Ophthalmic Arterial Pressure and Flow During Extracorporeal Perfusion of Carotid of Dogs and Monkeys

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As a result of recent emphasis upon the evaluation of cerebral blood flow from both a medical and a surgical therapeutic standpoint, several techniques have gained prominence: ophthamodynamometry, retinal fluorescein-appearance times, angioradiography, isotope-flow patterns, and direct carotid intravascular pressure and electromagnetic flowmeter readings. A comparison of the ophthalmic arterial pressure of each eye is a rapid and safe external means of predicting stenosis of the common or internal carotid artery before and after endarterectomy. In a somewhat reverse situation, ophthalmic arterial pressure has been used as a guide for day-by-day graded occlusions of the carotid artery for intracranial aneurysms. Direct measurements of intravascular pressure proximal and distal to carotid occlusions in the neck have been used acutely at the time of endarterectomy or application of an occluding clamp. The techniques of ophthalmic arterial pressure and intravascular pressure are based upon the development of a differential of pressure across a stenosis.

Carotid and vertebral angiography with contrast media has been used to demonstrate morphological changes of a macroscopic nature in the spatial position and patency of cerebral vessels.

The most important single parameter to be evaluated in studies of the cerebral circulation is flow itself. For this reason, the electromagnetic flowmeter is now used commonly for acute measurements of direct flow in the carotid artery in the neck, and chronic probe preparations are under investigation. Although this method yields accurate information regarding carotid flow in the neck and the direction of flow at its bifurcation with proximal occlusion of the common carotid artery, the peripheral intracranial disposition of this flow is quite another matter because of the shunting possibilities at the circle of Willis and the possible regional variations in flow. Difference in the time of appearance of fluorescein in the retina of each eye following intravenous injection of fluorescein is a function of rate of flow in the common and the internal carotid artery which supply the ophthalmic circulation; carotid stenoses prolong the time of appearance of fluorescein in the ipsilateral eye. The patterns of flow of intravascular radioisotopes can be monitored externally over each cerebral hemisphere and represent an indirect means of evaluating regional cerebral blood flow.

Our intent has been to study these various techniques simultaneously in experimental animals under conditions of controlled carotid flow and pressure. This paper reports preliminary observations on the suitability of dogs and monkeys for such experiments and the relation between carotid pressure, ophthalmic arterial pressure, and time of appearance of fluorescein in each animal.

Method

Technique of Perfusion. Three dogs and 2 monkeys underwent extracorporeal perfusion of the carotid during measurement of ophthalmic arterial pressure and fluorescein-appearance time. Each animal was anesthetized with pentobarbital, intubated, and placed on a respirator (100 per cent oxygen). The carotid arteries and jugular veins were isolated in the neck, and the femoral artery was isolated on one side for recording arterial blood pressure. The extracorporeal circuit consisted of a dual-channel pump, a bubble oxygenator, a heat exchanger, a bubble trap, and a venous reservoir bottle. Donor blood was used.

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as the perfusate, which was oxygenated with 100 per cent oxygen and heated to 38°C. Catheters threaded distally in the carotid artery(ies) and jugular vein(s) were connected to the inflow and outflow ends of the circuit, respectively. The animals' arterial blood pressure and the pressure of carotid perfusion were recorded on strain gauges.

**Techniques of Ophthalmic Arterial Pressure and Fluorescein-Appearance Time.** In each animal, sutures were placed in the eyelids for purposes of retraction and canthotomies were performed. The pupils were dilated widely with 10 per cent Neosynephrine and drops of 5 per cent homatropine. Visualization of the fundi with the animal in the supine position was facilitated greatly by use of the binocular indirect ophthalmoscope. Ophthalmic arterial pressure was measured with a Baillart ophthalmodynamometer. For recording fluorescein-appearance time, 0.5 cc. of 10 per cent sodium fluorescein was found to be an adequate volume, whether injected intravenously or in the carotid-inflow catheter. A cobalt blue filter was placed over the lighting system of the ophthalmoscope for recording fluorescein-appearance time.

**Procedures and Results**

It was noted in these experiments that the ophthalmic arterial pressure in the anesthetized dogs, prior to any operative procedure, frequently was significantly different in each eye. The 2 monkeys had equal ophthalmic arterial pressure prior to perfusion. It was also of interest that the actual control readings for ophthalmic arterial pressure were generally lower in dogs than in monkeys, although the systemic arterial blood pressures were similar.

Two dogs were perfused via one carotid artery and jugular vein; the third dog was perfused first unilaterally, then bilaterally. Each perfusion was begun with the perfusion pressure of the carotid equal to the animal's systemic arterial blood pressure; the perfusion pressure was adjusted by increasing or decreasing the speed of the extracorporeal pump. Increasing the perfusion pressure did not change significantly the ophthalmic arterial pressure or the fluorescein-appearance time, regardless of whether one or both carotids were being perfused. Unilateral or bilateral carotid occlusion in the dog produced no appreciable change in the ophthalmic arterial pressure or intravenous fluorescein-appearance time; a high residual intravascular pressure was always present in the carotid artery distal to the occlusion. Systemic hypotension secondary to bleeding caused a fall in ophthalmic arterial pressure. One cc. of 1:100 adrenaline given intravenously during bilateral carotid perfusion caused a rise in systemic arterial blood pressure, perfusion pressure, and ophthalmic arterial pressure, with no appreciable change in the intravenous fluorescein-appearance time. The appearance of the fundus was unchanged when the carotid arteries were clamped. However, high perfusion pressures of the carotid caused marked retinal arteriolar narrowing.

As regards the 2 monkeys, carotid occlusion caused a decrease in the ipsilateral ophthalmic arterial pressure; increasing the perfusion pressure (and flow) of the carotid resulted in an increased ipsilateral ophthalmic arterial pressure and a decreased ipsilateral fluorescein-appearance time.

**Discussion**

The applicability of various techniques for studying the cerebral circulation in experimental animals is subject to the anatomical and physiological peculiarities of each species. Several interesting observations were made in 1896 by Hill. 3

"I conclude, then, that the immediate effect of ligature of cerebral arteries in different species of animals is as follows:

"Horses and goats die from the effect of the ligature of the carotids only.

"Immediate death occurs in the great number of rabbits from ligature of the four cerebral arteries.

"In the case of cats, one-third die and two-thirds survive.

"Dogs all survive, and monkeys survive during the few hours they have been kept under observation."

Electromagnetic flowmeter readings on the carotid artery in the neck of the anesthetized dog and on the femoral artery at the groin reveal that, although the vessels are of comparable size, the flow was an average of 180 cc./min. through the carotid while it was an average of 80 cc./min. through the femoral
artery. However, of the total average flow of the common carotid, the flow was 150 cc./min. into the external carotid, leaving a flow of only 30 cc./min. into the internal carotid. Most of the carotid flow in the dog travels the route of the larger and more numerous external carotid vessels to the facial structures (Fig. 1). There are extracranial anastomoses between the internal and external carotid arteries and between the spinal artery and the basilar artery, which is the largest intracranial vessel (Fig. 2). Because of these shunting possibilities, alterations in cerebral blood flow probably would be dependent
upon strictly local, end-artery conditions or upon situations affecting the total-body circulatory dynamics. Thus, neither increasing the flow and pressure through the two carotid trunks nor completely occluding flow through these vessels caused changes in the ophthalmic arterial pressure or intravenous fluorescein-appearance time in dogs, whereas generalized hypotension did affect the ophthalmic arterial pressure.

Funduscopic observations in dogs during carotid perfusion proved interesting. A high perfusion pressure caused the funduscopic appearance of an arterial occlusion, perhaps resulting from vasoconstriction. The appearance of the fundus was normal with carotid occlusion.

In the case of monkeys, there are fewer extracranial arterial anastomoses, the internal carotid supplies an appreciable flow to the brain, and the ophthalmic artery is a branch off the intracranial internal carotid (Fig. 3), analogous to the situation in humans. The ophthalmic arterial pressure and carotid fluorescein-appearance time in monkeys were directly dependent upon perfusion pressure (and flow) of the carotid.

Summary

Marked differences of species in cerebral hemodynamics exist between the dog and the monkey. Neither increasing flow and pressure through the carotid arteries, nor completely occluding these vessels, caused changes in the ophthalmic arterial pressure or fluorescein-appearance time in the dog. In the monkey, however, there was a direct relationship between carotid pressure and ophthalmic arterial pressure. These studies would suggest that future experiments comparing the ophthalmic arterial pressure, fluorescein-appearance time, intravascular pressures, contrast angiography, carotid blood flow, and isotopic patterns of cerebral flow would be done best in monkeys, in which the anatomical and physiological relationships compare more closely with the human.

A comparison of these techniques for studying the cerebral circulation will be undertaken in monkeys subjected to graded carotid occlusion, experimental intracranial hemorrhage, carotid embolization, and obstructive hydrocephalus. Also, it should be possible to apply all of these techniques directly to some clinical situations.

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References


