THE EFFECT OF THE EXTIRPATION OF THE STELLATE GANGLIA ON THE MECHANICAL HEART HYPERTROPHY OF ALBINO RATS.

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With 3 Tables in the Text.

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We have worked out a method by which, through the narrowing of the descending aorta (HAJDU, M. BEZNÁK 1943, 1945), resp. the ascending aorta (M. BEZNÁK, HAJDU 1945, HAJDU, M. BEZNÁK 1947), a heart hypertrophy can be produced in albino rats. We have also proved that this hypertrophy does not take place in hypophysectomized animals. In our present investigation we wanted to decide what part the innervation of the heart played in the production of mechanical heart hypertrophy.

BRANDSBURG (1925) found degenerative changes in the heart muscle of rabbits after cutting the cervical sympathetic, or extirpating the inferior cervical ganglion, and of dogs after cutting the cervical vagosympathetic. IONESCU and RAILEANU (1929), on the other hand, found neither trophic nor inflammatory changes in the hearts of rabbits after the extirpation of the stellate ganglia. IONESCU et al. (1925, 1926), in several of their publications, maintain that the extirpation of the stellate ganglia has no damaging effect on the condition and adaptation-ability of the heart. DANIELOPOLU et al. (1929) state that, whereas extirpation of the stellate ganglia has hardly any effect on the normal heart, grave symptoms are produced on hearts which had previously been damaged (ligation of a coronary branch or of a part of the muscular wall).

It therefore seemed interesting to decide how the heart reacts after the extirpation of the stellate ganglia, if — by narrowing the aorta — the heart is forced to work harder. It seemed the more interesting as we have found, in the case of the suprarenal, that it can hypertrophize if hypertrophogen stimuli (acids, cholesterol, corticotropic hormone) reach it immediately, or soon after, the extirpation of the coeliac ganglion; while, if a longer time elapses between the denervation and the application of the hypertrophy-causing stimuli, no hypertrophy is produced by the denervated gland. (M. BEZNÁK, KORÉNYI, HAJDU 1940, 1942). In the case of the heart, the situation is different, as the heart, because of its autonomy, works continually. The other great difference is that in the rat, by extirpating the coeliac ganglion, the suprarenal becomes totally denervated, while the extirpation of the stellate ganglia deprives the heart probably only of its praeganglional fibres.

METHODS.

Our experiments were performed on 147 male albino rats weighing 188 ± 10 g. 37 rats served as controls. The stellate ganglia were extirpated from 110 rats in ether anaesthesia, from behind. The operation caused a mortality of about 10%. A smaller part of the deaths was caused by pneumothorax (1—2%, always on the right side), the greater part by sudden failure of the heart. The ascending aortae of some groups of rats were narrowed at different times after extirpating the stellate ganglia, with a silver ring of 1.5 mm diameter. (HAJDU, M. BEZNÁK 1947).

After the experimental period, the animals still alive were killed, their hearts cut out immediately, freed from blood and weighed. The two ventricles, the atria and the septum were weighed separately on a torsion balance, with an accuracy of ±1 mg. We divided the weight of the septum according to the left ventricle per right ventricle ratio and added the resp. weights to those of the ventricular wall found by direct weighing.

Part of the left ventricles were used for histological examinations. Some of them were fixed in 10% formalin and after imbedding in paraffin stained by the VAN GIESON method, and some observed in frozen slices stained with Sudan.

The dry-matter content was determined in the ventricular part of the heart, not including the atria.

EXPERIMENTAL RESULTS.

98 out of the 110 ganglionectomized rats survived the operation. These were divided in 5 groups. A separate group contained 37 normal rats (group 1.). Group 2. contained 13 rats, which were killed 3 days

after the extirpation of the stellate ganglia. They served as controls to the 3rd group of 23 rats, whose ascending aorta was narrowed 3 days after ganglionectomy. The animals began to die — as described in earlier publications (BEZNÁK M., HAJDU, and HAJDU, M. BEZNÁK l. c.) — 3 days after the narrowing, in consequence of aortic rupture. The surviving animals were killed 1 week after the narrowing. The 4th group served as control to this final date, its 22 animals being killed 9 days after stellate ganglia extirpation. The ascending aorta of the 16 rats forming the 5th group was narrowed 2 weeks after ganglionectomy and the surviving animals killed 7 days after the narrowing. Group 6 served as control, containing 24 rats whose stellate ganglia had been removed 20 days previously. (The Tables contain the data of only 22 rats, as 2 died in the course of the 3 weeks following ganglionectomy).

Table I. contains the data of the groups whose stellate ganglia had been extirpated at different times previously. Comparing the results of these groups, we see that the extirpation of the stellate ganglia causes a gradual increase in the total heart weight. 3 days after ganglionectomy (group 2) there is no increase, on the 9th day (group 4) the increase is 6% and on the 21st day (group 6) 11%. With the increase in the heart weights the significance of difference between the mean values also increases.

The 2nd part of Table I. contains the ratio of left ventricle per right ventricle. As is seen from the Table, this ratio remains the same in all stellate-extirpated groups as in the normal. It follows, therefore, that the left and right ventricles take an equal part in the hypertrophy caused by stellate ganglia extirpation.

TABLE I.

Heart weights in mg of ganglionectomized animals.

1. Normal	2. 3 days after stellate ganglia extirpation	4. 9 days after stellate ganglia extirpation	6. 3 weeks after stellate ganglia extirpation
No. M. ± μ	No. M. ± μ	No. M. ± μ	No. M. ± μ
37 665 65	13 649 69	22 707 89	22 737 55

(1 vs 2) k = 0.7, D = 2% (1 vs 4) k = 2.2, D = 6% (1 vs 6) k = 4.6, D = 11%

Left ventricle per right ventricle ratio of ganglionectomized animals.

1. Normal			2. 3 days after			4. 9 days after			6. 3 weeks after		
			stellate ganglia extirpation								
No.	M.	$\pm\mu$	No.	M.	$\pm\mu$	No.	M.	$\pm\mu$	No.	M.	$\pm\mu$
37	2.64	0.3	13	2.67	0.60	22	2.69	0.29	22	2.69	0.39

k = 0.2, D = 1% k = 0.6, D = 2% k = 0.5, D = 2%

Table II. answers the question how the hearts whose stellate ganglia had been extirpated at different times previously react to hypertrophy-producing stimuli. In group 3, the stellate ganglia had been extirpated 3 days, in group 5, 14 days before narrowing the aorta. In both groups the narrowing ring was allowed to act at the most for 7 days. On comparing groups 3 and 4, we see that there is practically no difference between them: that is, between the weights of hearts sympathectomized 9 days previously and those whose aortae had been narrowed on the 3rd day after ganglionectomy. On the other hand, in group 5, where the narrowing took place 14 days after stellate extirpation, the heart weights are 9% higher than in group 6, where ganglionectomy alone took place. The significance of difference between groups 5 and 6 is 3.2. It follows from these results that the later the hypertrophy-causing stimulus reaches the heart after ganglionectomy, the greater its resulting hypertrophy.

TABLE II.
Heart weights in mg.

1. Normal			3. 7 d. narrowing 3 days after stell. ggl. ext.			4. 9 days after stell. ggl. ext.			5. 7 d. narrowing 2 weeks after stell. ggl. ext.			6. 3 weeks after stell. ggl. ext.		
No.	M.	$\pm\mu$	No.	M.	$\pm\mu$	No.	M.	$\pm\mu$	No.	M.	$\pm\mu$	No.	M.	$\pm\mu$
37	665	65	23	717	84	22	707	89	16	801	78	22	737	55

k = 2.6, D = 8% k = 2.2, D = 6% k = 6.2, D = 20% k = 4.6, D = 11%

k = 0.4, D = 1% k = 3.2, D = 9 %

Left ventricle per right ventricle ratio.

1. Normal			3. 7 d. narrowing 3 days after stell. ggl. ext.			4. 9 days after stell. ggl. ext.			5. 7 d. narrowing 2 weeks after stell. ggl. ext.			6. 3 weeks after stell. ggl. ext.		
No.	M.	$\pm\mu$	No.	M.	$\pm\mu$	No.	M.	$\pm\mu$	No.	M.	$\pm\mu$	No.	M.	$\pm\mu$
37	2.64	0.36	23	3.06	0.36	22	2.69	0.29	16	3.22	0.34	22	2.69	0.35

k = 4.2, D = 16% k = 0.6, D = 2% k = 5.8, D = 22% k = 4.5, D = 2%

k = 3.7, D = 14% k = 4.8, D = 21%

The 2nd part of Table II. shows the left per right ventricle ratios. We see that in group 3, where the aorta was narrowed 3 days after ganglionectomy, this ratio is 16% higher than in the normal, and 14% higher than in the 4 th group, where stellate ganglia extirpation had been carried out without consecutive narrowing. That the ratio is increased in group 3 shows that narrowing the aorta 3 days after stellate ganglionectomy, causes hypertrophy of the left ventricle.

To elucidate the nature of the weight increase caused in the heart by stellate ganglia extirpation, estimations of the water content and histological examinations were carried out. That the weight increase after ganglionectomy is not caused by the accumulation of water is shown in Table III. It is seen from this Table that the percentual dry-matter content remains the same in all stellate extirpated groups

TABLE III.

Dry-matter content in %.

1. Normal			2. 3 days after stellate ganglia extirpation			4. 9 days after stellate ganglia extirpation			6. 3 weeks after stellate ganglia extirpation		
No.	M.	$\pm\mu$	No.	M.	$\pm\mu$	No.	M.	$\pm\mu$	No.	M.	$\pm\mu$
37	21.4	1.06	13	21.6	0.70	22	21.1	0.43	22	21.0	0.61

k = 1.6 k = 0.4 k = 1.9

as in the normal. The dry-matter content of the hearts of the narrowed groups was the same as that previously described (HAJDU, M. BEZNÁK l. c.) The histological examinations of the hearts at different times after stellate ganglionectomy (VAN GIESON and sudan staining) showed no difference as compared with the normal picture of the heart.

DISCUSSION.

Summing up our results, we can conclude that bilateral stellate ganglia extirpation causes a gradual increase in the heart weight. We are as yet unable to state the nature of the increase. According to the literature, degeneration, trophical and inflammatory changes could have been expected. BOYD and MCCULLAGH (1938) reported the accumulation of interstitial tissue in rabbits' hearts after cutting the buffer nerves. A. B. L. BEZNÁK and HASCH (1937) as well as HAUSBERGER (1934, 1935) found accumulation of connective fat in those regions whose sympathetic innervation had been severed. We, however, were unable to show an accumulation of connective tissue or fat by histological examinations of the hearts after ganglionectomy. The differences in species and in time elapsing between desympathisation and histological examination may, however, — at least to some extent — be the cause of the divergent findings. Neither can the weight increase of the heart be caused by an accumulation of water, as the percentual dry-matter content remained unaltered.

If the ascending aorta of rats is narrowed at different times after stellate ganglia extirpation, a further hypertrophy is caused. There is hardly any difference between the weight of the whole hearts of groups 3 and 4 — as was seen in the upper parts of Tables I and II — yet the left per right ventricle ratio is significantly greater in group 3 (where narrowing took place) than in group 4 (only ganglionectomy). This apparent discrepancy can be explained in two ways. Narrowing 3 days after ganglionectomy causes either an exclusive left ventricle hypertrophy with no, or a correspondingly smaller, right ventricle hypertrophy due to ganglionectomy, or an exclusive left ventricle hypertrophy which is superimposed on the general hypertrophy caused by stellate ganglia extirpation. Owing to the rather small weight of the right ventricles, the question cannot be decided from uor present data. When, however, the narrowing takes place 14 days after ganglionectomy (group 5), it causes a considerably greater total hypertrophy, with a greater increase of the left per right ventricle ratio. It is certain here that narrowing produces an exclusive left ventricle hypertrophy which is superimposed upon the general hypertrophy caused by the ganglionectomy, preceding the narrowing by 14 days.

The conclusion seems, therefore, warranted that the longer the time elapsing between stellate ganglia extirpation and narrowing of the aorta, the greater the hypertrophy of the heart in consequence of the narrowing. This is an interesting difference, when compared with the behaviour of the rats' suprarenals. It was shown by us earlier that the suprarenals of rats atrophise in consequence of the extirpation of the coeliac ganglion. If hypertrophy-causing stimuli reach the suprarenals soon after coeliac ganglion extirpation, a suprarenal hypertrophy is produced. The longer the time elapsing between denervation and the application of the hypertrophy-causing stimuli, the smaller the resulting hypertrophy. This difference may be accounted for by the fact that in the rat the removal of the coeliac ganglion causes a total denervation of the suprarenals, depriving them of all postganglional fibers, whereas in the heart the parasympathetic postganglional fibres in particular remain after the extirpation of the stellate ganglia.

SUMMARY.

1. Extirpation of the stellate ganglia causes in albino rats a gradual increase in the heart weight. This weight increase is not caused by the accumulation of water, nor was an accumulation of connective tissue or fat detected by histological examinations.

2. If the ascending aorta of rats is narrowed at different times after stellate ganglia extirpation, an exclusive left ventricle hypertrophy — as is the case in normal animals — is caused, which is superimposed on the general weight increase due to stellate ganglia extirpation. The hypertrophy is, however, the greater the longer the time elapsing between stellate ganglionectomy and narrowing of the aorta.

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