Injury to Brain Tissue

The adult brain weighs about 1500 g, or 2% of total body weight, but accounts for 20% of the total body oxygen consumption. Because the brain cannot store much energy, dysfunction results after only a few minutes of deprivation when either oxygen or glucose content is reduced below critical levels. In the resting state, normal total cerebral blood flow is 50 mL/min per 100 g of brain tissue.

Neuronal dysfunction occurs at cerebral blood flow levels below 50 mg/dL, and irreversible neuronal injury begins at levels below 30 mg/dL. Both the degree and duration of reductions in cerebral blood flow are related to the likelihood of permanent neuronal injury. When blood supply is completely interrupted for 30 seconds, brain metabolism is altered; after 1 minute, neuronal function may cease. After 5 minutes, anoxia initiates a chain of events that may result in cerebral infarction; however, if oxygenated blood flow is restored quickly enough, the damage may be reversible, as with a TIA.

Research into the cellular basis of cerebral ischemia has led to the concept of the "ischemic cascade." As perfusion of the brain decreases, a chain of events at the neuronal level begins with failure of the membrane sodium/potassium (Na/K) pump, the depolarization of the neuronal membrane, the release of excitatory neurotransmitters such as glutamate and glycine that hyperstimulate their receptors, and the opening of calcium channels. Calcium enters the neuron through various voltage-sensitive and receptor-mediated channels (e.g., the *N*-methyl-d-aspartate receptor). The influx of calcium is at the root of further neuronal injury, with damage to organelles and further destabilization of neuronal metabolism and normal function resulting. These events may lead to delayed neuronal death, even after restoration of blood flow, and are a target of experimental neuroprotective strategies.

Recent research has distinguished between the "core" infarct and an "ischemic penumbra," or shadow. The core represents a central region of necrosis, or tissue that dies very quickly after blood flow ceases. The penumbra represents the surrounding region of brain tissue, in which neurons are dysfunctional but potentially salvageable. Recanalization of occluded vessels with blood flow into infarcted tissue, particularly when delayed, results in "reperfusion injury." Increased use of MRI has shown that petechial hemorrhagic infarction is very common, occurring in the majority of strokes, even when not suspected clinically.

CLINICAL PRESENTATION

The signs and symptoms of strokes are varied, and depend on the type of stroke, the region of the nervous system affected by the lack of flow or hemorrhage, and the patient's handedness (Table 116-3). In general, embolic ischemic strokes are characterized by the sudden onset of a neurological deficit, generally painless. Thrombotic strokes may have a stuttering or progressive course due to fluctuating hypoperfusion and gradual occlusion. Arterial dissections, as well as hemorrhages, are more often associated with headaches than ischemic stroke. Hemorrhagic strokes and large hemispheric infarcts can lead to decrease in consciousness due to increased intracranial pressure.

TABLE 116-3 CLINICAL MANIFESTATIONS OF ISCHEMIC STROKE

OCCLUDED VESSEL	CLINICAL SIGNS
ICA	Ipsilateral blindness (variable) MCA syndrome
MCA	Contralateral hemiparesis, hemisensory loss (face or arm more than leg) Aphasia (dominant) or anosognosia (nondominant) Homonymous hemianopsia (variable)
ACA	Contralateral hemiparesis, hemisensory loss (leg more than arm) Abulia (especially if bilateral)
VA or PICA	Ipsilateral facial sensory loss, hemiataxia, nystagmus, Horner syndrome Contralateral loss of temperature or pain sensation Dysphagia
SCA	Gait ataxia, nausea, vertigo, dysarthria
BA	Quadriparesis, dysarthria, dysphagia, diplopia, somnolence, amnesia
PCA	Contralateral homonymous hemianopsia, amnesia, sensory loss

ACA, Anterior cerebral artery; BA, basilar artery; ICA, internal carotid artery; MCA, middle cerebral artery; PCA, posterior cerebral artery; PICA, posterior inferior cerebellar artery; SCA, superior cerebellar artery; VA, vertebral artery.

Most emboli occur in the territory of the MCAs. Lesions of the dominant (almost always left) hemisphere are characterized by variable combinations of right hemiparesis, right hemisensory loss, right visual loss, impaired gaze to the right side of space, and language disturbance. When the superior division of the middle cerebral artery is affected, the language impairment is predominantly motor: the patient either cannot speak or produces sparse, agrammatic speech, despite an ability to fully comprehend spoken and written material. When the inferior division is affected, the patient may produce fluent, prosodic, but nonsensical speech and be unable to follow instructions. Larger infarcts of the dominant hemisphere produce a total loss of language function, leaving the patient mute and uncomprehending.

Lesions of the non-dominant (right) hemisphere produce deficits of the left side of the body. Language is preserved but the patient may demonstrate impaired attention, particularly to the left side of space and fail to appreciate the presence of people or objects to their left, and may even fail to recognize the left side of their own body (asomatagnosia). This neglect phenomenon may extend even to an awareness of any deficit of functioning on their part, and they may be unaware there is a problem (anosagnosia). These patients may be found at home, lying on the floor paralyzed yet unaware that anything is the matter; their unawareness can delay their presentation to the hospital for treatment and similarly limit their participation in rehabilitation. Lesions in the right hemisphere may also cause dysprosody, the non-dominant equivalent of aphasia, which is characterized by a lack of the emotional and gestural components of speech, despite preservation of its semantic content; many of these patients have a flat affect or appear to be depressed.

Infarcts in the territory of the anterior cerebral arteries often cause weakness limited to the legs, due to location of the representation of the legs in the medial part of the hemispheres. They may have incontinence, lack initiative (abulia), and have gaze