RELATIONSHIP BETWEEN SECRETION AND BLOOD SUPPLY OF THE SUBMANDIBULAR GLAND DURING STIMULATION OF THE CHORDA TYMPANI AT DIFFERENT FREQUENCIES

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Experiments in which the chorda tympani was stimulated electrically (duration 2 msec, amplitude 4 V, frequency 0.2, 0.4, 0.6, 0.8, 1, 2, 4, 5, 10, 20, 25, and 50/sec) showed that the blood supply to the submandibular gland is a linear function of the frequency of stimulation.

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The increased blood supply of the secreting salivary glands is attributed to the influence of special vasodilator fibers [6, 10, 15]. This view has been held ever since it was shown that atropine blocks the secretory effect of stimulation of the chorda tympani but does not prevent the increase in blood flow [15]. However, the possibility of an increase in metabolism in the activated gland cells during the action of atropine cannot be ruled out [5]. Some workers consider that metabolites formed during excitation of glandular cells give rise to the accompany vasodilatation [5, 14, 16]. Others criticizing this view point out that in that case a strict correlation must exist between indices of metabolic activity (in particular, oxygen consumption) and the degree of increase in blood flow both before and after the action of atropine [9, 17]. In fact, during stimulation of the chorda tympani at different frequencies an approximately linear relationship has been found between the volume of saliva secreted and the additional oxygen consumption [17, 18]. However, no correlation was present between the additional oxygen consumption and the increase in blood flow. On the contrary, Gesell [14] found that with a decrease in amplitude of stimuli applied to the chorda tympani, the electrical potential of the gland which, in his opinion, reflects metabolic activity, changes parallel with the change in blood flow. It has also been shown that during prolonged stimulation of the chorda tympani at frequencies of 8-30/sec the volume of saliva and the addition blood flow increase parallel with each other [19].

The question whether the increased blood supply to the secreting salivary glands is due to special vasodilator fibers or whether it is secondary to excitation of the gland cells [8] thus remains unanswered. Some help in providing the answer may be obtained from quantitative comparison of the secretory and vasomotor reactions developing in response to stimulation of the chorda tympani at different frequencies, and the present investigation was carried out for this purpose.

EXPERIMENTAL METHOD

Experiments were carried out on cats anesthetized with urethane (2 g/kg) or a combination of urethane and chloralose (300 and 50 mg/kg respectively). The salivary ducts, lingual nerve, and chorda tympani were exposed by the classical method. The small branch running from the lingual nerve to the mucous membrane of the mouth was divided. A segment of the divided lingual nerve lying proximally to the point of departure of the chorda tympani was stimulated for 1 min with square pulses 2 msec in duration and 4 V in amplitude. The frequency of the pulses was increased during successive stimulations in the following order: 0.2, 0.4, 0.6, 0.8, 1, 2, 4, 5, 10, 15, 25, and 50/sec. The intervals between stimuli were 3-15 min depending on the frequency of stimulation. The effect of stimulation at frequencies of up to 0.8/sec on the volume of saliva secreted and the blood flow was investigated in only 6 experiments while the effect of higher frequencies was studied in all 11 experiments. A polyethylene cannula connected to a small receiver filled with distilled water was introduced into a duct of the submandibular gland. The saliva dis-

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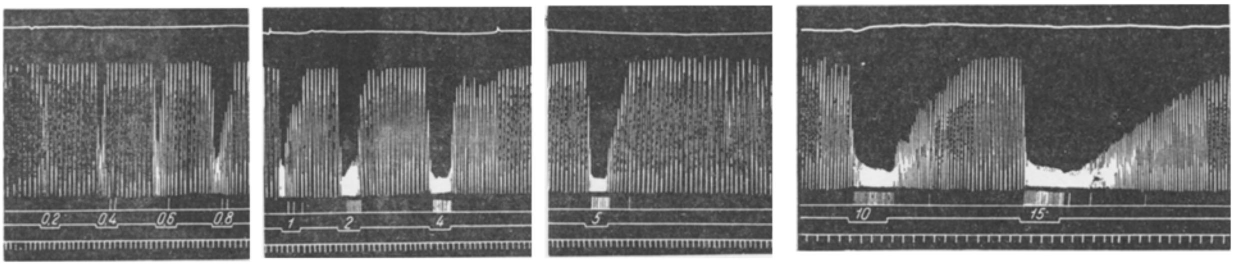

Fig. 1. Increase in secretion and blood supply of the submandibular gland during an increase in frequency of stimulation of the chorda tympani. From top to bottom: arterial pressure, outflow of blood from gland, drops of saliva, marker of stimulation (numbers indicate frequency of pulses), time marker 15 sec.

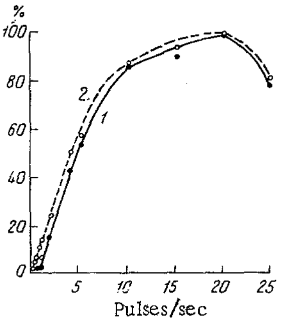

Fig. 2. Relationship between secretion of saliva (1) and increase in blood supply of gland (2) (in percent of highest possible values) and frequency of stimuli applied to chorda tympani. Here and in Fig. 3, mean results of 11 experiments.

placed water which passed along a short, narrow polyethylene tube drop by drop (volume 10 μl) into the chamber of a photoelectric recorder. The anterior facial, lingual, and transverse cervical veins were ligated. A cannula connected to a second photoelectric recorder was inserted into the external jugular vein [4]. The blood then reentered the cardiac end of the same vein through a cannula passing into the vena cava. The volume velocity of the blood flow was recorded on an intervalograph [3]. At the same time the number of drops of blood was recorded by a counter automatically switched on and off together with the stimulus. The arterial pressure was recorded by a mercury manometer. Clotting of the blood was prevented by heparin (15 mg/kg).

EXPERIMENTAL RESULTS

As the results of preliminary experiments showed, the durations and amplitudes of the square pulses indicated above result in maximal secretion of saliva and increased blood flow characteristic for each frequency of stimulation.

In 8 of the 11 experiments the minimal frequency to produce a flow of saliva from the duct was 1/sec, in one experiment it was 2/sec, and in the other two experiments secretion of saliva was observed at a frequency of 0.2-0.4/sec. It will be clear from Fig. 1, which is a record of one of these experiments, that the blood flow actually increased at a frequency of 0.2/sec. This was the threshold frequency for an increase in blood flow in 4 of the 6 experiments, and in the other 2 experiments the blood flow increased at a frequency of 0.4/sec. The values of the threshold frequency for secretion of saliva in these experiments agree with those reported by Beznak and Farkas [7]. As in experiments by other workers [1, 2, 11, 13], maximal secretion of saliva occurred at a frequency of 10-20/sec. The increase in blood outflow reached a maximum at 5-20/sec. Compared with the resting state, the blood flow under these conditions was increased by 3.7-21 times (mean 8-10 times). At frequencies higher than 20-25/sec both secretion and blood flow were reduced. To what extent does the increase in blood flow correspond to the volume of saliva secreted? In Fig. 2 the values of both these indices are shown as a function of the frequency of stimulation. Over the greater part of the frequency range the curves are parallel. The curve of blood flow lies above the curve of secretion of saliva.

To obtain a clearer picture of the relationship between the volume of saliva secreted and the additional blood supply, the second of these values is represented in Fig. 3 as a function of the first. If the values of secretion and blood flow increased equally as the frequency of stimulation was increased, all the points on Fig. 3 would lie on the straight line shown on the graph as a broken line. In fact, they were displaced toward the axis of blood flow, and this displacement was particularly marked in the region below 2/sec.

The results of these experiments thus show that a linear relationship exists between the volume of saliva secreted and the increase in blood flow at frequencies exceeding 2/sec. Deviation from the linear relationship in the lower frequency region may be attributed to the fact that the volume of saliva measured

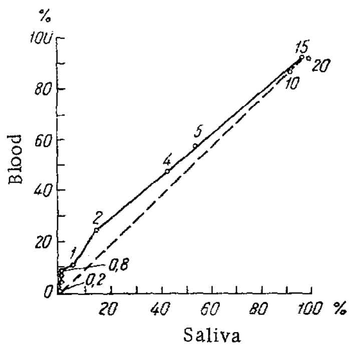

Fig. 3. Volume of saliva secreted as a function of increase in blood supply to the gland (in percent of highest possible values).

was not equal to the volume formed by the gland cells. At frequencies of 1 and 2/sec the mean volume of saliva secreted was 21.5 and 54 μl. Meanwhile in the cat, the maximal volume of the ducts of the submandibular gland is 100-150 μl [12]. Clearly the saliva produced by the gland can remain in the ducts. Furthermore, saliva is absorbed from the duct [20]. It is difficult to assess what proportion of the total saliva formed is lost for this reason. However, it can be accepted that this factor will have a particularly marked effect at low frequencies of stimulation, when the interval between stimuli is several seconds in duration. Evidently, deviation of the straight line (Fig. 3) in the range 2-10/sec from the broken line corresponding to a strictly equal increase in both parameters is also explained by loss of some of the saliva by distention of the ducts and absorption. With an increase in frequency, and a corresponding increase in the volume of saliva secreted, this systematic error in assessment of the intensity of the secretory process is diminished.

Allowing for the systematic error of measurement of the volume of saliva, it can thus be concluded that correlation between the volume of saliva secreted and the increase in blood supply exists throughout the range of frequencies. This relationship is found not only as an average for the group of experiments (Fig. 3), but also in each individual experiment. However, it should be pointed out that the ratio between the volume of saliva and the blood supply of the gland during stimulation of the chorda tympani by pulses of the same frequency may differ very considerably, by 4-5 times. It follows, therefore, that if the ratio between these indices is plotted on correlation graphs [17, 18], the corresponding points will show considerable scatter. This led the authors cited to reach the unwarranted conclusion that no quantitative relationship exists between the volume of saliva and the increase in blood flow.

The existence of a linear relationship between the volume of saliva secreted and the increase in blood supply to the submandibular gland during stimulation of the chorda tympani at different frequencies suggests that the increased blood supply is not due to special vasodilator fibers but to excitation of the gland cells, i.e., that it is a working hyperemia.

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