case in which he ligated the ureter, hydronephrosis followed, rather than atrophy of the kidney?

With regard to the spread of infection up through the pyramids to the cortex of the kidney, Mr. Morison's experiments seemed to confirm the experience of old cases of obstruction due to enlarged prostate. When he was a student he remembered the surgeons operating on these cases and that, if uræmic, the patient died within forty-eight hours after rigors; also that, post mortem, one found, throughout the substance of the kidney, some hydronephrosis, and from there upwards one could see, macroscopically, tracts of pus right up the cortex. In early days one washed out the kidneys with collargol, and if too much was used, one saw beautiful pictures of the collargol going through the whole substance of the kidney and beyond.

Mr. ZACHARY COPE said that in Mr. Morison's able paper there was little or no mention of the route whereby absorption took place into the general system.

The change in the general symptoms which took place when a hydronephrosis became infected was well known and must be caused by absorption, and he was sure Mr. Morison must have some observations and opinions on this question which would be of great interest.

Mr. J. SWIFT JOLY (President) said that he had been much impressed by the statement that the dyes were first collected at the junction between the calyces and the papule itself. According to Wildbolz, that was the first point at which tuberculous lesions were found in the kidney, the disease spreading thence directly up to the cortex.

A second point which had impressed him was that of absorption by the lymphatics in early cases, and by absorption in the tubules in the later cases. Mr. Morison had raised the question whether the thickened epithelium over the tip of the papillæ did not act as a valve in preventing absorption by the tubules in early cases. He was reminded by this of a paper which he had read before the Section four years ago and in which he had pointed out a similar mechanism preventing evacuation of the bladder in patients with an enlarged prostate. The pressure of the vesical contents tended to squeeze the intervesical projection of the prostate towards the urethra from all sides and so to prevent the evacuation of urine.

The question of the spread of infection from the renal pelvis to the kidney itself was a third point which Mr. Morison had, at least indirectly, touched upon. It had a very direct importance, because it showed the inefficiency of the renal lavage. One knew how inefficient urinary antiseptics were when given by the mouth, so that one was really, in this matter, "between the Devil and the deep sea" to know what was the best treatment in this type of infection.

In cases of hydronephrosis due to obstruction of the ureter, a rapid degeneration of the kidney ensued, and the question arose as to the length of time a kidney could remain obstructed, and yet regain its function. The results of experiments designed to settle this question differed a good deal, therefore he would like to know whether Mr. Morison had done work on the point and, if so, what were his conclusions.

Mr. MORISON, in reply to Mr. Jeans, said that in advanced back-pressure, such as that from an enlarged prostate, the arcuate arteries passing round at the base of the renal pyramids, were put on the stretch, thus reducing the calibre of these vessels. When back-pressure was removed suddenly, these arteries, like elastic tubes, tended to spring back and in so doing re-established their former lumen. This permitted an increased blood flow and congestion which resulted in tubular embarrassment and anuria, proceeding even to glomerular rupture with hæmaturia. That, he thought, might be the mechanism in advanced cases, but this was put forward as a tentative suggestion, requiring proof.

Mr. Winsbury White had spoken of the angle at the base of the pyramid, at the junction where the wall of the pyramid joined the base. That was the hinge on which all the movement of back-pressure occurred. [Drawing.] Employing autopsy material in which there was not so much elasticity as in living tissues, he found one was apt to get a tear at this site, and with increasing pressure, a definite rupture. If, however, a stage of back-pressure was already established, the hinge was not so likely to give. If slight overfilling had occurred in a pyelogram showing "clubbed" calices, one saw striæ radiating from the tips of the papillæ up into the pyramids, indicating a flow of the pyelographic medium up the main

collecting tubules, pre-existing back-pressure having rendered the mouths of the papillary ducts patent and in free communication with the cavity of the renal pelvis.

Mr. Jocelyn Swan had asked about chronic *B. coli* infections of the urinary tract. It was an important and interesting question. He (the speaker) thought a case of *B. coli* pyelitis was one of continuing re-infection in the pelvis, due to stasis and produced by faulty ureteral drainage. [Drawing.] People with chronic pyelitis were treated with instillations of silver nitrate, with the idea of desquamating off the lining epithelium, and thus getting rid of the organisms. The results of this mode of treatment were not too convincing. More recently he had been carrying out a series of ureteral dilatations in such cases and had obtained more gratifying results.

The President had referred to renal calculus. One of the etiological factors of calculus formation would appear to be stasis, therefore before removing a renal calculus, it was one's duty to remove this factor. A preliminary series of ureteral dilatations should be carried out. This procedure by improving drainage would lessen any infection present, and provide a better surgical field for the ultimate removal of the calculus.

With regard to the question as to how long after complete obstruction recovery could occur, experimental work on the dog had shown that even after three weeks of total obstruction, kidney function would come back sufficiently to support life, provided the opposite healthy kidney was removed. If, however, a kidney was obstructed for only two weeks, and then relieved, without removing the opposite already compensating kidney, the recovery of that kidney was partial and temporary, and the kidney ultimately atrophied. It would appear that the greatest recovery of functional activity only occurred when the stimulus for full work was present, as after removal of the other kidney. The subject had received special attention from Hinman, who referred to it as renal counterbalance.

Mr. Neligan had enquired as to the incidence of primary atrophy following total ligation of the ureter. Throughout the present series of experiments he (the speaker) had not encountered the condition. He had, however, on previous occasions seen two instances in which primary atrophy had supervened.

Mr. Kenneth Walker had asked about the physiology of absorption, and also regarding lymphatic spread within the kidney. With reference to absorption, he (the speaker) had had the opportunity, last year, of showing some of the present work to Professor A. N. Richards, of Philadelphia, who had expressed his opinion that this retrograde absorption of dye particles into the cells of the convoluted tubules, simulated closely his own findings in which he had introduced dyes directly into Bowman's capsule and found that in their passage down the lumen of the tubule, these dyes were absorbed by the cells of the convoluted tubules. The findings would tend to strengthen the "filtration and re-absorption theory" of renal secretion. With regard to lymphatic spread, the only kidney he had seen which suggested this route, was the one he projected on the screen, in which there was interstitial nephritis.

Mr. Zachary Cope had asked concerning the mode of absorption into the general system from these sites. One could appreciate from the symptomatology that such a re-absorption readily occurred. The difficulty remained, however, of demonstrating the exact mode of the transference. In the instance of interstitial nephritis cited, the dye particles were observed to have been absorbed into the cells of the convoluted tubules, and thence had apparently passed through the basement-membrane into what appeared to be lymphatic spaces. The spleen showed some scanty dye particles in the cells of the reticulo-endothelial system but none could be seen in the liver.