FUNCTIONAL ORGANIZATION OF THE BULBAR VASOMOTOR CENTER

COMMUNICATION I. EXCITABILITY OF THE NEURONE OF THE PRESSOR AND DEPRESSOR ZONES IN DIFFERENT FUNCTIONAL CONDITIONS

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Considerable evidence has accumulated in recent years to show that the reaction of the vasomotor center is not diffuse. In a study of circulatory reflexes from various receptor zones, focal stimulation of the bulbar vasomotor center causes unequal changes in the tone of the different regional vessels and in the rate of flow of impulses along sympathetic nerves to the vessels of the various viscera [1, 4, 6, 8, 10]. These results indicate the complex structure of the vasomotor center: different changes in its activity are induced by afferent impulses from different sources [5, 7, 9, 15].

We still do not know what underlies this complexity. Possibly it could be accounted for in terms of distribution of the afferent fibers running to the reticular neurones of this center.

However, there is contrary (though incomplete) evidence of the convergence of fibers from different afferent systems on to single reticular neurones [11, 20, 22]. Many authors [11, 22] hold that the effect is not brought about by sparial distribution of the afferent fibers but by a temporal encoding of afferent impulses. Records have been made of impulses in reticular neurones of the midbrain and the response of a single neurone to various centripetal stimulations has been observed; however, the latent period, total number of spikes, and the intervals between the spikes differed according to the afferent system stimulated. Some neurones were stimulated in response to the firing of $A\alpha$ and $A\beta$ fibers, whereas others responded only to stimulation of the $A\sigma$ fibers. From these results we might suppose that the various groups of neurones of the bulbar vasomotor center differ in their sensitivity to different characteristics of the stimulating impulse, with the result that only certain groups of neurones are excited when a particular kind of afferent impulse is received. We have investigated this problem by applying different kind of squarewave impulse to different parts of the pressor and depressor zones of the bulbar reticular formation.

The presence of pressor and depressor zones in the bulbar reticular formation [10, 12, 13, 18, 23] shows the delimitation of function between the different neurones of the vasomotor center. However, many investigators [2, 3, 14, 16, 17] have shown that a change in the frequency of stimulation may produce opposite responses from the vasomotor centers of the reticular formation of the hypothalamus and of the medulla oblongata. Some workers [2, 3, 16] consider the effect to be an artifact resulting from the spread of current loops due to stimulation with large voltages. However, others [17. 19] have observed a change in response when low intensity and low frequency stimulation has been applied. Possibly this divergence of the results results from different functional conditions of the reticular neurones.

In the present investigation we have investigated the extent to which neuronal function in the pressor and depressor zones of the medulla is specific and consistent in various functional conditions.

EXPERIMENTAL METHOD

The experiments were carried out on cats weighting 2-3 kg under 1.5 g/kg intravenous urethane anesthesia. The

head was fixed in a stereotactic device using the Szentagothai head-holder arranged so that the head could be rotated through 45° around a horizontal axis joining the two ears. A hole was drilled in the occipital region of the skull 10-12 mm caudal and 5 mm lateral to the lambdoid suture. For stimulation we used steel electrodes 50-70 μ in diameter insulated for the whole of their length except for the terminal 0.25 mm. The electrodes were introduced through the cerebellum and were placed in accordance with the Sentagotai atlas [21] in the lateral, medial, small-celled and large-celled nuclei of the bulbar reticular formation, and in the medial and lateral part of the medulla 1-2 mm rostral to the obex. The indifferent electrode consisted of a silver plate which was fixed to the muscles of the neck. Stimulation was obtained from a squarewave generator and was applied for 5-15 seconds at intervals of 3-5 minutes. Arterial pressure was recorded from the femoral artery by a mercury manometer, and respiratory movements by a plethysmograph and a Marey's capsule.

The functional condition of the neurones of the pressor and depressor points investigated was altered by polarization or by the passage of a direct current of 4-15 μA through the stimulus electrode.

In the polarization experiments we used chlorided silver microelectrodes; the indifferent electrode was also coated with silver chloride. We altered the general functional condition of the vasomotor center reflexly by elminating the mechanoceptors of the carotid sinus (by compression of both carotid arteries), by stimulation of the interoceptors of the urinary bladder (by inflation with air), or by stimulation of the central end of the cut femoral nerve.

EXPERIMENTAL RESULTS

We investigated 180 points on 40 cats. From 80 we elicited a pressor, from 26 a depressor, and from 10 a mixed (pressor-depressor or depressor-pressor) response. Sometimes a rebound effect was observed at the end of stimulation (Fig. 1, a and g). There was no change in arterial pressure in response to stimulation of 64 of the points. When the arterial pressure did change usually there was a reduced, though sometimes an increased, frequency or an arrest of respiration which could occur during an inspiration or expiration. The respiratory change was not related to the direction of the arterial blood pressure change.

Pressor and depressor points were found in all the structures studied, but the first kind were found mostly in the rostral and the second kind in the mediocaudal formations. We must note that depressor and pressor points may lie quite close to each other. When the electrode was moved 0.5 mm rostrally, caudally, or ventrally the sign of the response might change (Fig. 1, d). This result indicates that with point stimulation there was no appreciable spread of the current.

To study the effect of the nature of the stimulus we used: 1) different frequencies while maintaining a constant amplitude and duration, 2) different durations at constant frequency and amplitude, and 3) different amplitudes at constant frequency and duration.

We found a variation in the threshold in the optimal frequencies and durations as between different pressor or different depressor points, and that there was also a difference in this respect between pressor as compared with depressor points. For different pressor points the optimum frequency varies from 50 to 200 impulses/sec. In this experiment illustrated in Fig. 1, a, the optimum was 200 impulses/sec, and in Fig. 2, a, 100 impulses/sec. For depressor points the optimum frequency was somewhat higher and varied from 100 to 250 impulses/sec (Fig. 1, d).

We also found the optimum duration for all pressor points was higher than for depressor points. For the different pressor points the optimum duration varied from 1 to 4 mseconds (see Fig. 1, b), while for depressor points it ranged from 0.2 (Fig. 1, f) to 3 mseconds.

An increase in the intensity of the stimulus from 0.5 to 3.5 v at constant frequency and duration caused an increased response when applied to pressor or to depressor points (Fig. 1, c, g). In most experiments the threshold was higher for depressor than for pressor points.

The features characterizing the excitability of neurones of opposite function are well shown in ten cases, where small changes of the stimulus caused either pressor or depressor or a biphasic reaction to occur (Fig. 1, h). In these cases neuronal elements having the reverse vasomotor function must have lain close beneath the electrode. According to their excitability and to its relation to the different stimulus parameters the response of either the one, the other, or both neuronal elements could be elicited.

In the remaining points which gave either a pressor or depressor response on stimulation, increase of intensity up to 10 v or a change in frequency and duration caused no alteration of the reaction. Increase of intensity above 10 v might alter the response, but then somatic response (movements of the animal) occurred, indicating an extensive spread of stimulus.

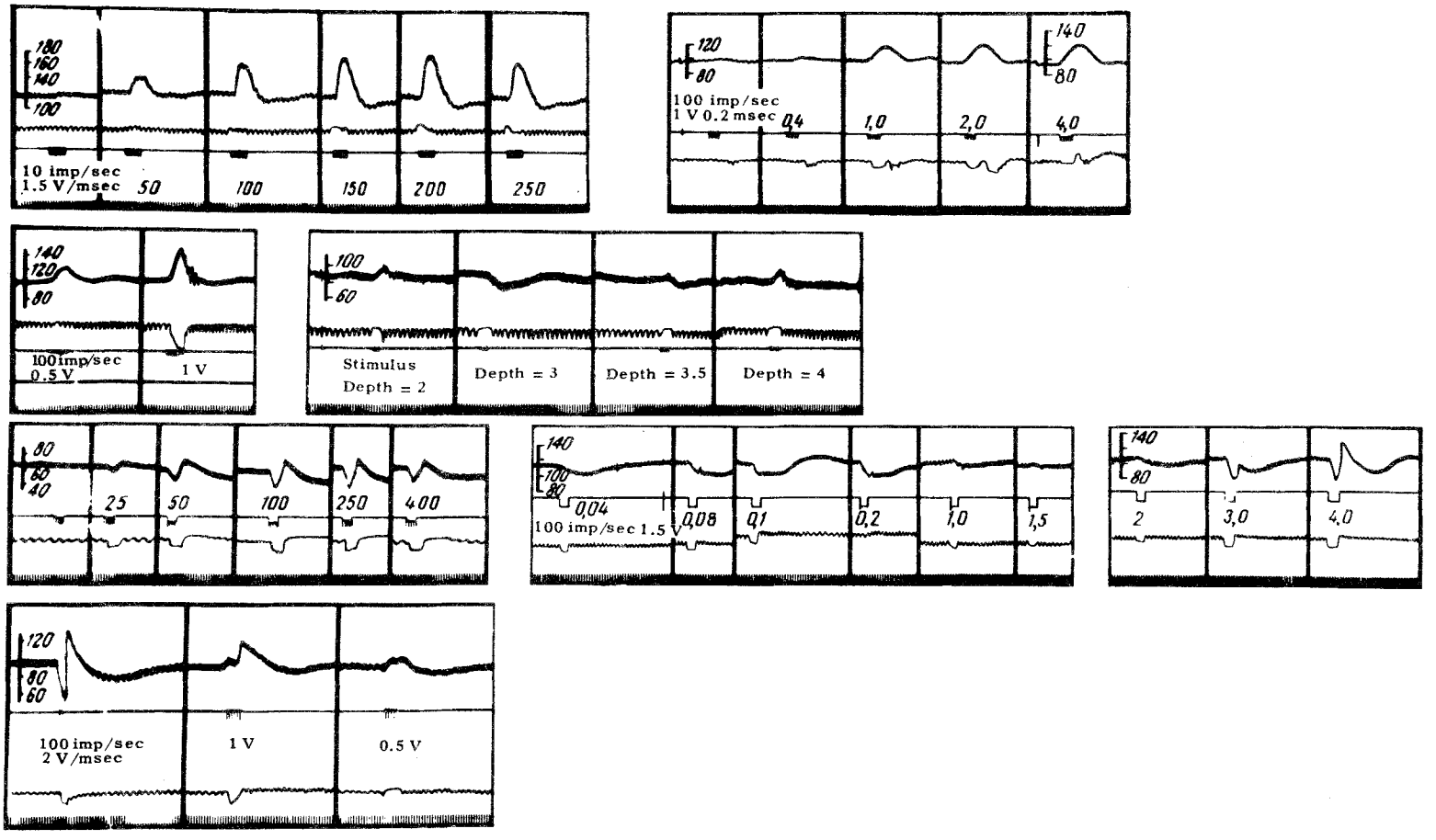

Fig. 1. Effect of various parameters of squarewave stimuli applied to depressor and to pressor points of the bulbar reticular formation. Pressor points: a) effect of impulse frequency, optimum 200 impulses/sec, electrode in the lateral nucleus; b) effect of duration of impulse, optimum 4 mseconds, electrode 1 mm rostral and 2 mm lateral to the obex; c) effect of amplitude of impulse, electrode in medial nucleus. Depressor points: d) effect of frequency, electrode in large-celled nucleus, optimum 250 impulses/sec; e)effect of duration of impulse, optimum 0.2 mseconds, electrode in large-celled nucleus; f) effect of amplitude of impulse, electrode in large-celled nucleus; g) effect of stimulation at depths of 2, 3, 3.5, and 4 mm from the bottom of the IV ventricle, in the region of the large-celled nucleus; h) effect of stimulation at different amplitudes in a mixed point, electrode in the large-celled nucleus. Curves, from above downwards: a, c, d, – arterial pressure, respiration, stimulus marker, time marker (1 sec); b, e, f, g, h, – arterial pressure, stimulus marker, respiration, time marker (1 sec). The stimulus parameters are indicated on the chymograms.

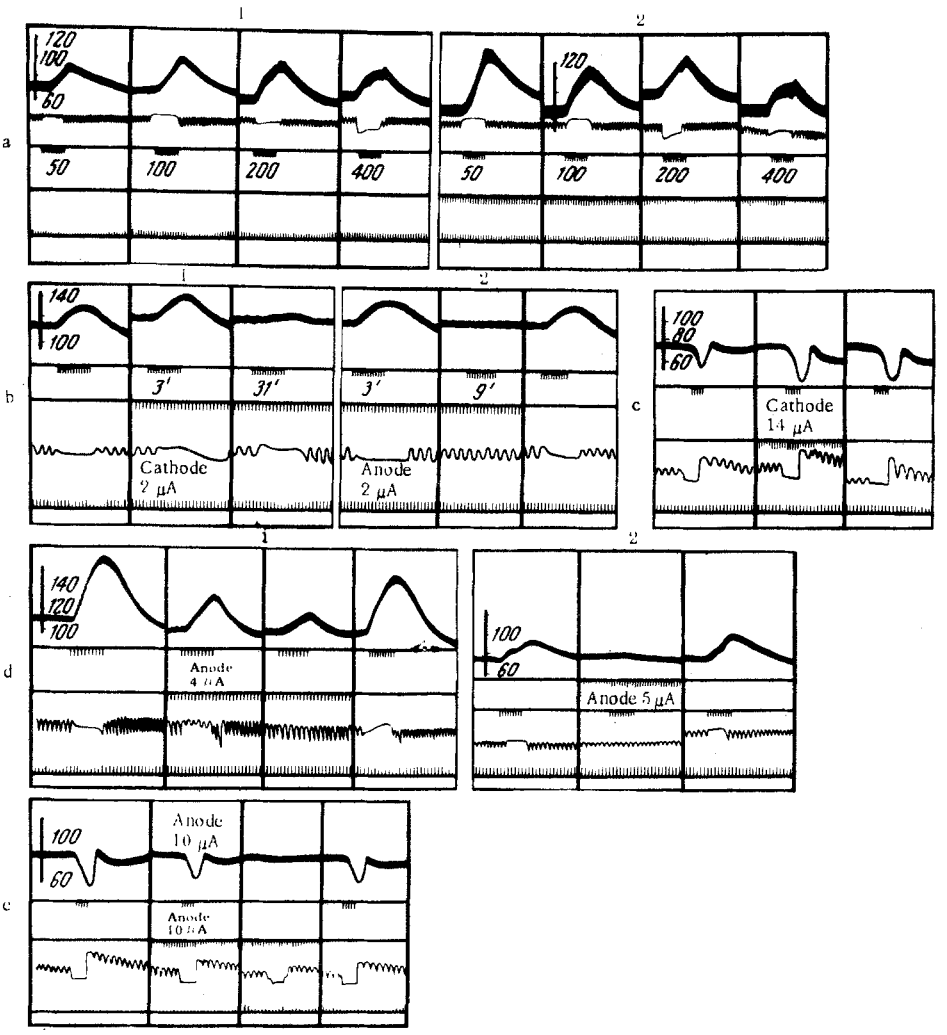

Fig. 2. Influence of local polarization. a) Catelectronus at a pressor point (cathode, 10 μA); 1) before polarization; 2) during passage of current of 10 μA electrode in lateral nucleus; parameters of stimulus current: 3 v, 1 μsec, at different frequencies; b) depression caused by prolonged cathodic treatment (2 μA): 1) disappearance of response after 31 min treatment with cathode; 2) removal of depression by application of anode (2 μA) and subsequent anodic depression. Electrode in large-celled nucleus; parameters of stimulus: 1 v, 100 impulses per sec, 1 msecond; c) before, during, and after treatment with cathode of depressor point with D.C. of 14 μA electrode in large-celled nucleus; parameters the same; d) treatment with anode of a pressor point: 1) 4 μA D.C.; 2) 5 μA electrode in lateral nucleus, 2 v, 100 impulses per second, 1 msecond; e) treatment of a pressor point with anode, 10 μA D.C., electrode in large-celled nucleus (1 v, 100 impulses per second, 1 msecond). Curves, from above downwards: for a) arterial pressure, respiration, time marker, marker indicating period of polarization, time marker (1 second); for b, c, d, and e) arterial pressure, stimulus marker, marker indicating polarization, respiration, time marker (1 second).

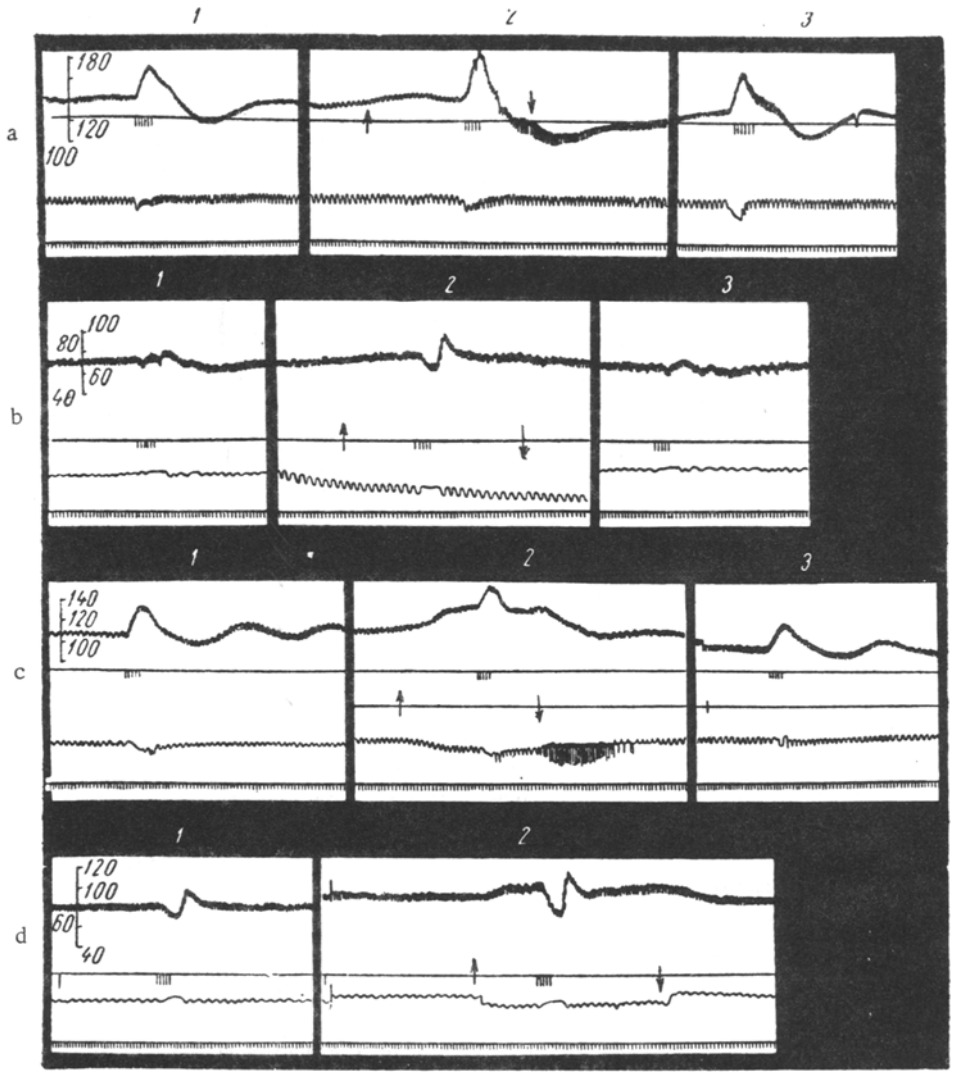

Fig. 3. Changes of excitability in reflex changes of the functional condition of the vasomotor center. a) Stimulation of a pressor point; b) of a depressor point: 1) initial conditions; 2) vasomotor effect due to compression of both carotid arteries; 3) 10 min after compression of the carotid arteries; c) stimulation of a pressor point; d) of a depressor point: 1) initial conditions; 2) effect superimposed on vasomotor response while inflation of urinary bladder subsides (60 mm mercury); 3) 10 min after inflation of urinary bladder. Electrode positions: a) in lateral nucleus, b, d) in large-celled nucleus; c) in medial nucleus. Curves, from above downwards: arterial pressure, stimulus marker, respiration, time marker (1 sec). The arrows indicate the beginning and end of compression of the carotid arteries and of disinflation of the urinary bladder.

These results show that the neurones of the reticular formation of the medulla responsible for pressor-depressor effects have a specialized function and their excitability is related to the stimulus parameters.

Results of experiments on the change of functional condition of these two groups of neurones leads to the same conclusion. Cathodic polarization with direct current applied to depressor or pressor points increased the effect of the test stimulus (Fig. 2, a, b, c). There was then a shift of the optimum frequency. The kymograms of Fig. 2, a, show

that before polarization by the cathode the optimum frequency was 100 impulses/sec, and during this polarization it was 50 impulses/sec. Prolonged cathodic polarization showed a cathodic depression: the response was reduced, and then disappeared entirely (Fig. 2, b). This depression was eliminated by application of the anode.

Anodic polarization reduced the effect of a test stimulation applied to pressor or depressor points, and when it was applied more intensely the response disappeared entirely (Fig. 2, d, and e).

When a change in the functional condition of the vasomotor center occurred reflexly there were unequal changes in the excitability of the neurones of the pressor and of the depressor points, the change being related to the reflex zones whose stimulation elicited the reflex. During the pressor response induced by the carotid reflex the excitability was increased in both pressor and depressor points: the response to the test stimulus became greater than it had been originally (Fig. 3, a and b).

During the pressor response induced by stimulation of the interoceptors of the urinary bladder or femoral nerve the response to test stimulation of the pressor points was reduced (Fig. 3, c), while stimulation of a depressor point caused an increased effect (Fig. 3, d). Therefore excitation was enhanced in the depressor and reduced in the pressor region. In no case of a change of the functional condition of the neurones induced either by polarization or reflexly was there any alteration in the nature of the reaction elicited by stimulation of pressor or depressor points.

The results obtained indicate that the distinguishing features observed between the different neurones of the vasomotor center may be one of the circumstances whereby afferent impulses from different sources act selectively on different groups of neurones, according to their excitability.

SUMMARY

Experiments were carried out on cats under urethane anesthesia. A study was made of pressor and depressor "points" in the reticular formations of medulla oblongata. The vasomotor effects were recorded by local stimulation with electric current with different parameters of retangular impulse. The data obtained show the following: 1) there was no strict space division between the groups of neuronal elements with pressor and depressor function: both of them were present in all the formations studied; however, the pressor ones were more frequently encountered in the rostrolateral, whereas depressor – in the mediocaudal formations; 2) both types of neuronal elements, some of which when stimulated provoked only a pressor, while others – only a depressor effect, possess different specialized functions and their excitability in response to the parameters of the stimulating current differed: diverse frequency optimums, length of the current impulse, and intensity thresholds. Neuronal elements within each type also differed by their excitability; 3) alteration of the functional state of the neuronal elements by local polarization and reflexly led to changes of their excitability, which could have different directions in the neuronal elements with pressor and depressor function.

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