THE UPTAKE OF RADIOACTIVE PHOSPHORUS (P^{32}) BY VARIOUS STRUCTURES OF THE HEART

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The whole complexity and diversity of the cardiac activity are determined by a clear interrelationship of its structures, which possess different functional characteristics. The principal functional properties of cardiac muscle — automatism, excitation, conduction, contractility — are inherent to a varying degree in different structures of the heart, and only under pathological conditions do radical changes develop in these characteristics, so that the functional interrelationships of the divisions of the heart are disturbed. The generally accepted view now is that the heart is a functionally nonhomogeneous excitatory system [2, 9, 10, 11, 12, 15, 16].

There is no doubt that the functional characteristics of the structures of the heart are determined by the specific biochemical processes which take place in them. In the study of the biochemical transformations in the heart, however, the specific metabolic processes in its structures have not yet been taken into consideration. By this approach, all the distinctive features of metabolism inherent in the various divisions of the heart, its neuromuscular apparatus, conducting system and nerve ganglia are obliterated.

We consider that the radioactive isotope method, by making it possible to study biochemical conversions even in microstructures, will enable the characteristic features of the metabolism of the different elements of the heart to be compared. In our first move toward the solution of this problem it was important to determine the rate of uptake of labeled atoms in the divisions of the heart — the right and left atria, the right and left ventricles — and in the individual links of the conducting system of the heart — the sino-auricular and atrioventricular nodes and the bundle of His. Bearing in mind the importance of high-energy phosphorus compounds in metabolic processes in the heart, we studied the uptake of radioactive phosphorus in the different structures of the heart.

EXPERIMENTAL METHOD

Experiments were carried out on 28 rabbits. The animals received intravenous injections of 50 μC (16 experiments) or 150 μC (12 experiments) of radioactive phosphorus.

After different intervals of time — 4, 24, 48 and 96 hours — the animals were killed and the heart taken out. Equal samples by weight were taken from the various divisions of the heart. The correct selection of the weighed samples for the investigation was checked morphologically — sections were prepared from corresponding areas of the heart. In order to determine the radioactivity of the areas, in some cases the weighed sample was chopped up into small pieces on the target, in an area of 5 × 5 mm, after which the number of impulses was counted by means of a B-2 counting apparatus. In other cases samples weighing 30-50 mg were incinerated together with 300 mg of starch in a muffle furnace, then evenly distributed on the target, and two drops of celloiden were then allowed to fall on the resulting preparation. No difference in principle was observed between the results in each case.

EXPERIMENTAL RESULTS

The general conclusion from our investigations was that a definite topography existed in the uptake of P^{32} in the various structures of the heart. The most intensive uptake of radiophosphorus took place in the muscle of the left ventricle. This fact was confirmed in all the experiments. Another important discovery was that the radioactivity of the left ventricle greatly exceeded the radioactivity of the blood and of all other divisions of the heart, including the right ventricle. The intensity of uptake of radioactive phosphorus in the left ventricle now and then was 2-3 times greater than in the other divisions of the heart. The comparative data of the intensity of uptake of P^{32} in the various divisions of the heart are shown in Fig. 1.

As may be seen from this figure, in the majority of experiments the following sequence was observed in the intensity of uptake of P^{32} in the division of the heart: left ventricle, right ventricle, left atrium, right atrium. In experiment No. 4, for instance, the number of impulses per minute over and above the background level from a sample taken from the left ventricle was 730, from the right ventricle 400, the left atrium 240 and the right atrium 186; in experiment No. 11 the corresponding figures were: left ventricle 918, right ventricle 598, left atrium 502 and right atrium 400.

In all the experiments we also determined the number of impulses in the elements of the conducting system — the sino-auricular and atrioventricular nodes and the bundle of His. The fact that the sino-auricular and atrioventricular nodes showed low radioactivity was of importance in principle. The intensity of uptake of P^{32} in the nodes of automatism was minimal — significantly less than in all the other structutures of the heart. P^{32} was taken up more intensively by the elements of the bundle of His.

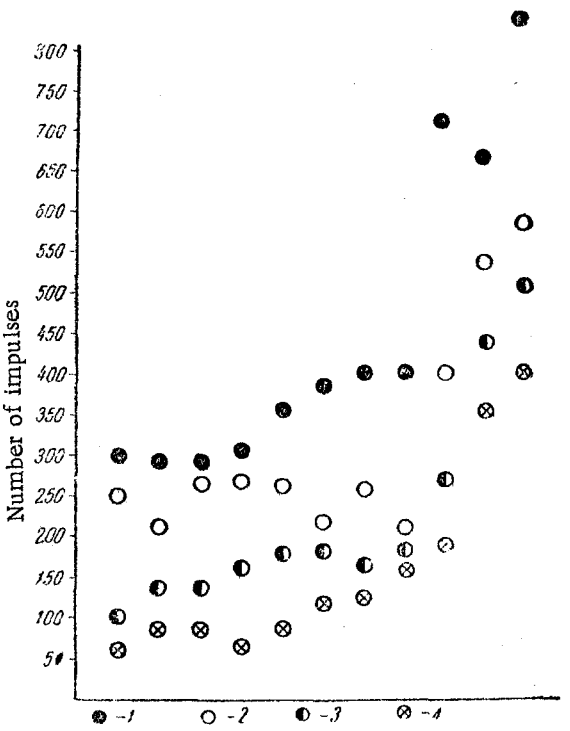

Fig. 1. Intensity of uptake of P^{32} in the left ventricle (1), the right ventricle (2), the left atrium (3) and the right atrium (4).

In Fig. 2 are shown the results of experiments enabling the intensity of uptake of P^{32} by the different structures of the heart to be compared.

It might have been assumed that the topography of distribution of radioactive phosphorus which we found in the heart was largely determined by differences in the blood supply of the heart structures [1, 4, 5, 6, 7, 8, 13] and by the resulting inequality in the blood content of the samples. Both direct and indirect proof was present of the groundlessness of this assumption. In the first place, the radioactivity of some structures of the heart was considerably higher than that of the blood; in the second place there was no parallel between the abundance of the blood supply of the various divisions of the heart and the activity of uptake of P^{32} therein.

In order to prove the relationship between the uptake of P^{32} by the structures of the heart and the intensity of the metabolic processes in these structures, we carried out a series of experiments. The heart of experimental animals was perfused for a long time with physiological saline through a cannula introduced into the aorta. By this means the blood was thoroughly washed from the system of coronary vessels. The intensity of uptake of P^{32} by the various structures of the heart was then determined. The results of these experiments are shown in Fig. 3. We can see that flushing out the coronary vessels did not alter the topography of the intensity of uptake of P^{32} by the structures of the heart.

The known morphological and functional characteristics of the structures of the heart were thus reinforced by our findings of the specificity of the course of the metabolic processes taking place within them. From our point of view a fact of particular interest is that of the minimal uptake of P^{32} by the sino-auricular and atrioventricular nodes, the functional peculiarity of which is their power of automatic activity, which was more pronounced.

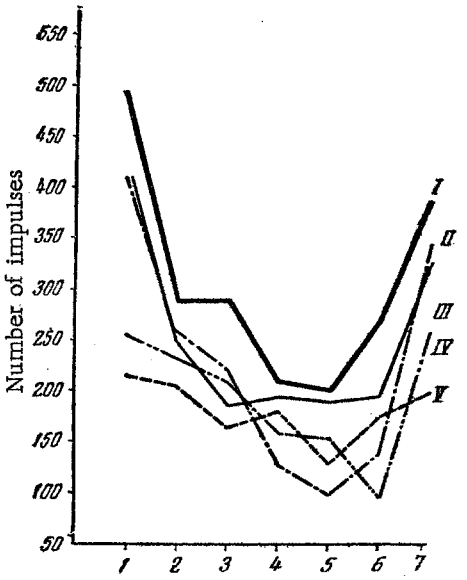

Fig. 2. Intensity of uptake of P^{32} in the different structures of the heart. 1) Left ventricle; 2) right ventricle; 3) left atrium; 4) right atrium; 5) sino-auricular and 6) atrioventricular nodes; 7) bundle of His.

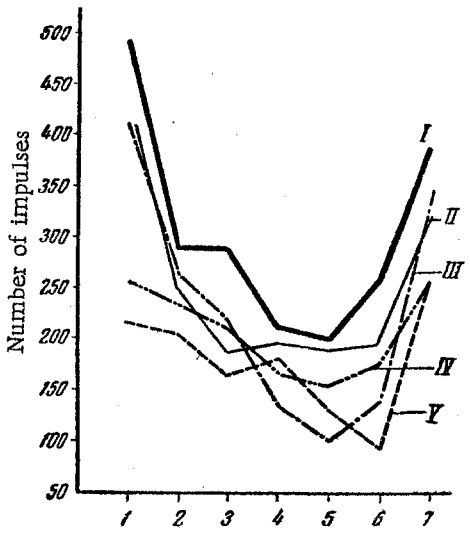

Fig. 3. Intensity of uptake of P^{32} in the different structures of the heart after perfusion of the organ. 1) Left ventricle; 2) right ventricle; 3) left atrium; 4) right atrium; 5) sino-auricular node; 6) atrioventricular node; 7) bundle of His.

in the sino-auricular node. The intensity of uptake of P^{32} by the sino-auricular node was always greater than that of the atrioventricular. The high radioactivity of the bundle of His agrees with the physiological data of its well marked conducting power and contractility.

The information which we gained on the uneven intensity of uptake of P^{32} by the various divisions of the heart – the right and left atria, and the right and left ventricles – indicates the fine adaptation of the metabolic processes to the conditions of normal cardiac activity. Further study of the course of the metabolic processes in the structures of the heart will permit an explanation of the most intimate mechanisms responsible for determining the varied nature of the reaction of the heart to the constantly changing conditions of existence of the animal.

SUMMARY

Experiments were performed on rabbits. There was a definite topography of radiophosphorus (P^{32}) inclusion into different portions and structures of the heart.

The intensity of this inclusion decreased in the following sequence: left ventricle (maximal intensity), right ventricle, left auricle, right auricle. It was also demonstrated that in experimental conditions the radioactivity of the left ventricle is much greater (by 3-4 times) than that of the other portions of the heart and blood. The centers or nerve ganglions governing automatic control are characterized by a minimal intensity of the P^{32} inclusion. The inclusion of radiophosphorus is more intense in the elements of the bundle of His than in the sino-auricular and atrioventricular nodes.

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