SECRETORY REACTIONS OF THE SALIVARY GLANDS DURING STIMULATION OF THE HYPOTHALAMUS IN RELATION TO THE FREQUENCY, STRENGTH, AND DURATION OF STIMULATION

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(Presented by Active Member AMN SSSR A. V. Lebedinskii)
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 57, No. 2, pp. 16-20, February, 1964
Original article submitted January 19, 1963

The character of the influence of the hypothalamus on the secretion of saliva in normal conditions and after frontal lobectomy and the paths of transmission of these influences on the secretory activity of the salivary glands have been studied previously [3, 4, 6]. In these investigations we stimulated various parts of the hypothalamus with an electric current of optimal frequency and minimal strength. An alternating sinusoidal current and a stream of rectangular pulses were used. Since the strength, frequency, and duration of the current, and also its other characteristics have a significant bearing on the reactions of the digestive apparatus to stimulation of the hypothalamus, it was necessary to study how the salivary glands would react to stimulation of the hypothalamus with a sinusoidal current and a stream of rectangular pulses differing in frequency and strength. These problems are important, not only for the technical aspect of the investigations, but also to elucidate certain properties of the structures of the hypothalamus and their sensitivity to electric currents possessing different characteristics.

The present paper describes the results of a study of the secretory reactions of the salivary glands during stimulation of the hypothalamus by a stream of rectangular pulses and a sinusoidal current, and their dependence on the frequency, the strength, and the duration of action of the stimulating current.

EXPERIMENTAL METHOD

Investigations were made in the course of a chronic experiment on 9 dogs in which the common ducts of the mixed salivary glands were exteriorized by the Pavlov–Glinskii method and multipolar electrodes implanted into the hypothalamic region.

The technique of implantation of electrodes into the hypothalamic region was described in previous papers [1, 2]. The essence of it is that multipolar electrodes, mounted in a thin horseshoe-shaped plate made of plexiglass or thin motion picture film (after removal of the emulsion), are applied to the hypothalamic region around the pedicle of the hypophysis (anteriorly or posteriorly to it) through a burr hole in the temporal bone. The plexiglass block with the pins for connecting the stimulating current was fixed to the frontal bone by means of a specially constructed attachment. The investigations were carried out on dogs with 4- and 6-pole electrodes implanted into the various parts of the hypothalamic region. The position of the electrodes was verified after the operation roentgenographically and macroscopically in sections of the hypothalamus.

The various parts of the hypothalamus were stimulated for 3-5 min by an electric current from a stimulator generating rectangular pulses with frequencies of between 6 and 300 pulses/sec (duration of pulse 0.2 millisec, voltage 0.7-0.8 V) or with a sinusoidal current from a type ZG-10 audiofrequency generator, with frequencies of between 20 and 200 cps and a strength of between 0.1 and 1 mA. Bipolar and unipolar stimulation of the hypothalamus were used.

The saliva secreted during definite time intervals (1, 3, and 5 min) by the mixed salivary glands during and after stimulation of the hypothalamus was collected in separate portions. The volume of saliva was measured and its refractive index and content of solid residue and of organic and inorganic matter determined. The refractive

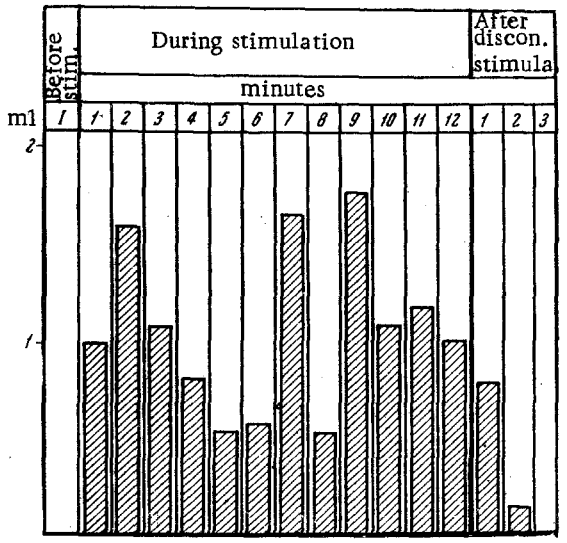

Fig. 1. Secretion of saliva by mixed glands in the dog Tikhii during prolonged (12 min) stimulation of the hypothalamus at the level of the infundibulum (middle electrodes) with a stream of rectangular pulses (0.2 millisec, 0.7 V, 40 pulses per sec), Experiment on March 21, 1960.

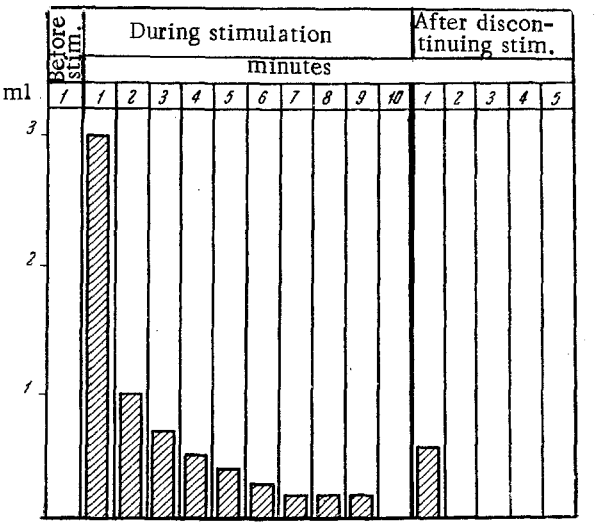

Fig. 2. Secretion of saliva by mixed glands in the dog Tikhii during prolonged (10 min) stimulation of the hypothalamus (at the level of the indibulum) with a sinusoidal current (0.1 mA, 40 cps). Experiment on March 14, 1960.

index was determined in a type RLU refractometer at a constant temperature of 20°. During stimulation of the hypothalamus observations also were made on the animal's behavioral reactions. the reactions of its pupils, defecation, urination, and so on.

EXPERIMENTAL RESULTS

Stimulation of different parts of the hypothalamus with a sinusoidal electric current and with a stream of rectangular pulses caused salivation, which ceased after stimulation was discontinued. The volume of saliva secreted in these conditions and the rate of secretion varied with the part of the hypothalamus stimulated. The greatest intensity of salivation was observed during stimulation of the anterior and middle parts of the hypothalamus. During stimulation of the posterior part of the hypothalamus much less saliva was secreted. The percentage of solid residue and of organic matter and also the refractive index increased in most experiments with an increase in the intensity of salivation. No significant change took place in the concentration of inorganic substances under these circumstances.

Unipolar and bipolar stimulation of one side (right or left) of the hypothalamus caused greater salivation from the gland situated on the ipsilateral side. Stimulation of the side of the hypothalamus opposite to the gland caused the secretion of a much smaller volume of saliva or had no effect on secretion, thus confirming our previous findings.

To explain the differences between the stimulating action of the sinusoidal current and the stream of rectangular pulses on the structures of the hypothalamus, experiments were conducted in which prolonged stimulation was applied to the same part of the hypothalamus. Prolonged stimulation of the middle parts of the hypothalamus with a stream of rectangular pulses caused the secretion of saliva throughout the period of its action, and the volume of saliva secreted during each minute remained at a high level. Small amounts of saliva continued to be secreted for some time after the cessation of prolonged stimulation. The results of an experiment conducted on the dog Tikhii are shown in Fig. 1. During stimulation of the middle part of the hypothalamus with a stream of rectangular pulses for 12 min, intensive secretion of saliva took place, and this was maintained at a high level throughout the period of stimulation. In 1 min approximately 1 ml of saliva was secreted, and 13 ml during the whole period of stimulation (12 min). After stimulation was discontinued the secretion of saliva continued for a further 2 min.

Prolonged stimulation of the same part of the hypothalamus with the sinusoidal current had a rather different effect on the function of the mixed salivary glands. It will be clear from Fig. 2 that during stimulation of the hypo-

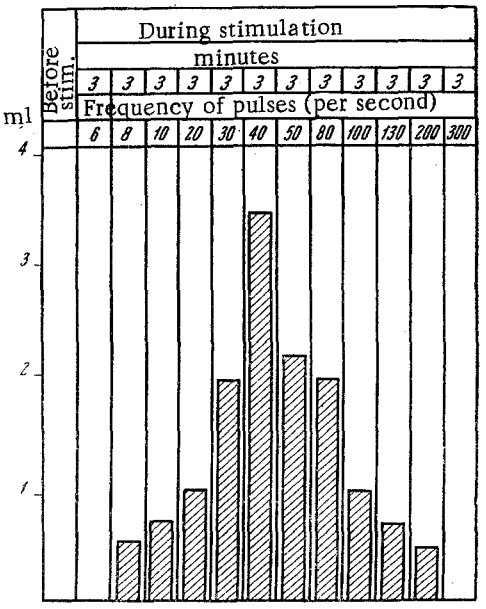

Fig. 3. Secretion of saliva by mixed glands in the dog Zhuk during stimulation of the right side of the hypothalamus with a stream of rectangular pulses of different frequencies (0.2 millisec, 0.8 V). Experiment on April 8, 1960.

thalamus with the middle electrodes, the greatest intensity of secretion of saliva (3 ml) was observed during the 1st min of stimulation. The secretion of saliva fell rapidly in the 2nd min of stimulation, and then fell more gradually ceasing completely in the 10th min. This phenomenon was evidently associated with adaptation of the nervous structures of the hypothalamus to prolonged stimulation with the sinusoidal current. After stimulation had been discontinued a slight secretion of saliva continued to occur for 1 min. Brief stimulation of the hypothalamus with a sinusoidal current caused approximately the same salivatory effects as brief stimulation with a stream of rectangular pulses.

The character of the secretion of saliva during stimulation of the hypothalamus with a current of different frequency was also studied. The effect of the frequency of the stimulating current on the intensity of secretion of saliva was demonstrated by N. E. Vvedenskii [5] after experimental stimulation of the chorda tympani in dogs. He found that the optimal frequency of stimulation of the chorda tympani in the dog is 40/sec. The use of higher frequencies – from 100 to 250/sec – did not produce secretion from the submandibular gland.

Maltesos and Weigmann [7] recorded the highest rate of secretion during stimulation of the chorda tympani with a low-frequency alternating current (10-20 cps). If a current of higher frequency (from 50 to 100 cps) was used, polyphase secretory responses developed.

In our experiments to study the secretion of the mixed salivary glands in response to stimulation of different parts of the hypothalamus with electric currents of different frequencies, a relationship was established between the volume of saliva secreted and the frequency of the simulating current. Secretion of saliva appeared during stimulation of the hypothalamus with rectangular impulses with a frequency of 6-8/sec, but its intensity was very low (0.5 ml saliva in 3 min). With an increase in the frequency of the stimulating current the intensity of saliva secretion also increased, to reach its highest level at a frequency of 40/sec (3.5-5 ml saliva in 3 min). With a further increase in the frequency of the current, the intensity of saliva secretion fell, and at a frequency of 300-400/sec the secretion of saliva ceased (Fig. 3).

The rate of secretion of saliva during stimulation of the hypothalamus was dependent, not only on the frequency, but also on the strength of the stimulating current. An increase in the strength of the current from 0.1 to 0.6 mA, keeping the frequency constant, led to a parallel increase in secretion of saliva. A further increase in the strength of the current to 0.8-1.0 mA was accompanied by a lowering of the intensity of saliva secretion. Corresponding changes took place in the amount of dry residue and organic matter in the saliva. The content of mineral substances showed no significant change in these experiments.

In the experiments described above the maximal secretion of saliva was observed during stimulation with a current with a strength of 0.5-0.6 mA. A long period after implantation of the electrodes into the hypothalamus or after repeated stimulation by means of an electrode, a thick layer of connective tissue is formed around the electrodes in the hypothalamus. Therefore, in order to obtain the same secretory effect on the salivary glands during stimulation of the hypothalamus in these cases it was necessary to increase the strength of the stimulating current slightly.

Besides the changes in the secretory activity of the mixed salivary glands, during stimulation of the hypothalamus various reactions developed in other organs. Stimulation of the hypothalamus from the posterior electrodes caused a reaction of licking and sniffing in all the animals. Stimulation from the lateral electrodes in most cases led to the appearance of a food seeking reaction. A pupillary reaction was observed in all the animals, and in some of them it depended on the site of stimulation of the hypothalamus. During stimulation of the anterior and middle parts of the hypothalamus constriction was observed, and during stimulation of its posterior parts – dilatation of the pupils. In some animals, during stimulation of any part of the hypothalamus, irrespective of the intensity and frequency of the stimulating current, either constriction or dilatation of the pupils and of the palpebral fissure was recorded.

The following conclusion may be drawn from these experimental results. The hypothalamus takes part in the regulation of the secretory activity of the salivary glands. The volume of saliva secreted and the rate of secretion are dependent on the duration of stimulation of the hypothalamus, and the frequency and strength of the stimulating current. Prolonged stimulation of the hypothalamus with a stream of rectangular pulses causes secretion of saliva throughout its course. During prolonged stimulation with a sinusoidal current, the maximal secretory effect was observed only during the 1st min, after which it fell considerably, and ceased at the 10th min of stimulation. However, not all parts of the hypothalamus play an equally important role in the regulation of the secretion of saliva. The most intensive secretion of saliva is observed during stimulation of the anterior and middle parts and the least – during stimulation of the posterior parts of the hypothalamus.

SUMMARY

Chronic experiments were staged on 9 dogs with multipolar electrodes implanted into the hypothalamus. The amount of saliva secreted and the rate of its secretion in hypothalamic stimulation depends on the frequency and the stimulating current. The maximum amount of saliva secretion is observed at 40 pulses per sec (pulse duration – 0.2 millisec, 0.7-0.8 and the sinusoid current of 0.5-0.6 mA (frequency 40-50 cycles per sec). Prolonged stimulation of hypothalamus by rectangular current pulses provokes saliva secretion during the whole course of stimulation. Prolonged stimulation by a sinusoidal current causes the greatest secretory effect only during the first minute, after which it decreases considerably and is completely arrested in the 10th minute of stimulation. Salivary secretion also depends on the portion of hypothalamus stimulated.

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