EFFECT OF PERIPHERAL DIVISION OF THE SYMPATHETIC NERVOUS SYSTEM ON MORPHOLOGY AND FUNCTION OF THE PANCREATIC INSULAR SYSTEM

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Following sympathetic denervation of the pancreas or prolonged subcutaneous injection of adrenalin, increases are found in the tolerance of albino rats to double loading with glucose, the area of the incretory tissue, the size of the β-cells in the islets of Langerhans, and in the zinc content of these cells.

Some authorities consider that the participation of the sympathetic nervous system in control of carbohydrate metabolism is effected through the adrenal medulla, i.e., by a neurohumoral mechanism, through an increase in the secretion of adrenalin in response to hypoglycemia [2, 9, 10]. Meanwhile, after abdominal sympathectomy, cytological and cytometric evidence is observed of increased functional activity of the endocrine cells of the islets of Langerhans [8].

This paper describes morphological and physiological data indicating a direct influence of sympathetic nerve fibers on β-cells of the pancreatic insular system.

EXPERIMENTAL METHOD

Experiments were carried out on 250 male albino rats weighing 150-200 g, subdivided into 5 groups with 50 animals in each group: group 1 was the control; bilateral subphrenic division of the splanchnic nerves was performed on the animals of group 2; the lumbo-sacral part of the lateral sympathetic trunks was removed from the rats of group 3; a bilateral perinephric block with 0.5% procaine solution in a dose of 1 ml/100 g body weight was carried out daily for 10 days on the animals of group 4; the rats of group 5 received subcutaneous injections of adrenalin (2 mg/kg) twice a day for 14 days. The animals of groups 2, 3, and 5 were killed with ether 14 days after the beginning of the experiment, and those of group 4 were sacrificed after 10 days. To test the function of the incretory system of the pancreas, the blood sugar level was determined before and on the 7th day of the experiment, in a fasting state and after a double loading with glucose (2 g/kg) body weight). At the end of the experiment, changes in the histological structure of the pancreas were studied, and the content and histotopography of zinc in the gland were determined. Zinc accumulates in the cytoplasm of the islet cells and is a reliable histochemical index of their functional activity [6, 11].

The blood sugar was determined by the Hagedorn–Jensen method. The histological structure of the pancreas was studied in sections stained with hematoxylin–eosin or with azan. The zinc content was determined polarographically [1], and its histotopography by a silver sulfide method [7, 11]. The numerical data were analyzed statistically by the method of direct differences [3].

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TABLE 1. Blood Sugar of Albino Rats, Some Indices of Histological Structure of the Pancreas, and Zinc Content in the Pancreas (M ± m)*

Experimental conditions	Blood sugar (in mg%) on 7th day of experiment						Richardson and Young's index	Diameter of β-cells (in μ)	Zinc content† (in μg/g fresh tissue)
	fasting	after 1st glucose loading		after 2nd glucose loading					
		30 min	60 min	30 min	60 min	90 min			
Control	86±1	102±2	111±2	108±2	100±2	90±2	0,75±0,05	16,6±0,1	16,2
Bilateral subphrenic division of splanchnic nerves	73±2	78±3	82±3	79±3	81±3	69±3	1,12±0,05	12,0±0,2	21
P	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	9%	
Lumbo-sacral sympathectomy	67±1	85±1	90±1	85±1	75±1	67±1	1,30±0,05	12,0±0,2	29
P	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	9%	
Perinephric block with procaine	76±3	94±2	92±3	86±4	85±3	79±4	1,00±0,05	12,1±0,1	30
P	0,2%	0,9%	0,1%	0,1%	0,1%	0,1%	0,1%	0,2%	
Subcutaneous injection of adrenalin	80±2	90±1	99±1	90±3	85±3	82±2	1,2±0,06	12,1±0,2	23
P	5%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%	

*Statistical analysis as in [3].

†Zinc content determined in 20 pancreases from each group of animals.

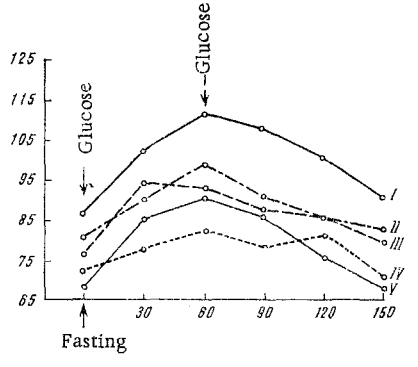

Fig. 1

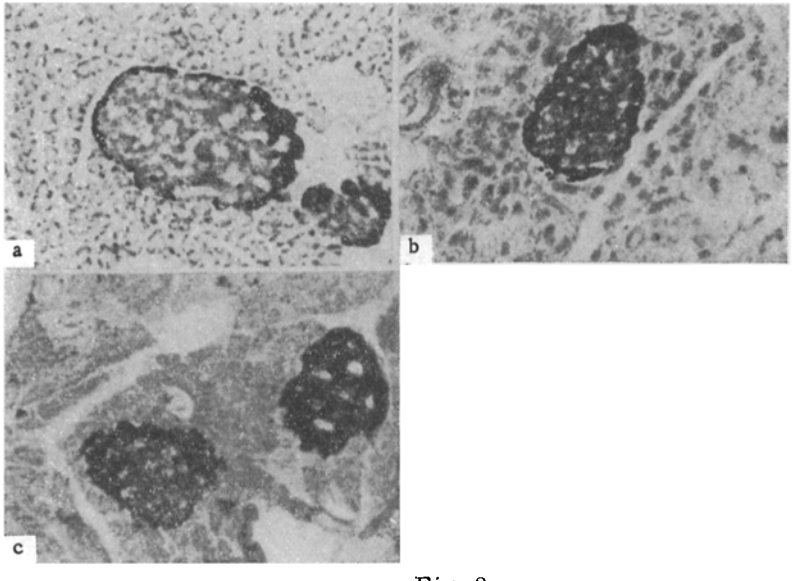

Fig. 2

Fig. 1. Blood sugar curves before experiment (I), on 10th day of injection of adrenalin (II), after 7 procaine blocks (III), 7 days after division of splanchnic nerves (IV), and after sympathectomy (V). Abscissa, time (in min); ordinate, blood sugar (in mg %).

Fig. 2. Zinc in pancreas of intact rat (A), 14 days after sympathectomy (B), and after 28 injections (14 days) of adrenalin (C). Silver sulfide method, hematoxylin, 100×.

EXPERIMENTAL RESULTS

Division of the splanchnic nerve and removal of the lumbar part of the lateral sympathetic trunk was followed by lowering of the fasting blood sugar (Table 1), in agreement with data in the literature.

The blood sugar curves obtained after a double loading with glucose, for all experimental animals including those receiving prolonged administration of adrenlin, indicated high tolerance to carbohydrate loading (Fig. 1). A characteristic feature of these curves was the comparatively low initial blood sugar level, its slight increase after the first dose of glucose, and the fall in the blood sugar after the second loading.

Morphological changes in the pancreas of the animals of the experimental groups consisted essentially of well marked hyperemia of the organ (sinusoidal capillaries of the islets of Langerhans were particularly dilated), an increase in the area of incretory tissue, and an increase in the size of its β-cells. The zinc content in the organ was increased (Table 1).

Histochemical sections treated by the silver sulfide method to detect zinc showed very clearly that the increase in the content of this trace element in the pancreas took place mainly through its accumulation in the cytoplasm of the β-cells of the islets of Langerhans, since the reactions for zinc in the α-cells and cells of the exocrine parenchyma was unchanged (Fig. 2).

The predominantly sympathetic denervation of the pancreas is thus accompanied by changes in the blood sugar, in the histological structure of the organ, and in the content and histotopography of zinc in it, characteristic of increased functional activity of the β-cells of the islets of Langerhans.

The lowering of the blood sugar and increase of tolerance to carbohydrate loading could be attributed to the hypoadrenalinemia arising after desympathization, for as long ago as in 1909, Cheboksarov [5] showed that after division of the splanchnic nerves the production of adrenalin by the adrenal medulla falls sharply. Khalitova [4] has shown that after blocking of the splanchnic nerves with procaine, liberation of adrenalin into the blood ceases. However, it is hardly likely that the increase in quantity of incretory tissue of the pancreas, the increase in size of its β-cells, and the accumulation of zinc in them could be explained by hypoadrenalinemia. On the contrary, in the present experiments the prolonged administration of adrenalin to rats also led to an increase in the area of the islets of Langerhans and to the accumulation of zinc in the cytoplasm of the β-cells.

Consequently, the histological structure of the pancreas and the zinc content in the β-cells of its islets showed identical changes following sympathetic denervation, in the presence of hypoadrenalinemia, and during repeated injections of exogenous adrenalin. These facts suggest that the increase in area of the islets of Langerhans, in the size of their β-cells, and in the zinc content in their cytoplasm following desympathization took place, not as a result of any decrease in adrenalin production by the adrenal medulla, but through blocking of the direct inhibitory effect of sympathetic nerve fibers on the insular system. In all probability, adrenalin acts indirectly on the β-cells, by raising the blood sugar level, and it is this which stimulates function of the β-cells. Prolonged feeding of experimental animals with sugar in fact leads to the same changes in their pancreas as prolonged administration of adrenalin [6].

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