ELECTRICAL REACTIONS IN SPINAL CORD OF FROG WITH AORTIC REFLEXOGENIC ZONE SUPPRESSED

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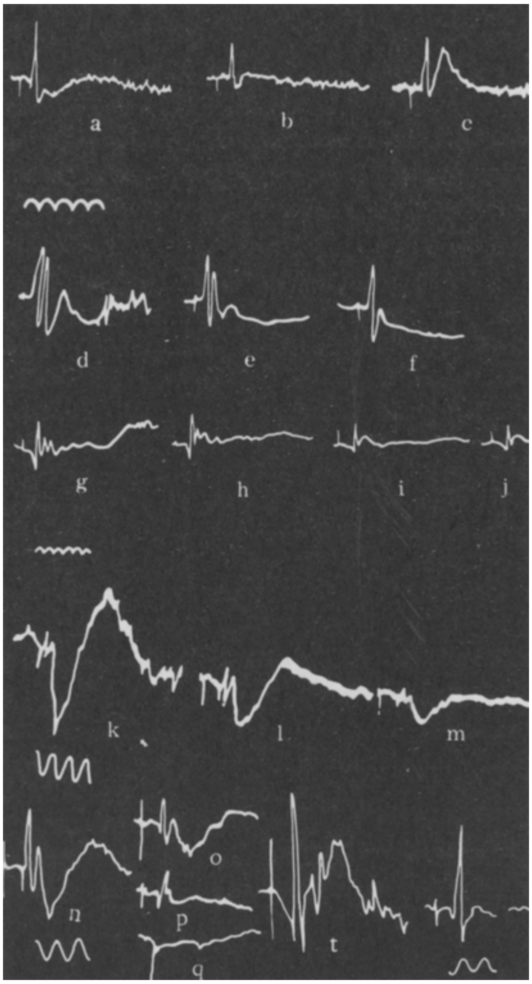
While studying respiratory center depression in the frog with the aortic reflexogenic zone suppressed, Kravchinskii [4] recorded almost simultaneous suppression of spinal reflexes. This was not, however, observed when the spinal cord had previously been isolated, and the author therefore concluded that the depressed respiratory center was, under these circumstances, the source responsible for the spinal cord depression. Orbeli [6] concluded an analysis of this phenomenon with these words: "It follows from this that impulses from the aortic walls normally counteract inhibitory effects from other reflex zones and ensure maintenance of a normal balance between excitation and inhibition in the central nervous system." These observations are of considerable importance for an understanding of the mechanism responsible for spinal shock, in which the underlying factor may possibly be, as Sherrington [9] had already noted, arrest of afferent impulse activity. Orbeli [6] was also of the opinion that "a phenomenon very closely resembling shock has recently been discovered by Kravchinskii . . . ." It is suggested that loss of the afferent stream from the aortic reflexogenic zone, which leads, as the author [2, 3] has demonstrated, to local depression of the inspiratory region only, is obviously associated with relative intensification of inhibitory effects from the descending reticular formation in the medulla on the spinal cord. This is rendered even more probable by the position and structural features of the inspiratory section of the respiratory center, the efferent part of which is situated in the region of the descending reticular formation [7, and others], and also by virtue of the fact that the respiratory center can influence the spinal cord through the reticular formation [8]. It should at the same time be noted that, in the frog, the strictly "automatic" center of the inspiratory region is situated in the nucleus of the sensory bundle of the fasciculus solitarius, which receives impulses from this bundle through the sensory branches of the vagus nerve.

It was established in earlier experiments [3], the purpose of which was to explain the nature of this spinal cord depression, that this depression was accompanied by sharp reduction of rheobase, increase of chronaxie and increase of accommodation constant in the dorsal region of the spinal cord.

The present investigation, which is a continuation of that just mentioned, has demonstrated the nature of electrical reactions in the dorsal and motor regions of frog spinal cord when the aortic reflexogenic zone is suppressed.

METHOD

The experiments were carried out on intact R. esculenta and R. ridibunda in various months of the years 1960-1961. Potentials were recorded from points in the spinal cord by means of a glass-insulated electrode 30 μ in diameter. The position of the tip was verified histologically after the experiment. After amplification, the signals were fed to a cathode-ray oscillograph. Deflection of the beam upwards signified negativity. The frog's heart, spinal cord and tibial nerve were dissected out before an experiment. The nerve was divided distally and picked up on a ligature. All ventral roots in the lumbosacral region of the cord were divided. First of all, single opening shocks of optimum strength were delivered to the tibial nerve from an induction coil every 3 min for half an hour, and the electrical responses to such orthodromic stimulation of the reflex arc were recorded. Stimulation and sweep were synchronized by a Helmholtz pendulum. After the aortic reflexogenic zone had been treated with 2% novocain (with resultant arrest of respiration), spinal cord potentials were recorded every 3 min for an hour. Calibration was effected with a generator of sinusoidal current of amplitude 75 μV and period length of 2.66 msec.



Potentials in frog spinal cord. a) From 8th dorsal root (normal); b) from its point of entry into spinal cord (normal); c) from dorsal surface of cord, nearer to midline at level of entry of 8th dorsal root (normal); t) same but with supraliminal stimulation; d) potential from gray substance of dorsal cornu, just behind level of central canal (normal); e) same 3 min after application of novocain to aortic reflexogenic zone; f) after 15 min; g) potential from gray substance of posterior cornu slightly below level of central canal (normal); h) same 3 min after application of novocain to aortic reflexogenic zone; i) after 15 min; j) after 30 min; k) potential from region of motorneurons (normal); l) same 3 min after application of novocain to aortic reflexogenic zone; m) after 30 min; n) potential from ventral root on orthodromic stimulation (normal); o) same, 30 min after application of novocain to aortic reflexogenic zone; p) after 1 h; q) same, in narcotized frog. Scale below each series of recordings (amplitude 75 μV, period 2.66 msec).

Similar results were obtained in 35 of the 40 experiments; one of these experiments is described in this paper.

RESULTS

Certain conclusive facts concerning synaptic transmission in the central nervous system were established for the first time as a result of experiments on frog spinal cord [10, and others], in which electrical activity was recorded from the surface of the cord and its roots. Systematic analysis of intramedullary potentials in the frog spinal cord [11, 13, 14, 16, 18] has shown that four electronegative components are recorded after the current looping effect when dorsal roots are stimulated and potentials are recorded from the dorsal surface of the cord or from an electrode inserted into the gray substance. In recordings from the dorsal surface the first component is a spike potential of the afferent volley, the second and third, manifestations of activity in primary and secondary intercalary neurons respectively, and the fourth, a manifestation of activity in tertiary intercalary elements of dendritic ramifications of motoneurons. When the electrode is inserted progressively into gray substance, the last three components are successively converted into positive potentials, starting with the first, at a depth of 0.3 mm. The last to change is the fourth component, at a depth of 0.8 mm. As the electrode is inserted further into the ventral cornu, the hitherto electronegative dorsal potentials are replaced by – as indicated by the time of their occurrence – electropositive oscillations, which are associated with a long complex negative wave on which spike discharges are superimposed. These latter develop after a latent period similar to that observed when reflex discharges are recorded from ventral roots. Some authors [12, 16] have demonstrated the occurrence of monosynaptic activity in the ventral cornu of frog spinal cord, and also in recordings from ventral roots, after the current looping effect, on the evidence of the time of its occurrence and other indications. The existence of monosynaptic connections in the ventral cornu of the frog spinal cord is also confirmed by the fact that the connections of afferent fibers with cells in the ventral cornu are well developed in the frog [14].

The phenomena just described were noted when potentials were recorded from the dorsal surface of the intact frog spinal cord (see the figure: a, b, c, t), and when the recording electrode was inserted into the dorsal cornu (figure, d and g). Figure, l and o are recordings from the region of the ventral cornu and ventral root respectively. When, in these experiments in which the aortic reflexogenic zone was suppressed, spinal cord depression developed as a result of the arrest of respiration, the fourth component (figure, e and f) was the first to disappear from recordings from the dorsal cornu (within 3 min), which meant that the activity of intercalary neurons of the third order in the dorsal cornu was suppressed. Concurrently, there was considerable depression of the activity of the third component, i.e., the activity of secondary intercalary neurons. At this time the second component, representing the activity of first intercalary neurons, was still prominent. After novocain had been applied to the aortic reflexogenic zone for about 15 min the fourth and third components had disappeared and the second was very greatly depressed (see the figure, c). In the motor zone the long positive wave which developed after the oligosynaptic components and the succeeding long electronegative wave were greatly reduced after about 3 min (figure, l). There were preactically no superimposed discharges on the latter. The monosynaptic potential was, however, still in evidence. After 15 min (figure, n and m) the electropositive and succeeding electronegative wave were reduced still further, and at about this time the amplitude of the monosynaptic potential began to decline. A similar picture could be recorded from the ventral root (figure, n; o, and q). These phenomena in the ventral region were apparently secondary, and they developed in consequence of the great reduction in the normal background stream of continuous impulse activity from the dorsal neurons. Lorente de No [15] and Renshaw [17] were also of the opinion that reduction of background flow might be the reason for the reduced excitability of motoneurons, as a background stream of impulses from dorsal to motor elements is an important condition for normal activity of the latter.

The results of the present experiments thus indicate that the depression that develops in the spinal arcs of the frog as soon as poisoning of the aortic reflexogenic zone begins affects first of all polysynaptic elements in the dorsal cornu. When these findings are considered in conjunction with our earlier measurements of physiological parameters [3], it is seen that complete arrest of spinal reflex responses coincides with a sharp decline of excitability, slowing of accommodation in the region of the nerve elements in the dorsal cornu, and progressive depression of electrical reactions in tertiary, secondary and primary intercalary neurons.

This spinal cord depression thus has some of the features of a profound anelectronic effect and occurs mainly in the region of the polysynaptic pathways.

SUMMARY

It was found that as early as 3 min after shutting out the aortic reflexogenic zone in the frog with a 2% novocain injection there develops inhibition of the intercalated elements of the 3rd and 2nd order in the dorsal horn of the spinal cord. By the 15th min there occurs a decrease also in the first postsynaptic potential, while the second and the third ones disappear altogether. In the ventral horn the monosynaptic reaction diminished by the 15th min. Thus, depression of the spinal cord in the frog after blocking the influx of impulses from the aortic reflexogenic zone to the respiratory center is at first confined to the intercalated neurons, which is followed by a decrease in the excitability of motor neurons. The earlier experiments with measurements of the physiological parameters warrant the conclusion that the above-described suppression has certain anelectronic features.

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