RELATIONSHIP BETWEEN THE CEREBROSPINAL FLUID PULSE AND THE TONE OF THE CEREBRAL VESSELS

A. I. Naumenko and N. N. Vasilevskii

Central Research Laboratory (Head – Dr. Med. Sci. S. I. Yakovlev), Academician I. P. Pavlov
First Leningrad Medical Institute
(Presented by Active Member AMN SSSR P. S. Kupalov)
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The cerebrospinal fluid (CSF) pulse is the rhythmic increase in pressure in the subarachnoid space arising at the time of the systolic increase in the arterial pressure in the vascular system of the brain. It is generally accepted that the CSF pulse is vascular in origin. Adequate studies have been made of its form, its magnitude, and the velocity of its spread in the subarachnoid space [5, 7, etc.].

The CSF pulse has a number of special features. First, in all species of animals and in man its magnitude in normal conditions is comparatively small, being measurable in mm H_2O. Secondly, it has the form of the typical peripheral pulse. Frequently its descending portion shows a dicrotic peak.

The information in the literature concerning the influence of intra- and extracranial factors on its form and amplitude is scanty and conflicting. The opinion has been held, starting with the work of Becher [5], that its amplitude is mainly determined by the intracranial pressure. Becher, Bering [6], and others believe that a CSF pulse of high amplitude is observed with a raised subarachnoid pressure, and vice versa. This point of view lay at the root of the explanation of the changes in the CSF pulse in terms of the simultaneous changes in the intracranial pressure. The role of the tone of the cerebral vessels, which are the actual source of the pulse, seems to have escaped attention [8].

The object of the present investigation was to ascertain the effect of various factors on the CSF pulse and to judge the changes in the tone of the cerebral vessels so far as possible from the amplitude of the CSF pulse.

EXPERIMENTAL METHOD

The investigation was carried out on cats (40 experiments) under medinal and urethane anesthesia. The CSF pulse and intracranial pressure were measured through a suboccipital puncture with the animal lying on its side. The femoral arterial pressure was recorded at the same time.

Tensometric manometers of our own design [1] were used to record the CSF pulse and the arterial and CSF pressures. These parameters were studied during inhalation of atmospheric air, a mixture of 10-15% CO_2 with pure oxygen, and pure oxygen, or during hyperventilation and artificial elevation of the arterial pressure by means of compression of the abdominal aorta. During inhalation of the gas mixtures and hyperventilation, a tracheotomy cannula with valves and a breathing bag were used. This particular mixture of CO_2 and pure oxygen was selected because when it is inhaled by animals under general anesthesia marked changes are observed in the cerebral circulation [8].

EXPERIMENTAL RESULTS

Several series of experiments were conducted. In all experiments in each series the normal initial values were first recorded. The mean amplitude of the CSF pulse was 6.3 mm H_2O (4-10 mm), the CSF pressure was 73 mm H_2O (20-115 mm), the maximal arterial pressure 100-170 mm Hg, and the minimal arterial pressure 52-126 mm Hg.

In the first series of experiments the CSF pulse was studied during an increase in tone of the cerebral vessels. According to reports in the literature, the cerebrovascular tone is raised during inhalation of pure oxygen and hyperventilation (on account of the hypercapnia). In our experiments we observed that during inhalation of pure oxygen and hyperventilation, the amplitude of the CSF pulse either remained unchanged or fell by 1-2 mm H_2O, while the

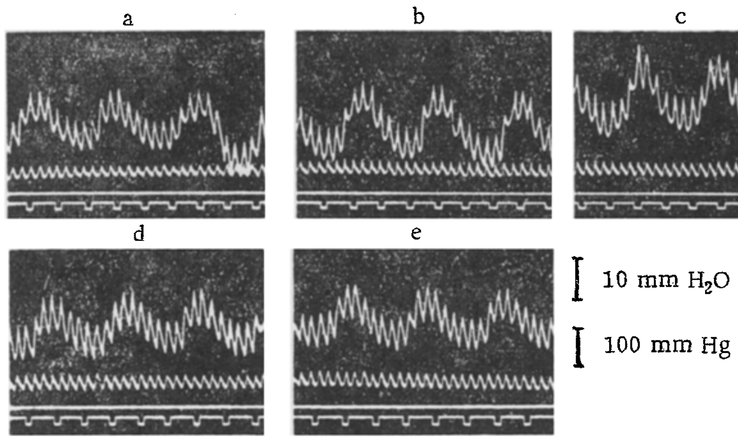

Fig. 1. Oscillograms of the CSF pulse and arterial pressure during inhalation of O_2 for 3 min: a) initial values; b) 1 min after; c) 2 min after beginning of inhalation of O_2; d) 3 min after; e) 6 min after cessation of inhalation of O_2. Significance of the curves (from above down): CSF pulse; arterial pressure (in this and subsequent figures); lower curves – time marker (1 sec), and above it – zero line.

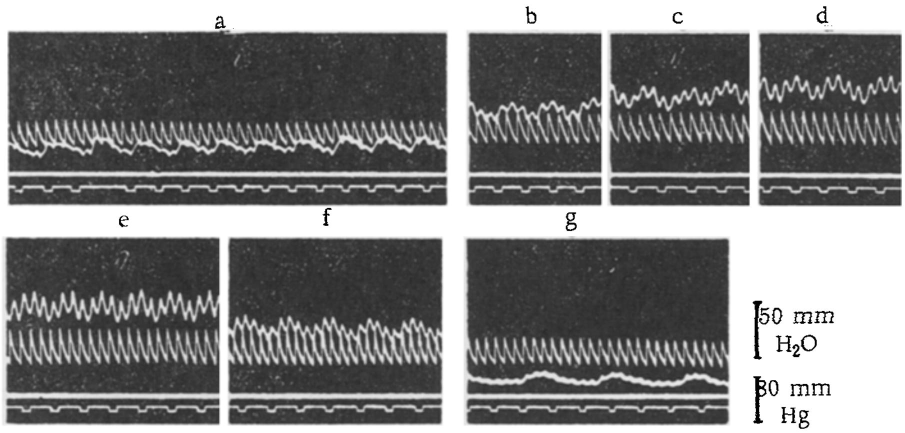

Fig. 2. Oscillograms of the CSF pulse, and of the intracranial and arterial pressures in a cat during inhalation of CO_2 for 3 min: a) initial values; b) 1 min after; c) 1.5 min after; d) 2 min after; e) 3 min after beginning of inhalation of CO_2 (inhalation of CO_2 ceased at the beginning of the 4th minute); f) 1 min after; g) 10 min after cessation of inhalation of CO_2. Significance of the curves (from above down): arterial pressure; CSF pulse.

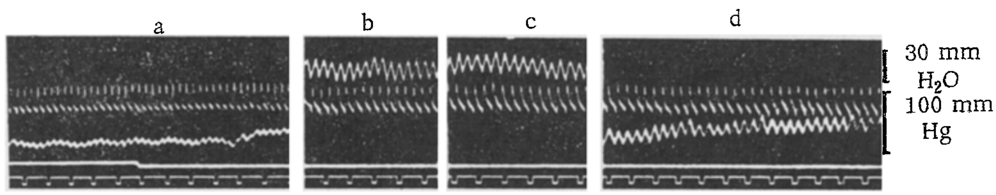

Fig. 3. Oscillograms of the CSF pulse and arterial pressure in an experiment in which the intracranial pressure was lowered during inhalation of CO_2. a) Initial values; b) 1 min; c) 2 min after beginning of inhalation of CO_2; d) immediately after withdrawal of 10 drops CSF. Significance of the curves (from above down): arterial pressure; CSF pulse.

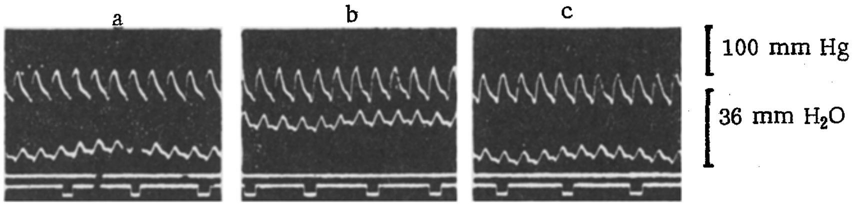

Fig. 4. Oscillograms of the CSF pulse and arterial pressure in the subclavian artery of a cat in an experiment with artificial elevation of the arterial pressure by compression of the abdominal aorta. a) Initial values; b) at the moment of compression; c) 1 min after compression. Significance of the curves (from above down): arterial pressure; CSF pulse.

intracranial and arterial pressures remained practically constant. The tensograms of one experiment in this series are shown in Fig. 1.

The comparatively insignificant reaction of the cerebral vessels and CSF pulse confirms the earlier observation [2,3] that in normal conditions the cerebral vessels are in a state of considerable tonic contraction. The increase in tone can therefore be only very slight. We observed more marked changes in the CSF pulse during a fall in the cerebrovascular tone in response to administration of CO_2. At the 2nd-3rd min of inhalation of a gaseous mixture rich in CO_2, the CSF pulse rose to several times (from 3 to 8) its original value, its average level (in 14 experiments) being 29.3 mm H_2O. The pulse curve frequently showed small, accessory waves, which are considered by N. N. Savitskii [4] to be additional evidence of a lowering of the vascular tone.

It should be noted that the increase in the amplitude of the CSF pulse during inhalation of CO_2 was observed to be accompanied by an increase in the intracranial and arterial pressures. The intracranial pressure rose on the average by 87 mm H_2O (43-162 mm). The maximal and minimal arterial pressures rose by 10-30 mm Hg, although in some cases they remained unchanged. Typical changes in the CSF pulse, and in the intracranial and arterial pressures are shown in the oscillograms from one of these experiments, given in Fig. 2.

What caused the increased amplitude of the CSF pulse; a lowering of the tone of the cerebral vessels or an increase in the intracranial or arterial pressure? To provide the answer to this question, two additional series of experiments were carried out.

In nine experiments, at the height of development of the effect of CO_2 inhalation (2nd-3rd minute), some of the CSF (5-10 drops) was drawn off through a three-way cock connecting the puncture needle with the tensomanometer. The intracranial pressure thereupon fell to normal, and in some experiments below normal. However, the CSF pulse fell by only a few mm H_2O, and remained several times higher than initially, when the cerebrovascular tone was normal. As an example we give oscillograms from one of the experiments (Fig. 3).

In five experiments the arterial pressure was raised artificially by compressing the aorta below the origin of the renal vessels. When the arterial pressure was raised in this manner, very slight changes in the intracranial pressure resulted. An increase of 30-60 mm Hg in the arterial pressure did not cause any increase in the CSF pulse. The oscillograms of one experiment of this series are shown in Fig. 4.

The results of the two last series of experiments demonstrate that the increase in the amplitude of the CSF pulse was associated principally with a lowering of the tone of the cerebral vessels. When the cerebrovascular tone was low, their increase in volume at every systole was evidently greater than in normal conditions or when the tone was increased. The observations of N. N. Savitskii indicate that such a mechanism is possible [4].

To some extent, therefore, the CSF pulse reflects the state of the tone of the intracranial vessels. This being so, we consider that the study of the form and amplitude of the CSF pulse, with other factors taken into consideration, is a promising method for use in experimental and clinical investigation. The intracranial pressure and CSF pulse can be measured clinically in the course of diagnostic and thereapeutic subarachnoid punctures. The use of simple physiological tests (holding the breath, inhalation of carbogen or pure oxygen, etc.), may yield valuable information regarding the changes in the CSF pulse, the intracranial pressure, and so on, and may give some idea of the state of the cerebrovascular tone and of its variations.

SUMMARY

Experiments were performed on cats. The effect of the tone of cerebral vessels on the amplitude of cerebrospinal pulse was studied experimentally. As shown, with the rise of the tone of cerebral vessels, the cerebrospinal pulse either remained unchanged or decreased by 1-2 mm H_2O. With reduction of the cerebral vascular tone, caused by the inhalation of gas mixture, rich in CO_2, cerebrospinal fluid pulse increased several times (3- to 8-fold). In these conditions the role of the intracranial and arterial pressure was insignificant and secondary.

The authors suggest investigation of the amplitude and the form of cerebrospinal fluid pulse in the patients during diagnostic and therapeutic punctures of subarachnoid space. The changes of the pulse in response to the simple physiological stimuli (breath detention, inhalation of carbogen, etc.) could serve as a valuable index for qualitative evaluation of the cerebral vascular tone.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.