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*AJNR Am J Neuroradiol* 1988, 9 (6) 1123-1128

<http://www.ajnr.org/content/9/6/1123>

This information is current as  
of August 10, 2025.

## Efficacy of MR vs CT in Epilepsy

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We studied 59 seizure patients with CT, MR, and EEG to determine the efficacy of each in the detection of an epileptogenic focus. EEG was most sensitive (67%), MR was next (53%), and CT was least sensitive (42%). MR detected an abnormality in five patients (8%) in whom CT was negative. EEG was positive in each of these patients. CT failed to demonstrate any focal lesion not detected by MR. MR and CT detected focal abnormalities in seven patients (12%) who had negative EEGs. Five of the seven patients had brain tumors. Eighteen of the 26 patients who underwent surgery had positive CT and MR; 14 of these patients had tumors. The remaining eight patients who had surgery all had temporal lobectomies for intractable seizures; none had tumors. In the complex partial seizure subgroup of 34 patients, MR was positive in 44%, CT was positive in 29%, and EEG was positive in 80%.

We consider MR to be the imaging procedure of choice for the detection of an epileptogenic focus in seizure patients. When indicated, CT may be performed as a second procedure to try to distinguish neoplasm from thrombosed vascular malformations and other lesions.

MR imaging is an important new imaging technique. As it is expensive, and because it competes with a good existing imaging method—CT—it is important to determine the efficacy of MR vs CT as it applies to the detection of epileptogenic foci in seizure patients. Further, if MR is significantly superior to CT, and CT fails to detect any disease not detected on MR, then it may be possible to use MR only in the evaluation of future seizure patients. For this reason, all patients with seizures who had MR and CT examinations between January 1985 and June 1986 were analyzed. After the sensitivities of MR and CT were determined, the sensitivity of each of these methods was compared with that of EEG.

### Materials and Methods

Seventy-two patients with seizures had neuroimaging studies between January 1985 and June 1986. Of these, 59 patients had CT, MR, and EEG studies. Many of the patients in this series were referred to our epilepsy center for chronic, medically intractable seizures. Twenty-six of these patients ultimately had surgery. We reviewed CT, MR, and EEG data to determine the efficacy of each in the detection of epileptogenic foci.

All of the CT examinations were performed on a GE 8800 or 9800 scanner. All patients had contrast enhancement. Slice thickness was 10 mm. MR imaging was performed on a 1.5-T GE system with spin-echo pulse sequences, 500/25 and 2000/40,80 (TR/TE). Section thickness was 5 mm. MR was considered "positive" when an increased signal intensity was noted on the T2-weighted images when compared with the signal from the opposite hemisphere or when a mass was detected. Although structural lesions with very intense signal (long T2 relaxation time) were thought more likely to be intrinsic neoplasms, and foci with a less intense signal were thought more likely to be mesial sclerosis or gliosis, for purposes of sensitivity and tabulation in this study, each has simply been called "positive."

EEG was performed routinely; electrophysiologic studies were supplemented by 3- to 7-day hospitalizations with continuous TV and simultaneous EEG recording so that seizures

This article appears in the November/December 1988 issue of *AJNR* and the February 1989 issue of *AJR*.

Received September 21, 1987; accepted after revision March 8, 1988.

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*AJNR* 9:1123-1128, November/December 1988  
 0195-6108/88/0906-1123

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could be detected and recorded during sleep as well as during waking hours. An EEG was considered positive when epileptiform activity was noted, whether or not slow waves were present. In addition, depth electrodes were placed in 11 (18.6%) of the 59 patients; eight of the 11 electrodes were placed in patients who had negative imaging studies. The contribution of depth electrode data in the remaining three was excluded from this study because depth electrode placement is very invasive and should not be used in comparing non-invasive studies. These data have been included in another publication [1].

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## Results

The results are summarized in part in Tables 1–3. Overall MR displayed an abnormal signal in 31 (53%) of the 59 patients. In no instance did MR fail to detect a lesion seen on CT. When patients with positive EEGs were added to those with negative EEGs and positive MR, 44 (79%) of the 59 patients had positive findings. MR was positive in five patients (16%) in whom CT was negative. Three of the patients with negative CT and positive MR scans had subtle, poorly defined hyperintense foci in the temporal lobe on T2-weighted images. Two of the three had aspiration partial lobectomies with relief of seizures. An aspiration lobectomy was used early in the series; this technique did not permit classical neuropathologic examination in these two patients, but no tumor was found. The third had bitemporal EEG foci and is being treated medically. One patient had atrophy, and one patient was thought to have vascular disease.

**TABLE 1: CT and MR Findings in Seizure Patients**

	MR+ (n = 31)		MR–, CT– (n = 28)
	CT+	CT–	
Operated:			
Neoplasms	14	0	0
Other	4	2	8
Subtotal	18	2	8 <sup>a</sup>
No operation	8	8	20 <sup>b</sup>
Total	26	10	28

<sup>a</sup> Three of these patients had mesial sclerosis.

<sup>b</sup> Drug therapy.

**TABLE 2: Seizure Patients with Negative CT and Positive MR Findings**

Case No.	Age	Gender	Clinical Findings	MR Findings	Radiologic Diagnosis	Pathology
1	17	F	CPS, 14 years	↑ intensity on T2-weighted images of medial temporal lobe (L)	Probable gliosis	No pathologic tissue identified <sup>a</sup>
2	32	F	CPS	↑ intensity focus on T2-weighted images of medial temporal lobe (L)	Focal atrophy, ?gliosis	No pathologic tissue identified <sup>a</sup>
3	19	F	CPS	↑ intensity focus (subtle) on T2-weighted images of medial temporal lobe (L)	?Gliosis	Not operated
4	60	M	CPS vs dementia	↑ intensity on T2-weighted images of temporal lobe (L)	Atrophy	Not operated
5	73	F	Seizure	Single 1-cm high-intensity focus on T2-weighted images of left frontotemporal area (subcortical)	Vascular disease	Not operated

Note.—L = left; CPS = complex partial seizure(s).

<sup>a</sup> In these two early cases, aspiration partial lobectomy was used; lobectomy or partial lobectomy has been used subsequently.

**TABLE 3: Seizure Patients with Negative EEG, Positive CT, and Positive MR Findings**

Case No.	Age	Gender	Clinical Findings	CT/MR Localization	Pathology
6	33	F	CPS, 5 years	↑ intensity focus in temporal parietal area	Oligoastrocytoma
7	17	M	Focal seizures, 6 months	High convexity in right frontoparietal area	Pleomorphic astrocytoma
8	17	F	Intractable temporal-lobe seizures	Left temporal lobe	Astrocytoma
9	59	M	Focal seizures, 6 months	↑ intensity in left frontoparietal area involving cortex	Oligodendroglioma
10	60	M	Elemental partial seizures, right leg weakness	↑ intensity on T2-weighted images in left centrum semiovale	Glioma
11	43	M	Motor vehicle accident, age 16	Left focal temporal atrophy	Focal atrophy; not operated
12	12	M	Elementary partial seizures	↑ intensity on T2-weighted images in left parietal area	Hemiplegic migraine; not operated

Note.—CPS = complex partial seizure(s).



Both MR and the CT were positive in seven patients who had negative EEG findings; five of these seven patients had tumors, one had hemiplegic migraine, and one had focal atrophy after cerebral trauma.

In the complex partial seizure subgroup of 34 patients, MR was positive in 15 (44%), CT was positive in 10 (29%), and EEG was positive in 27 (80%).

Twenty-six (44%) of the 59 patients had lobectomies or partial lobectomies. Of these 26, 14 (54%) had neoplasms.

Eighteen of the 26 patients who underwent surgery had positive CT and MR scans; 14 of these patients had tumors. The remaining eight patients who had surgery had no CT or MR abnormalities and had temporal lobectomies for intractable seizures; none had tumors. Two had subpial aspiration lobectomies in which no diagnosis could be made, three had mesial sclerosis, and in three no diseased tissue was found. Twenty-eight patients, including eight with positive MR scans, did not undergo surgery. These patients are being managed with drug therapy. In 19 of the 26 patients who underwent surgery, seizure control was a major goal. Fourteen (74%) of these 19 are now seizure-free, and four (21%) are greatly improved, with a greater than 75% reduction in the incidence of seizures. One patient was improved but had less than a 75% reduction of seizures. The mean follow-up period was 20.5 months (range, 12–30 months).

## Discussion

Several reports have addressed the use of MR in surveying seizure patients for a seizure focus that might lead to epilepsy surgery. Laster et al. [2] reported 100 patients with CPS;

Latack et al. [3] reported 50 patients with CPS, 14 of whom underwent positron emission tomography as well. Twenty-three of the patients had positive MR. We thought it would be useful to provide statistics on consecutive patients with seizures between January 1985 and June 1986 as an overall indicator of the efficacy of MR vs CT, and to compare both imaging techniques with the existing neurologic standard, EEG. Our series is exceptional because of the large number of tumors found, because of the relatively large number of patients who have had lobectomies for treatment of their seizures, and, finally, because of the high percentage of surgical cures of the epilepsy.

The results of our study are summarized in part in Tables 1–3. Of the five patients with positive MR and negative CT results, three had subtle but definite increased signal in the temporal lobe on T2-weighted images. Two of these went on to have a partial lobectomy by aspiration at craniotomy (Figs. 1 and 2); these patients were thought to have had mesial sclerosis or gliosis, but because of the nature of the surgical resection, histology was not available. Since then, en bloc removal of the mesial temporal structures during temporal lobectomy has been used at our institution. This allows excellent histologic analysis of the hippocampus and amygdala, and one hopes will provide pathologic correlation with the mesial temporal abnormalities on T2-weighted images. The third patient had similar subtle focal increased signal on T2-weighted images of the temporal lobe, but because of bilateral EEG findings this patient did not have surgery. MR appears to have the capacity to detect abnormal foci on T2-weighted images within the temporal lobe that are not visible on enhanced CT scans of the brain. Each of the two patients with

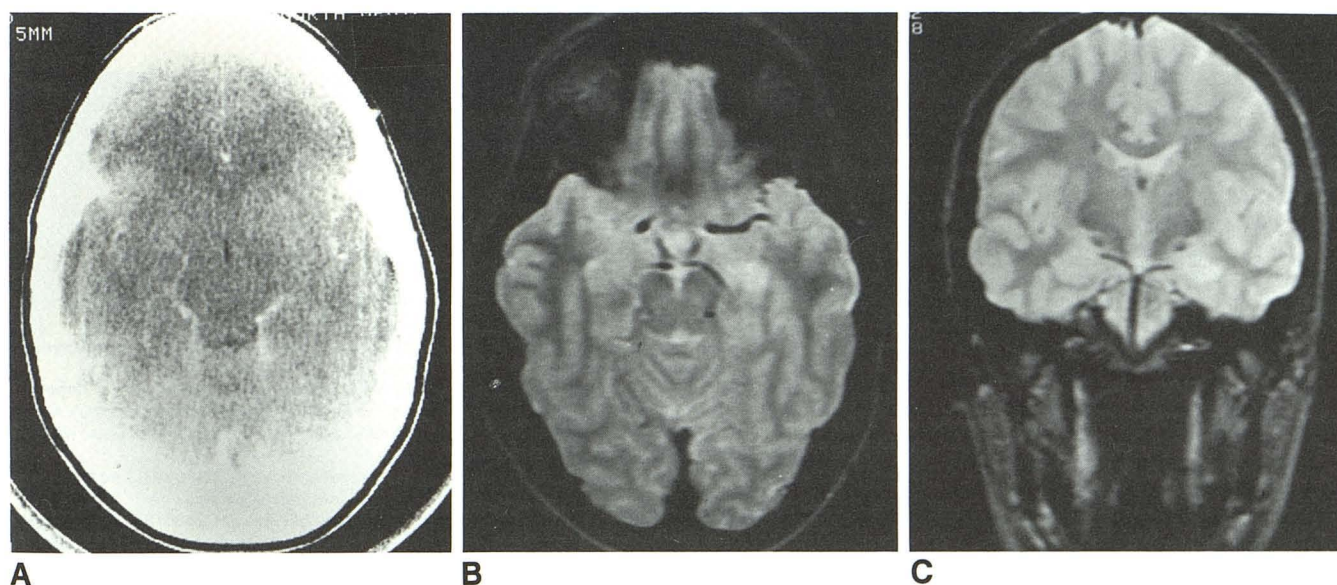


Fig. 1.—Case 1: 17-year-old woman with complex partial seizures for 14 years. Scalp EEG: left spike focus. Depth electrodes: left temporal focus. CT negative; MR positive.

A, Contrast-enhanced CT scan is normal.

B, Axial MR image, 2500/80. Hyperintense focus in medial third of left temporal lobe.

C, Coronal MR image, 2500/80. Hyperintense focus on fully T2-weighted sequence is in pes hippocampi.

Partial temporal lobectomy was performed by aspiration. (This technique subsequently was changed to partial lobectomy with en bloc removal of specimen.) No tumor was found.



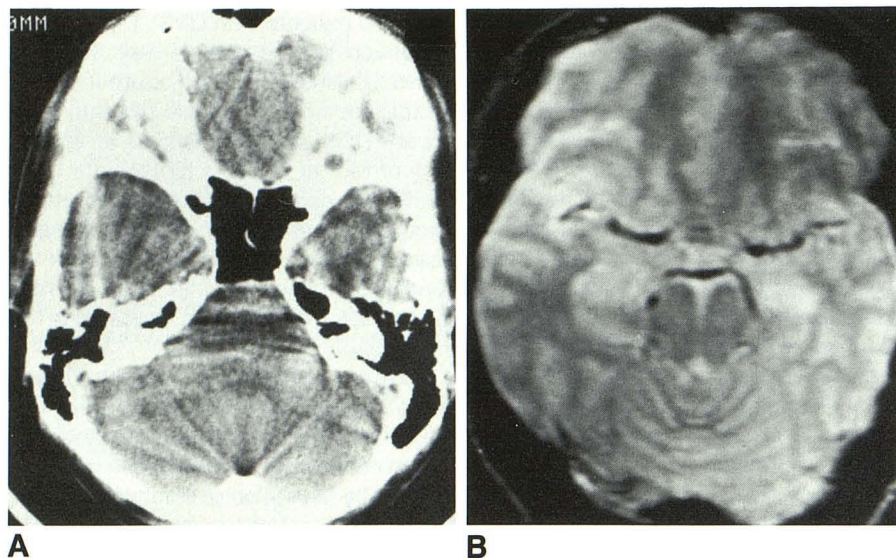


Fig. 2.—Case 2: 32-year-old woman with complex partial seizures for 31 years. Scalp EEG: focus in left temporal lobe.

A, Contrast-enhanced CT scan shows no enhancing structural lesion. However, note that left temporal fossa is slightly smaller than right.

B, Axial T2-weighted MR image, 2500/80. Hyperintense focus in medial third of left temporal lobe. Also, volume of left temporal lobe may not be as great as right.

Left temporal lobectomy was performed by aspiration. No tumor was found.

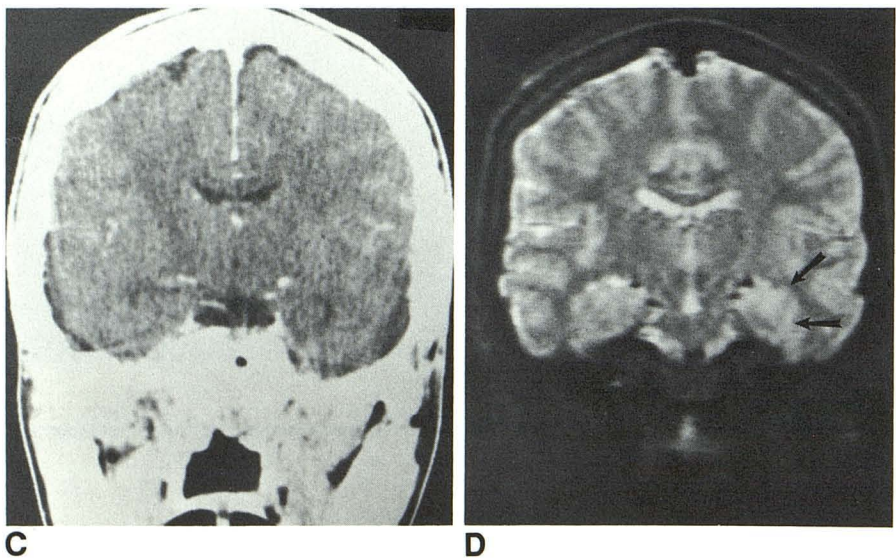
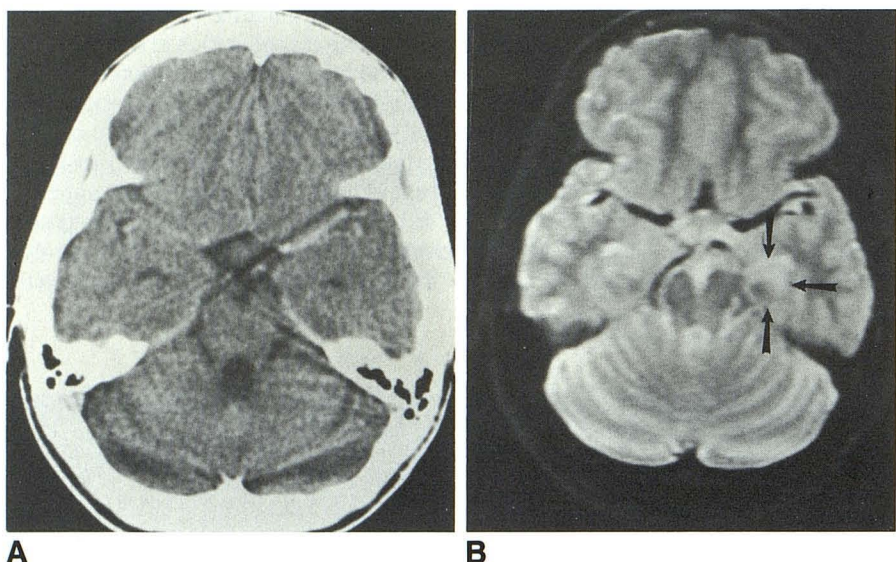


Fig. 3.—Case 3: 19-year-old woman with intractable partial complex seizures.

A, Axial contrast-enhanced CT scan shows no abnormality in left temporal lobe.

B, Axial MR image, 2500/80, shows hyperintense focus in left temporal lobe (arrows). Medications altered with control of seizures. No operation.

C, Coronal contrast-enhanced CT scan shows no definite structural lesion.

D, Coronal MR image, 2500/80. Definite hyperintense focus in medial portion of left temporal lobe (arrows).

This patient was thought to have an abnormality, but, based on Figs. 1 and 2, the lesion was thought to be mesial sclerosis or gliosis, and not a brain tumor. Because the abnormality was located in her dominant hemisphere and her seizures could be controlled with an altered drug regimen, she has been followed medically.



positive MR and negative CT results are seizure-free after partial aspiration lobectomies. Therefore, the capacity of MR to display a signal abnormality in the brain at the site of an epileptogenic focus is superior to that of CT. However, at least three of our patients had lobectomies after positive EEG and negative MR and CT scans, and were shown to have prominent mesial sclerosis on histology. It appears that although mesial sclerosis may be associated with positive MR findings, it also may be present in patients with negative MR images of the temporal lobe.

The determination of increased T2 signal from the temporal lobe is not always straightforward. Frequently a "shading" artifact is seen in which one temporal lobe has a higher-intensity T2 signal than the opposite side. Another artifact is

created by carotid artery pulsations, which are projected over the temporal lobes when the phase-encoding direction is at right angles to the sagittal plane of the head. When one patient with questionable findings was placed in the scanner and the phase-encoding direction was altered by 90° to parallel the sagittal axis of the head, the "lesion" disappeared. We now routinely image seizure patients with the phase-encoding gradient in the sagittal plane.

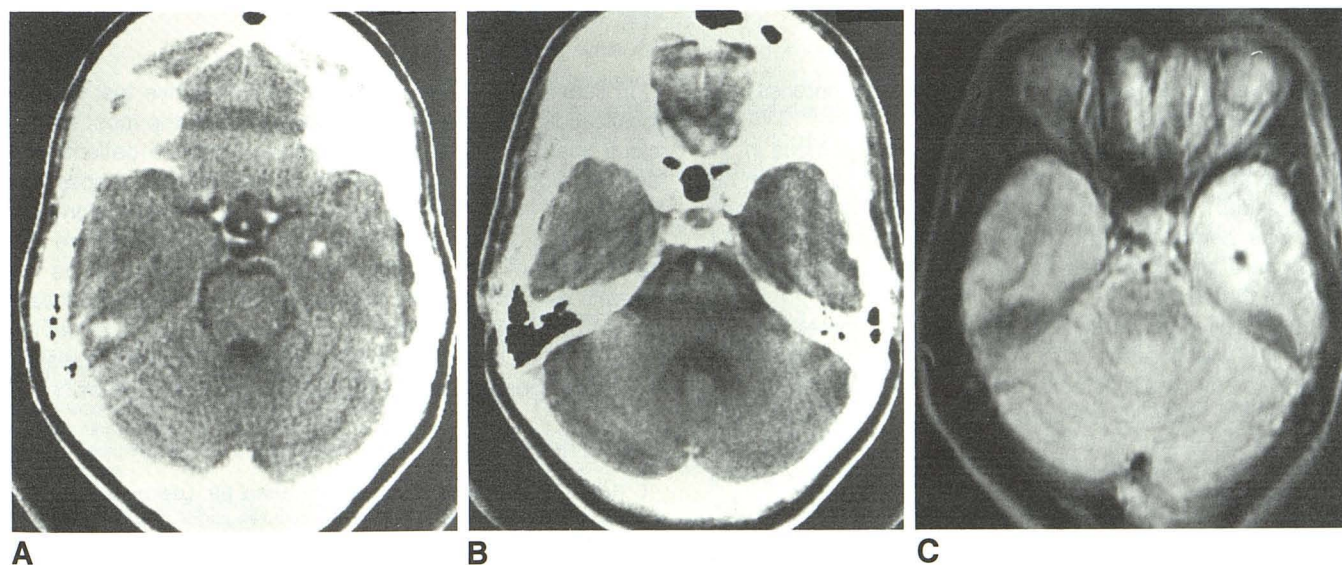
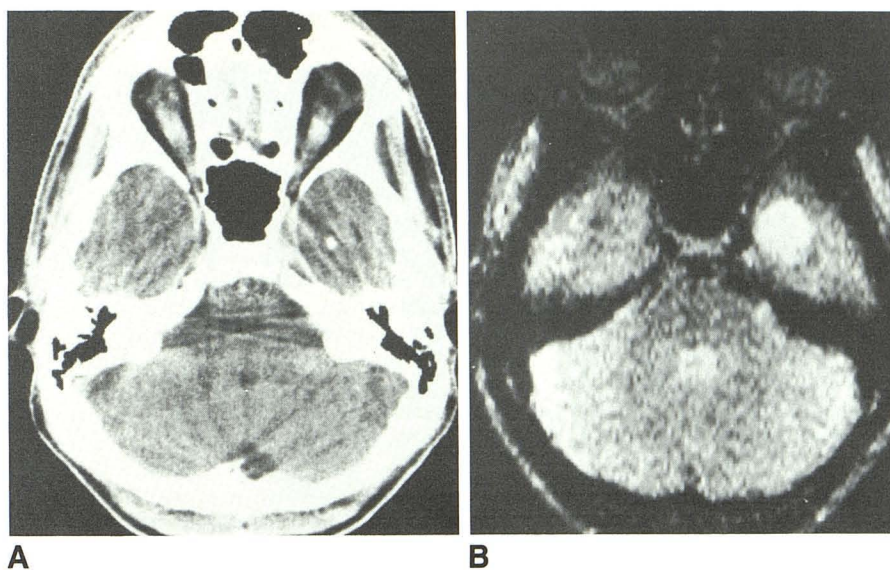
Although other series have demonstrated intrinsic neoplasms on MR that were not detected on CT, none of our tumors were in this category. However, in at least three patients said to have positive MR and CT scans, the CT changes were minimal. In two of the three only a 2- to 3-mm calcification in the temporal lobe was detected. In contrast,

**Fig. 4.**—Case 13: 18-year-old man with complex partial seizures for 10 years. Scalp EEG: left spike focus.

**A,** CT scan shows small calcification in medial third of left temporal lobe.

**B,** MR image obtained with low-field-strength magnet at another institution. High-intensity focus in medial 50% of left temporal lobe on T2-weighted image.

Left temporal lobectomy revealed astrocytoma.



**Fig. 5.**—Case 14: 28-year-old woman with complex partial seizures for 5 years.

**A,** Contrast-enhanced CT scan shows a 3- to 4-mm density in medial third of left temporal lobe. Nonenhanced scan showed this to be calcium.

**B,** Slightly inferior section shows no convincing tissue abnormality.

**C,** MR image, 2500/40, shows high-intensity focus surrounding focal area of signal void, which corresponds to calcification in A. Lobectomy confirmed an astrocytoma.



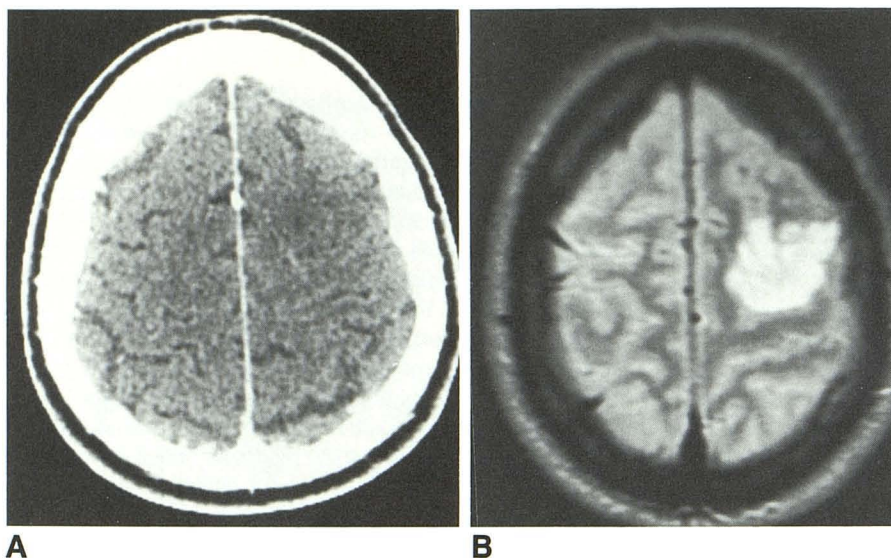


Fig. 6.—Case 9: 59-year-old man with elemental partial seizures for 3 weeks. No scalp EEG focus detected.

A, Contrast-enhanced CT scan. High-convexity sulci are less conspicuous on left. Slight hypodensity. No other mass effect.

B, T2-weighted MR image, 2500/80. Large hyperintense focus in frontoparietal area of left high convexity.

Surgery yielded oligodendroglioma.

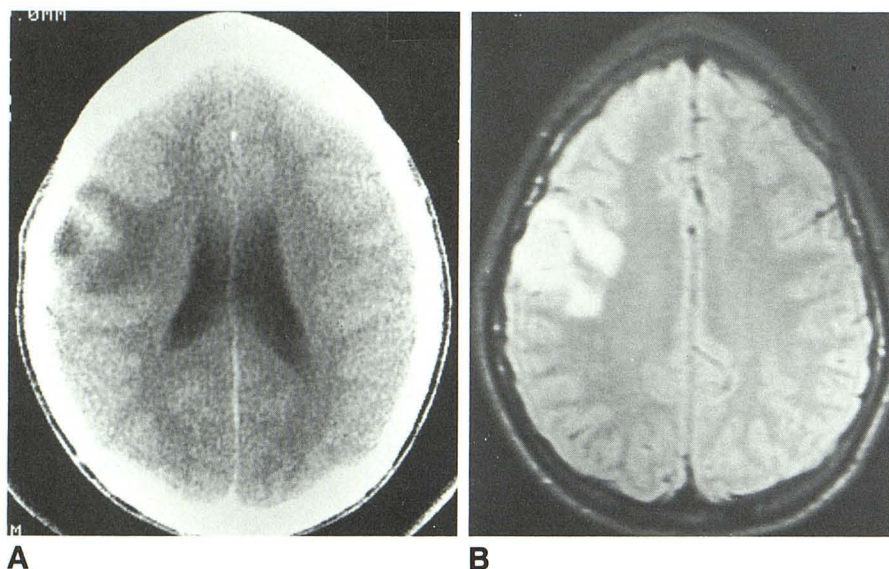


Fig. 7.—Case 7: 17-year-old man with new onset of complex partial seizures. Scalp EEG: negative.

A, Contrast-enhanced CT scan shows focal mass, probably intrinsic neoplasm.

B, T2-weighted MR image, 2500/80. Focal mass is surrounded by hyperintense cortex with adjacent vasogenic edema of high intensity.

Surgery revealed astrocytoma. This is an example of a patient with a neoplasm in whom the EEG was normal.

MR showed an obvious large area of increased intensity on T2-weighted images (Figs. 3–5).

MR was able to document a potential seizure focus in 31 (53%) of the 59 patients in our study (Figs. 6 and 7). In no instance did MR fail to detect a lesion seen on CT. When EEG was performed, and then supplemented by MR, 44 (79%) were shown to have an abnormality as the probable cause of the seizures.

The complex partial seizure subgroup comprised 34 patients. MR was positive in 15 (44%) and CT was positive in 10 (29%). Not unexpectedly, the EEG was positive in 27 (80%). These statistics are comparable to those in the series of Latack et al. [3], in which MR scans were abnormal in 42%. Forty to fifty percent of patients with complex partial seizures are considered to be appropriate candidates for lobectomy [4] because their seizures cannot be controlled medically and lobectomy may provide a cure or significant relief. MR is a major advance in the presurgical evaluation of these surgical candidates. In our series 94% of carefully selected patients were significantly improved or seizure-free after lobectomy.

In summary, EEG remains the most sensitive test for the localization of an epileptogenic focus. MR is the most efficacious imaging test in the evaluation of seizure patients for defining a potential surgical focus as a cause for the epilepsy. CT did not detect any lesion not seen by MR. Therefore, on the basis of our series and the two series that compare the sensitivities of MR and CT [2, 3], there appears to be no specific need to perform CT when MR is normal. However, as MR has a high sensitivity but poor specificity, CT may be done as a second procedure to try to distinguish neoplasm from thrombosed vascular malformations and other lesions.

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