reaction and loss of vertical and adduction movements of the eyes suggests that the lesion is in the upper brainstem where the nuclei subserving these functions reside. Conversely, preservation of pupillary light reactivity and of eye movements absolves the upper brainstem and indicates that widespread structural lesions or metabolic suppression of the cerebral hemispheres is responsible for coma.

Coma Due to Cerebral Mass Lesions and Herniations In addition to the fixed restriction of the skull, the cranial cavity is separated into compartments by infoldings of the dura. The two cerebral hemispheres are separated by the falx, and the anterior and posterior fossae by the tentorium. Herniation refers to displacement of brain tissue by an overlying or adjacent mass into a contiguous compartment that it normally does not occupy. Coma and many of its associated signs can be attributed to these tissue shifts, and certain clinical features are characteristic of specific configurations of herniation (Fig. 328-1). They are in essence "false localizing" signs because they derive from compression of brain structures at a distance from the mass.

In the most common form of herniation, brain tissue is displaced from the supratentorial to the infratentorial compartment through the tentorial opening; this is referred to as transtentorial herniation. Uncal transtentorial herniation refers to impaction of the anterior medial temporal gyrus (the uncus) into the tentorial opening just anterior to and adjacent to the midbrain (Fig. 328-1*A*). The uncus compresses the third nerve as the nerve traverses the subarachnoid space, causing enlargement of the ipsilateral pupil (the fibers subserving parasympathetic pupillary function are located peripherally in the nerve). The coma that follows is due to compression of the midbrain against the opposite tentorial edge by the displaced parahippocampal gyrus (Fig. 328-2). Lateral displacement of the midbrain may compress the opposite cerebral peduncle against the tentorial edge, producing a Babinski sign and hemiparesis contralateral to the hemiparesis that resulted from the mass (the Kernohan-Woltman sign). Herniation may also compress the anterior and posterior cerebral arteries as they pass over the tentorial reflections, with resultant brain infarction. The distortions may also entrap portions of the ventricular system, resulting in hydrocephalus.

Central transtentorial herniation denotes a symmetric downward movement of the thalamic structures through the tentorial opening with compression of the upper midbrain (Fig. 328-1*B*). Miotic pupils and drowsiness are the heralding signs, in contrast to a unilaterally enlarged pupil of the uncal syndrome. Both uncal and central transtentorial herniations cause progressive compression of the brainstem, with initial damage to the midbrain, then the pons, and finally the medulla. The result is an approximate sequence of neurologic signs that corresponds to each affected level. Other forms of herniation are transfalcial herniation (displacement of the cingulate gyrus under the falx and across the midline, Fig. 328-1*C*) and foraminal herniation (downward forcing of the cerebellar tonsils into the foramen magnum, Fig. 328-1*D*), which causes compression of the medulla, respiratory arrest, and death.

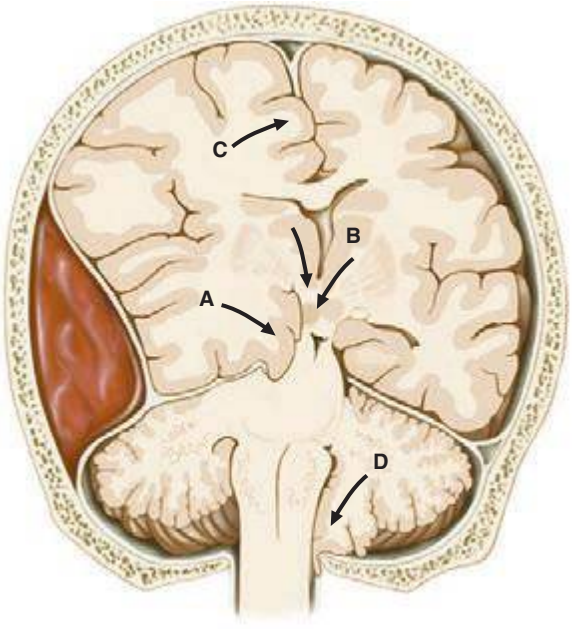
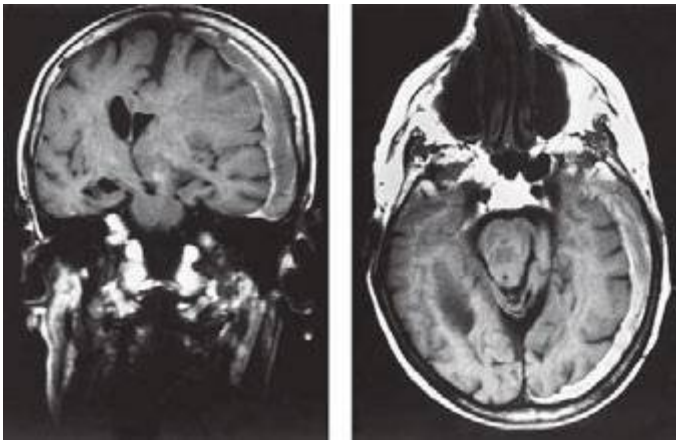


FIGURE 328-1 Types of cerebral herniation: (*A*) uncal; (*B*) central; (*C*) transfalcial; and (*D*) foraminal.



A *B*

FIGURE 328-2 Coronal (*A*) and axial (*B*) magnetic resonance images from a stuporous patient with a left third nerve palsy as a result of a large left-sided subdural hematoma (seen as a gray-white rim). The upper midbrain and lower thalamic regions are compressed and displaced horizontally away from the mass, and there is transtentorial herniation of the medial temporal lobe structures, including the uncus anteriorly. The lateral ventricle opposite to the hematoma has become enlarged as a result of compression of the third ventricle.

A direct relationship between the various configurations of transtentorial herniation and coma is not always found. Drowsiness and stupor can occur with moderate horizontal displacement of the diencephalon (thalamus), before transtentorial herniation is evident. This lateral shift may be quantified on axial images of computed tomography (CT) and magnetic resonance imaging (MRI) scans (Fig. 328-2). In cases of acutely enlarging masses, horizontal displacement of the pineal calcification of 3–5 mm is generally associated with drowsiness, 6–8 mm with stupor, and >9 mm with coma. Intrusion of the medial temporal lobe into the tentorial opening is also apparent on MRI and CT scans as obliteration of the cisterna that surrounds the upper brainstem.

Coma due to Metabolic Disorders Many systemic metabolic abnormalities cause coma by interrupting the delivery of energy substrates (e.g., oxygen, glucose) or by altering neuronal excitability (drugs and alcohol, anesthesia, and epilepsy). The metabolic abnormalities that produce coma may, in milder forms, induce an acute confusional state. Thus, in metabolic encephalopathies, clouded consciousness and coma are in a continuum.

Cerebral neurons are fully dependent on cerebral blood flow (CBF) and the delivery of oxygen and glucose. CBF is ~75 mL per 100 g/min in gray matter and 30 mL per 100 g/min in white matter (mean ~55 mL per 100 g/min); oxygen consumption is 3.5 mL per 100 g/min, and glucose utilization is 5 mg per 100 g/min. Brain stores of glucose are able to provide energy for ~2 min after blood flow is interrupted, and oxygen stores last 8–10 s after the cessation of blood flow. Simultaneous hypoxia and ischemia exhaust glucose more rapidly. The electroencephalogram (EEG) rhythm in these circumstances becomes diffusely slowed, typical of metabolic encephalopathies, and as substrate delivery worsens, eventually brain electrical activity ceases.