A METHOD FOR STUDYING CEREBRAL VASCULAR TONE VARIATIONS IN ANIMALS

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Up to the present time there has been a dearth of information concerning cerebral blood supply in healthy subjects and its changes under pathological conditions and in response to the action of drugs and to the composition of the inspired air; this is largely due to experimental difficulties.

The methods used at present are not without serious defects. Thus, the best method at the present day, that of the "skull window" suffers from the limitation that only the superficial vessels of the brain and meninges are visible. The gas method of investigating intracranial circulation is not easy. Many of the methods for measuring variations in intracranial pressure or volume associated with changes in the volume of the cerebral vessels, give valuable information about cerebral vascular tone. However the main shortcoming of these methods is that the cranial cavity is no longer hermetically sealed, and this, in the opinion of many authors, causes alterations in intracranial circulation.

These difficulties can be overcome by use of the electroplethysmograph described by A. A. Kedrov and A. I. Naumenko [1]. This method gives a more accurate record of cerebral vascular tone, but also suffers from certain defects; the curve obtained represents not only variations in the volume of the cerebral vessels but also changes in the blood flow in them.

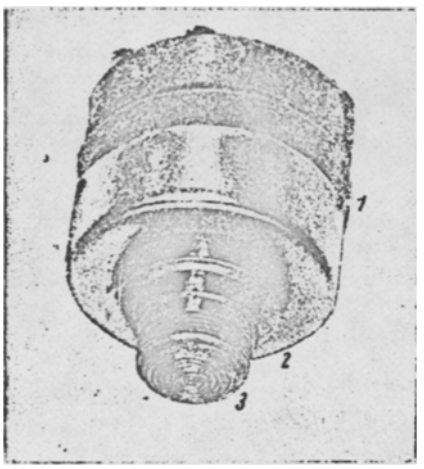

Fig. 1A. Strain gauge assembly for recording intracranial pressure.
1) Metal box enclosing the strain gauge; 2) projection with screw thread; 3) sensitive membrane.

As H. Sigward's [6] calculations showed, rapid (pulse) changes in cranial volume cannot be completely compensated by movement of the fluid. Considering that the brain is situated in a hermetically sealed space with inextensible walls, it is clear that every change in its volume must be accompanied by both a displacement of cerebrospinal fluid and a change of intracranial pressure.

In order to study intracranial circulation in animals, we used the method of recording the pressure variations. While admitting that there are rhythmical variations in the intracranial pressure corresponding to variations in the extent of filling of the blood vessels which in turn are associated with the heart beat and with respiratory movements, we consider these variations to be very small.

Any method used for measuring intracranial circulation must fulfil the following conditions: 1) the receiving device must be sensitive to very small pressure variations;

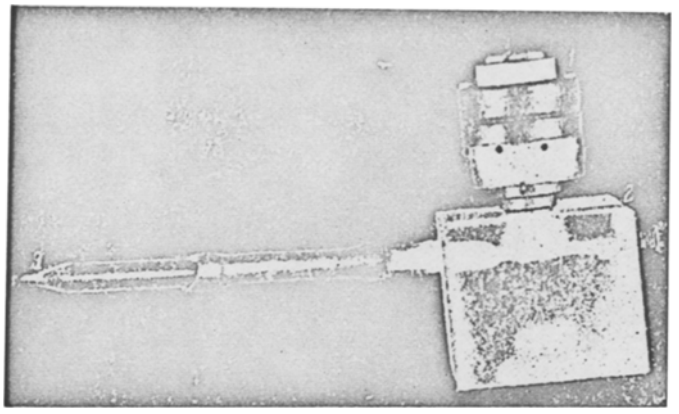

Fig. 1B. Strain gauge assembly for recording arterial pressure.
1) Strain gauge; 2) plexiglass vessel into which gauge is screwed;
3) cannula for insertion into artery.

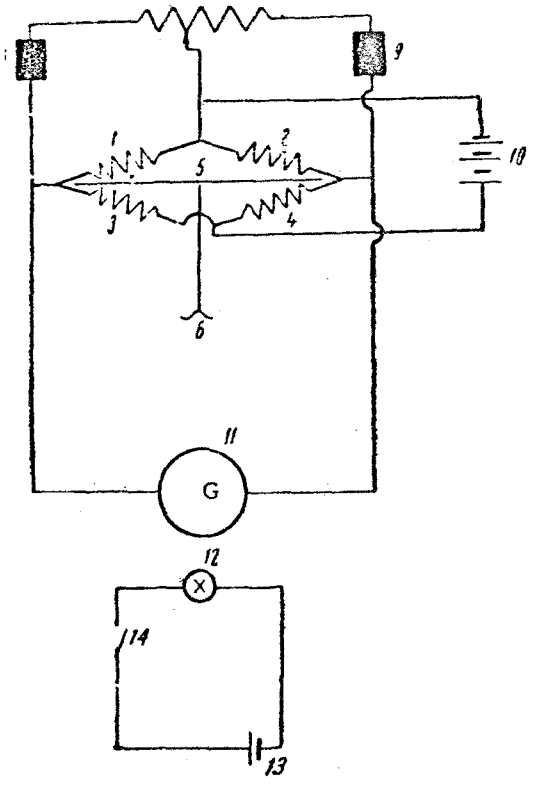

Fig. 2. Diagram of the apparatus.
1, 2, 3, 4) Strain gauge resistances (diameter of wire 0.02 mm, resistance ~ 200 ohms); 5) disk to which stain gauge is fixed; 6) corrugated membrane receiving oscillations; 7) resistance for balancing bridge (10,000 ohms); 8, 9) resistances for balancing bridge (5,000 ohms); 10) 12 volt batteries; 11) short period galvanometer (10^{-9}amp.); 12) galvanometer lamp; 13) 3.5 volt battery; 14) lamp switch.

2) it must be equally sensitive to rapid and slow changes; 3) the recording of the changes must be carried out by a device which is substantially free from inertia; 4) the skull must remain hermetically sealed.

Therefore we chose a method which allows very small variations in pressure to be transformed into voltage variations. Many such transducers are known, including electromagnetic, piezoelectric, etc.

In view of the requirements outlined we decided to use a strain gauge which was prepared for us by S. A. Evdokimov. The gauge had no inertia, it was superior to other devices in that it was equally sensitive to rapid pressure variations and to constant pressure changes. Its sensitivity was very high: it was capable of recording pressure changes equal to a few mm of water, which corresponds to the intracranial pulse pressure variation in experimental animals (cats). The gauge consisted of four wires with a resistance of 200 ohms each connected in a bridge circuit supplied by a 12-volt accumulator. Each resistance was made of a very fine wire of a special high resistance alloy wound to form a so-called sensitive network. The wire was fixed with a special adhesive to the surface of a metal disk. Changes in the shape of the disk caused deformation of the wire and so changed its resistance.

When not deformed the currents through the different arms of the bridge are equal, and the voltage output from the bridge is zero.

Deformation causes resistance changes in the arms, and this leads to potential changes which are proportional to the deforming force, i.e., to the pressure on the gauge.

The apparatus is contained in a small metal box (Fig. 1A and 1B) which ends in the central projection bearing a screw thread 2. This projection acts as a

stopper which screws hermetically into the trepanned opening in the skull. The distal end of the projection is covered with a thin corrugated membrane (6), which is connected by a wire to the bridge network of the strain gauge (Fig. 2). The membrane receives the pressure variations directly and transmits them to the strain gauge where the deformation of the resistance wires causes a voltage change in the network. These are recorded directly by a short period galvanometer on light-sensitive paper.

We used a similar but less sensitive gauge for recording intra-arterial pressure changes by connecting it to a cannula inserted into the artery (see Fig. 1B). Simultaneous recording of intra-arterial and intercranial pressure changes was then possible.

A diagram of the apparatus is shown in Fig. 2.

In acute experiments on cats under medinal anesthesia, using this apparatus, the following curves of arterial and cranial pressure were obtained (Fig. 3). In both of the curves changes associated with pulse and respiration are clearly shown. An increase in pressure corresponds to a movement of the line upwards, and a fall to a movement downwards. The amplitude of the curve depends on the sensitivity of the gauge, and this can be varied by changing the voltage supply to it.

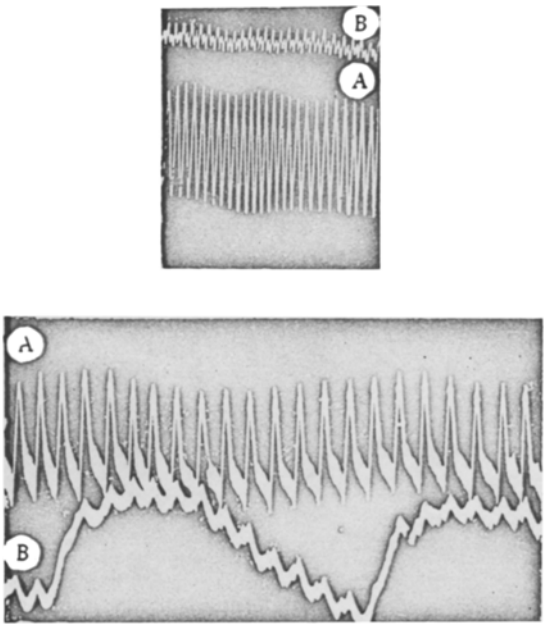

Fig. 3. Curves of (A) arterial and (B) intracranial pressure.

It has been suggested by B. N. Klosovskii [2] that pulsation of the cerebral vessels may occur only when the skull is not hermetically sealed; we therefore made a recording of the intracranial pressure in cats while maintaining the skull hermetically sealed by using the screwed-in gauge, as well as when it was not sealed. Pulse variations were less when the skull was not sealed.

These changes are quite understandable, since when there is an increase in blood flow to the brain during systole, the intracranial pressure increases much more in the case when the brain is unable to expand.

Thus, by using strain gauge recording of variations of intracranial pressure, we have confirmed the results obtained by other methods (electroplethysmograph, piezomanometer), which showed that there are variations in intracranial pressure associated with pulse and respiration, and that both in cerebral and other vessels these variations are due to irregular variations in the circulation.

By using the apparatus described to record changes in intra-arterial and intracranial pressures and their variation in response to pulse and respiration, and by comparing the results, we have been able to determine the variation in cerebral vascular tone under different conditions.

SUMMARY

The level and pulse variations of the arterial and intracranial pressure in animals were studied for evaluation of the changes of the tone of brain vessels which take place under the effect of various pharmacological substances.

Parallel registration of the variations of intracranial and arterial pressure was done by the tensiometric method. A detailed description of the apparatus and the scientific basis for the use of this method are presented in this paper.

It was established that pulse variations of the intracranial pressure which occur as a result of pulsation of the brain vessels appear only in such conditions in which the cranium is hermetic.

The curves of intracranial and arterial pressure of a cat are presented as an example. These curves were obtained under the effect of substances which greatly reduce the tone of the brain vessels (carbon dioxide) or those which increase it (oxygen).

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* In Russian.

** Original Russian pagination. See C. B. Translation.