ARTERIALIZATION OF THE VENOUS SYSTEM OF THE BRAIN

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Hemorrhagic strokes are a frequent complication in patients with atherosclerosis and essential hypertension, and in 38-61% of cases they terminate in death [2, 3, 5, 7, 8]. However, in atherosclerosis it is the arteries which are affected and the veins remain intact [1]. If the nutrition of the brain tissues could be maintained by supplying them with arterial blood via the venous vessels, this would enable blood pressure in the affected arteries to be reduced (in these cases venous blood from the brain would flow through them) to zero, and in that way the hemorrhage could be prevented, or terminated once it had begun. Such a suggestion is not groundless, for the cerebral veins have no valves, and the wall of these veins can withstand a high blood pressure. It is also known that the exchange of water, gases, salts, and other substances can be effected in the arterial as well as the venous end of capillaries [4, 6].

The aim of this investigation was to study the possibility that nerve tissue can survive under conditions of a reversible circulation, when arterial blood flows to the brain along its veins, and drains from the brain along the arteries. No mention of any such investigations having been performed previously could be found in the literature.

EXPERIMENTAL METHOD

Under hexobarbital anesthesia (100 mg/kg body weight; premedication with 2.5 mg/kg of morphine hydrochloride) the central end of one or both common carotid arteries in 71 mongrel dogs was connected by means of polyethylene cannulas to the peripheral end of one or both external jugular veins, and the peripheral ends of the common carotid arteries were connected with the central ends of the external jugular veins. Arterial blood was directed into the venous bed of the brain either along both external jugular veins or (in most experiments) along only one of the jugular veins. In these cases forceps were applied to the artery and vein on the opposite side. In all experiments the vertebral arteries and their accompanying veins were ligated. Viability of the brain tissue was judged by recording cortical electrical activity and brain-stem (corneal and pupillary) reflexes. The ECG and pneumogram, the systemic arterial pressure (in the femoral artery), the arterial blood pressure in the veins of the head (in the peripheral end of the divided jugular vein, and also in the superior longitudinal sinus of the dura mater), the venous blood pressure in the arteries of the head (the peripheral end of the divided vertebral artery), the cerebrospinal fluid (CSF) pressure, and the rheoencephalogram also were recorded. The volume of venous blood flowing from the brain along the common carotid arteries was measured. Vessels of the optic fundus were investigated by ophthalmoscopy, and control tests were carried out in which ink was injected into the arterial blood flow, directed into the venous bed of the brain.

EXPERIMENTAL RESULTS

On injection of ink into the peripheral end of the divided jugular vein (into the arterial blood flow) it filled the whole of the intracranial venous network and drained from the peripheral end of the divided common carotid artery. The entry of arterial blood into the brain via the two jugular veins (six dogs) led to the appearance of transient dyspnea and respiratory arrest after 2-5 min. When arterial blood entered the brain only via one jugular

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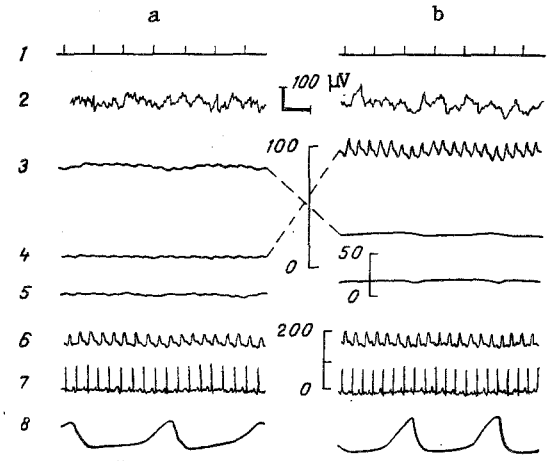

Fig. 1. Dynamics of principal parameters of state of cardiovascular system and cerebral cortex during arterialization of cerebral venous system (a male dog weighing 18 kg). 1) Time marker (1 sec), 2) EEG, 3) blood pressure in peripheral end of divided vertebral artery, 4) CSF pressure, 5) blood pressure in peripheral end of divided jugular vein, 6) systemic arterial pressure, 7) ECG, 8) pneumogram. a) During natural blood supply to the brain via one common carotid artery, b) with arterialization of the venous bed of the brain for 10 min.

vein, respiration and the circulation continued uninterrupted throughout the acute experiment (from 1 to 5 h) in 10 of 16 dogs. In these experiments, however, the possibility of a collateral blood supply to the brain through the vascular system of the soft tissues of the neck could not be ruled out. Accordingly, in the next series of experiments the blood flow in vessels of the soft tissues of the neck (except the trachea, esophagus, and neurovascular bundles) was interrupted by application of a special tourniquet. In 10 experiments the entry of arterial blood into the brain through one jugular vein led to the creation of an arterial blood pressure in the venous system of the brain of between 70 and 120 mm Hg. The venous blood pressure in arteries of the circle of Willis under these circumstances was 5-35 mm Hg. This pressure gradient maintained a reversed blood flow in the capillaries of the brain (in the direction from the venous toward the arterial end of the capillaries). The volume blood flow reached 12-16 ml/min. The dynamics of the principal parameters recorded during the period of arterialization of the venous bed of the brain is shown in Fig. 1. The CSF pressure level under these circumstances did not exceed 20-35 mm Hg. An increase in amplitude of the pulse waves was observed on the rheoencephalogram during the first 1-1.5 min, but later this disappeared, evidently due to the absence of pulse oscillations of the wall of the veins, distended with arterial blood.

The EEG when the blood flow was reversed was maintained in different animals for 7-22 min, with gradual extinction: high-frequency activity became periodic and then disappeared, the amplitude and frequency of the slow waves gradually diminished, and the isoelectric line was established. Activity of the pupillary and corneal reflexes also was reduced. Disappearance of these reflexes took place simultaneously with disappearance of brain electrical activity (EEG waves). After resumption of the natural blood supply to the brain the original EEG pattern and activity of the ocular reflexes were restored within 2-6 min. Thus creation of a reversible blood flow in the cerebral capillaries by arterialization of the venous system of the brain, with restriction of the collateral blood supply to the brain in acute experiments, maintained the vital activity of the brain tissue for several tens of minutes, as well as the ability of the functions of the CNS to be restored after resumption of the normal blood supply.

The possibility of preservation of brain function during reversal of the circulation under chronic experimental conditions is of great interest. In three dogs a reversed cerebral circulation was created under sterile conditions, in which arterial blood was supplied to the brain via one jugular vein, and venous blood drained from the blood along both common

carotid arteries. After closure of the operation wound in layers, features of a reversed circulation were detected in two dogs 8-10 h after recovery from anesthesia; stretching and distension of the veins of the mucous membranes and skin tissues of the head with blood, pulsating exophthalmos, congestion of the blood vessels of the optic fundus on ophthalmoscopy. Against this background the behavioral responses of the animals remained adequate. On the first day after the operation the dogs were able to move about unaided and to obtain food and drink. After 3-4 days the external manifestations of the reversed circulation in the vascular system of the head had disappeared. Despite the anticoagulant therapy, the cannulas along which the reversed blood flow was maintained were blocked by thrombi. By this time the normal arterial blood supply of the brain was restored through the opened collateral bed.

In another series of chronic experiments the possibility of the animal's survival after temporary arterialization of the cerebral venous system was studied. For this purpose a reversible cerebral circulation was created in seven dogs under sterile conditions. Its duration in three dogs was 10 min, in two dogs 30 min, and in another two dogs 60 min. The cannulas of the anastomoses were then removed and the natural blood flow was restored along the intact vessels of the opposite side of the neck (and also via the vertebral arteries). After suture of the operation wounds, the animals remained under observation for several weeks. On the day after the operation the state of the animals was quite satisfactory. No disturbances of CNS functions were noted. On all subsequent days the behavior of the animals after the operation was indistinguishable from that in the control.

The data given above are evidence that normal CNS functions can be maintained by a reversed circulation. It can accordingly be supposed that temporary creation of a reversed blood flow in the cerebral vessels may be used in the future in the presence of threatened or incipient intracerebral arterial hemorrhage as a palliative emergency surgical operation, capable of lowering the blood pressure in the affected brain arteries to very low values. This procedure will arrest or halt an incipient hemorrhage and facilitate the course of repair processes in the injured vessels.

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