Preliminary observation on the hemodynamics of the internal carotid artery following bilateral external carotid ligation in the monkey

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Ligation of the external carotid artery induced an increased flow in the internal carotid artery in the monkey (Macaca radiata). Bilateral external carotid artery ligations were then done in patients with ischemia resulting from "stroke"; studies of internal carotid artery blood flow showed a consistent increase in flow.

KEY WORDS • external carotid artery ligation • internal carotid artery blood flow

The hemodynamics of the internal carotid artery have intrigued investigators for a long time. The artery's importance in supplying blood to the brain and its convenient anatomical position have probably determined the variety of studies done.

After the advent of noncannulating electromagnetic flow meters, studies were done of the normal flow through the carotid and vertebral arteries. Changes in blood flow through the carotid arteries during increased intracranial tension, in different surgical positions, and with various anesthetic agents have also been recorded.

The hemodynamic changes in the internal carotid flow following ipsilateral common carotid occlusion was investigated in 1934 by Dorrance. He found that the flow was reduced by only 50% because of the reversal of flow that occurred in the external carotid artery, which permitted blood to continue cephalad via the internal carotid. Subsequently others have either supported this finding or produced results diametrically opposed. After occlusion of the common carotid artery in 12 patients, Hardesty, et al., found that blood flowed from the external to the internal carotid artery in 50% of cases, while the reverse was true in the other 50%. Tindall, et al., studied the direction of the blood flow in the internal and external carotid arteries following occlusion of the ipsilateral common carotid artery in 19 patients, and found a reversal of flow in the external carotid in eight of the patients, a reversal in the internal carotid in 10, and no appreciable flow in either vessel in one.

The internal carotid artery is unique in that a large outflow tract, the external carotid artery, is situated just at its origin. This disposition renders flow in the internal carotid dependent to a certain extent on flow characteristics of the external carotid arterial bed. Abraham and Margolis and coworkers have studied the differential reactivity of
neural and extraneural vasculature as it relates to the spinal cord and brain in dogs and have shown beyond dispute the subordinate status of the neural vasculature. In the dog there are rich anastomoses between the cerebral and extracerebral arterial trees, which facilitate the observation of modifying influences of pharmacological agents. In a state of normal vascular tone, an injection of contrast medium into the common carotid artery will be distributed to both external and internal carotid systems, with the former being dominant. Under vasoconstrictor stimulus, radiographic studies of flow demonstrate a constriction of the extracerebral vessels, a shutting down of anastomotic channels, and a dominance of the intracerebral angiogram. The converse picture is produced by a state of vasodilator-induced hypotonus. These same directional diversions of flow are seen in angiographic studies when injections are made respectively into either the external or the internal carotid artery. These findings are corroborated by electromagnetic flow meter studies of these two arterial trees. These findings in the dog have been further corroborated by studies on the Asian monkey, which also manifested the subordinate reactivity of the neural vascular bed and the phenomenon whereby internal carotid blood flow is determined to a certain extent by the peripheral vascular tonus of the external carotid artery bed.

Based on the observations above, we undertook to demonstrate the effect of bilateral external carotid artery ligation on internal carotid blood flow using noncannulating electromagnetic flow meters.

Material and Methods

Monkey Experiments

Eight adult monkeys (Macaca radiata) weighing from 10 to 17 lbs were used for the experiment. They were anesthetized with a single intravenous dose of 30 mg/kg of Pentobarbitone and permitted to breathe spontaneously. The blood CO2 level was checked prior to and following ligation of the external carotid arteries and found to be insignificantly altered.

The blood pressure was monitored by a catheter threaded into the aorta up to the level of the umbilicus via the left femoral artery and connected to a Statham pressure transducer.

The right common carotid artery was exposed from the root of the neck to the bifurcation, through a paramedian skin incision. A considerably smaller left lateral paramedian skin incision was made to expose the left common carotid bifurcation. Both arteries were dissected free of the sheath. A Statham electromagnetic flow probe type C of suitable size, usually 2 mm in diameter, was placed around the right common carotid artery and connected to a Model 4000-A Statham flow meter. The flow meter and pressure transducer were connected to a Model P7 Grass polygraph. A check on the temperature of the animal was maintained by a needle thermistor probe.

The right external carotid artery was ligated and the flow in the right common carotid artery taken as internal carotid flow. The left external carotid artery was then ligated and the change in blood flow noted in the right internal carotid artery.

The monkeys were operated on under sterile conditions and reassessed 10 and 14 days after the initial operation respectively. All readings were taken as valid only after verification of stop flow baseline.

Human Experiments

Two patients with evidence of cerebral ischemia due to thrombosis or embolism were operated on under general anesthesia. An experimental technique similar to that with the monkeys was followed. A Statham type Q probe, 6 mm in diameter, was placed around the common carotid artery. The ipsilateral external carotid artery was ligated and the flow recorded taken as that of the internal carotid artery. The contralateral external carotid artery was then ligated and the change in blood flow noted.

Results

In all the monkeys tested and in both the human subjects, an increase in blood flow was found in the internal carotid artery. The increase in flow was detected within a few seconds after ligation of the contralateral external carotid artery and maintained for a period of 30 to 40 minutes in the humans and 1 to 2 hours in the monkeys, after which the experiment was terminated.

J. Neurosurg. / Volume 35 / August, 1971 193
Monkey Experiments

The average percentage increase of blood flow in the internal carotid artery in the monkeys was approximately 70% of the preligation values (Figs. 1-3). Two monkeys were reassessed 10 and 14 days later, and in both the percentage of increase was noted to be higher than that recorded immediately after ligation. The percentage increase was in the range of 70% to 85% (Fig. 4).

Human Subjects

Case 1. In this 45-year-old patient with a left-handed hemiplegia of 9 months' duration, a right carotid angiogram had shown

![Fig. 1. Blood flow in the internal carotid artery before (left) and after (right) bilateral external carotid ligation. Acute preparation. Percentage increase = 52%.]

![Fig. 2. Blood flow in the internal carotid artery before (left) and after (right) bilateral external carotid ligation. Acute preparation. Percentage increase = 25%.]

![Fig. 3. Blood flow in the internal carotid artery before (left) and after (right) bilateral external carotid ligation. Acute preparation. Percentage increase = 120%.]
Hemodynamics of internal carotid artery after ligation

**FIG. 4.** Blood flow in the internal carotid artery before (left) and 2 weeks after (right) bilateral external carotid ligation. Chronic preparation. Percentage increase = 85%.

Evidence of ischemia in the middle cerebral territory with occlusion of the middle cerebral artery. After bilateral external carotid ligation, a 22% increase in blood flow over the preligation flow was noted in the right carotid artery.

**Case 2.** In this 27-year-old man with right-sided hemiplegia and aphasia of 2 years' duration, a left carotid angiogram had shown gross ischemia of the middle cerebral territory with occlusion of the main trunk of the middle cerebral artery. A bilateral external carotid ligation was done after which an increase in blood flow of 16.6% over the preligation value was noted in the left internal carotid artery at 5 min post-ligation, 33% at 15 min, and 50% at 25 and 35 min.

**Discussion**

Bilateral external carotid ligations in both man and monkey result in an increase in flow through the internal carotid arteries. The increase in flow probably persists for a prolonged period, although the longest period studied was 2 weeks. It is logical to assume that increasing blood flow through the internal carotid arteries would probably improve vascularization of ischemic areas in the brain by bringing into play latent leptomeningeal and direct artery-to-artery anastomoses. However, this assumption has yet to be proved, and the clinical benefits accruing from it must still be established. Eight human subjects have to date undergone bilateral external carotid artery ligations. Definite improvement in motor function, speech, and spasticity was noted. However, since no definite objective criteria are available, no conclusions are being drawn from this group. The finding of increased flow in the internal carotid artery following bilateral ligation of the external carotid arteries and its effect on ischemic lesions of short duration would perhaps be a fruitful avenue for further research.

**References**


neural vasculature. II. Contribution to the dynamics of cerebrovascular disease. (unpublished data)


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