

Magnetic Resonance Imaging in Focal Onset Epilepsy

by Charles B. Gover, M.D.

For more than 100 years, a cause-and-effect relationship between pathologic alterations in brain structure and seizure has been recognized. The precise mechanism by which seizures are produced is unknown; the association between structural pathology and focal onset seizures originating in or near the lesion is well accepted. This article focuses predominately on the magnetic resonance (MR) appearance of the known histologic substrates of recurrent seizures in patients with symptomatic focal onset epileptic syndromes. The use of computed tomography (CT) in epilepsy is not reviewed in this article. The properties of MR imaging (superior soft tissue contrast, multi-planar imaging, and lack of beam hardening artifacts) virtually allow detection of all pathologic abnormalities with greater sensitivity and accuracy than with CT. Thus, while epileptogenic lesions are visible by CT, the advantages of MR imaging are more pronounced for pathological conditions such as focal cortical dysplasia/migrational anomalies and mesial temporal sclerosis (MTS).

The Role of MR Imaging in Epilepsy

MR imaging plays several important and distinct roles in clinical management of patients with epilepsy. The most important is to locate and identify the epileptogenic lesion of partial onset seizures. By ascertaining the location and characteristics of an epileptogenic abnormality via MR imaging, it can be determined if surgical resection is feasible. Important information can be obtained such as the volume of tissue targeted for resection, the surgical approach, and the relationship of the lesion with regard to functionally important brain areas.

It can also help re-classify seizure type if a lesion is detected in patients with generalized seizures. For example, partial onset seizures that secondarily generalize rapidly can be misinterpreted as primarily generalized. Additionally, it can provide useful prognostic information following surgery. Certain lesions identified on MR imaging carry a favorable prognosis (e.g., MTS or cavernous angioma); but post-surgical patients with no lesion on MR imaging or with neuronal migrational abnormalities carry a poor prognosis.

Epileptogenic Lesion and Seizure Production

The concept that brain lesions produce seizure is regarded to be true. The precise mechanism by which brain lesions produce seizures is not that clear. It is presumed that seizures arise from neurons that lie adjacent to a lesion that is rendered by several possible mechanisms susceptible to spontaneous coherent discharge. Mechanisms that have been implicated include dis-function of the sodium/potassium ion pump, changes in N-methyl-D-aspartic acid receptor channels, abnormal regulation of gamma amino butyric acid (GABA), and abnormal glial calcium ion transport. An exception to the general lack of understanding of the seizure mechanism is MTS. It has been postulated by animal studies that synaptic reorganization in the dentate hilus of the hippocampus which creates abnormal intrinsic synchronous excitatory circuitry is a basic feature of MTS.

Tumors in Epilepsy

The histology and MR imaging features are different in patients with acute or chronic seizure presentation.

Acute Presentation

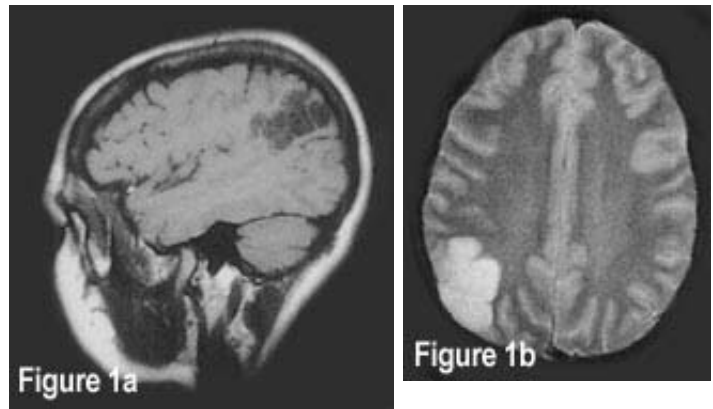
Tumors in acute seizure are primary or metastatic and are often high grade. Although all ages are represented, the older patient is generally affected. Typically a neurologic deficit is the most serious manifestation of the disease; seizures are of secondary importance. Complete resection is usually not performed when tumors are present; they are usually biopsied and treated with radiation or chemotherapy. On MR imaging tumors tend to be large, poorly demarcated from surrounding normal brain, and tend to enhance; and peritumoral edema and central necrosis are common with unusual calvarial remodeling.

Chronic Presentation

Only primary low grade tumors are found (not metastatic). Tumors are supratentorial and of glial or both glial and neuronal cell origin. An associated neurologic deficit is usually not present. Patients are usually pediatric, young

adults, or middle-aged. Surgical strategy is aimed at complete lesion removal. Typical tumor histologies are astrocytoma, oligodendroglioma, mixed oligodendroglial-astrocytic, dysembryoplastic neuroepithelial tumors, ganglioglioma, and hamartoma. On MR imaging, tumors tend to be small and well circumscribed, have little or no peritumoral edema, commonly remodel the inner table of the skull, have variable enhancement, usually cortical, typically lack central necrosis, and are supra tentorial extra ventricular (Figure 1).

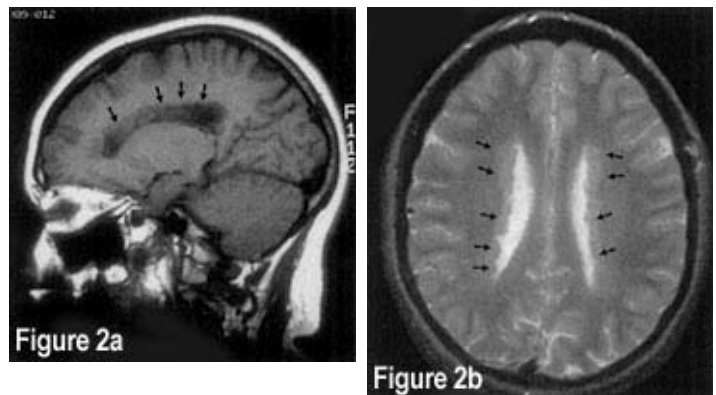
Figure 1. Low grade astrocytoma - Sagittal T1WI (s) and axial T2WI (b) demonstrate a right parietal cortical tumor hypointense on T1WI and hyperintense on T2WI. There is remodeling of the inner table of the parietal bone and no white matter edema.



Neuronal Migration Disorders

The spectrum of gray matter developmental abnormalities ranges from widespread gross deformities such as lissencephaly to small focal nodular gray matter heterotopias (Figure 2), and all are due to defects in neuronal migration and organization that occur in utero. These include gray matter migration abnormalities of the cortical mantle or cortical dysplasias (agyria, pachygyria, and polymicrogyria), abnormal location of gray matter or heterotopia (band, laminar, or nodular), schizencephaly (Figure 3), and hemimegalencephaly. It is the focal cortical dysplasias that are most often considered for surgical resection. The cerebral cortex is normally four millimeters thick; and cortical dysplasias appear as areas of thickened cortex, regardless of histologic description.

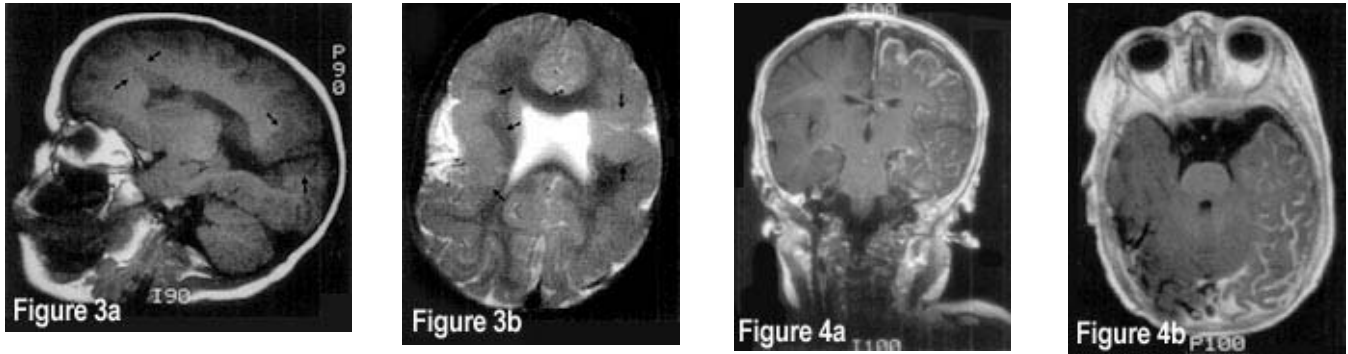
Figure 2. Nodular subependymal heterotopic gray matter nicely seen on sagittal T1WI and axial T2WI. (arrows)



Tuberous sclerosis (TS) is a phakomatosis syndrome characterized by papular facial nevus, seizure, and mental retardation (Figure 4). This triad is found only in 50% of patients. Hence the radiologic hallmarks of the disorder are very important and are now universally accepted as sufficient for diagnosis. The four major categories of intracranial lesions in TS are cortical tubers, white matter abnormalities, subependymal nodules, and giant cell astrocytoma. The defect in TS appears to be an abnormality in the radial neuron-glia unit in certain portions of the germinal matrix. Cortical tubers have been classified both as tumors and neuronal migration disorders. The appearance of cortical tubers on MR images is characteristic; it consists of a well-circumscribed area of increased T2 and decreased T1 signal intensity located immediately beneath the cortical gray mantle. Typically the involved gyrus is expanded. A ray-like projection of increased signal intensity from the base of the cortical tuber toward the ventricular surface is frequently observed.

Figure 3. Schizencephaly with cortical dysplasia - Sagittal T1WI (a) and axial T2WI (b) shows two left schizencephalic clefts in the frontal and parietal lobes lined by abnormally thick gray matter. In addition, there is bilateral abnormal cortical thickening of the frontal-parietal lobes (cortical dysplasia). (arrows)

Figure 4. Sturge Weber Syndrome - Coronal (a) and axial (b) postcontrast MR scans show atrophy of the left hemisphere. The pial leptomenigeal anoma enhances strongly.

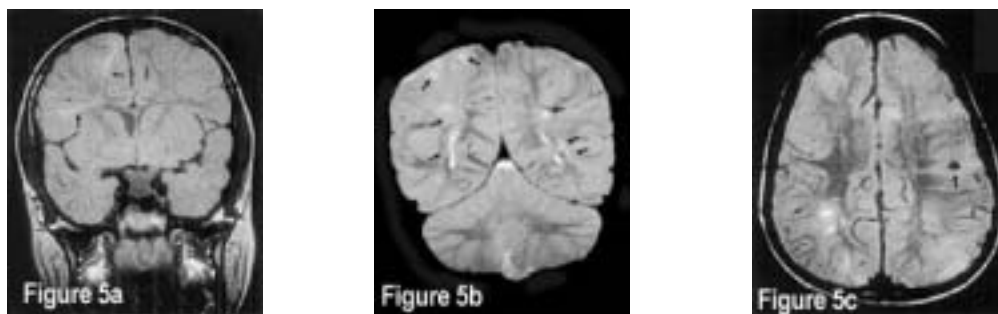


Vascular Malformation

In a manner similar to tumors, vascular malformations that are found in surgical epilepsy series are small, indolent lesions. These typically are the cryptic malformations, that is, capillary angiomas or cavernous angiomas. Arteriovenous malformations (AVM) can also present with seizures; however, they commonly present with acute hemorrhage.

Sturge-Weber disease is a phakomatosis syndrome characterized by facial, leptomenigeal, and ocular angiomatosis, mental retardation, and neurologic deficits that depend on the location of the leptomenigeal angioma (Figure 5). It is mentioned here because of the central role seizures have in the clinical manifestation of the disease. The intracranial hallmark is a pial angioma that is believed to represent persistent embryonic vasculature. Seizures are believed to occur because of the effects of this vascular malformation on the underlying brain. The MR imaging features of the syndrome include enhancement of the pial angioma and atrophy of the underlying cortex. The malformation is usually unilateral and located in the parietal-occipital region; and the ipsilateral choroid plexus enhances prominently.

Figure 5. Tuberos Sclerosis - Coronal T1WI (a) demonstrate straight radial bands of increased signal intensity in the right frontal lobe. Coronal T2WI (b) domonstrate right upper convexity, subcortical tubers and small subependymal nodules in the atria of the lateral ventricles. Axial T2WI (c) show bilateral frontal-parietal subcortical increased signal consistent with subcortical tubers. The one in the left parietal lobe with decreased signal is calcified. (arrows)



MTS

The origin of MTS remains obscure. It is felt by many to be due to complicated febrile convulsions that occur during a specific window in early childhood (about three months to five years of age). Calcium mediated excitotoxic cell injury is believed to be the primary noxious event that leads to this condition. MTS consists of cell loss and astrogliosis in the mesial temporal cortex, the hippocampal formation, amygdala, parahippocampal gyrus, and entorhinal cortex. These changes have been described in the hippocampus. Classic (Ammon's horn) sclerosis consists of marked pyramidal cell loss in CA1, CA3, and the dentate hilus with sparing of pyramidal cells in the CA2 sector. A second form known as end folium sclerosis consists primarily of cell loss and astroglial proliferation in the end folium with relative sparing of the other sectors.

Findings on MR imaging include hippocampal atrophy, increased signal intensity on T2 weighted images, loss of normal internal architecture of the involved hippocampus, and unilateral atrophy of the mammillary body, columns of fornix, amygdala, and white matter of the parahippocampal gyrus (Figure 6). Autopsy studies have demonstrated that MTS is present bilaterally in up to 80% of cases. However, it is usually asymmetric in that one side is more severely involved or the two hippocampi typically involve the site of origin of a patient's seizures.

Figure 6. Mesial Temporal Sclerosis - Oblique coronal inversion recovery (a) demonstrate bilateral hippocampal atrophy more prominent in the left side. Oblique coronal T2WI (b) show bilateral increased signal intensity of both hippocampi and left temporal lobe cortex. (arrows)

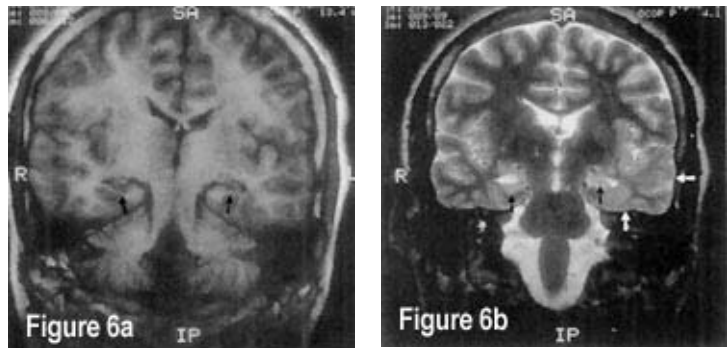
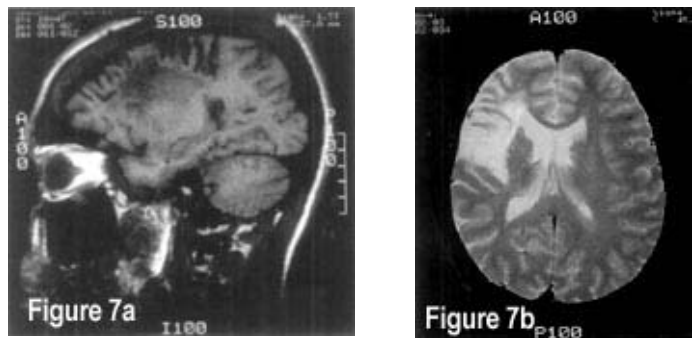


Figure 7. Chronic cerebral infarction in a patient with sickle cell with seizures since infarct - Coronal T1WI and axial T2WI demonstrate evidence of a right frontal lobe volume loss with cortical thinning with compensatory right lateral ventricular dilation.



Encephalomalacia or Gliosis

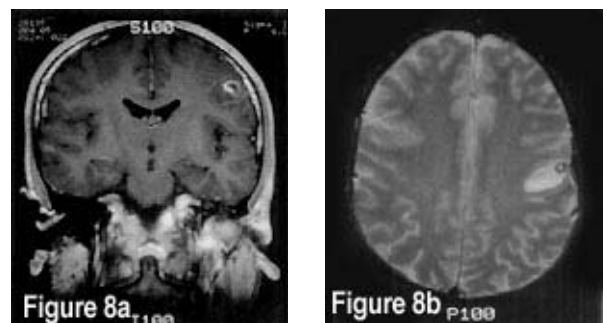
Cortical gliosis or scar can occur following any brain insult (trauma, infarction, infection, and/or inflammation). Any of those four mechanisms can produce an area of brain necrosis in which death of all cell lines has occurred. Necrosis is typically surrounded, however, by an area of sclerosis. Sclerosis regardless of the causal mechanism, has a common MR appearance (atrophy and signal change consistent with increased tissue water).

Epilepsy following head trauma is more frequent with missile injuries which penetrate the skull than with closed head injuries, particularly if they involve penetration of the dura. In cases of trauma hemosiderin deposition in atrophic cortical tissue often occurs.

Cerebral infarction is the most common etiology of new onset epilepsy in the elderly (Figure 7). At the other end of the age spectrum, perinatal or neonatal vascular insults may produce areas of cerebral infarction associated with seizures. Mechanisms of infarction in this age group are diverse: embolic, secondary to infection, trauma, hypoxia, and hemorrhage.

On a world-wide scale, infection is a much more common substrate of epilepsy than in North America and Europe. In areas where cysticercosis is endemic, a significant percentage of the population may be infected; and seizures are the most clinical manifestation of neurocysticercosis (Figure 8).

Figure 8. Neurocysticercosis (colloidal vesicular stage) - Coronal postcontrast T1WI (a) demonstrates a left lateral frontal ring-like enhancing lesion. On T2WI (b) it shows thick hypointense capsule with peripheral white matter edema.



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