EFFECT OF DAMAGE TO DIFFERENT PARTS OF THE CENTRAL NERVOUS SYSTEM ON THE CARDIAC ACTIVITY OF THE CHICK EMBRYO

O. V. Bogdanov

Department of Comparative Physiology and Pathology,
Institute of Experimental Medicine (Director, Active Member AMN SSSR Professor D. A. Biryukov) AMN SSSR, Leningrad
(Presented by Active Member AMN SSSR P. S. Kupalov)
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A great many studies have been made on the influence of different parts of the central nervous system on cardiac activity. In the last century, Tsion [11], and then later, other authors, established that there was a direct influence of the spinal cord on cardiac activity and that it had no marked influence on arterial pressure. In laboratory experiments, V. N. Bekhterev [3] showed that stimulation of the cervical region of the cord increased the heart rate. Recently, several authors [8, 2] have shown that when the spinal cord of a frog is divided, there is also a change in heart rate. As far back as 1874, V. Ya. Danilevskii [5] found a change in heart rate on stimulating the brain of a dog. It was shown subsequently [8, 10] that the cortex of subcortical structures exerted a control over the heart. It then became clear that a number of different levels of the central nervous system were involved in cardiac control. This discovery was in line with Pavlov's view of a nervous center as representing an association of neurons distributed at different levels in the nervous system, a point to which V. V. Frol'kis [10] has recently paid attention.

The question of the development of central nervous control over the heart in the embryo is particularly interesting. Very little work has been done on this problem. It has, however, been shown [6] that damage to the spinal cord in the embryo rabbit reduces the heart rate.

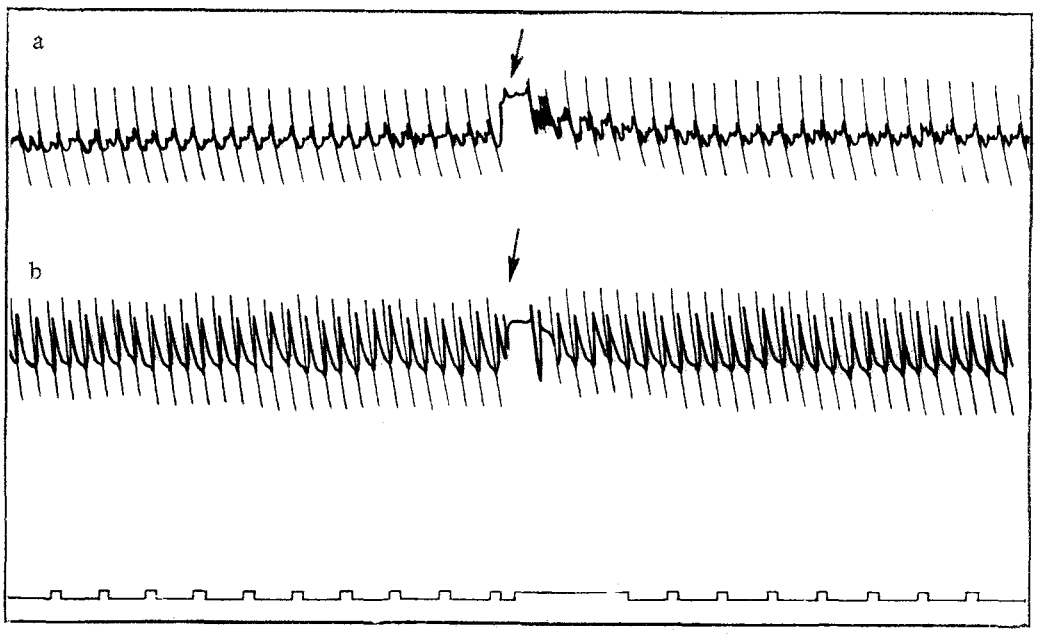

Fig. 1. No changes occur in the heart rate when the spinal cord in the chick embryos is destroyed. a) On the 12th day; b) on the 15th day. Curves, from above downward : EKG; time marker (in seconds); the arrow indicates the moment at which the spinal cord was destroyed.

The aim of the present investigation is to determine the extent of cardiac control by different sections of the nervous system and the times at which they are established in chick embryos; the method used has been to eliminate different portions of the nervous system.

METHOD

The work was carried out on 62 chick embryos at different stages of development. They were kept in an incubator at 38° and at a humidity of 50-60%, and were cooled daily for 20-25 minutes to room temperature. The heart rate was recorded by means of an electrocardiograph. To record the EKG the egg was placed in a specially warmed chamber, which was maintained at 38°. After dissecting away the embryonic membranes, the electrical potentials from the heart were conveyed to an amplifier by means of specially prepared electrodes, and were recorded on paper by a stylus [4].

After the normal value of the heart rate had been determined, the forebrain, midbrain and medulla were removed successively. The spinal cord was destroyed by means of a sharpened preparation needle introduced into the spinal canal. On the 14th day, the spinal canal was sectioned, and the brain removed entirely. During all manipulations, care was taken to avoid,as far as possible, damage to the yolk circulation. The experiments were performed on embryos between 11 and 19 days old. In the older embryos, the manipulations stimulated respiratory movements; fluid was then inevitably inspired, embryonic movements ceased, and the preparation became very much less viable. The EKG was recorded during the first 3 minutes after the destruction had been inflicted, because there were inevitable hemorrhages, and later recordings could have given false results.

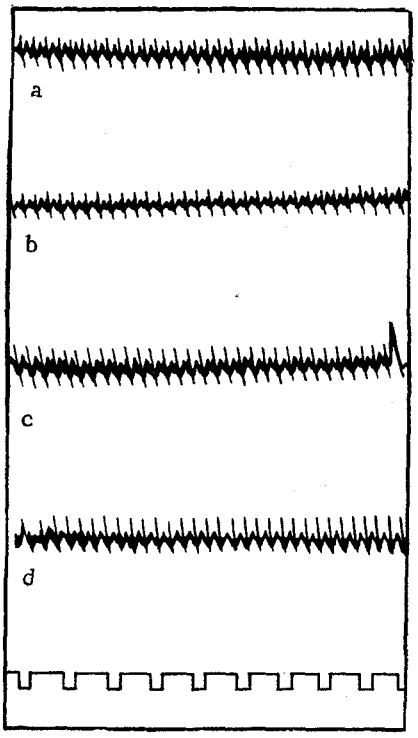

Fig. 2. No change in the frequency of the contractions after removal of the forebrain, midbrain, and medulla in an 18 day chick embryo. a) Initial frequency of contractions; b) after removal of the forebrain; c) after removal of the midbrain; d) after removal of the medulla. Curves as in Fig. 1.

RESULTS

It was found that successive destruction of the whole central nervous system caused no noticeable changes in the heart rate until the 15th day (Fig. 1).

On the 15th day, it was possible to observe only a very small and transient arrhythmia without any change in the rate. On the 16th day, the effect was quite different. Removal of the forebrain, as a rule,had no effect on the heart rate. In some cases, destroying the midbrain on the 18-19th day caused some small change in heart rate. Sometimes a considerable but transient arrhythmia developed after destruction of the medulla. However, no constant or well-marked changes in the heart rate could be observed; generally, after removal of the forebrain or midbrain or medulla there was no change in the frequency of the contractions (Fig. 2).

When the spinal cord was damaged, the results obtained were very clear-cut. Beginning on the 16th day, the effect was a quite marked fall in the heart rate. On each subsequent day, the effect was better shown (Fig. 3).

Thus, on the 16-17th day the average reduction in rate was 10-30%, but on the 18th day it was 30-50%, and on the 19th 14-60%. By the 19th day, in addition to a reduction in frequency, there was also a more or

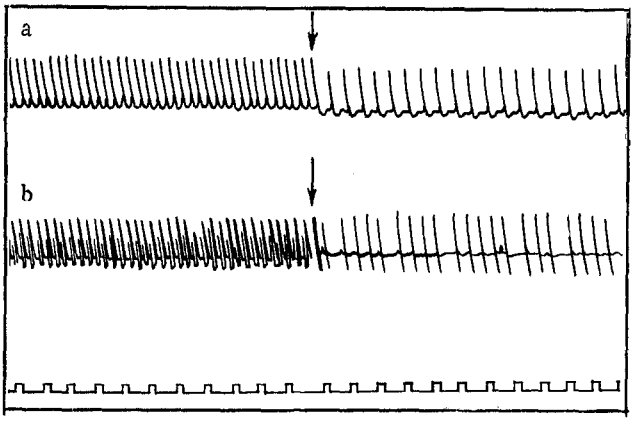

Fig. 3. Reduction in the frequency of the contractions of the heart following destruction of the spinal cord in chick embryos. a) On the 18th day; b) on the 19th day. Curves as in Fig. 1.

less well-marked arrhythmia. No relationship was found between the reduction in the heart rate after destruction of the spinal cord and its original rate.

Thus, the results indicate that at a certain stage there is a close relationship between the function of the spinal cord and heart rate, and at this stage the higher nervous centers exert no very definite influence on it.

V. M. Bekhterev [3] found no change in heart rate following stimulation of the cortex in newborn puppies during the first month of life. Changes in heart rate following stimulation of different parts of the brain in chick embryos have been reported. It has been shown [1] that in rabbit and dog embryos the vasomotor center is situated in the spinal cord, and does not move to the medulla until after birth. We may conclude that the heart first begins to contract at the stage when it consists of a nerveless epithelial tube, and that at this stage the nervous system is not involved. At approximately the sixth day, nervous elements appear for the first time [13].

During development, rudiments of the sympathetic nervous system develop as a number of cellular structures to the right and left of the aorta and they connect with the preganglionic fibers representing the axons of the sympathetic cells of the lateral horns of the spinal cord [7]. It has been shown [9] that in the spinal cord and brain, the autonomic centers are the last to be formed. For this reason, they are also the last to function. In this connection, the report [2] of sympathetic influence on the heart during embryogenesis is interesting. Destruction of the spinal cord in the mammalian fetus causes a marked reduction in heart rate through the removal of sympathetic control. The results which we have obtained indicate that by the 15-16th day, in the chick embryo, control by the spinal cord is established, and appears to be related to the development of function in the sympathetic cells of the lateral horns. The higher nervous centers exert no definite influence on heart rate of the embryo.

SUMMARY

In the chick embryo, up to the 16th day, successive destruction of the whole central nervous system causes no change in heart rate.

Later on, the destruction of the spinal cord causes a reduction in heart rate, but removal of the higher nervous centers has no definite effect. We conclude that at the 16th day the spinal cord begins to influence cardiac activity and the effect is due to the maturation of sympathetic cells of the lateral gray column. The higher nervous centers do not exert any definite influence on heart rate in chick embryos.

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* Original Russian pagination. See C.B. translation.