EFFECT OF STIMULATION OF EFFERENT FIBERS OF THE SPLANCHNIC NERVES ON RENAL TUBULAR ACTIVITY

V. F. Lysov

UDC 612.465.2:612.893

Stimulation of the peripheral end of the splanchnic nerve or of its renal branches is accompanied by a transient decrease in the blood flow and filtration and by a prolonged decrease in diuresis, an increase in the inulin concentration index, and an increase in the glucose reabsorption and diodrast secretion in the kidney on the side of stimulation, occuring independently of the effect first mentioned. In the opposite kidney only a transient increase in diuresis, filtration, and blood flow is observed.

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The results of morphological investigations published by several authors demonstrated the existence of sympathetic fibers innervating all parts of the nephron. Numerous experimental investigations have established the influence of these fibers on the renal vessels. However, the influence of sympathetic nerves on the epithelium of the renal tubules has not yet been studied.

In the present investigation the effect of stimulation of efferent fibers of the splanchnic nerves on renal tubular activity was studied.

EXPERIMENTAL METHOD

Chronic experiments were carried out on 5 dogs in which the ureters had previously been exteriorized onto the skin of the abdominal wall. The plasma flow and secretion were determined from the diodrast clearance, filtration from the inulin clearance, the glucose reabsorption was estimated, and the water reabsorption was obtained by calculation. The substances used to determine kidney function were injected intravenously into the animal during the experiment as a single solution containing 1% inulin, 30-40% glucose, and 1% (for determination of the blood flow) or 6-7% (for determination of the secretion) diodrast, equivalent to inulin at the rate of 0.5, diodrast at the rate of 0.5 or 6, and glucose at the rate of 40 mg/kg/min. The blood concentration in mg% of inulin (15-20), diodrast (3-5 for the blood flow and 20-25 for the secretion), and glucose (250-400) were kept relatively constant during the investigation. Blood samples were taken from the veins at the middle of the period of urine collection. Inulin was determined by Schreiner's method, glucose by the Hagedorn–Jensen method, and diodrast by the method of White and Rolfe.

The character and degree of the effect of stimulation of the sympathetic nerves on renal tubular activity was judged from the effect of stimulation of the peripheral end of the preliminarily divided splanchnic nerve or of the branches of this nerve to the kidneys. To stimulate the renal branches of the nerve electrodes were placed on the peripheral end of between 2 and 4 nerves accompanying the renal artery. All visible nerve trunks running toward the hilum of the kidney were divided. The experiments began 2-3 days after the operation. The nerves were stimulated by an induction current (1/sec, 2.5 V, distance between coils 14-18 cm). Stimulation usually continued for 50-60 sec and was repeated at intervals of 10-15 sec. The total duration of stimulation was 5 min.

EXPERIMENTAL RESULTS

According to the results of 18 experiments performed on three dogs (Milka, Dinka, and Belyanka), stimulation of both the right and the left splanchnic nerves was accompanied by a considerable (from 2 to 4 times) decrease in diuresis from the ipsilateral kidney. The blood flow (by 1.5-2 times) and filtration (by

Faculty and Department of Physiology, Kazan' Veterinary Institute (Presented by Academician V. V. Parin). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 66, No. 7, pp. 29-32, July, 1968. Original article submitted June 22, 1966.

TABLE 1. Effect of Stimulation of Efferent Fibers of the Splanchnic Nerve on Kidney Function, M ± m

Index of renal function	Kidney	Before stimulation	After stimulation of peripheral end of preliminarily divided splanchnic nerve for 5 min			
			Samples at 10 min intervals			
			1	2	3	4
Diuresis (in ml/min)	Experimental	1.6 ± 0.24	0.53 ± 0.12 P = 0.001	0.58 ± 0.8 P = 0.001	1.03 ± 0.1 P = 0.05	1.23 ± 0.32
	Control	1.4 ± 0.17	1.74 ± 0.25	1.34 ± 0.12	1.33 ± 0.23	1.21 ± 0.1
Plasma flow (in ml/min)	Experimental	135 ± 7.5	78 ± 5.7 P = 0.001	102 ± 6.9 P = 0.01	132 ± 9.9	139 ± 17.8
	Control	116 ± 8.1	174 ± 20.5 P = 0.05	129 ± 5.6	128 ± 13.5	111 ± 13.3
Filtration (in ml/min)	Experimental	30 ± 1.6	14 ± 1.4 P = 0.001	19 ± 2 P = 0.001	27 ± 2.3	29 ± 2.5
	Control	29 ± 1.2	41 ± 1.9 P = 0.001	32 ± 1.4	29 ± 2.2	26 ± 1.5
Inulin concentration index	Experimental	21 ± 1.4	30 ± 2.7 P = 0.01	31 ± 2.8 P = 0.01	28 ± 2.2 P = 0.02	26 ± 1.8 P = 0.05
	Control	23 ± 1.5	25 ± 2.3	25 ± 2.3	23 ± 2.3	23 ± 2.0
Reabsorption of glucose (in %)	Experimental	70 ± 1.9	85 ± 1.3 P = 0.001	87 ± 1.5 P = 0.001		81 ± 1.5 P = 0.001
	Control	80 ± 1.5	76 ± 2.4	78 ± 1.9		73 ± 2.5
Secretion (in mg/min)	Experimental	7.2 ± 0.53	6.0 ± 0.9			8.5 ± 0.5 P = 0.01*
	Control	8.6 ± 0.49	9.3 ± 0.65			7.9 ± 0.67

*Here and in Table 2 the difference method is used to determine the significance of the differences.

2-4 times) diminished significantly in this index. Meanwhile, the inulin concentration was increased (by 36-71%), indicating an increase in reabsorption of water in the tubules. Glucose reabsorption was increased by 15-26%, and the diodrast secretion by 37% (at the 40th minute). The changes in tubular processes after stimulation of the nerve were longer in duration than those affecting the glomeruli. The renal blood flow and filtration began to recover on the average after 20 min, whereas the reabsorption and secretory activity of the tubules was restored after 40 min or later (Table 1). The temporary decrease in the plasma flow and filtration volume resulted from excitation of the vasoconstrictor nerve restricting the blood flow to the glomerula capillaries. However, the decrease in diuresis and the increase in reabsorption of water and glucose and in diodrast secretion cannot be explained by this vascular effect, for they were also observed after recovery of the blood flow and filtration, and were obviously not connected with limitation of the circulation of blood in the kidney. In the contralateral (control) kidney an increase in diuresis, blood flow, and filtration (by 20-48, 34-58, and 27-51% respectively) was observed during the first 10-20 min after stimulation of the nerves. The tubular processes in this kidney were not significantly changed (Table 1). The absence or the slight character of the changes in tubular processes in the control kidney exclude the possibility of the hormonal nature of this increase in tubular activity in the experimental kidney during stimulation of the splanchnic nerve and suggests that the observed effect of stimulation (increased renal tubular activity) resulted from the influence of nervous impulses reaching the tubules.

To confirm this conclusion, the direct influence on the nerve on kidney function was investigated in another series of experiments on two dogs (V'yun and Smirnaya) by stimulating the renal nerve branches. After stimulation of each nerve in the experimental kidney the blood flow (by 20-48%) and filtration (by 23-56%) were decreased in the first 10-20 min. At the same time, the inulin concentration index was increased (by 18-46%) for a long period (40 min), glucose reabsorption was increased by 10-20%, diodrast secretion was increased by 14-18%, while the rate of diuresis was reduced by 38-48% (Table 2). In the contralateral (control) kidney no changes in renal processes could be detected. Evidently the activity of the tubular epithelium of the nepharon is stimulated through the sympathetic nerves of the kidney.

TABLE 2. Effect of Stimulation of Renal Efferent Nerves on Kidney Function

Index of renal function	Kidney	Before stimulation	Time after stimulation of renal nerve for 5 min		
			20 min	40 min	60 min
Diuresis (in ml/min)	Experimental	1.7 ± 0.37	0.6 ± 0.09 P < 0.05	1.2 ± 0.23 P < 0.05*	1.4 ± 0.24
	Control	1.05 ± 0.24	1.24 ± 0.16	1.07 ± 0.11	1.03 ± 0.1
Plasma flow (in ml/min)	Experimental	133 ± 10	90 ± 7.8 P < 0.01	131 ± 12.3	137 ± 12.4
	Control	90 ± 14	121 ± 12	86 ± 9	92 ± 11
Filtration (in ml/min)	Experimental	30 ± 2.4	17 ± 1.5 P < 0.001	28 ± 2.3	29 ± 2
	Control	23 ± 1.8	30 ± 2.1	22 ± 1.6	21 ± 1.9
Inulin concentration index	Experimental	21 ± 2.3	31 ± 2.8 P < 0.01	27 ± 1.6 P < 0.05	23 ± 2.2
	Control	22 ± 2.1	24 ± 2.2	21 ± 1.9	21 ± 2.5
Reabsorption of glucose (in %)	Experimental	71 ± 1.5	85 ± 1.3 P < 0.001	79 ± 1.6 P < 0.05*	70 ± 2.0
	Control	81 ± 2.1	78 ± 2.8	72 ± 3.1	71 ± 1.8
Secretion (in mg/min)	Experimental	6.2	5.2	7.6	8.1
	Control	7.7	8.2	7.3	7.6

Previous attempts to investigate the efferent innervation of the kidneys by stimulating the intact nerve shed little light on the problem of secretory renal nerve [4]. Smith [5] and other authors consider that the renal nerves influence only the vessels of the kidneys. A. G. Ginetsinskii and co-workers [1,2] carried out the first investigations on the effect of stimulation of the neurovascular bundle on kidney function under chronic experimental conditions excluding the possibility of afferent impulses from the stimulated area reaching the brain, and they showed that under these circumstances reabsorption of water and sodium from the tubules is increased. We found that the efferent fibers of the vagus nerves have a definite influence on activity of the renal tubules [3]. The results now described demonstrate the direct stimulant effect of the sympathetic nerves on the reabsorption and secretory activity of the tubules.

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