APPLICATION OF STATIC MUSCULAR CONTRACTION TO THE ANALYSIS OF THE MECHANISM OF VOMITING

A. A. Sukhanov

From the Chair of Normal Physiology (Director: Prof. N. K. Vereshchagin), Sverdlovsk Medical Institute

(Received April 10, 1957. Presented by V. N. Chernigovskii, Active Member Acad. Med. Sci. USSR)

According to a number of authors [1, 6, 9] many of the functions of the organism are inhibited when isometric concentrations of muscles are initiated. We thought it would be of interest to apply these features of static work to the analysis of the mechanism of vomiting. It is known that a whole complex of reactions, both of a somatic and of an autonomic nature, is involved in the act of vomiting. We examined the inhibitory effect of static work on the vomiting reaction.

EXPERIMENTAL METHODS

The experiments were performed on dogs with Basov gastric fistulae and with a Thiry -Vella fistula of the jejunum. Vomiting was induced in two ways: reflexly, by stimulating gastric receptors, and by direct action on the vomiting center by means of apomorphine, 0.1% solutions of which were prepared before the experiments, and were injected subcutaneously in small doses (0.03-0.05 mg/kg). At such dosage levels, apomorphine caused vomiting within 8-15 minutes. The experiments were performed at 3-day intervals, with a break of two days between them (under such conditions habituation of apomorphine did not take place [4]). Reflex induction of vomiting was achieved by introducing 500 ml of 15% potassium chloride through a gastric fistula, during 40 seconds. Vomiting ensued (1 or 2 attacks) after 5-7 minutes. In such experiments the potassium chloride solution acts reflexly on the vomiting center [2]. We registered the respiration of the animals, as well as gastric or small intestine contractions and the pulse rate. We evaluated the reaction of the abdominal muscles and diaphragm from the nature of the change in intra-abdominal pressure at the moment of vomiting, which affected the gastric contraction tracings. We also recorded the rate of onset of premonitory signs (licking of lips, salivation, lassitude).

The muscle loading consisted of fastening a sand-bag, half the weight of the animal, to its back. The load was maintained until the dog showed clear signs of fatigue. Vomiting was induced while it was still carrying the load. Experiments involving loading were alternated with control experiments. In all, we performed 212 experiments on 6 dogs, 65 of the experiments involving load-bearing.

RESULTS OF EXPERIMENTS

Evaluation of the effects of static work on vomiting showed that, in general, such tensions inhibited vomiting. The strength of the inhibitory effect depended on a number of factors. If loading was not applied initially, but only after a number of days, during which vomiting was induced 7-10 times, only very slight inhibitory effects were observed. If the load was applied at once, without previous induction of vomiting, its inhibitory effect appeared sooner, and was more considerable. The small inhibitory effect observed in the former conditions can be ascribed to elaboration of a stable "vomiting" stereotype, which was difficult to overcome.

The inhibition of vomiting produced in the first experiments with static loading became strengthened with time, to such an extent that double doses of apomorphine became ineffective. After a number of experiments involving load-bearing we found that inhibition of vomiting was produced merely by the experimental environment, i.e., by a conditioned reflex mechanism. In the control experiments (not under working conditions)

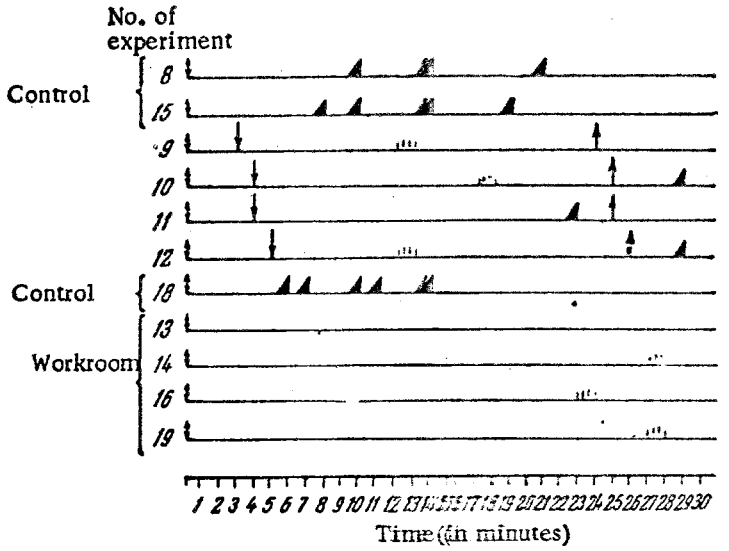

Fig. 1. Effect of static loading and of the working environment on the vomiting reaction.
Explanation of symbols: ◢ vomiting; ▥ dyspnea; ↕ injection of apomorphine; ↓ application of load; ↑ removal of load.

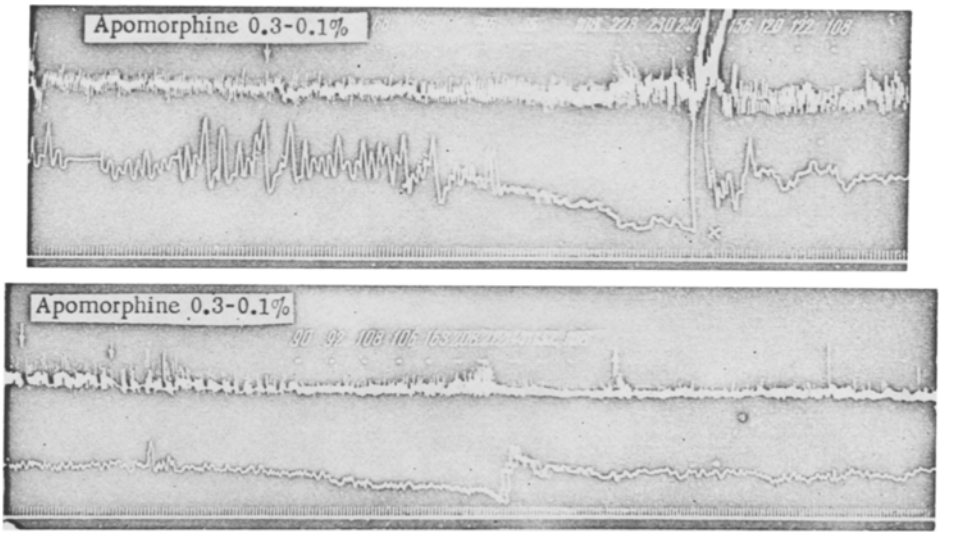

Fig. 2. Effect of static loading on the vomiting mechanism.
Explanation of tracings (from above down): respiration, stomach contractions, time marker (5 seconds), ↓ application of load, ↑ removal of load. Upper figures – pulse rates; × – abrupt rises in the gastric contraction tracing, due to contraction of abdominal muscles. Under conditions of load-bearing (lower kymogram) the reaction due to the abdominal muscles is inhibited, but the reactions due to the stomach, to respiration, and to the cardiovascular system are retained.

vomiting took place with the usual intensity (Figure 1). In many of the experiments conditioned reflex inhibition of vomiting exceeded unconditioned reflex inhibition. We thus see that the effect of the cerebral cortex, achieved in the given case according to the principle of the dynamic stereotype, is an important factor in the development of resistance of the organism to the action of emetics. Our findings agree in many respects with those of A. O. Dolin [3], who used different emetics.

Inhibition of reflex vomiting due to the action of potassium chloride proceeded in the same order, but was achieved somewhat faster and more readily. Here, too, we observed conditioned reflex inhibition of the vomiting reaction.

A detailed analysis of the effect of static loading on vomiting showed that this factor does not inhibit the different components of the vomiting reaction to the same extent. The soonest and the most readily inhibited component was that due to contraction of the skeletal muscles of the abdominal press (Fig. 2), which in effect prevented the onset of vomiting. The autonomic components, such as "vomitory" contractions of the stomach, salivation, dyspnea, and tachycardia, were much less affected. These reactions were retained in most of the experiments involving load-bearing. The complex of autonomic reactions encountered in vomiting due to potassium chloride was more profoundly inhibited than with apomorphine. Here the reaction from the respiratory center was missing, as well as that due to contraction of abdominal muscles.

Since static work inhibited only one of the components of the vomiting reaction, leaving the remaining components intact, we proceeded to study the extent of suppression of vomiting under conditions of more profound inhibition of the central nervous system, viz., under narcosis. Our experiments, performed on 10 dogs, showed that narcosis had a more powerful inhibiting effect on vomiting due to injection of apomorphine, in doses of 0.15-2 mg per kg, than did static loading. Not all the autonomic components were abolished here, however. Apart from inhibition of the abdominal muscle component, we observed inhibition of gastric contractions and of salivation, but the blood pressure and respiration components were more persistent (Fig. 3).

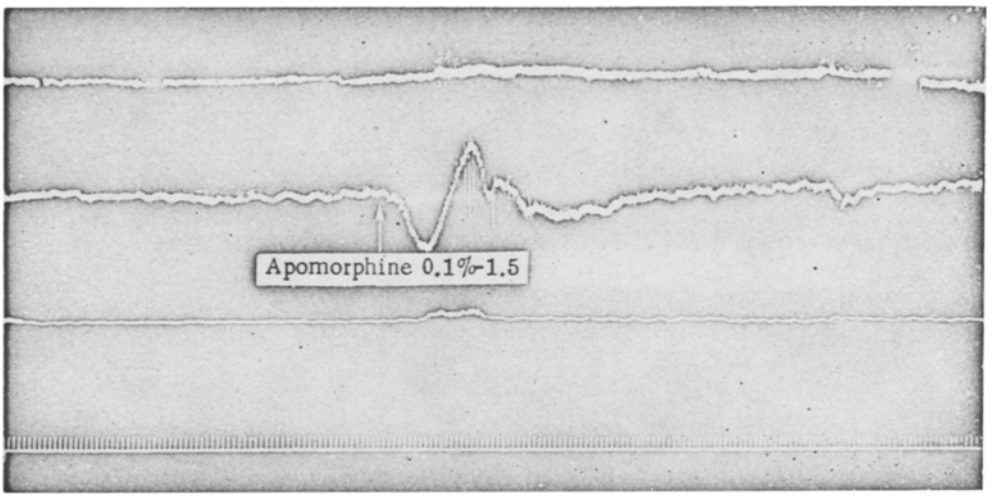

Fig. 3. Reaction of anesthetized dogs (chloroform-ether mixture) to apomorphine. Explanation of tracings (from above down): respiration, blood pressure, gastric contractions, time marker (5 seconds). Reactions from the stomach and from the abdominal muscles are abolished. Reactions from blood pressure and respiratory components are retained.

Our observations showed that the individual components of the vomiting mechanism enter into operation in a fixed sequence. As is evident from Fig. 2, the first reaction to introduction of apomorphine is from the stomach, in the form of a gradual fall in its tonus. This is soon followed by reactions from other systems. This permits one to assume that the vomiting mechanism begins with excitation of the motor centers of the gastrointestinal tract. This excitation increases in intensity, and radiates to a number of other centers: the salivation center (the dog starts licking its lips), the cardiovascular center, the respiratory center, and then to motor centers of the skeletal muscles. As appears from Fig. 2 (lower kymogram), stimulation of the motor centers of the gastrointestinal tract bears a clearly-expressed inductive-reciprocal nature: prolonged and profound inhibition of stomach contractions is followed at the moment of expected vomiting by violent contractions. The effect here is one of sequential inversion of stimulatory processes in the autonomic centers: stimulation of sympathetic centers is followed by their inhibition, and the previously reciprocally inhibited parasympathetic centers now enter into

a state of powerful stimulation. The stimulation of these centers is the more powerful the more prolonged the phase of inhibition.

We often observed in our experiments that the somatic muscles did not immediately enter into the vomiting mechanism, i.e., that there was a time lag in the passage of stimulation from the autonomic to the somatic centers. A time lag of this sort was first described by Sherrington [11], although not for the vomiting reaction. A hindrance to passage of stimulation from autonomic to somatic centers has also been noted by V. N. Chernigovskii and O. S. Merkulova [8].

From the above considerations we conclude that the realization of the act of vomiting is made possible by the considerable intensification of stimulation of autonomic centers, mediated by inductive-reciprocal relations. The stimulatory process, reinforced in this way, is enabled to overcome the impedance, and thereby to pass over from the autonomic to the somatic centers.

As is evident from the above, we do not consider that the existence of special formations corresponding to the concept of a vomitory center is essential. It follows that we do not admit the existence of a single center regulating the motor activity of the gastrointestinal tract, moderate stimulation of which assures normal working of the stomach, while stronger stimulation causes vomiting. This view coincides with that of A. I. Mordovtsev [5].

In accordance with I. P. Pavlov's teaching regarding centers [7], we should take a much broader view of the vomiting center, in its topographic aspect. We believe that the mechanisms regulating vomiting are located not only in the medulla oblongata, but also in other parts of the central nervous system. Thus the observation that the application of static loading results in the first place in the abolition of the press effect of the abdominal muscles and the diaphragm justifies the assumption of a special location of somatic muscle centers participating in the act of vomiting. This assumption agrees with the findings of Openchowski [10], who showed that the somatic component of the vomiting mechanism may be abolished by destroying certain subcortical formations of the brain. We think that the meaning which is now attached to the concept of the vomiting center should be restricted to the afferent limb of the reflex arc only, represented in the medulla oblongata both by sensory cells and by special chemoceptors [12]. As Pavlov showed, it is this receptor part which is the most important for any center. The efferent part is to be regarded as being purely executive in function; one and the same efferent apparatus may be applied for various purposes.

On the basis of the foregoing considerations regarding the regulation of the mechanism of vomiting, we consider its inhibition by application of static work to be the result of negative induction from certain definite cells of the motor analysor, in which a concentrated focus of excitation is formed under the influence of impulses from proprioceptors arising at the moment of static loading. It is evident that inductive inhibition will in the first place affect somatic muscle centers. The autonomic centers will be less powerfully inhibited. Although "vomitory" stimulation could arise in them, it would not be powerful enough to reach the somatic muscle centers and to stimulate them to activity.

SUMMARY

Static muscular work which consisted in holding a load on the back inhibited the act of vomiting which was induced by apomorphine or by stimulation of the stomach receptors by a solution of potassium chloride. The act of vomiting was inhibited by placing the dog under conditions in which the experiment was formerly conducted (following several experiments with the load, i.e., by way of conditioned reflex). Various components of the act of vomiting were inhibited differently. The mildest depression was found in the activity of somatic muscles (abdominal press). The autonomic component of the act of vomiting (secretion of saliva, dyspnea, stomach contraction, increased rate of cardiac contractions) was only slightly inhibited. With increase of inhibition (anesthesia) the reactions of blood pressure and respiration were found to be the most stable components out of the whole autonomic complex of vomiting reactions. A definite sequence of introduction of various components of the act of vomiting was established in experiments without the load. Several new suggestions are made concerning the regulation of the act of vomiting.

LITERATURE CITED

[1] I. S. Aleksandrov, Arkh. Biol. Nauk SSSR, 32, No. 5-6, 364-374 (1932).

[2] I. A. Bulygin, Biull. Eksptl. Biol. i Med. 29, No. 6, 95-99 (1950).

[3] A. O. Dolin, in: I. P. Pavlov's Teaching in Theoretical and Practical Medicine,* 409-447, Moscow 1953.

[4] F. G. Dubinin, Arkh. Biol. Nauk SSSR 42, No. 3, 16-19 (1936).

[5] A. I. Mordovtsev, Biull. Eksptl. Biol. i Med. 36, No. 9, 19-21 (1953).

[6] V. A. Novi, Transactions VIII All-Union Congress of Physiol., Biochem. and Pharmacol. 451-453, Kiev, 1955.

[7] I. P. Pavlov, Twenty Years of Experience of Objective Study of Higher Nervous Activity in the Behavior of Animals,* p. 95, Moscow 1951.

[8] V. N. Chernigovskii and O. S. Merkulova, Biull. Eksptl. Biol. i Med. 29, No. 1, 43-47 (1950).

[9] R. A. Shabunin, "Effect of Static Exertion on Unconditioned and Conditioned Vascular Reflexes in the Human" (Thesis) Sverdlovsk 1955.*

[10] Openchowski, Arch. f. Anat. und Physiol. 1889, H. 1-2, pp. 549-556.

[11] C. Sherrington, The Integrative Action of the Nervous System, Cambridge, 1906.

[12] S. G. Wang and H. L. Borison, Gastroenterology, 1952, Vol. 22, pp. 1-12.

* In Russian.