CEREBRAL CIRCULATION UNDER REFLEX INFLUENCES

COMMUNICATION I

CEREBRAL BLOOD SUPPLY ON STIMULATION OF SMALL INTESTINE INTEROCEPTORS

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Studies conducted at this laboratory have established that the lumen of cerebral vessels alters in opposite directions when hypertension is elicited in two different ways – by hypothalamic stimulation and by compression of the carotid arteries. Stimulation of the hypothalamic area produced cerebral hyperaemia and dilatation of cerebral vessels, while decreased impulses from the carotid sinus baroceptors (compression of the carotid arteries) was accompanied by decreased cerebral blood supply and constriction of cerebral blood vessels. Analysis of such differences in the blood supply to the brain led to the conclusion that the different vascular reactions associated with the same increase in arterial pressure must indicate the participation of different mechanisms. As the experiments showed, the increased tonus of cerebral vessels observed on compression of the carotid arteries was determined by the decrease in impulses from the carotid sinus baroceptors. Increased cerebral blood supply accompanying centrally induced hypertension, on the other hand, was determined by the combination of raised arterial pressure with diminished tonus of the cerebral vessels caused by an increase in impulses from the carotid sinus baroceptors. The present work was undertaken to make further analysis of factors affecting the tonus of cerebral vessels possible; a study was made of cerebral blood supply in hypertension induced by stimulation of interoceptors in a segment of the small intestine.

A great number of communications have appeared in the last decade dealing with the effect of interoceptor stimulation on arterial blood pressure and respiration (V. N. Chernigovsky and collaborators [3, 4]). The work of Meyer and Pribram [6] concerning the effect of gastric interoceptor stimulation on the pial vessels is well known. There are several investigations [1, 2, 5, 7, 8, 9] devoted to the study of the lumen of pial vessels on stimulation of sensory nerves (femoral and sciatic). Some of the workers found constriction while others found dilatation of the cerebral vessels, the inconsistency being explained by changes in arterial blood pressure level and in respiration.

EXPERIMENTAL

Experiments were performed on 34 adult dogs weighing between 6 and 10 kg. Operation was carried out under morphine-urethane anesthesia. Changes in the rate of blood flow in the dura and pia were determined by the thermoelectric method and were taken as an indicator of cerebral blood supply. In three experiments the rate of blood flow was recorded from the hypothalamic area. A trephine opening was made in the parietal, occipital or temporal bone and special flat thermoelectrodes, constructed in the laboratory, were placed on the dura. The thinness of the dura permits the assumption that the thermoelectrode would pick up changes in the rate of blood flow both in the dura and the underlying pia. Needle thermoelectrodes (Jibbs type) were used for

the determination of the rate of blood flow in the hypothalamic area; they were introduced through the trephine opening at the intersection of the coronary and sagittal sutures. The needle thermoelectrodes were inserted through the dura to a depth of 32-34 mm.

Arterial blood pressure was recorded by means of a mercury manometer from the femoral artery; respiratory movements were recorded by a pneumograph connected to a Marey's tambour. Rate of cerebral blood flow, arterial pressure and respiratory movements were recorded synchronously on a photokymograph. Stimulation of the interoceptors was produced by inflation of a loop of small intestine within the abdominal cavity with air under 60-120 mm (of mercury) pressure. The most effective stimulation in these experiments proved to be that obtained with 80 mm pressure. Repeated stimulations were applied at intervals of not less than 15 minutes.

RESULTS

In 32 (of 34) experiments inflation of a loop of small intestine was seen to be accompanied by a rise of arterial blood pressure by 10-15 mm of mercury (in different experiments). The rise in pressure usually started 2-3 seconds after the beginning of inflation continuing to rise until the end of stimulation or, having reached a maximum within 15-20 seconds, beginning to fall but never reaching the original level while inflation was in progress. On cessation of inflation the return of arterial pressure to the initial level was delayed in most cases: the pressure remained raised for 2-3 minutes or longer. Only in 3 experiments did the arterial pressure reach the initial level in the course of the first minute after cessation of inflation. The changes in cerebral blood flow were not stereotyped. In 22 experiments increased rate of blood flow was observed. In 19 of these experiments the rate of blood flow increased during stimulation synchronously with the rise in arterial pressure and on cessation of stimulation the return of arterial pressure and blood flow to the original level occurred parallel.

The synchronous increase in the rate of cerebral blood flow and in arterial pressure does not provide information as to the state of the cerebral blood vessel lumen, since it can depend on raised pressure within the vessels (increased rate of blood flow and passive stretching of the vessel wall) as well as on active stretching of vessels. However, in 3 experiments the inter-relations of changes in cerebral blood flow and in arterial pressure were such as to suggest active cerebral vasodilatation associated with stimulation of the intestinal receptors. The kymogram of one of these experiments is given in the Figure, (a). In this experiment the rate of blood flow in the meninges and in the hypothalamic area during inflation of the small intestine increased as the arterial pressure rose. On cessation of stimulation the arterial pressure remained at the raised level, reached at the end of stimulation, for 40 seconds, after which it slowly began to fall. The rate of blood flow, however, continued to increase, reaching a maximum after 30 seconds, and then began to decrease slowly.

These experimental findings suggest that the increased cerebral blood supply during interoceptor stimulation is ensured not only by passive stretching of the vessels under the influence of increased pressure within the vessels, but also by an active decrease of the tonus of cerebral vessels (as the result of nervous or humoral factors).

Changes of the rate of cerebral blood flow observed in the remaining 10 experiments also indicate that interoceptor stimulation leads to changes in the tonus of cerebral blood vessels. Thus in 5 of these experiments a diphasic reaction of the rate of blood flow was seen: an initial rise followed by a decrease. Part (d) of the illustration shows a kymogram of an experiment in which the rate of blood flow began to drop after an initial rise (over 20 seconds). On cessation of stimulation the rate of blood flow continued to drop below the initial value against the background of still raised arterial pressure; only after 28 seconds gradual restoration of blood flow occurred as the arterial pressure decreased. In another case (b) the initial rise was followed by a drop of both the rate of blood flow and of arterial pressure, but the blood flow began to decrease earlier and fell markedly below the initial level towards the end of stimulation. Its decrease continued after the end of stimulation for a further 15 seconds, after which it gradually returned to the original value. Arterial pressure, however, returned to pre-stimulation level 15 seconds after cessation of stimulation, followed by a small rise.

A small but definite decrease in the rate of blood flow was observed throughout the period of stimulation against a background of relatively little increased arterial pressure in an experiment represented by the kymogram in part (c) of the illustration. Further confirmation of the presence of factors increasing the tonus of cerebral vessels during stimulation of intestinal interoceptors is furnished by the data of the following four experiments. In these experiments no change in the rate of blood flow occurred against a background of pronounced rise in

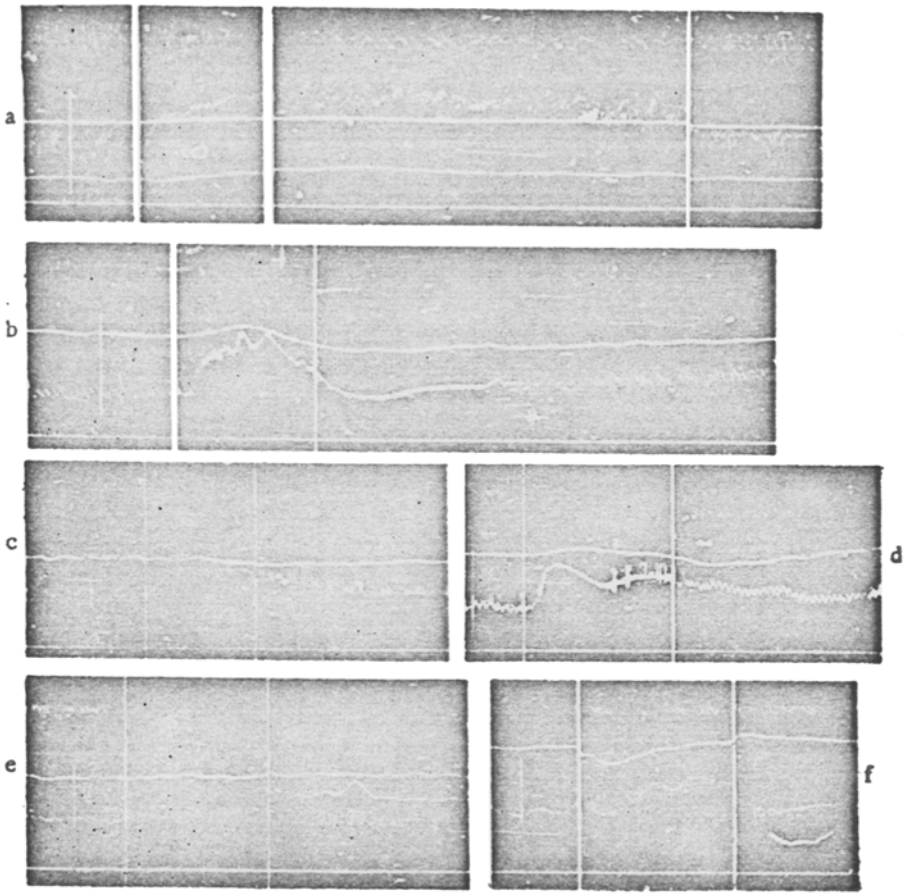

Fig. Reaction to inflation of a loop of small intestine in different animals. Records from above downward: a) respiratory movements, rate of blood flow in hypothalamic area, arterial pressure, rate of blood flow in dura and pia, time marker; b), d) rate of blood flow in dura and pia, arterial pressure, time marker; c), e), f) respiratory movements, rate of blood flow in dura and pia, arterial pressure, time marker (seconds).
Time marker) 2 seconds. Dotted line—level of factors under investigation before stimulation; vertical lines—start and end of stimulation.

arterial pressure (e), which is only possible with constriction of cerebral blood vessels. The absence of changes in the rate of cerebral blood flow could not be due to inertness of the thermoelectrode, since considerable changes in cerebral blood flow were recorded in the same experiments on compression of the carotid arteries (f).

These experimental results lead to the conclusion that the nature of the changes in cerebral blood supply can depend on the inter-relation of vasodilatory and vasoconstricting influences elicited by interoceptor stimulation. In cases where a decrease in tonus is associated with increased arterial pressure, an increase of blood supply results. When the tonus is increased the raised arterial pressure may not overcome it and in these cases the cerebral blood supply either remains unchanged or decreases on interoceptor stimulation.

The diversity of reaction to interoceptor stimulation in different animals can depend on: 1) the functional state of the vasomotor center and 2) the tonus of cerebral vessels at the moment of stimulation. The fact that a stereotyped reaction of arterial pressure—a rise—was observed in all the experiments speaks against the first

factor. Moreover, no changes were seen in the arterial pressure reaction to carotid pressor reflex in different animals.

It would appear that the different reaction of cerebral vessels to stimulation of the interoceptors of the small intestine is determined chiefly by the initial tonus of the vessels.

SUMMARY

Changes of the blood velocity in the dura and pia mater of the brain and in the hypothalamus region in the case of the inflation of the small intestine loop have been analyzed by the application of the thermoelectrical method on 34 dogs under morphine-urethane anesthesia.

In the majority of the experiments the stimulation of the interoceptors of the small intestine brings about the increase of the blood circulation in the brain with synchronous rise of the arterial pressure; in other cases under the same rise of the arterial pressure the decrease of blood circulation, or a biphasic response, i.e., the original increase followed by the decrease of blood circulation is observed. Such different responses of the blood vessels of the brain and the interoceptors being stimulated is connected with the different tonus of the blood vessels of the brain at the moment of stimulation.

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