CIRCULATORY CHANGES FOLLOWING OCCLUSION OF THE MIDDLE CEREBRAL ARTERY AND THEIR RELATION TO FUNCTION*

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The sudden onset and rapid recovery from a neurological deficit is relatively common in the course of cerebrovascular disease in man. Thereafter recurrent attacks of a similar nature may occur with a varying degree of recovery.1,2,4,7,26 Careful review of the history together with observation at the bedside show that a number of factors may precipitate these transient ischemic attacks. Commonly such attacks are preceded by impaired cardiac output or a fall in blood pressure.24 More rarely anoxia appears to have provoked an attack. A well-defined understanding of these hemodynamic crises is important in planning rational treatment but the sequence of events in the cerebral circulation during these attacks is not yet fully understood.25

Pathological studies have clarified the anatomical background but have not resolved the physiological basis for these transient ischemic attacks.7,15 In general, a patchy softening is present in the distribution of the diseased vessel which usually is found to be the internal carotid or basilar artery and, less commonly, a vessel comparable in size to the middle cerebral artery. Occasionally cerebral infarction is found without demonstrable occlusion of a cerebral vessel. The functional deficit present in life is frequently far greater than can be accounted for by the anatomical extent of the lesion and only hypothesis can be offered to explain recovery from preceding attacks. Anatomical studies have shown the rich supply of small arterial anastomoses which supply additional adjustments in the cerebral collateral circulation other than the circle of Willis.30 Presumably these vessels play a major role in supplying the circulatory demands of the compromised territory.

In order to define the nature of the neurological deficit following vascular occlusion a series of acute experiments have been made while recording

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localized changes in blood flow and oxygen tension from several areas of the brain during occlusion of cerebral vessels.\textsuperscript{6,16,19–21} Following occlusion of a cerebral vessel there is reduction of the cerebral oxygen tension within the territory of its supply, the severity of which depends on the effectiveness of the collateral circulation provided by arterial anastomoses. These arterial anastomoses may be observed in the pia with a microscope.\textsuperscript{11,20} For example, when the middle cerebral artery is occluded in the monkey the collateral circulation is provided largely from arterial anastomoses in the pia derived from the anterior and posterior cerebral arteries. These vessels measure 50–250 \textmu{}m in size. The most important stimulus for increase in the collateral circulation appears to be a localized reduction in intraluminal pressure so that blood flows from high- to low-pressure areas; local reduction in pH and oxygen tension are less potent stimuli.\textsuperscript{20}

Cortical ischemia can proceed to the point of failure of the electroencephalogram and the production of a potential of injury caused by depolarization of nerve cells without damage to vessels, but prolongation of ischemia beyond that point causes anoxic damage to the vascular endothelium, resulting in stasis beginning in the venules. Soon after its production this stasis is reversible by such measures as increasing the blood pressure and the administration of heparin. Infarction appears to result primarily from damage to vascular endothelium with resulting edema, hemoconcentration, sludging and stasis.\textsuperscript{6}

Experiments in monkey and later in man\textsuperscript{22,23} demonstrate the high consumption of oxygen and small reservoir of oxygen in healthy cerebral tissue. Polarograms in monkeys\textsuperscript{6,20} and in man\textsuperscript{20} show that oxygen tension and oxygen metabolism are reduced in freshly infarcted cortex but in bordering zones the oxygen tension is the same or higher than in undamaged regions of the brain. In man, under local anesthesia measurements of cortical oxygen tension were correlated with the functional state of the cerebrum as judged by clinical tests and electroencephalogram as the carotid artery was occluded in the neck. Reduction of the cortical oxygen tension to low levels results in temporary impairment of cortical function and slow activity in the electroencephalogram. If the collateral circulation is adequate, compensation begins within 45 seconds of occlusion and the oxygen tension rises towards the steady state prior to release of the artery and functional impairment does not occur. After occlusion of a cerebral vessel the collateral blood flow continues to increase for many days. In the monkey, a relatively controlled degree of cerebral infarction in the Sylvian region may be produced by placing a clip on the parasellar portion of the middle cerebral artery and lowering the blood pressure to 70 mm. of mercury or lower.\textsuperscript{20,27,29}

Occlusion of the middle cerebral artery for periods of less than 15 minutes produces only temporary impairment of motor function. To produce a degree of impairment as severe as that associated with permanent occlusion it is necessary to occlude the vessel for at least 50 minutes;\textsuperscript{13,14} in this study,