A STUDY OF THE ACTION OF CATHODIC AND ANODIC POLARIZATION ON THE FROG RESPIRATORY CENTER DEPRESSED BY ELIMINATION OF AFFERENT IMPULSES

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The phenomenon of respiratory center inhibition in the frog, when the afferent nerve impulses from the aortic reflex zone are interrupted [3], is of special interest in connection with the problem concerning the nature of the specific activity of the nerve centers. Our experiments [2] showed that the induction of such inhibition led to a sharp decrease in functional level [2] only in the nerve tract elements of the inspiratory center.

We must determine the means whereby the constant stream of afferent impulses is supplied to the central nervous elements during their normal activity; we must determine also the conditions under which the normal respiratory center is able to exert its specific influence, and ascertain what influences are required to restore this activity. According to the Wedensky-Ukhtomskii School the greater part of the action on the excitable substrates may exert an influence either of the anodic or cathodic type.

D. A. Lapitskii [4] has shown that the cathode stimulates and the anode depresses normal respiration in the frog when the polarization is applied to the region of the medulla. We have observed this effect in experiments on cathodic stimulation of the inspiratory region in the cat. Excessive cathodic polarization leads to arrest of respiration after a phase of maintained tetanus of the ipsilateral muscles.

Recently an electrophysiological method has given similar results on the inspiratory neurones of the cat.

Here we present results obtained by cathodic and anodic polarization of the nervous elements of the inspiratory respiratory center in a frog; depression of the center was first produced by suppression of the afferent flow of impulses from the aortic receptor zone.

EXPERIMENTAL METHOD

The experiments were carried out on the frogs Rana esculenta and Rana ridibunda. Records were made of the respiratory movements of the base of the oral cavity.

The aortic reflexogenous zone was put out of action by a filter paper soaked in 1.5-2% novocaine. Polarization was produced in the required parts of the respiratory center by means of an exponentially increasing current. The active electrode was made of soft nichrome wire 30 μ in diameter coated on the sides with glass. The electrode was introduced into the required part. The end of the wire was free from glass. The position of the stimulating and lead-off microelectrode was first determined from the local threshold contractions of the corresponding respiratory muscles in response to local stimulation of the corresponding part of the medulla with square-wave pulses; after the experiments confirmation was made histologically. The indifferent electrode consisted of a plate placed on the cranium.

Currents were led off from the ipsilateral respiratory center and taken to a two-channel cathode-ray oscilloscope containing a balanced amplifier. The pneumogram was recorded as an electrical signal from a semi-conductor type photocells whose window was illuminated during contraction or relaxation of the inspiratory muscles. Consequently both active contraction of the muscles of the base of the oral cavity during "inspiration" (swallowing of

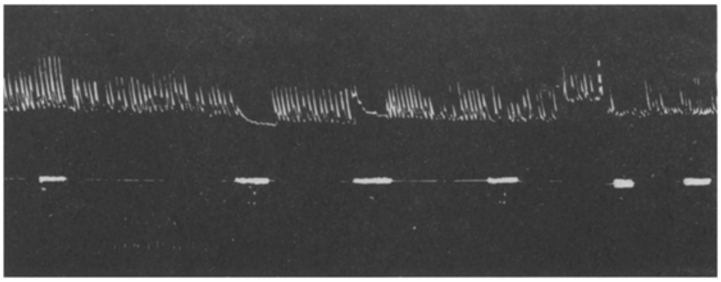

Fig. 1. Action of (K) cathodic and (A) anodic polarization of different parts of the base of the rhomboid fossa (upper third, middle and lower angles) during normal respiration. Upper curve—normal pulmonary respiration (movement of the base of the oral cavity), lower curve—recording of electromagnetic marker indicating polarization.

air into the lungs), and depression of these same muscles below the zero line during "aspiration" (the moment at which air is drawn into the mouth, and which in the physiological sense is part of the act of inspiration as a whole) was recorded in our oscillograms as an elevation of the pneumogram upwards. "Expiration," i.e. the moment when air was expelled from the lungs into the mouth through the action of the external oblique muscles was recorded by a return of the trace to the base line.

EXPERIMENTAL RESULTS

In the first set of experiments the different parts of the base of the rhomboid fossa were polarized either cathodically or anodically during normal respiration. It was found that the increase of respiration in response to cathodic action and its depression by anodic stimulation [4] occurs only during the influence of a direct current applied to the upper third of the base of the fourth ventricle, particularly in the region where the VII, VIII and IX cranial nerves emerge (Fig. 1).

It has frequently been shown [8, 12, 13] that in the frog in this region these nerves carry impulses from the respiratory muscles and from the mucous membranes of the respiratory organs, and that the fibers concerned contribute to the fasciculus solitarius. At the point where these nerves enter the brain the nucleus of the tractus solitarius lies at a so-called "strategic point" of the nervous system in relation to visceral function [12]. The idea has also been proposed [5] that the nucleus of this bundle is a truly "automatic" center.

According to our findings [2] the inspiratory center lies precisely at this point. It is interesting that other workers [9] have found in warm blooded animals a region of inspiratory neurones lying close to the tractus solitarious on its ventral side and not far from cranial nerve nuclei IX and X. In experiments in which cathodic polarization was applied to the middle part of the base of the fourth ventricle in the frog we obtained only depression of respiration, while anodic polarization always enhanced respiration. When local excitation was applied as short electrical discharges to the dorsal part of this region, local contractions of the external oblique muscles occurred causing air to be pushed out from the lungs into the oral cavity, i.e. causing "expiration." The motor region controlling these muscles was centered on C_{3-8}. The same intensity of polarization applied to the lower angle of the base of the fourth ventricle caused no change in respiration. Increased stimulation produced the same effect as did stimulation of the middle region.

In experiments in which the afferent impulses from the aortic reflexogenous zones were eliminated and in which the ultimate effect was arrest of respiration it was shown that only cathodic stimulation applied to the inspiratory center can restore respiration, whereas anodic stimulation can never do so (Fig. 2).

Thus elimination of the constant flow of afferent impulses from the aortic reflexogenous zone caused depression in the nervous elements of the ipsilateral region. This depression was eliminated only by cathodic action on the ipsilateral side. The influence of the cathode on other regions of the respiratory center was ineffectual in restoring respiration, and the anodic action was even less effective. We may note that the restorative influence of the cathode on the respiratory center under these conditions can be observed only during the first 15-20 min of development of the suppression which we have described, at a time when responses to short single stimuli could be obtained.

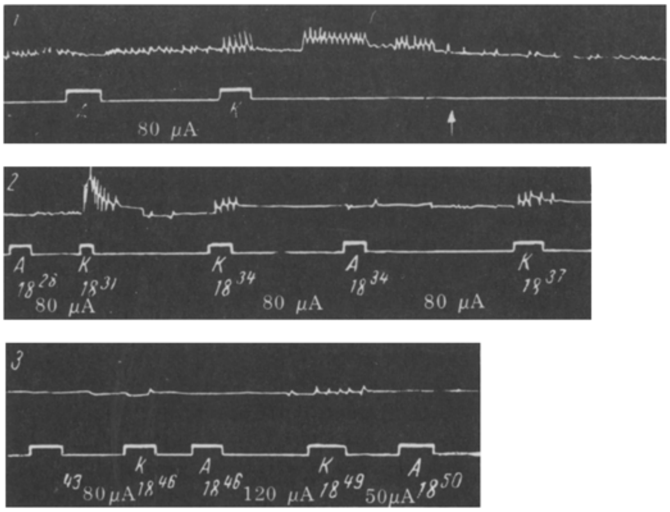

Fig. 2. Action of (K) cathodic and (A) anodic polarization on the ipsilateral center during normal pulmonary respiration and during elimination of respiration by drugs applied to the aortic reflexogenous zone. 1) Onset; 2,3—continuation and end of trace. Figures below indicate intensity of polarizing current (in μa). In each pair of traces the upper curve represents respiration, and the lower indicates the polarizing current. Arrow—time of application of 2% novocaine.

Therefore these experiments showed that for a normal automatic activity of the ipsilateral center to develop an initial depolarized condition is necessary.

Here we may note that as far back as 1901 N. E. Wedensky, following his theory, proposed that nervous centers appeared to be in a condition as it were of "self-excitation." Subsequently the initial depolarization of the nervous centers was observed in experiments performed by many workers [6, 7, 11, 14, 15].

When we consider this fact in connection with the results obtained in our experiments we are led to conclude that a condition of a certain degree of initial depolarization is one of the fundamental properties of the nervous centers and must play an important part in the organization of their specific activity (for example automatism). Because of this condition the centers may readily react not only to stimuli but also to the cessation of stimuli. As we have already pointed out it is in this way that the respiratory center may become suppressed. Our experiments have shown that this suppression has its own special features. In particular it is eliminated by cathodic action, and, as experiments in which measurements of the physiological parameters of the inspiratory center have shown [2], its characteristic features are an increased rheobase, a prolonged chronaxie, and a reduced accommodation constant, i. e. elimination of the original depolarized state of the nervous centers leads to a reduction in excitability, to a functional lability, and to an increased rate of accommodation. These features of the depression which we have observed may be explained if we assume that the original depolarization of the nerve cells is developed to a moderate extent such as is optimal for their activity, whereas, as is well known, excitability and functional mobility are enhanced and the rate of accommodation reduced. With such a degree of depolarization "automatic" activity and multiple discharges in response to isolated stimuli may appear. It is well known that these very features are characteristic of many neurones.

Therefore the elimination of the initial optimal depolarization of the nerve cells ought to destroy their original heightened functional level, which our experiments appear in fact to have done.

To a certain extent the results of our experiments in which the electrical activity from the nerve cells of the inspiratory center was recorded (Fig. 3) are in line with such a hypothesis. It was found that elimination of the afferent impulses from the aortic reflexogenous zone resulted in both a cessation of respiration and complete disappearance of the otherwise maintained electrical activity within 3-5 minutes. Also in many other experiments [2] it has been shown that restoration of these multiple discharges occurs only under the influence of receptor zones which influence the inspiratory center in the same way as does a cathode.

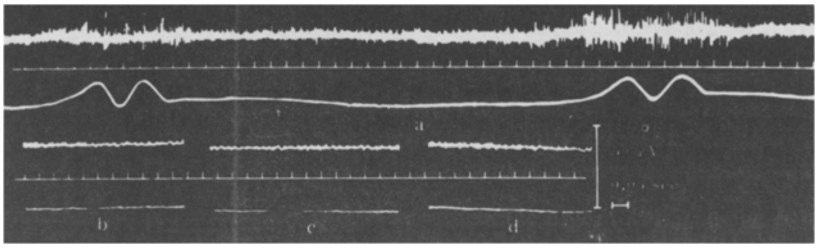

Fig. 3. Effects on background electrical activity of the inspiratory center of elimination of the flow of afferent impulses from the aortic reflexogenous zone. In each trace (a, b, c, d) the upper curve represents electrical activity, the lower the signal from the resistance-photocell. The first elevation of the line corresponds to aspiration (drawing air into the oral cavity), and the second indicates that air has been swallowed into the lungs, the stage of true "inspiration." The pause indicates expiration.

As has been demonstrated many times [2, 4, 9] a mild additional cathodic polarization applied to a normally functioning respiratory center will increase its automatic activity, while a strong one will depress it.

Thus this evidence also confirms the biphasic reaction of the respiratory center to cathodic action and illustrates that a slight but optimal degree of depolarization is normally present in the inspiratory center.

The initial state of depolarization of the inspiratory center and the dependence of the general level of electrical activity related to this condition confirms an idea which has been put forward by several authors [6, 7] that a condition of depolarization may be responsible for the background activity of nervous centers. Our experiments have shown that this condition results in turn from the action of a steady flow of afferent impulses originating in various receptor zones.

SUMMARY

Frog respiration was arrested by elimination of afferent impulses originating in the aortic reflexogenous zone; it could be restored only by local cathodic polarization of the nerve cells of the inspiratory area of the respiratory center. Elimination of this stream of impulses also caused background electrical activity to cease.

LITERATURE CITED

1. N. E. Wedensky, Complete collected works [in Russian], Leningrad, 4, (1953), p. 128.
2. Z. S. Dontsova, Abstracts reports of the scientific conference on problems of N. E. Wedensky parabiosis [in Russian], Leningrad, (1957), p. 37; Abstracts of reports at the sectional sessions of the 9th congress of the All-Union society of physiologists, biochemists, and pharmacologists, Moscow, Minsk, 1, (1959), p. 191; Abstracts of reports at the 6th conference of the Ukrainian physiological society. Kiev, (1961), p. 140. (in Ukrainian).
3. B. D. Kravchinskii, Uspekhi sovr. biol., 19, No. 3, (1945), p. 291.
4. D. A. Lapitskii, In book: New contributions to reflexology and to the physiology of the nervous system [in Russian], 3, (1929), p. 56.
5. A. I. Roitbak, Fiziol. zh. SSSR, 33, No. 2, (1947), p. 171, and p. 183.
6. E. D. Adrian, J. Physiol. (Lond.), 72, (1931), p. 132.
7. E. D. Adrian and F. J. Buytendijk, Ibid., 71, p. 121.
8. J. W. Barnard, J. comp. Neurol., 65, (1936), p. 503.
9. R. Baumgarten,K. Balthasar, and H. P. Koepchen, Pfüg. Arch. ges. Physiol., Bd. 270, S. 504, (1960).
10. B. D. Burns and G. C. Salmoiraghi, J. Neurophysiol., 23, (1960), p. 27.
11. J. C. Eccles, J. Physiol. (Lond.), 85, (1935), p. 464; 103, (1944), p. 27; J. Neurophysiol., 9, (1946), p. 87.
12. C. J. Herrick, J. comp. Neurol., 50, (1930), p. 33.
13. C. U. A. Kappers, et al., The Comparative Anatomy of the Nervous System of Vertebrates Including Man. New-York, 1, 2-14, (1936).

14. S. W. Kuffler, J. Neurophysiol., 5, (1942), p. 309; 8, (1945), p. 77.
15. R. Lorente de No, Ibid., 2, (1939), p. 402.
16. A. Rosenblüth, J. H. Wills, and H. Hoagland, Am. J. Physiol., 133, (1941), p. 724.

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.