Factors Influencing the Autoregulation of the Cerebral Blood Flow During Hypotension and Hypertension

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It is well known that during ranges of hypotension and hypertension an autoregulation of human cerebral blood flow occurs, which keeps the cerebral perfusion relatively constant. This autoregulation accompanies such diverse conditions as hypertension due to toxemia of pregnancy, essential hypertension, the administration of norepinephrine, and moderate hypotension due to spinal anesthesia or arfonad administration. In the intact cerebrovascular system, autoregulation fails only with marked hypotension.

Despite the autoregulation phenomenon, clinical observations have shown that it is very important to maintain an elevated systemic blood pressure in patients with certain carotid and cerebral arterial diseases. Farhat has reported cases in which the neurological deficit developing after aneurysmal surgery, angiography, and craniotomy for tumor was improved by elevating the systemic blood pressures above normal. It is reasonable to assume that these patients had an altered and probably a compromised cerebral circulation. Their improvement with induced hypertension suggests that cerebral blood flow was increased. If this were true, it would appear that the autoregulation of cerebral blood flow, which has been proven so often in the normal situation, is not effective when the arterial tree is compromised. Our experiments have been directed toward a study of this autoregulation phenomenon under conditions of a normal and an impaired arterial tree.

Materials and Methods

We chose goats as the experimental animals because their cerebrovascular system is favorable for the study of gross blood flow to the brain with electromagnetic flow probes. The vertebral arteries are quite small and ineffective. The carotid arteries supply most of the blood to the brain, and clamping them above the mandibular and occipital arteries causes almost immediate death. Thus a nearly total blood supply to the brain is contained within the easily-accessible carotid arteries, and makes them a satisfactory channel for the study of changes in over-all cerebral blood flow.

Repeated observations were made on 18 goats weighing 16 to 44 kg. After the animals had been heparinized and anesthetized with sodium secobarbital, a tracheostomy was performed and breathing was controlled with a Bird respirator. The left femoral artery was cannulated for constant blood-pressure recordings using a Statham strain gauge. The right femoral artery and vein were also cannulated so that blood could be removed or reinfused as needed during the hypotensive study. Cisternal pressure measurements were made through an 18-gauge spinal needle connected to a Statham strain gauge. The carotid arteries were exposed from the bifurcation of the brachiocephalic artery to the base of the skull. The carotid sinuses were denervated and all branches of the carotid arteries were ligated and divided. Statham Medicon flow probes were placed on each carotid artery and connected to a dual-channel Medicon flow meter. All the measurements were recorded with a Honeywell eight-channel Visicorder. During the first portion of the experiment the animals were normotensive. One carotid artery was occluded and the blood flow in the opposite carotid artery was recorded. This was repeated with the occluded and monitored vessels reversed. In the second part of the study, each animal was made hypertensive with norepinephrine, and hypotensive by allowing it to bleed from the femoral artery. Blood flow measurements were recorded with both carotid arteries open and with alternate occlusion of each carotid artery during the blood pressure alterations.

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Two patients who were having carotid-artery blood-flow studies were also observed in a limited manner during hypotension and hypertension.

Results

Animal Studies. When one carotid artery was occluded, there was the expected prompt increase in blood flow through the contralateral carotid artery (Fig. 1). There was little change in the systemic blood pressure. The average flow rate in each carotid artery with both carotids open was 92 ml per minute. The average increase in blood flow in the ipsilateral carotid artery following contralateral carotid occlusion was 48.4%. Single carotid occlusion resulted in a 26% reduction in the total blood flow to the head as compared to that with both carotids open. The cisternal CSF pressure remained within normal limits throughout the studies.

When hypertension was induced by infusion of norepinephrine, with both carotid arteries open (Fig. 2), the carotid artery flow rate remained relatively constant or fell slightly, despite the marked increases in the systemic blood pressure.

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![Fig. 1](image1.png)

Fig. 1. A recording of the effect of unilateral occlusion of each carotid artery. A prompt increase in contralateral flow occurs as the flow in the occluded carotid falls to its respective baseline. (BP—femoral artery blood pressure; LCF—left carotid blood flow; RCF—right carotid blood flow.)

![Fig. 2](image2.png)

Fig. 2. A recording of the effect on right (RCF) and left carotid artery flow (LCF) with blood pressure (BP) elevation. In this instance there is a slight decrease in carotid flow as the blood pressure is elevated.