PATHOLOGICAL PHYSIOLOGY AND GENERAL PATHOLOGY

CHANGES OF RENAL FUNCTION PRODUCED BY HEMISECTION OF THE SPINAL CORD IN DOGS

COMMUNICATION I. THE EFFECT UPON RENAL FUNCTION OF UNILATERAL HEMISECTION OF THE SPINAL CORD AT THE CERVICAL LEVEL

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The homeostatic adjustments of an organism, which manifest themselves after an injury inflicted upon the central nervous system, have been investigated almost solely in the sphere of somatic functions (in the laboratories of F. Holtz, L. Luciani, V. M. Bekhterev, I. P. Pavlov, A. Bete, P. K. Anokhin, E. A. Asratyan and others). The adjustments made in the realm of disturbed vegetative functions have not been really studied even though they are of considerable interest for clinical medicine, especially in the field of neurosurgery and neuropathology. In this field neither the clinician nor the clinical experimenter have much material except what has been picked up accidentally while working on other problems.

The first experiments, having as their deliberate goal the study of the homeostasis of the autonomic system following surgical damage to the central nervous system, were performed by the associates of E. A. Asratyan: in part by Ya. M. Pressman [2] who examined in dogs the role played by the cerebral hemispheres in the adjustments made by the salivary glands, and also by R. O. Barsegyana [1] who examined the effect exerted upon dog gastric functions by the sectioning of the anterior half of the spinal cord. These are the only known experiments studying the homeostatic mechanisms existing within the vegetative system and which make the compensatory adjustments following injury of this or that portion of the central nervous system.

Considering the interest which this problem presents for physiology, as well as for clinical medicine, at the suggestion of E. A. Asratyan, we undertook during the course of 1954-1955 an investigation which sought experimental answers to the questions of how kidney function is disturbed by hemisection of the spinal cord (severing a lateral half); is the function restored in time and what are the dynamics of this restoration, if it occurs ? We also had the thought that these studies might shed light on the question of the nervous regulation of kidney function which has so far been a topic of lively discussions.

EXPERIMENTAL METHODS

The studies were conducted on four dogs operated by the Pavlov-Orbeli method whereby the ureters are individually brought out to the surface of the animal's skin with their natural orifices intact.

This method is especially convenient when there is a desire to compare the working of the two kidneys over a long period of time.

After determining the basic functional condition of both kidneys, a right hemisection of the spinal cord was done on dogs: two at the level of the fifth cervical segment, and two others – the first cervical segment.

In our experiments we thus were able to utilize the comparison of the activities of the two kidneys: the kidneys situated on the operated side and the kidneys lying on the opposite side, as our preoperative expectations were that there would be more malfunctioning on the part of the kidney situated on the same side on which the spinal cord hemisection had been performed.

The reason for this expectation lies in the fact that the spinal vegetative centers, homologous with the operated side, lose their closely-knit structural and functional connection with the higher centers as a result of the spinal cord hemisection.

As before, so after the operation the functional state of the kidneys of each operated dog was determined by observing the diuresis, percentage quantity of chlorides, urea and creatinine in 30 minute samples of urine collected from each ureter over experiments lasting 3-6½ hours, under usual kidney states, as well as when functionally burdened with water (400 cc), table salt and urea (10 grams in 150 cc of diluted milk). In addition, the urine was checked qualitatively for albumin.

Chlorides were determined by Moore's method, urea – by decomposition of the alkalinized bromate in the Borodin apparatus, creatinine – by the colorimetric method, employing the concentrating photocolorimeter, while the qualitative test for albumin was performed with the aid of sulfasalicylic acid.

Our experimental animals were under observation from 7½ up to 16 months. The four dogs had a total of 193 experiments performed upon them in the course of which over 5000 biochemical urine analyses were done.

EXPERIMENTAL RESULTS

On two dogs – Kashtan and Belki – the functional state of the two kidneys was studied before and after right-sided spinal cord hemisection at the level of the fifth cervical segment.

Our studies demonstrated that, before surgery, individual differences between the activities of the left and right kidneys were quite insignificant. As an illustration, we append the protocols of two experiments performed on Kashtan and Belki (see Table).

After the right-sided operation, considerable alterations in the activity of the kidney of the same side could be noted. These changes followed definite cyclic intervals.

In the first period (on the 3rd postoperative day) there were no changes in either kidney when compared with their preoperative base level.

It must be admitted that in one dog (Belki) the concentration and amount of chlorides produced by the kidney of the operated side was somewhat depressed.

In the second period (from the 7th to 22nd-28th postoperative days) the kidney of the operated side developed an increasing diuresis. The kidney on the operated side during the time of the experiment (4-5 hours) produced from 10-40% more urine than the opposite kidney and as compared with its preoperative function. Some individual 30 minute samples from the right kidney produce twice the amount put out by the left.

Along with this diuresis, the urine from the kidney of the operated side showed a diminution in its content of urea and ceatinine. Along with this the concentration of the chlorides rose sharply in Kashtan (sometimes 2-4 fold) while remaining depressed in dog Belki.

In the third period (in Kashtan, from 22nd to 47th, in Belki from 28th to 70th days) urinary output from the right side diminished to only a half of that from the left, in some samples to one-third.

Associated with this there was noted a marked rise in the concentration of the urea, creatinine and chlorides in urine samples from this kidney (2-4 fold) as compared with the concentrations of the same substances from the left kidney.

In the fourth period, in Kashtan beginning with 47th day, in Belki from 70th day, the relationships of these indicators reverted to their normal state.

TABLE

Diuresis, Urea, Chlorides and Creatinine Before and After Right Sided Hemisection of the Spinal Cord at the Fifth Cervical Segmental Level in Dogs Kashtan and Belki

30 min. sample	diuresis (in cc)			urea (in %)			chlorides (in %)			creatine (in %)		
	left kidney	right kidney	correlation	left kidney	right kidney	correlation	left kidney	right kidney	correlation	left kidney	right kidney	correlation
Kashtan. Before surgery. Exp. No. 14 March 26, 1954												
1	7.0	6.5	100 : 93	1.34	1.34	100 : 100	0.04	0.04	100 : 100	0.050	0.051	100 : 101
	Table salt given											
2	13.0	12.5	100 : 96	3,35	3,3	100 : 98	1.09	1.18	100 : 101	0.147	0.152	100 : 103
3	26.5	25.5	100 : 96				1.77	1.8	100 : 101			
4	54.5	54.0	100 : 99				1.8	1.83	100 : 101			
5	68.0	66.0	100 : 97	0,22	0,22	100 : 100	1.8	1.83	100 : 101			
6	34.0	33.5	100 : 98				1.97	1.98	100 : 100	0.008	0 008	100 : 100
7	22.5	21.0	100 : 93				1.9	1.9	100 : 100			
8	15.0	15.0	100 : 100				1.99	1.88	100 : 99			
9	9.0	8.5	100 : 94	0,77	0,7	100 : 91	2.07	2.11	100 : 102	0.034	0.035	100 : 100
7th day after operation. Exp. No. 27, May 3, 1954												
1	3.7	3.0	100 : 81	3.052	2.051	100 : 67	0.092	0.350	100 : 380	0.101	0.076	100 : 75
	Water given											
2	3.6	3.5	100 : 97	4.197	3.052	100 : 72	0.058	0.174	100 : 300	0.116	0.081	100 : 69
3	35.5	35.0	100 : 98									
4	62.0	60.5	100 : 97	0.477	0.381	100 : 80	0.022	0.038	100 : 172	0.0062	0.006	100 : 96
5	47.0	50.0	100 : 106									
6	11.0	15.0	100 : 136									
7	4.0	5.3	100 : 133	1.908	1 526	100 : 80	0.058	0.122	100 : 210	0.077	0.06	100 : 78

TABLE (continued)

30 min. sample	diuresis (in cc)			urea (in %)			chlorides (in %)			creatine (in %)		
	left kidney	right kidney	correlation	left kidney	right kidney	correlation	left kidney	right kidney	correlation	left kidney	right kidney	correlation
					26th postoperative day. Exp. No. 35, May 22, 1954							
1	6.0	2.2	100 : 36	2.926	7.457	100 : 255	0.339	1.426	100 : 420	0.065	0.162	100 : 249
	Table salt given											
2	6.0	2.2	100 : 36	2.501	6.985	100 : 279	0.467	1.648	100 : 353	0.063	0 176	100 : 279
3	8.0	6.1	100 : 76				0.613	1.706	100 : 278			
4	40.0	28.7	100 : 71				1.777	2.461	100 : 138			
5	59.5	33.0	100 : 55	0.424	0.802	100 : 189	1.66	2.379	100 : 143	0.007	0.013	100 : 185
6	44.5	23.2	100 : 52				1.666	2.583	100 : 155			
7	35.5	19.0	100 : 53				1.665	2.624	100 : 157			
8	25.0	14.0	100 : 56				1.638	2.718	100 : 166			
9	20.5	11.5	100 : 56	0.66	1.321	100 : 200	1.59	2 776	100 : 174	0.015	0.034	100 : 226
					Belki. Before surgery. Exp.No.16 March 26,1954							
1	3.0	3.0	100 : 100	3.54	3.35	100 : 95	0,08	0.08	100 : 100	0.129	0.116	100 : 89
				Table salt given								
2	4.0	4.0	100 : 100				0.33	0.33	100 : 100			
3	5.0	5.0	100 : 100	2.15	1.77	100 : 82	1.71	1.64	100 : 96	0.068	0.052	100 : 76
4	27.5	27.5	100 : 100	0.62	0,48	100 : 77	1.84	1.75	100 : 85	0.017	0.015	100 : 88
5	28.0	28.0	100 : 100				1.87	1.8	100 : 96			
6	17.5	17.0	100 : 97				1.94	1.89	100 : 97			
7	11.0	11.0	100 : 100				1.99	1.91	100 : 96			
8	7.5	7.5	100 : 100				2.07	1.94	100 : 94			
9	7.0	6.5	100 : 93				1.98	1 87	100 : 94			
10	4.5	4.0	100 : 89	1.15	1.1	100 : 96	2.05	1.94	100 : 94	0.059	0.051	100: 86

TABLE (continued)

30 min. sample	diuresis (in cc)			urea (in ‰)			chlorides (in ‰)			creatine (in ‰)		
	left kidney	right kidney	correlation	left kidney	right kidney	correlation	left kidney	right kidney	correlation	left kidney	right kidney	correlation
19th postoperative day. Exp. No. 34 May 15,1954												
1	2.1	2.5	100 : 119	6.72	5.184	100 : 77	1.034	0.596	100 : 58	0.152	0 096	100 : 62
				Table salt given								
2	2.2	2.8	100 : 126	6.144	4.608	100 : 75	1.479	0.847	100 : 57	0.148	0.098	100 : 67
3	4.8	5.5	100 : 115				2.835	2.145	100 : 76			
4	30.5	41.0	100 : 134				2.332	1.964	100 : 72			
5	32.0	57.0	100 : 178	0.72	0.24	100 : 34	2.279	1.853	100 : 81	0.011	0.006	100 : 54
6	29.6	34.5	100 : 116				2.239	2.016	100 : 90			
7	21.0	35.0	100 : 166				2.502	2.046	100 : 82			
8	25.0	28.0	100 : 112				2.32	2.005	100 : 86			
9	15.5	19 5	100 : 126				2.331	2.057	100 : 88			
10	13.5	15.0	100 : 111	1.344	0.432	100 : 32	2.519	2.104	100 : 83	0.026	0.018	100 : 69
28th postoperative day. Exp.No.34 May 15,1954.												
1	5.7	2.7	100 : 47	3.414	6 638	100 : 192	0 859	1.432	100 : 166	0 156	0.253	100 : 162
				Water given								
2	9.5	5.0	100 : 52	2.987	5.263	100 : 175	1.23	1.853	100 : 150	0.093	0.131	100 : 140
3	37.3	27.0	100 : 72									
4	56.7	47.5	100 : 83	0.367	0.486	100 : 132	0.277	0.295	100 : 107	0.011	0.013	100 : 118
5	28.0	19.0	100 : 67									
6	15.7	9.2	100 : 58									
7	13.2	7.2	100 : 54									
8	12.0	6.1	100 : 51	2.086	3.746	100 : 179	0.774	1.131	100 : 146	0.056	0.090	100 : 160

Kashtan, in addition, had a fifth period (from 52nd to 73rd day) characterized by a secondary diuresis accompanied by correspondingly diminished concentrations of urea, creatinine and chlorides in the kidney on the operated side. Only after that was their return to base level in the kidney functions studied.

The basic data is presented in the table.

We also examined this problem from the standpoint of spinal cord hemisection well above the spinal sympathetic centers, i.e., at the level of the first cervical segment. This experiment was conducted also on two dogs — Zolushke and Rzhei.

Essentially, the changes observed were similar to those seen in the fifth cervical sement hemisections except that they were less pronounced and characterized by certain peculiarities. In part, the kidney on the operated side failed to develop a diuretic phase accompanied by increased concentrations of urea, creatinine and chlorides which was a characteristic of the dogs who underwent surgery at the fifth cervical segment level.

Judging by our accumulated data, in all the operated dogs kidney functions were fully back to normal within $2^1/_2$-3 months after the hemisections of either the higher or lower cervical spinal cord segments. Somatic functions—standing, walking and running— returned in these same animals within 35-40 days, i.e., 2 times more quickly than the kidney functions.

In regard to the albumin which was determined qualitatively, the following was noted. After right-sided hemisection at the fifth cervical segment, both kidneys developed traces of albumin, the right in a slightly greater amount. Within 7 days the albumin was gone from the left-sided specimens although still present at 7-10 days in samples obtained from the right side. In dogs subjected to hemisection at the level of the first cervical segment, albumin appeared only in specimens from the operated side and then was gone within the week.

SUMMARY

Four dogs with individual fistulae of each ureter operated by the Pavlov-Orbeli method were studied. Before and after hemisection of the spinal cord at the level of the cervical segments, diuresis, urea, chlorides and creatinine concentration have been estimated in the urine of each kidney separately on the normal and operated side. Hemisection of the spinal cord at the level of the first or fifth cervical segment caused phasic changes in the function of the kidney on the operated side, the more so when hemisection was performed at the level of the fifth segment. All tests performed indicated that disturbed renal function is fully restored in the course of 2,5-3 months, while somatic functions of the same dogs were fully restored in 35-40 days.

LITERATURE CITED

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[2] Ya. M. Pressman, Sovetskaya Psikhiatriya, 1941, No. 6, pp. 501-511.

* In Russian.