COMPENSATORY CHANGES IN THE KIDNEY AFTER UNILATERAL NEPHRECTOMY

V. I. Fedenkov

Course of Pathological Physiology and Laboratory Diagnosis (Head – Docent M. L. Kolpakov) Stanlin Institute of Higher Medical Study (Director – Docent G. L. Starkov)

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Compensatory processes are among the more important of the adaptive mechanisms. Defects due to damage of one of a pair of organs may be largely made good by compensation on the part of the uninjured member. Such a compensatory process may be involved in the recovery of human patients.

Simon in 1867 investigated compensation following unilateral nephrectomy. He showed that after removal or functional elimination of one kidney, there is a considerable increase in the activity of the other. This process included firstly the involvement of reserve nephrons and an increase in blood flow, and there was also a hyperplasia and hypertrophy of the nephron cells [6, 7, 8].

A great deal of work has been done on compensatory changes following unilateral nephrectomy. However, these were carried out at a time when methods had not yet been developed which allowed detailed renal investigations to be made [5, 9].

At present, owing to the development of more perfect methods of study of renal function [3, 11, 12, 13], it has been possible to make a full investigation of functional changes involved in the compensatory reorganization of the remaining organ, and such methods have been used in the present study.

METHOD

The experiments were carried out on 6 female dogs aged 3 to 4 years in which an operation using the method of Pavlov-Orbeli was performed. The filtration rate was measured in terms of thiosulfate clearance (F) and was calculated from the formula $F = \frac{ID}{P}$, where P represented the thiosulfate content in mg per ml of plasma; I the thiosulfate content in mg per ml of urine; D the diuresis in ml per minute. The reabsorption of water (R) was determined from the formula R of water = F-D, where F is the filtration rate in ml per minute.

For an accurate estimation of the filtration and reabsorption rates, it is necessary to maintain the concentration of the substances concerned at a constant level. This was achieved by using an intravenous drip. At the start of the experiment, an amount of water equal to 5% of the body weight was introduced into the stomach through a tube. For 10 minutes a solution containing 3.5% sodium thiosulfate was introduced as a drip. The urine for analysis was collected 25 and 40 minutes after giving the water. Blood was taken halfway between these two times. The concentration of sodium thiosulfate in the urine and in the plasma was determined by titrating with iodine.

The results were expressed as ml per minute and referred to unit surface area. This method made it possible to compare the results obtained on various animals [3]. In order to obtain a complete picture of the compensatory functional changes in the remaining kidney, all the results of the experiment on each dog were averaged over a period of one month. This procedure is necessary on account of the considerable fluctuations in renal function.

TABLE 1

Changes in the Diuresis of the Right Kidney after Removal of the Left (in ml per minute per m^2)

Name of dog	Before operation	After operation, monthly averages			
		I	II	III	IV
Swallow	6.1	10.9	17.9	18.7	14.7
Naida	6.6	16.2	13.6	11.3	10.3
Rose	7.6	10.1	9.4	19.3	7.1
Lady	6.9	10.6	15.5	17.9	15.7
Palm	7.6	9.1	8.3	8.3	7.9
Gerta	8.0	11.3	12.0	13.0	12.5

TABLE 2

Changes in the Filtration Rate of the Right Kidney after Removal of the Left (in ml per minute per m^2)

Name of dog	Before operation	After operation, monthly averages			
		I	II	III	IV
Swallow	74.3	91.1	119	140	99
Naida..........	80.2	90.1	97.6	92.5	85.8
Rose...........	62.0	65.7	83.1	77.3	67.2
Lady...........	74.4	98.6	147	144	121
Palm	47.8	65.8	62.2	66.8	58.3
Gerta	65.5	94.3	70.7	86.3	78.3

After carrying out 5-6 determinations to establish the normal renal function, the left kidney was removed. Measurements on the function of the remaining organ were made daily for four months.

RESULTS

The results showing rates of diuresis, filtration, and water reabsorption by the remaining kidney are shown in Tables 1, 2, and 3.

As can be seen from the results given in the tables, the diuresis after one month is far greater than the original values (on the average, by 140%).

Subsequently, in 3 of the 6 animals, the diuresis increased still further. During the fourth month the rate in these animals was somewhat reduced, and approximated to the values found during the first month following the operation.

For 3 dogs (Naida, Rose, and Palm) the maximum increase in the diuresis occurred in the first month after the operation, after which it returned almost to its original level.

One month after the operation there was an increased filtration in all cases. Subsequently, in most of the animals, there was a further increase, and in some the maximum occurred in the second month after the operation, and again in others in the third. In Gerta, the greatest filtration rate was attained one month after the operation, after which it fell somewhat. In the fourth month the increased filtration showed some reduction, and in all the animals it returned to the value found during the first month after the operation.

The absolute values of the monthly averages of the water reabsorption increased, just as did the diuresis and filtration. Water reabsorption in the third month increased in all the animals to 140% of the original value.

It was found that the function of the remaining kidney underwent considerable change. These changes are expressed as the absolute values of diuresis, filtration, and water reabsorption. It must be appreciated that all three quantities change in the same way.

TABLE 3

Changes in the Water Reabsorption Rate of the Right Kidney after Removal of the Left

Name of dog	Absolute values in ml per minute per m^3					Reabsorption, as percentage of filtration				
	before operation	after operation, monthly averages				before operation	after operation, monthly averages			
		I	II	III	IV		I	II	III	IV
Swallow	68.2	80.2	101.1	121.3	84.3	91.8	88	84.9	86.6	84.1
Naida	73.6	73.9	84.0	81.2	75.5	91.7	82	86.1	87.7	88
Rose	54.4	55.6	73.7	68.0	60.1	87.7	84.6	88.7	88	89.4
Lady	67.5	88	131.5	126.1	105.3	90.7	89.2	89.4	87.6	87
Palm	40.2	56.7	53.9	58.5	50.4	82.2	86.2	86.6	87.6	86.4
Gerta	57.5	83	58.7	73.3	65.8	87.8	88	83	84.9	84

The determination of the reabsorption as a percentage of the filtration is a considerable help in interpreting the results.

When the water reabsorption is expressed in this way, it can be seen that in spite of the increased absolute amount of reabsorption in the remaining kidney, the percentage reabsorption was in all cases reduced below the original value. Calculation of the percentage water reabsorption reveals the reason for a certain difference in changes in the diuretic rates. Thus, for example, the maximum increase in Naida in the first month after operation can be seen to be due not to increased filtration, but to a marked reduction in water reabsorption; this effect cannot be seen from the absolute figures, but is apparent immediately when water reabsorption is expressed as a percentage of filtration (82% as compared with 91.7% before the operation).

In Palm, 2-3 months after the operation the filtration increased considerably, but the small increase in diuresis at this time was probably due to an increased water reabsorption (87.6% as aganist 82.2% before the operation).

Regulation of renal function is complex and consist of many reflex processes including hormonal action [1, 4].

Probably changes in the rates of diuresis, filtration, and reabsorption are evidence of compensatory reorganization of the remaining kidney which are brought about by changes in neuro-humoral regulation.

SUMMARY

Compensatory changes in the intact kidney following unilateral nephrectomy in dogs were studied. Diuresis, filtration, and water reabsorption were determined. The absolute values of diuresis, filtration, and water reabsorption were increased in the majority of animals after 2-3 months from the time of the operation.

In the author's opinion, the compensatory changes in the intact kidney is due to alterations in neuro-humoral regulation.

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