Effect of Hypotension on Internal and External Carotid Blood Flow

Demonstration of a Homeostatic Mechanism Peculiar to Cerebral Vessels and Its Importance in Cerebrovascular Occlusion*

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The blood flow in the internal carotid artery and that in the external carotid artery differs in the response to changes in systemic blood pressure, CO₂ inhalation or the administration of papaverine and other drugs. In a previous study, it was apparent that the flow in the internal carotid artery remained stable during moderate changes in blood pressure, but that the flow in the external carotid artery was much more dependent on blood pressure; indeed, slight changes in blood pressure considerably influenced external carotid flow. Differences of this sort might influence the response of these vessels during hypovolemic hypotension, particularly when they function as a cerebral collateral circulation following the occlusion of the opposite carotid artery.

The present study was designed to measure cerebral (internal carotid) and extracerebral (external carotid) blood flow before and after carotid occlusion during induced hypovolemic hypotension. This being determined, the part played by the sympathetic innervation in the differences of response of the two systems was examined.

Materials and Methods

Macacus monkeys weighing from 3 to 6 kg. were used. Animals were subdivided into two groups, acute and chronic. Each animal was anesthetized with intravenous pentobarbital sodium, 30–35 mg./kg., which was then supplemented as required.

A tracheostomy was performed on animals in the acute group, and endotracheal intubation for those in the chronic group. Endotracheal CO₂ concentration (TrCO₂) was monitored by means of a Beckman infrared gas analyzer. Respiration was spontaneous in all animals and endotracheal CO₂ concentration was maintained between 2 and 4 per cent during all procedures.

The systemic blood pressure was recorded with a Statham strain gauge and catheter threaded into the abdominal aorta via the femoral artery. The femoral vein was cannulated with a polyethylene catheter for administration of fluids and fractional withdrawal of blood.

A midcervical incision was made and the carotid arteries were exposed on both sides. In several animals the vertebral and the subclavian arteries were also exposed. In cases in which the subclavian artery was exposed, the cervical incision was extended caudally to the level of the third intercostal space, and the sternum was divided. In the groups in which cervical sympathectomy was carried out, the cervical sympathetic chains and stellate ganglia were excised, the adventitia of the carotid artery was stripped, and the soft tissues of the neck were profusely infiltrated with a 2 per cent solution of Xylocaine.⁰

Measurements of the blood flow were made with electromagnetic flow-meters. Two Metroflo flow-meters were used for measurement of the carotid artery flow. When the flow in the vertebral artery was measured, a Medicon flow-meter was used. Details concerning simultaneous use of multiple flow-meters, their calibration in vitro and determination of zero reference in vivo have been described in previous papers.⁴ ⁸

Because of technical difficulties in placing the flow-meter probe on either the internal carotid or the external carotid artery, the blood flow in the internal and external carotid artery could not be assessed directly. Thus, when measuring the flow in the common carotid artery, the remaining flow after occlusion of the external carotid artery was arbitrarily called internal carotid flow, and

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† Series 6000, Avionics Research Corporation, Los Angeles, California.
§ Microflow flow-meter, Model FM 6, Medicon Division of Statham Instruments, Inc., Los Angeles, California.

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the remaining flow after occlusion of the internal carotid artery was called external carotid flow.

Anatomically, a portion of the flow in the cervical internal carotid artery supplies several extracerebral structures. To measure this extracerebral flow, the homolateral internal carotid artery was occluded intracranially at a point proximal to the posterior communicating artery, and the flow in the cervical internal carotid artery was measured as described above.

The systemic blood pressure was reduced slowly over a 30 to 60 minute interval by fractional withdrawal of 60–120 cc. of venous blood. Changes in mean pressures in the artery were calculated by adding \( \frac{1}{3} \) of the pulse pressure to the diastolic pressures. The effect of reducing systemic blood pressure on internal and external carotid flow was assessed and the effect of hypotension on the cerebral collateral circulation after experimental cerebrovascular occlusion was measured. These determinations were then repeated after cervical sympathectomy.

Results

Changes in Common Carotid, and Internal, External and Extracerebral Internal Carotid Flow Induced by Hypovolemic Hypotension. Nine studies were made. When the systemic blood pressure was gradually reduced, the flows in the common, internal, external and extracerebral internal carotid arteries all decreased but the pattern of decrease was different for the separate vessels. When the mean arterial blood pressure (MABP) was reduced below 30–40 mm. Hg, flow measurements were no longer possible because the arteries collapsed and no longer made contact with the flow-meter probes.

The patterns of decrease in flow between the internal, external and common carotid arteries were different and quite consistent. A typical example is illustrated in Fig. 1. The flow in the common carotid artery showed a more or less linear descent when the blood pressure was slowly reduced. In the monkey shown in Fig. 1, common carotid flow was 31.5 cc./min. in the steady state when the MABP was 98 mm. Hg. This decreased to 7.5 cc./min.; when the MABP was reduced to 30 mm. Hg, changes between these two blood pressures were linear.

The pattern of changes in flow in the internal carotid artery was quite different. In Fig. 1, internal carotid flow was 21.0 cc./min. in the steady state with an MABP of 100 mm. Hg. The flow remained at 20.0 cc./min. when the blood pressure was reduced to 70 mm. Hg. However further reduction of blood pressure below 70 mm. produced a steep gradient of decrease in flow, so that at an MABP of 30 mm. Hg, internal carotid flow amounted only to 9.5 cc./min. (45.2 per cent of the resting value). In general, when the blood pressure was reduced slowly, internal carotid flow decreased little or not at all until a critical blood pressure was reached; thereafter, the flow fell rapidly. Thus, critical blood pressures in 9 studies were distributed within the range of 60 to 70 mm. Hg of the mean arterial pressure.

On the contrary, there was no critical level for flow in the external carotid artery where the gradient of decrease changed abruptly. Thus, in Fig. 1, although the external carotid flow decreased continuously, the pressure-flow curve showed a steeper gradient of fall at higher levels of blood pressures than at the lower levels. This is just the opposite of the pressure-flow curve for the internal carotid artery. The extracerebral internal carotid flow showed a pressure-flow curve similar to that of external carotid flow.

Effect of Induced Hypovolemic Hypotension on Carotid Collateral Circulation after Contra-lateral Carotid Occlusion. When the internal