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THE HEMODYNAMIC COMPONENT OF COMPENSATION IN THE BRAIN AFTER UNILATERAL BLOCKING OF THE SOMATOSENSORY CORTEX

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In experiments on anesthetized and waking cats the dynamics of the cerebral blood flow was investigated by a thermoelectric method in one hemisphere during experimental injury to the somatosensory area of the opposite hemisphere. Temporary cold blocking of this area of the cortex gives rise to definite hemodynamic disturbances in the opposite hemisphere, namely a biphasic vascular response: an initial decrease in the blood supply followed by a long after-effect of an increase in the blood flow. Similar vascular responses also were observed after unilateral extirpation of the somatosensory cortex. Vascular responses of this type are evidence of increased activity of the cortical structures in the intact hemisphere and can be regarded as a compensatory response to local injury of particular areas of the cortex.

KEY WORDS: thermoelectric method; dynamics of the cerebral blood flow; somatosensory cortex.

Reactive brain changes to pathological effects arising as a result of head injuries, brain tumors, or neurosurgical operations are constantly being observed in clinical practice. Experimental and clinical observations over a period of many years have yielded convincing evidence that after injury to cortical structures the disturbed integrative activity of the brain gradually recovers [1, 4, 5, 8, 9]. To analyze the dynamics of these compensatory reactions it is useful to study interhemispheric relations in patients with lesions affecting only one hemisphere. For instance, in patients with tumors of this localization definite changes in brain function were discovered in both the affected and the intact hemispheres [2, 6, 7]. Inactivation of the cells of the affected hemisphere was shown to be accompanied by desynchronization and activation of the EEG in the symmetrical region of the opposite hemisphere. This enhancement of functional activity is regarded as a manifestation of replacement and compensatory processes. Considering the close correlation between the functions of the brain and its blood supply, it can tentatively be suggested that an essential factor in the recovery process must be hemodynamic shifts arising in response to a disturbance of brain function.

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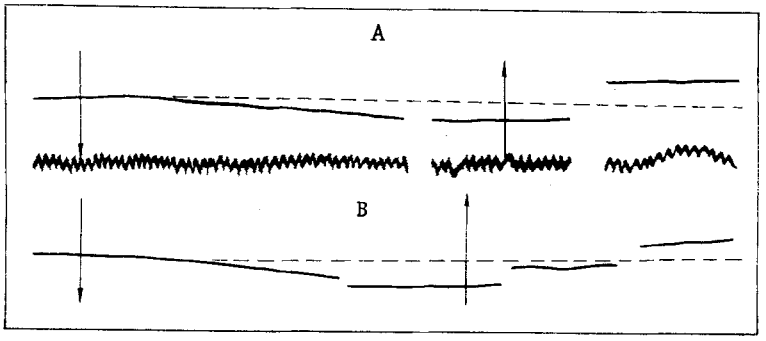

Fig. 1. Effect of cold blocking of somatosensory area of one hemisphere on blood supply in somatosensory (A) and visual (B) areas of opposite hemisphere. Anesthetized cat (arrows indicate beginning and end of cold application).

However, the role of the vascular component in the formation of compensatory brain reactions has so far received little study.

The object of this investigation was to study the dynamics of the local blood flow in one cerebral hemisphere after experimental blocking (by cold or extirpation) of certain cortical zones in the other hemisphere.

EXPERIMENTAL METHOD

In experiments on anesthetized (26) and waking (3) cats the local cerebral blood flow in the somatosensory-parietal and visual areas of the cortex of one hemisphere was determined by a thermoelectric method after temporary cooling or injury to the opposite somatosensory area.

There were two series of experiments. In series I the cerebral blood flow in the above-mentioned cortical structures of one hemisphere after temporary cooling of the opposite somatosensory area was studied in cats anesthetized with urethane. Local cooling was produced by application of ice to the somatosensory area. After cooling ended, the area concerned was irrigated with warm Ringer's solution. The systemic blood pressure in the femoral artery was recorded simultaneously with the cerebral blood flow.

In series II experiments were carried out on waking animals. Under sterile conditions a special insert for the contact thermoelectrode and for cold blocking of the cerebral cortex was implanted in the skull [3]. The insert for cooling was implanted epidurally and equipped with a screw-in cover. At the end of the postoperative period, a capsule consisting of a cylinder with silicone rubber membrane, which was in contact with the dura, was fitted into the above-mentioned insert. The opposite part of the capsule was connected to inlet and outlet pipes for the cooling liquid, the temperature of which was maintained at 15-20°C. The temperature of the outflowing fluid also was measured by means of a temperature sensor. The results were subjected to statistical analysis by the use of the criterion of signs. Of the 26 observations, 19 were significant with a level of probability of 95-97.5%.

EXPERIMENTAL RESULTS

The experiments on anesthetized animals showed that temporary cooling (15-20 min) of the somatosensory cortex of one hemisphere caused definite hemodynamic shifts in the symmetrically opposite area (Fig. 1A). These changes were expressed as a decrease in the blood supply: The blood flow fell not only during the procedure, but also for the next 10-15 min. Next followed the second phase, that of recovery of the blood supply or its enhancement, lasting 1-1.5 h. The experiments showed that cooling the somatosensory cortex of one hemisphere causes a distinct vascular response not only in the symmetrical area, but also in other areas, notably in the visual and parietal cortex of the opposite hemisphere. The blood supply in these areas was found to decrease at first, then to recover, and later to be considerably increased. Special experiments in which the blood supply was recorded in the visual cortex revealed no significant difference during the development of the vascular reactions in this area (Fig. 1B). Similar vascular reactions also were observed after unilateral

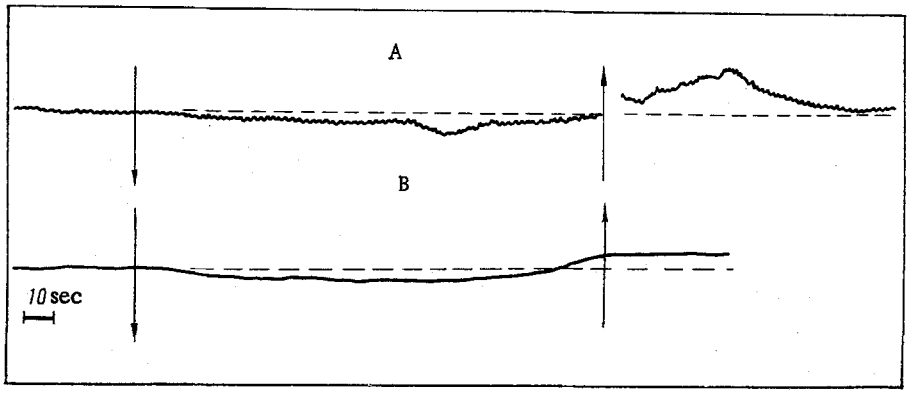

Fig. 2. Effect of cold blocking of somatosensory area of one hemisphere on blood supply in somatosensory (A) and visual (B) areas of opposite hemisphere. Waking cat.

extirpation of the somatosensory cortex. Consequently, the hemodynamic shifts in the opposite hemisphere did not depend on the nature of injury but were a nonspecific response to disturbance of the integrity of the cortical structures.

Observations on the dynamics of the local cerebral blood flow in waking cats were made before, during, and over a period of 2-2.5 h after the end of cooling. The experiment usually began with adequate stimulation (stroking the animal, motor excitation, shining a light into the eyes). Stimulation of this kind always evoked an increase in the blood flow in the somatosensory or visual cortex of the intact hemisphere. In the waking animals blocking the somatosensory area of one hemisphere (cooling for 20-40 min) caused distinct hemodynamic changes in the opposite hemisphere (Fig. 2). These changes affected both the symmetrical and the nonsymmetrical areas of the intact hemisphere. By contrast with what was observed under acute experimental conditions, in the waking animals the development of the vascular reaction differed somewhat. During cooling of the somatosensory area the initial fall in the blood flow in the opposite hemisphere was of shorter duration (8-10 min). Even during cooling, the blood supply in the intact hemisphere was observed to recover, and later to be substantially increased. The raised level of the blood flow persisted for 1.5-2 h.

The experiments on waking cats thus showed that local tempory blocking (cooling) of the somatosensory cortex of one hemisphere evokes a biphasic vascular response in the opposite hemisphere: an initial fall in blood supply followed by a prolonged after-effect, consisting of an increase in the cerebral circulation.

In agreement with existing views on the close correlation between unit activity and the cerebral blood flow, it can be postulated that the biphasic vascular response observed in these experiments reflects functional shifts in the cortical substrate. The first phase corresponds to a decrease in the level of function of the cortical cells of the intact hemisphere, the second phase — a marked increase in blood supply — indicates activation of the neuronal substrate. Vascular responses of this type are evidence of increased activity of the cortical structures in the intact hemisphere and can be regarded as a compensatory response to local injury of certain regions of the cortex.

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