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FUNCTIONAL AND MORPHOLOGICAL CHANGES OF THE KIDNEY IN DEHYDRATION

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Changes in Renal Circulation

It has been shown earlier that in dehydration the disorder of renal function is due partly to the diminished filtration pressure in the glomeruli and partly to the decrease in the speed of renal circulation *(Gömöri* and al. 9, 11, 18). The decrease in filtration pressure results from the decrease of blood pressure and the increase in the osmotic pressure of plasma colloids. Both factors are direct sequels of the fluid loss, i. e. of concentration and decrease in volume of the circulating plasma. The progress of the clearance method has made it possible to determine the amount of blood passing through the kidney of normal animals suffering from exsiccosis.

Method. The experiments were carried out on dogs, after perineotomy. Dehydration was produced by ligating the pylorus (vomiting). The amount of blood passing through the kidney was determined by means of para-amino hyppuric acid clearance and the values were expressed by the quantity of plasma passing the kidney in a time unit renal plasma flow, C_{PAH}. Glomerular filtration was estimated with the endogenous creatinine clearance (C_k). From the two data, the filtration fraction, i. e. the glomerular filtrate extracted from the plasma passing through the kidney (Ff), was calculated. In all experiments the determinations were performed before, then 24, 48 and 72 hours after, the ligature of the pylorus. In all experiments 2 or 3 periods were observed and only those experiments were recorded the periods of which showed a good accordance. The tables give mean values of the single periods.

The experiments led to the uniform result that dehydration caused a marked reduction of the amount of plasma passing through the kidney (C_{PAH}, Table I). As in our earlier experiments, the decrease of glomerular filtration was obvious, but the reduction of C_K and that of C_{PAH} displayed no parallelism, the former lagging behind the latter. Owing to this fact the filtration fraction showed a considerable increase pointing to a *contraction of the efferent arteriole.* Having earlier observed [12] that dehydration due to ligation of the pylorus results in anatomical changes in the tubules, it had to be assumed that in exsiccosis the excretion of para-amino hippuric acid would be decreased because the tubules did not completely extract the compound from the blood passing them. Therefore, the value of C_{PAH} would be lower than the one actually corresponding to

the quantity of plasma which passed through the kidney. It seemed therefore necessary to examine this problem experimentally.

TABLE I

	Diuresis ml/min.	Glom. filtr. ml/min. C_K	Renal plasma flow ml/min. C_{PAH}	Filtr. fract. Ff	N. P. N. mg %
1.					
Before } pyloric	2,12	75	217	34	22
1 day after } ligation	0,358	33	90	37	26
3 days after }	0,250	22	39	58	40
2.					
Before } pyloric	3,8	25	78	37	24
1 day after } ligation	0,135	27	47	56	38
3 days after }	0,090	13,3	21,3	62	86
3.					
Before } pyloric	4,46	12,5	56,5	22	20
2 days after } ligation	0,095	13,8	20,2	44	28
4.					
Before } pyloric	7,4	36,6	128,3	28	30
3 days after } ligation	0,041	5,6	9	61	60
5.					
Before } pyloric	0,68	23,5	134,5	17	26
3 days after } ligation	0,02	11	30	37	58

Method. For estimating the extraction rate of para-amino hippuric acid, it is necessary to know the concentration of the compound both in the whole circulating blood and in the venous blood of the kidney. The extraction rate was estimated first in normal control dogs, then in dogs three days after their pylorus had been ligated. Venous blood was obtained from the kidney by direct exposure. In normal dogs the extraction of para-amino hippuric acid was on an average 80 per cent, in good accordance with the data of other authors *(Philips* [21]; 85 per cent). On the third day after ligation of the pylorus the mean value of extraction amounted to 62 per cent. (Single values, 53, 60, 62, 65, 69.)

TABLE II

Values calculated on the basis of the PAH extraction

	C_K	C_{PAH}	Ff
1.			
Before } pyloric ...	25	108	23
3 days after } ligation ...	13	34	38
2.			
Before } pyloric ...	37	177	21
3 days after } ligation ...	5,6	15	37

According to the results, ligation of the pylorus undoubtedly results, on the third day following the operation, in the decrease of the extraction rate of para-amino hippuric acid. The decrease may amount to from 20 to 25 per

cent of the initial value. If this is taken into account and the C_{PAH} values obtained in the experiments are re-calculated, their decrease following pyloric ligation will be naturally less than the one calculated without regard to the extraction rate. The decrease is, however, still considerable. The two extreme cases are demonstrated in Table II, the case displaying the smallest change and another in which it surpassed all other experiments. The increase in the filtration fraction is also well marked, even after re-calculation. There can be no doubt that *in dehydration due to pyloric ligation the quantity of blood passing through the kidney is diminished*, even if the decrease in the extraction rate of para-amino hippuric acid has been taken into consideration.

Beyond this, other problems too have been pointed out in these experiments. According to the results, *the reduction of renal circulation in exsiccosis exceeds by far the value ascribable to the general failure of circulation*, even if the decrease in the filtration rate has been substracted. Similar conditions exist in cardiac decompensation (*Merill*, [19]) and in posthaemorrhagic shock (*Van Slyke* et al, [20]), a state in which the reduction in the amount of blood passing through the kidneys surpasses the decrease in minute volume. In addition, the experiments demonstrated a considerable increase of the filtration fraction in dehydration, as a sign of the contraction of the efferent vessels. A similar increase of the filtration fraction occurs in cardiac decompensation. All these facts suggest that *in dehydration the reduction of renal circulation is by no means a simple mechanical sequel of the general circulatory failure* but other factors too, such as the contraction of the preglomerular vessels, must play a role. Evidently, the contraction of the efferent arteriole is a compensatory phenomenon capable of raising to a certain extent the glomerular filtration rate which would otherwise suffer a decrease in consequence of the reduced renal circulation. This phenomenon, together with the reduction of renal circulation (contraction of the afferent arteriole) is doubtlessly governed by a *regulatory mechanism*. The circulatory failure occurring in exsiccosis, in cardiac decompensation [19] and shock [20] apparently endangers the oxygen supply of the brain, lungs, and myocardium. This danger is averted by a process in the course of which the blood is diverted from the kidney, a less important organ for the moment, toward the organs mentioned. Investigations into this problem in general and into the details of the regulatory mechanism are in progress (*Gömöri*, *Kovách*, *Földi*, *Szabó*, *Nagy*, *Takács*, *Wiltner* [8]).

Beside functional examinations *morphological* ones were also performed. These have been briefly reported in Hungarian in 1948 and in 1952 (*Gömöri* and *Romhányi* [12, 13]).

Method. Hypochloraemic exsiccosis was produced in cats ligating the pylorus. A total of 25 animals was employed. They were sacrificed at different times after the ligation. The kidneys were fixed in formaldehyde and alcohol, stained with haematoxylin-eosin and fat dyes, and the Kossa, phosphatase, and benzidine reactions were applied.

The benzidine reaction revealed in the kidneys of normal animals the usual conditions. The cortex was moderately hyperaemic, the subcortical zone seemed to contain more blood than normal while there was only little blood in the zone of Henle's loops, the inner part of the medullar substance and the system of the vasa recta ; this part of the kidney was pale.

In animals suffering from exsiccosis the circulation underwent a characteristic change as early as two days after the pylorus had been ligated. The severity of this circulatory change was found to increase in a direct proportion with time being more extensive in animals killed later. Essentially the change consisted in an uniform and marked hyperaemia of the cortex and medulla. Beside diffuse hyperaemia multiple miliary hyperaemic patches also occurred in the cortex *(Fig. 1)*. Under the microscope these patches consisted of greatly distended peristatic capillaries which formed fields of various size.

These changes gave a definite answer to the question whether or not *Trueta*'s phenomenon appears in exsiccosis. On the basis of the picture described, the presence of *Trueta*'s phenomenon could be excluded.

There is, however, a contradiction between the results of the functional examinations and the morphological picture. The former indicated that dehydration results in a marked reduction of the amount of blood passing the kidney. In contradistinction to this, histology revealed hyperaemia with enlarged tufts *(Fig. 2)* and peculiar multiple peristases *(Fig. 3)*. The elimination of this incongruity required a detailed comparative study of the functional and morphological data. The functional examinations demonstrated, beside the reduction of renal circulation, also an increase in the filtration fraction, i. e. the intensive contraction of the efferent arterioles. A revision of the morphological picture with regard to that fact has shown that the site of the multiple peristases is without exception periglomerular, i. e. a tuft can invariably be found at one of their poles or in their centre. It could be observed in the initial stage that the peristasis observed was circumscribed, involving solely the immediately postglomerular section of the capillary network.

These phenomena could readily be interpreted with the intense spasm of the efferent arteriole. The swelling and hyperaemia of the tufts were obviously due to the contraction of the efferent vessels ; the increase in intraglomerular pressure resulted in swelling, enlargement, of the glomeruli. Our experiments have furnished the first evidence that *a contraction of the efferent arteriole resulted in a visible enlargement of the tuft.* There is a further point which follows from the enlargement of the tufts. The fact that in exsiccosis the tufts become enlarged permits, with regard to the considerable increase in the filtration fraction, of the conclusion that the contraction of the efferent arteriole is so intense that it represents a serious hindrance to renal circulation. It may therefore be inferred that in dehydration the diversion of blood from the kidneys toward other organs is due not only to the contraction of the afferent arteriole but also to that of the efferent one. On the basis of these facts the reason for the postglomerular capillary stasis becomes clear. The contraction of the afferent

and efferent arterioles results in a decrease of the renal blood flow and consequently in hypoxaemia. Owing to the latter the capillaries become paralyzed and undergo dilatation. It is in this way that in exsiccosis the slow circulation and the hypoxaemia developing from other causes too (*Kerpel-Fronius* et al, 17) result in postglomerular stasis.

Consequently, no actual incongruity exists between the findings of the functional and the morphological examinations. The amount of blood passing through the kidney is diminished, but in the kidney there is still congestive hyperaemia. The congestion results from the intense contraction of the efferent arterioles and the hypoxaemic stasis of postglomerular capillaries.

Tubular Changes

In further experiments the functional and anatomical problems of the tubules, first of all the re-absorption of urea in the tubules, were studied. This problem was first investigated by *Gömöri*, *Bálint* and *Hársing* [7]. Dehydration was produced in their rabbit experiments by repeated intraperitoneal injection, and re-aspiration, of isotonic dextrose solution. In these experiments the clearance of both urea and creatinine were found reduced; the reduction of the latter substance surpassed that of the former, owing to the increased tubular re-absorption of urea. Prior to dehydration 22 to 23 per cent of the filtrated urea became re-absorbed, while after dehydration 80 to 90 per cent. The increased re-absorption of urea was independent of the re-absorption of fluid and of the minute diuresis.

Starting from these experiments *Kenney* [15] also determined the tubular absorption of urea after water restriction in man, and confirmed the data of *Gömöri*, *Bálint* and *Hársing* [7]. In his experiments the ratio urea clearance per glomerular filtration rate decreased from the preexperimental mean of 0,45 to 0,21 on the fourth day of thirsting. This undoubtedly indicates an increased absorption of urea in the tubules. The reduction in both, glomerular filtration and renal circulation of the plasma, and the increase in the filtration fraction observed by *Kenney* were similar to those found in our experiments.

Kenney states in another paper (*Barclay*, *Cook* and *Kenney*, [1]) that the reduction of the filtration fraction is followed by an increase of the ratio urea per glomerular filtration rate, in some cases even above *1*. This observation shows that urea is in such cases partly secreted. *Kenney* [15], on the basis of these experiments and of those cited above, contended that the excretion of urea depends mainly on the actual haemodynamic conditions of the kidney. In dehydration, the haemodynamic changes alone should consequently be made responsible for the increased tubular absorption of urea found by *Gömöri*, *Bálint* and *Hársing* [7] and *Kenney* [15]. In our opinion, this standpoint cannot be adopted, first because, as mentioned above, dehydration leads to anatomical changes in the tubules, i. e. to a condition predisposing to the passive tubular re-diffusion of urea. The possibility that under certain conditions urea may passively diffuse was demonstrated by several Hungarian authors, among them by *Földi*, *Rusznyák* and *Szabó* [6] in uranium poisoning, *Bálint*, *Hársing*, *Lenner* and *Rusznyák* [3] produced tubular injury by the administration of large quantities of salt, *Bálint*, *Hársing* and *Lenner* [2] by saccharose. The clearance showed in all cases an increased rediffusion of urea.

All these experiments point to the fact that it is the *anatomical lesion of the tubules* and not the change in haemodynamics which is responsible for the

TABLE III

Day	Diuresis ml/min.	Glom. filtr. ml/min. C_K	Urea clearance ml/min. C_U	N. P. N. mg %	$C_U : C_K$
Days before ligation of the pylorus 1.	0,065	18	13	18	0,72
2.	2,5	25	18	—	0,72
3.	4,9	22	22	16	1,00
1 day after ligation	0,093	22,5	17	24	0,70
2 days « «	0,088	17,5	13	26	0,74
3 days « «	0,078	12	2,7	56	0,22!

increased tubular absorption of urea. There is still another argument supporting this opinion. We repeated in dogs those experiments which had been carried out by *Gömöri*, *Bálint* and *Hársing* [7] in rabbits. Dehydration was induced by ligating the pylorus. Minute diuresis, urea clearance, and creatinine clearance were estimated before and after the ligature. As seen from the table (Table III), the ratio urea clearance per creatinine clearance was on the first day after the ligature the same as before the operation. The same value was obtained on the following day. On the third day the value of the ratio decreased to 0,22. This is indicative of the fact that rediffusion of urea did not take place before the third day. The haemodynamic changes, as it has been demonstrated in the aforementioned experiments (Table I), set in on the first and second day already and the blood flow exhibited a marked decrease to below the initial value. In one of our experiments 24 hours after the ligature the C_{PAH} was lower than half the starting value. In a second experiment, one day after the ligature we found 50 per cent, and two days later, in a third experiment, one third, of the initial value. This makes it evident that there is no correlation between the haemodynamic changes and the passive rediffusion of urea.

Thus, in our opinion, the cause underlying urea rediffusion is to be sought in the anatomical change of the tubules, all the more so since the onset of the injury sets in usually three days after the pyloric ligature. At the same time, the experiments may be regarded as a confirmation of the results *Gömöri*, *Bálint* and *Hársing* [7] had found in rabbits with another method. In addition, the experiments have furnished a reliable proof of the claim that the passive rediffusion of urea and diuresis are independent of one another. (Minute diuresis remains practically unchanged from the second to the third day after the operation while no rise in the tubular absorption rate takes place before the third day.)

The *morphological* examination yielded the following results.

a) Characteristic changes occur *in the epithelial cells of the convoluted tubules*. They first appear in the straight medullary part, subsequently to extend to the whole system of convoluted tubules (Fig. 4). Similar phenomena occur in the cortical distal convoluted tubules in which the changes are less prominent, there being no hypertrophic basal membrane. By the third day the early changes become well recognizable. In the epithelium of the proximal convoluted

tubules there appears, below the brush-border, a hydropic zone which in the subsequent days becomes gradually broader, until finally only an endothelium-like flattened plasma border remains at the basal side of the cell next to the capillaries. At that time, the hydropic loosened brush-border represents the major part of the cell. During the whole change the cytoplasm exhibits a passive behaviour. The hydropic zone does not react to fat stains. Fat droplets cannot be seen except in the flattened cytoplasm as a remainder of the physiological lipoid content of the tubular epithelium. At a later stage (on the 7th to 8th day) the change of the brush-border makes the cells of the convoluted tubules similar to those of mucinous glands, with a nucleus pressed toward the base of the cell. Following the changes described there appear, especially in the lumina, colloid droplets and, at some sites, a blurred granular structure, which may occasionally occur also in the loosened hydropic brush-border. This hydropic degeneration of the tubular epithelium in dehydration, first observed in 1948 by *Gömöri* and *Romhányi* [12], was described also by *Bell* [4] in his monograph published in 1950.

b) Simultaneously with the epithelial changes, the *phosphatase activity in the tubular epithelium* is also altered.

Under normal conditions the phosphatase content of the cortex is confined to the epithelium, stricter to the brush-border, of the convoluted tubules. In the cat's kidney, a moderate phosphatase activity is present also in the thicker ascending branch of Henle's loop, the epithelium of the distal convoluted tubules, and the tufts. The thin segment of Henle's loop is free from the enzyme.

In dehydration the phosphatase activity of the epithelium disappeared parallel with the development of anatomical changes. In the initial stage small groups of tubules containing no phosphatase become visible in the cortex, mostly in the distal convoluted tubules *(Fig. 5)*. Then the areas free from phosphatase gradually increase in extent, until the majority of the proximal convoluted tubules have lost their activity. Nearly all tubules of the cortex show a complete lack of the enzyme while in their lumina calcium granules appear *(Fig. 6)*. The lack of enzyme activity is diffuse, but confined to the cortex. The inactivity of the brush-border is complete or nearly complete. The thick branch of Henle's loop exhibits an unchanged activity even in the hypochloraemic kidney. The reduction of phosphatase activity precedes the precipitation of calcium in the tubules. This is why calcium granules are present solely in tubules lined with inactive epithelium.

The question is what significance have the anatomical changes of the tubular epithelium and the decrease of its phosphatase activity. It is not easy to decide this problem. Earlier histomorphologic examinations had been unable to demonstrate the functional significance of the brush-border as an active border zone in tubular action. The recently revealed submicroscopic lipoid-protein honey-comb structure of the brush-border *(Romhányi*, [22]) may present means for clarifying this. The brush-border represents a powerful lipoid-protein

borderline zone with a special grid structure. A similar hypertrophied borderline zone is present, for instance, on the surface of the intestinal epithelium active in absorption (cuticle). Thus, the brush-border represents a lipoid-protein grid, a filtering apparatus, which, however, does not yet possess the biological activity necessary for functioning by itself. Function is made possible, among others, by the high phosphatase activity. These facts involve the question of the phosphatase activity of the brush-border in dehydration. As it has been mentioned the phosphatase activity is greatly reduced in that state. The change affects diffusely the epithelium of the convoluted tubules at the site where the hydropic change of the brush-border occurs. This means that the active borderline zone responsible for selective absorption has decomposed both structurally and energetically. There can be no doubt that the double lesion exerts a deleterious effect on tubular function. One must not forget that the glomerular filtrate, unlike any fluid injected into the tissues, undergoes selective absorption, i. e. certain of the substances the filtrate carries become retained or concentrated. This function is due mainly to the intactness of the active borderline zone.

The lesion of the borderline zone must, therefore, be followed by an impairment of tubular function. As shown in dehydration urea absorption is considerably increased, but it remains still an open question whether for the increased absorption an active cellular function or the passive rediffusion should be accounted for. Many authors believe that under normal conditions the tubular absorption of urea is a diffusion process, considering that urea represents one of the most readily diffusible substance in the organism and its excretion depends, among others, also on the intensity of diuresis.

Whatever the case, the excretion of urea is governed by a precise regulatory mechanism which enables the intact kidney always to excrete so much urea as necessary, independently of the urinary output. This makes it obvious that the tubular epithelium is capable of regulating the absorption of urea. On the other hand, in dehydration the tubules are gravely affected and still the absorption of urea is increased. Is it warranted to presume that the damaged tubular epithelium would, by means of some »active« cellular function, absorb more urea than under normal conditions? Evidently not. Therefore, the increased tubular absorption of urea in exsiccosis is doubtlessly a consequence of passive rediffusion made possible by the tubular lesion, the failure of the selective function of the brush-border.

Thus the structural and energetical decomposition of the active borderline zone of the renal epithelium will be followed by a gradually increasing passive non-selective rediffusion. It is for this reason that in relation to the glomerular filtration rate the clearance of urea becomes greatly decreased, rediffusion of urea occurs, and, in some of the cases, hyposthenuria is developed.

c) The problem of the so-called »hypochloraemic calcium nephrosis« was also studied.

It is a well-known fact that in hypochloraemic exsiccosis calcium is deposited in the kidney whereby, according to some authors, so grave necroses may result which suffice, without any additional factor, to bring about uraemia *(Fahr,* [5]). Calcium deposits could be observed during both our earlier *(Gömöri* and *Sármai,* [14]) and the present examinations and this is why it has been endeavoured to clarify the pathomechanism of calcium precipitation. Calcium was found in the lumina of the tubules after the fourth day following ligation of the pylorus. No necrosis was present in the tubular epithelium only the already mentioned, hydropic swelling of the brush-border and its lack in phosphatase activity. There was in all cases *a correlation between the lack of phosphatase activity and the presence of calcium deposits.* The latter occurred in those tubules only in which the lining epithelium showed no, or at most a very low, phosphatase activity *(Fig. 6).* It seems most probable that the phosphatase escaping from the brush-border combines with organic phosphate and the inorganic phosphate split off combines with calcium. In this way a compound practically insoluble in alkaline media is produced. Hypochloraemic exsiccosis being associated with alkalosis, it is very likely that precipitation of calcium occurs in accordance with the above mechanism. This theory is supported by the facts that deposited calcium is invariably found in the lumina of the tubuli, and that, as stated by *Kerpel—Fronius* and *Martyn* [16], calcium precipitation occurs only in alkalosis. This means that the old concept according to which in hypochloraemic nephrosis calcium deposition is a secondary process, to the analogy of mercury poisoning where calcium is deposited in the severely injured epithelium, cannot be maintained any longer. This old theory must all the more be discarded, since in the tubular epithelium hydropic degeneration and a decrease or complete lack of the phosphatase activity were always present *but necrosis not in one single case.*

It is an important question whether »hypochloraemic nephrosis« is a condition of clinical significance. As mentioned above, there can be no doubt that it is the anatomical lesion of the tubules that promotes the passive rediffusion of urea. In addition, the calcium precipitated obstructs the tubules and forms a serious hindrance to urinary outflow. By themselves, however, *these changes cannot be made responsible for the azotaemia developing in exsiccosis.* This problem has been fully clarified also by *Gömöri* and *Sármai* [20], who produced hypochloraemic exsiccosis in cats by ligating the pylorus. On the 6th day after the operation they removed one kidney for histological examination, liberated the pylorus and administered an infusion of physiological salt solution. Diuresis started immediately and the nitrogen output was also abundant. These experiments demonstrate that by itself the renal lesion discussed does not bring about a severe deterioration of renal function. After the haemodynamic conditions

had been restored by salt infusion the normal function of the kidney was immediately resumed. The disturbance of renal function occurring in dehydration must therefore be due to the decrease in filtration pressure, i. e. to a failure of the circulation while the passive rediffusion of urea through the injured tubular epithelium plays the role of an additional factor. It is very probable that the so-called calcium nephrosis in itself does not result in a grave functional disorder of the kidney unless hypochloraemia has lasted for a sufficiently long time to bring about severe alterations. Similar cases no longer occur in human pathology, and the case reported by *Fahr* [5] represents a rarity.

Conclusions

If now the question is raised which of the factors should be made responsible for the failure of renal function and the azotaemia in dehydration the following may, with respect to both our earlier and the present experiments, be designated :

(I) The *decrease in filtration pressure* as a sequel of the reduction of blood pressure and of the increase in the colloid-osmotic pressure of the plasma.

(II) *The reduced speed of the circulation*, resulting in a decrease of the amount of plasma passing the kidney. The rate of diminution is, however, greater than it might be expected from the general deterioration of the circulation. It follows that the reduction of renal circulation is not merely a simple sequel of the deterioration of general circulation ; it is partly brought about by other regulating factors which divert the blood from the kidneys toward other organs which at the time given play a more important role. The action of this regulatory mechanism is injurious to function of the kidney damaged by exsiccosis and leads to a further deterioration of renal function.

(III) *Owing to the anatomical lesion of the tubules an increased rediffusion of urea occurs.* This is, together with the decrease in filtration pressure and the reduction of renal circulation, a factor increasing nitrogen retention.

(IV) As *Gömöri* et al. had demonstrated [10] in previous experiments, exsiccosis is accompanied by an *intense desintegration of protein.* This is, beside the deteriorated renal function, a significant additional factor resulting in azotaemia.

As a final result it may be established that in exsiccosis several anatomical and functional factors combining with each other are responsible for the development of azotaemia, resp. uraemia.

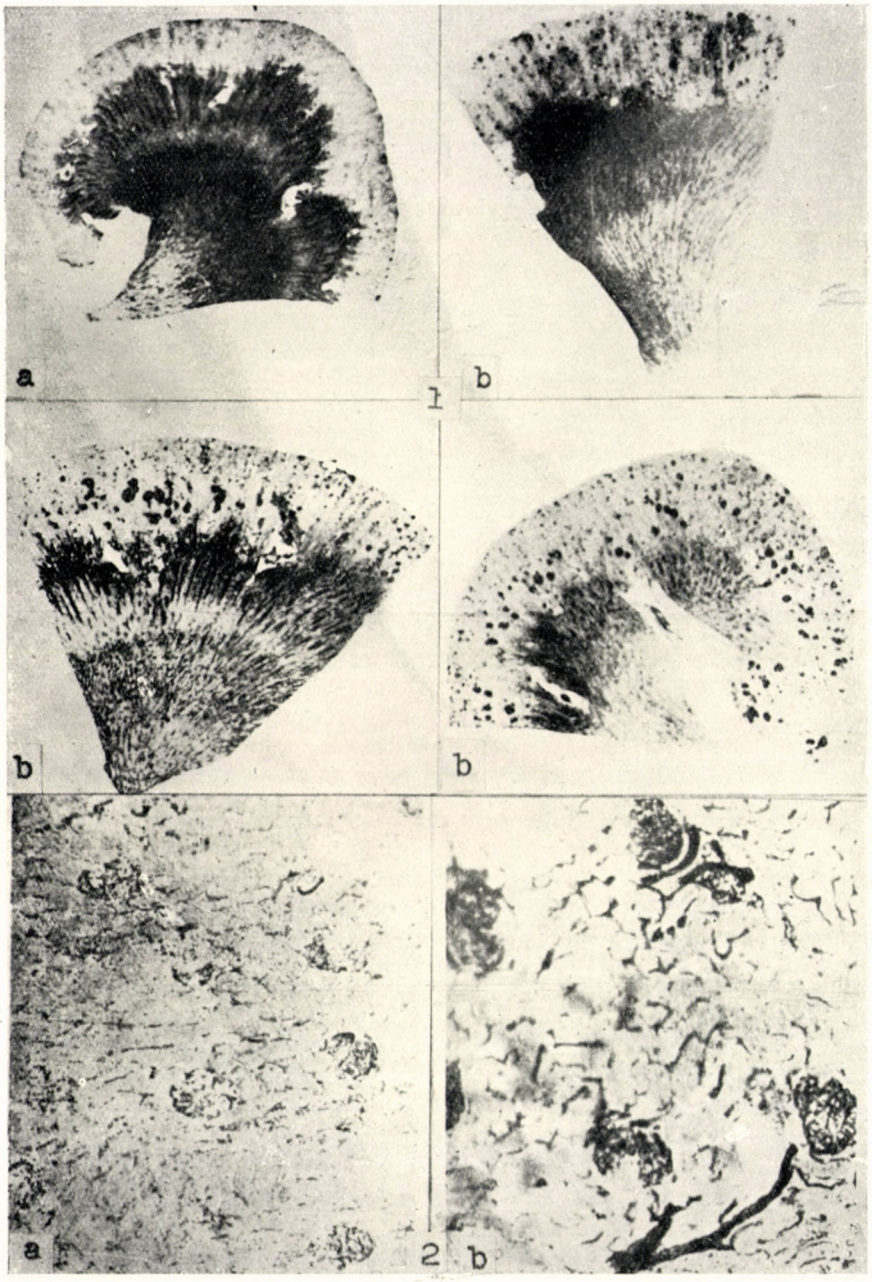
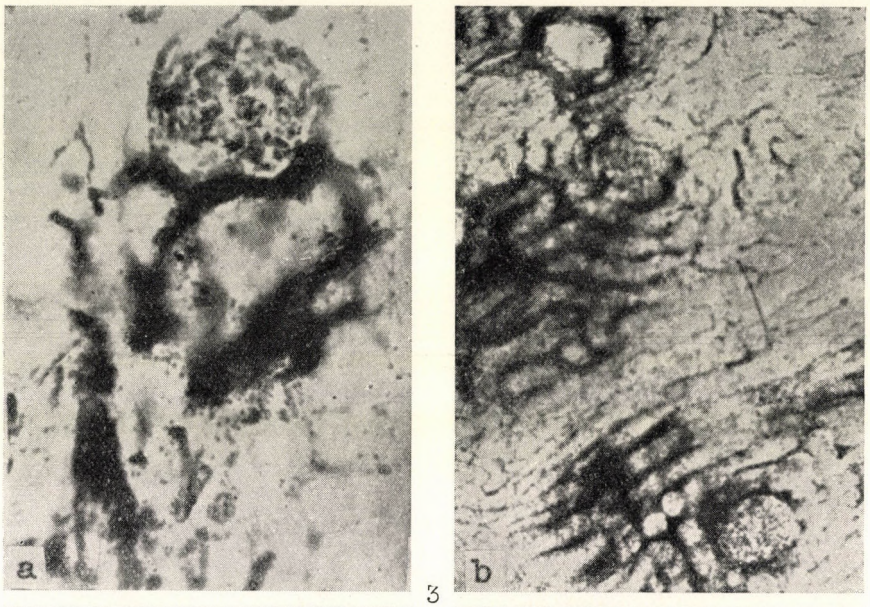


Fig. 1. a) Control kidney. Benzidine reaction. Normal blood content
b) Benzidine reaction in the kidney 3, 5, 7 days after ligation of the pylorus. Numerous small haemorrhages in the cortex
Fig. 2. a) Benzidine reaction of a kidney with normal blood content
b) Swollen and hyperaemic tufts 4 days after ligation of the pylorus



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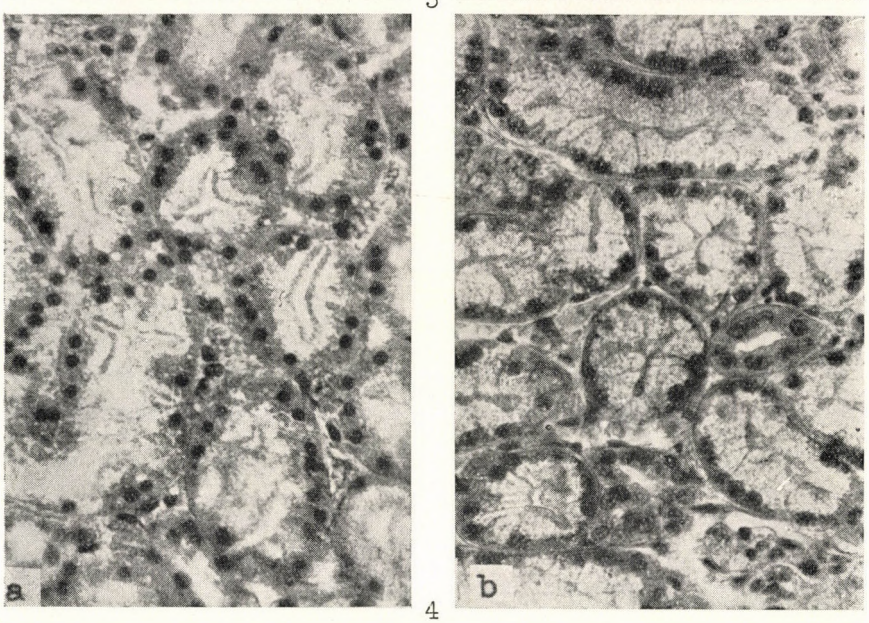

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Fig. 3. a) and *b)* Peristases in the postglomerular capillary network which correspond to the hyperaemic areas in the cortex shown in *Fig.* 1

Fig. 4. a) Hydropic degeneration of the brush border 4 days after ligation of the pylorus (light zones at the inner border of the lumina)

b) Intense hydropic swelling 7 days after ligation of the pylorus

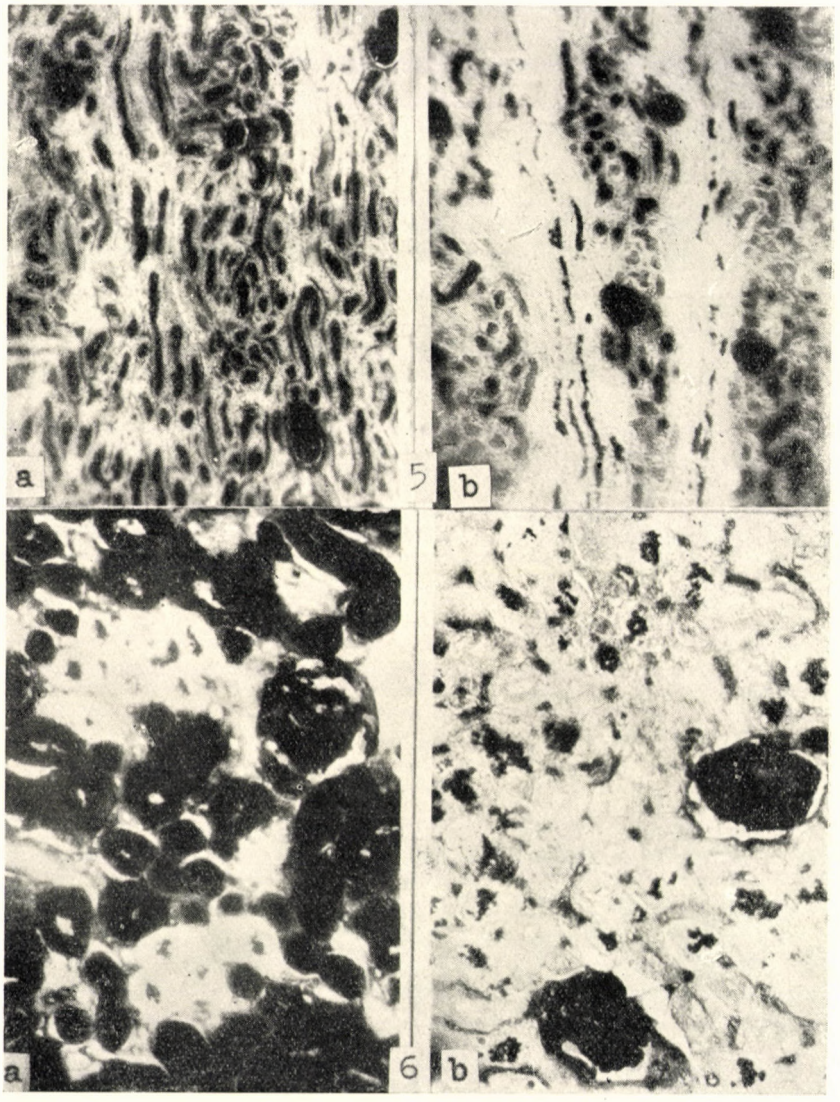

Fig. 5. a) Phosphatase reaction in a normal kidney. Positive reaction in the tufts and cortical tubules

b) Marked decrease of phosphatase activity 5 days after ligation of the pylorus. The black granular stripes running in the white fields correspond to calcium deposits in the tubules deprived of phosphatase

Fig. 6. a) 4 days after ligation of the pylorus. Initial calcium precipitation in the white tubules devoid of phosphatase

b) 7 days after ligation of the pylorus. All tubules are devoid of phosphatase. Calcium granules giving a positive silver reaction in the lumina. The phosphatase activity of the tufts is preserved

Summary

(I) In dehydration produced by ligating the pylorus the renal blood flow is greatly diminished. The rate of diminution is considerably greater than it could be expected from the deterioration of circulation. From this fact it is inferred that in dehydration a regulating mechanism is active, diverting the blood from the kidneys to other organs, the vital importance of which is greater at the time given. The efferent arteriole undergoes a compensatory contraction by which an anatomical, visible enlargement of the tufts ensues. In the postglomerular capillaries stasis occurs.

(II) In the tubuli, hydropic degeneration and decrease of the phosphatase activity can be observed and, at the same time, a passive tubular rediffusion of urea. The cause of the latter must be sought for in anatomic changes of the tubuli.

(III) The calcium nephrosis associated with hypochloraemic exsiccosis is undoubtedly a sequel of the alkalosis and the liberation of phosphatase. Calcium is deposited in the lumina of the tubuli only and no necrosis can be demonstrated in the tubular epithelium. Hypochloraemic nephrosis has no role in the development of azotaemia.

(IV) The disturbance of renal function observed in dehydration is a sequel of the combined effect of several factors such as the decrease in filtration pressure, the deterioration of renal circulation, and the anatomical lesion of the tubuli.

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ФУНКЦИОНАЛЬНЫЕ И МОРФОЛОГИЧЕСКИЕ ИЗМЕНЕНИЯ ПОЧЕК ПРИ ЭКСИККОЗЕ

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Резюме

1. При эксиккозе (вызванной перевязкой привратника) количество крови, проходящей через почек (C_{PAN}), резко снижается. Снижение значительно, превышает степень, которую можно было ожидать по общему нарушению кровообращения. Из этого следует, что при эксиккозе какой-нибудь регулирующий механизм направляет кровь в другие, в данном моменте более важные для организма органы. Выводящий сосуд почечного клубочка компенсаторно сужается, а это ведет к увеличению клубочка, устанавливаемого анатомическим исследованием. В постгломерулярных капиллярах наблюдается стаз.

2. В почечных канальцах наблюдается гидропическое перерождение и уменьшение активности фосфатаза. Одновременно с этим наблюдается в канальцах пассивная редиффузия мочевины. Причиной этого явления является анатомическое изменение почечных канальцев.

3. Причиной известкового нефроза, наблюдаемого при гипохлоремической форме эксиккоза, по всей вероятности являются освобождение фосфатазы и алкалоз. Известковые глыбы встречаются исключительно в просвете почечных канальцев, в клетках канальцев явления некроза не наблюдаются. Известковый нефроз, сопровождающий гипохлоремическую форму эксиккоза, не играет роли при возникновении азотемии.

4. Нарушения функции почек, наблюдаемые при эксиккозе (падение фильтрационного давления, нарушения кровообращения почек, анатомические изменения почечных канальцев) являются последствиями совместного действия некоторых факторов.