AJNR

Magnetic resonance imaging in infections of the central nervous system.

H D Davidson and R E Steiner

AJNR Am J Neuroradiol 1985, 6 (4) 499-504
http://www.ajnr.org/content/6/4/499

Magnetic Resonance Imaging in Infections of the Central Nervous System

Harold D. Davidson[1]
Robert E. Steiner[1]

The magnetic resonance (MR) images in 24 patients with infections of the central nervous system (CNS) were reviewed, and the use of a paramagnetic contrast agent (Gd-DTPA) in two cases is reported. The clinical diagnoses in the patients, aged neonate to 71 years old, comprised meningitis, meningitis and subdural empyema, meningoencephalitis, encephalitis, and single or multiple cerebral abscesses. A new sign of CNS infection, the pial-ependymal line, is described. Other consequences of infection, such as atrophy, delayed myelination, periventricular cerebrospinal fluid extravasation, changes in T1 and T2, and mass effect, are reported and discussed. MR imaging may have a significant application in the study of CNS infections because of the importance of early diagnosis in instituting effective treatment.

The principles of magnetic resonance (MR) were first described in 1946 [1, 2], but it was not until 1971 that its potential in detection cf pathology was demonstrated [3], and not until 1973 that Lauterbur [4] produced the first image. Since that time, a variety of technologic improvements has made possible excellent demonstration of both anatomy and pathologic changes. This has been particularly true in the central nervous system (CNS) [5, 6]. The MR imaging features of benign and malignant neoplasms, cerebral infarction, intracranial hemorrhage, aneurysms, arteriovenous malformations, and demyelinating diseases have been described at considerable length in recent literature, but little has been written about the MR features of CNS infections. We report our clinical experience to date with MR imaging in 24 patients with CNS infectious disease examined since 1981.

Materials and Methods

The MR images of all patients referred for examination between March 26, 1981, and November 15, 1984, with a clinical diagnosis of CNS infection were evaluated in a retrospective study. All images were obtained with an imaging system based on a cryogenic magnet operating at 0.15 T (6.5 MHz) using a 256 × 256 display matrix. A variety of pulse sequences was used including saturation-recovery (SR), inversion-recovery (IR), and spin-echo (SE) (table 1). Gadolinium-DTPA was administered in two cases according to a previously described protocol [7].

Results

The material thus acquired consisted of 33 examinations on 24 patients (10 males and 14 females). The patients ranged in age from neonates to 71 years old. Five patients were younger than 1 year old, two were 1–10, three were 11–20, three were 21–30, two were 31–40, three were 41–50, one was 51–60, four were 61–70, and one was 71–80. Their etiologic diagnoses are summarized in table 2, their clinical diagnoses in table 3, and their MR findings in table 4.

Two examinations were poor, primarily because of patient motion, but definite

Received August 1, 1984; accepted after revision January 16, 1985.

This work was supported in part by Schering AG, Berlin (gadolinium-DTPA), and the Medical Research Council and the Department of Health and Social Security.

[1] Department of Diagnostic Radiology, Royal Postgraduate Medical School, Hammersmith Hospital, Du Cane Rd., London W12 OHS, England. Address reprint requests to R. E. Steiner.

AJNR 6:499–504, July/August 1985
0195–6108/85/0604–0499

TABLE 1: **MR Pulse Sequences Used in Imaging Patients with Infections of the Central Nervous System**

Pulse Sequence	Interval (msec)		
	TR	TI	TE
SR 1000	1000	...	...
IR 1400/400	1400	400	...
IR 1500/500/44	1500	500	44
IR 1800/600	1800	600	...
IR 1800/600/44	1800	600	44
SE 1080/80	1080	...	80
SE 1160/160	1160	...	160
SE 1580/80	1580	...	80

Note.—TR = repetition time; TI = inversion time; TE = echo time; SR = saturation recovery; IR = inversion recovery; SE = spin echo.

TABLE 2: **Etiology of Central-Nervous-System Infections in Patients Studied with MR Imaging**

Etiology	No. of Cases
Tuberculous	7
Viral:	
Herpes simplex	2
Rubella	2
Varicella	1
Subtotal	5
Bacterial:	
Diplococcus pneumoniae	2
Staphylococcus aureus	1
Escherichia coli	1
Pseudomonas aeruginosa	1
Subtotal	5
Fungal (*Candida albicans*)	1
Protozoan (*Toxoplasma gondii*)	1
Cysticercosis	1
Miscellaneous:	
Meningitis	1
Brainstem encephalitis	2
Retained surgical swab	1
Subtotal	4
Total	24

TABLE 3: **Clinical Diagnoses in Patients with Infections of the Central Nervous System Studied with MR Imaging**

Clinical Diagnosis: Etiology	No. of Cases
Meningitis:	
Escherichia coli	1
Pseudomonas aeruginosa	1
Diplococcus pneumoniae	1
Tuberculous	2
Nonspecific	1
Meningitis and subdural empyema	1
Meningoencephalitis: Tuberculous	3
Encephalitis:	
Herpes simplex	2
Rubella	2
Varicella	1
Nonspecific	2
Cerebral abscess (single or multiple):	
Staphylococcus	1
Tuberculous	2
Candida albicans	1
Toxoplasma gondii	1
Cysticercosis	1
Foreign body–retained swab	1
Total	24

TABLE 4: **MR Imaging Findings in Infections of the Central Nervous System**

MRI Parameter	No. of Cases (n = 24)			
	Tb	Viral	Bacterial	Other
Ventricular enlargement	2	1	2	2
Periventricular line of increased T2	1	1	0	0
Increased subarachnoid space	0	0	1	0
Subdural accumulation	1	0	1	0
Mass effect:				
Ventricle deformed/displaced	1	1	1	1
Sulci effaced	1	1	0	0
Midline structures displaced	0	0	1	2
Delayed myelination	0	0	1	2
Altered brain relaxation times:				
PEL of increased T1	2	2	2	0
Loss of gray-white matter contrast	5	3	2	2
Increased T1 and T2	4	4	0	2
Increased T1 with no SE scan	0	1	2	0
Normal T1 and increased T2	0	0	0	1
Increased T2 with no IR scan	1	0	0	0
Decreased T1 after Gd-DTPA	1	0	0	1
Decreased signal intensity due to calcification	2	0	1	1

Note.—Tb = tuberculous; PEL = pial-ependymal line; SE = spin echo; IR = inversion recovery.

abnormalities were still visible. The other studies were of good quality. One examination showed no abnormality. This patient had an established diagnosis of brainstem encephalitis at the time of the MR examination, although clinically she was much improved and approaching normal. Abnormalities were identified in all the other 23 patients. Allowance was made for age in determining abnormal size for ventricles and subarachnoid space. In fact the only subarachnoid space enlargement was in a child (fig. 1).

In 19 cases specific etiologic agents were identified (table 2). In two cases of brainstem encephalitis, the specific etiologic agent was not identified, but the combination of clinical, computed tomographic (CT), and MR findings as well as the favorable response to steroid therapy, left little doubt about the diagnosis. In the case listed only as meningitis and in another associated with a retained surgical swab, an offending organism was not isolated. The case of cysticercosis was diagnosed elsewhere, and confirmatory data were unavailable.

The choice of repetition time (TR) and echo time (TE) was critical in the detection of lesions of the brain. For example, the high-intensity signal of the periventricular line of increased T2 was seen easily on SE 1580/80 images contrasted against the relatively low-signal intensity of the adjacent ventricles

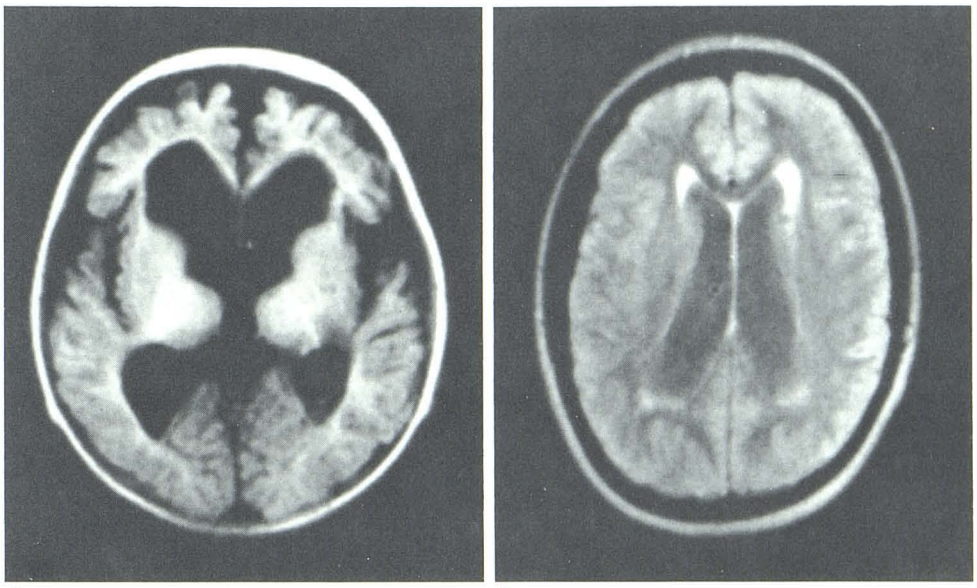


Fig. 1.—10-month-old child with previous pneumococcal meningitis. IR 1500/500/44 scan. Large subarachnoid space, communicating cisterns, and ventricles. Less white matter than usual for this age.

Fig. 2.—27-year-old woman with tuberculous meningitis. SE 1580/80 scan. Periventricular line of increased T2 (white) at margin of lateral ventricles.

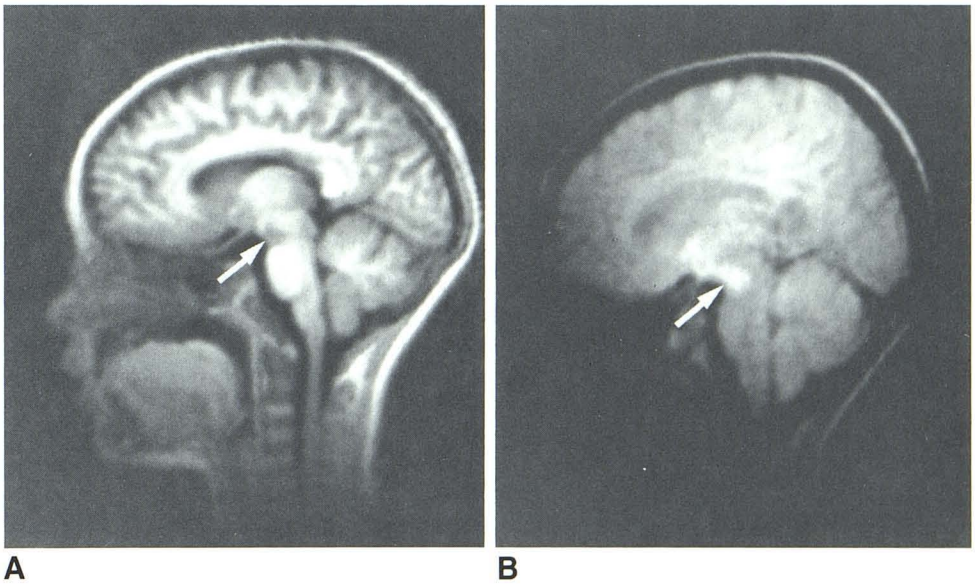


Fig. 3.—5-year-old girl with varicella brainstem encephalitis. IR 1500/500/44 (**A**) and SE 1580/80 (**B**) scans. Upper brainstem lesion seen on both scans (*arrows*).

and white or gray matter (fig. 2). However this periventricular line was obscured by the high signal intensity of cerebrospinal fluid using the SE 1160/160 sequence. Similarly, with SE techniques, lesions of increased T2 within the substance of the brain become more apparent with longer values of TE using SE sequences (fig. 3B).

The subdural empyema had a long T1 (dark on IR sequences) and was crescentic or lentiform in shape (fig. 4A). The liquid pus of intracerebral abscess also had a long T1 (fig. 5). The mass effects on the ventricles, sulci, and septum pellucidum were essentially identical to CT.

In six cases a serpentine line (occasionally more than one) of increased T1 was observed extending from the pial surface of the brain to the ependymal lining of the ventricle (figs. 4B and 6A). This was related to the frontal horn or atrium, and radiated anteriorly or anterolaterally if situated in the frontal lobe and posteriorly, posteromedially, or posterolaterally if situated in the parietal or occipital lobe. In all instances it accompanied another abnormality with which it was often in contact.

The gray-/white-matter contrast displayed on IR pulse sequences was reduced in the two cases of subdural empyema (fig. 4A).

Lesions causing alterations of T1 and T2 were found in

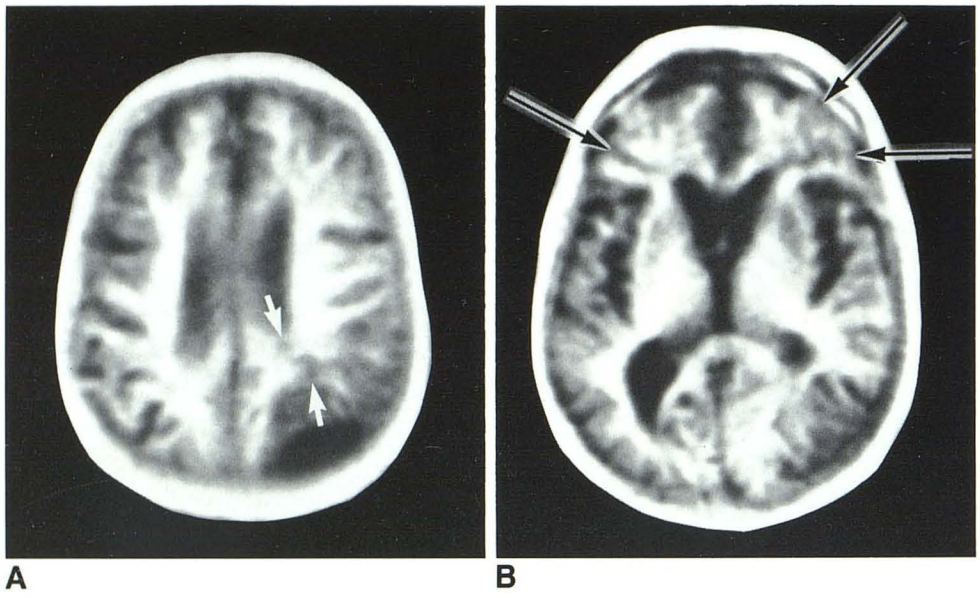


Fig. 4.—62-year-old man with pneumococcal meningitis and subdural empyema. IR 1400/400 scans. **A**, Lentiform extracerebral (subdural) empyema is displayed and pial ependymal line is seen (*arrows*). **B**, Bilateral frontal pial-ependymal lines (*arrows*) are out of contact with other visible abnormality.

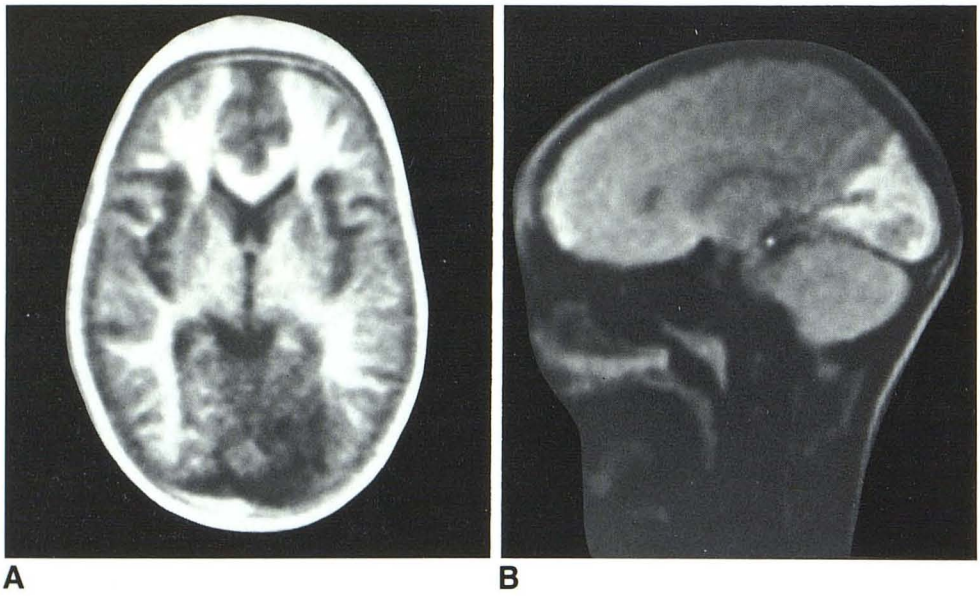


Fig. 5.—13-year-old girl with occipital *Candida albicans* abscess. **A**, IR 1400/400 scan. Both edema and pus are dark within occiptal lobe. **B**, SE 1080/80 scan. Edema is separated from pus.

nearly all areas of the brain. However, only three cases (two herpes simplex and one rubella) exhibited any specific localization. In these three cases the temporal lobes displayed extensive lesions of increased T1 and T2, including the external capsule (fig. 7).

In three cases a delay in the development of myelination relative to that in normal controls was observed, as has been described previously [8].

In the case of toxoplasmosis, scattered lesions with increased T1 and increased T2 were associated with low-signal areas due to calcification. Zones of increased T2 and decreased T1 in the subependymal germinal matrix were believed to be secondary to hemorrhage. CT and sequential MR examinations confirmed these impressions.

An aneurysm was seen in the region of the bifurcation of the internal carotid artery into anterior and middle cerebral arteries. This was characterized by low signal on IR and SE pulse sequences in a patient with a probable tuberculous lesion of the adjacent brain and meninges.

In the patient with tuberculosis who received Gd-DTPA, the long T1 of the lesion was reduced (fig. 6). In another patient with a posterior fossa space-occupying lesion, marked contrast enhancement was observed 8 months after surgery for glossopharyngeal neuralgia (fig. 8). At reexploration four pieces of cotton gauze were removed from within a multilocular abscess.

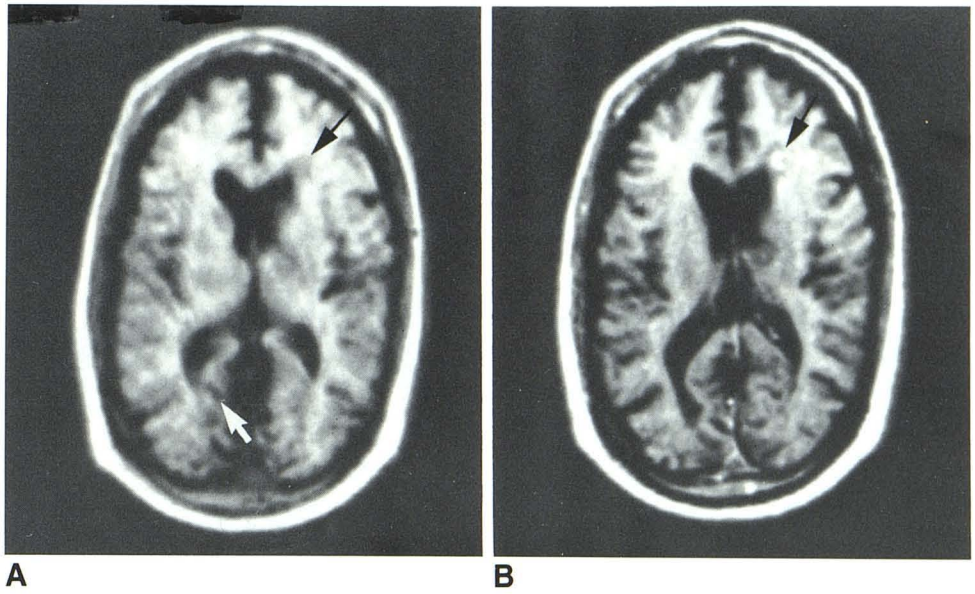


Fig. 6.—71-year-old man with tuberculous encephalitis/meningitis. IR 1500/500 scans before (**A**) and after (**B**) Gd-DTPA. **A**, Long T1 lesions adjacent to right lateral venticle (*black arrow*). Left occipital pial-ependymal line (*white arrows*). **B**, Enhancement of anterior lesion (*arrow*).

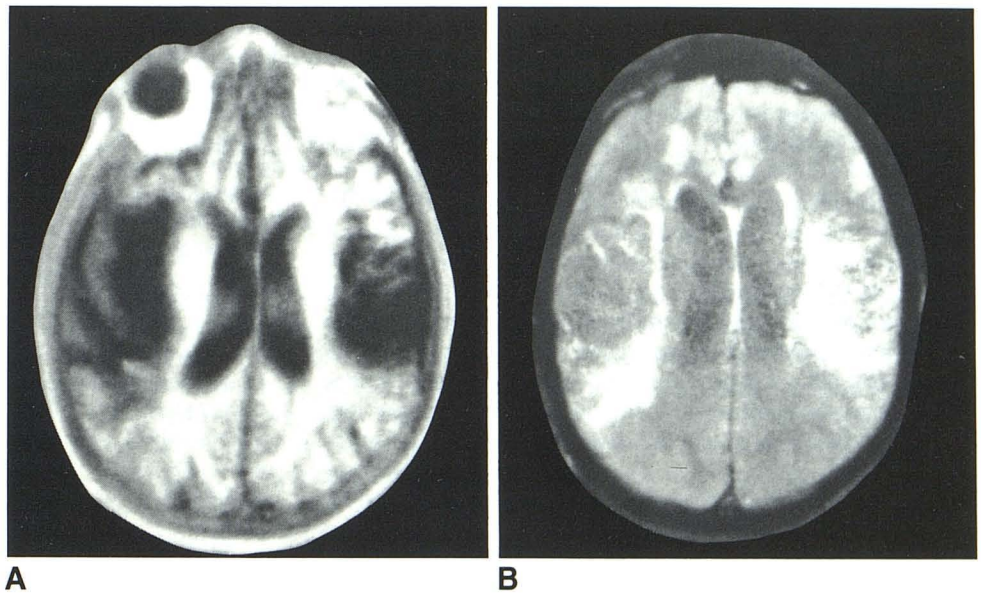


Fig. 7.—38-year-old man with herpes simplex encephalitis. IR 1500/500/44 (**A**) and SE 1580/80 (**B**) scans. Long T1 of lesions and abrupt medial margin at external capsule. Frontal lobe lesions are also seen.

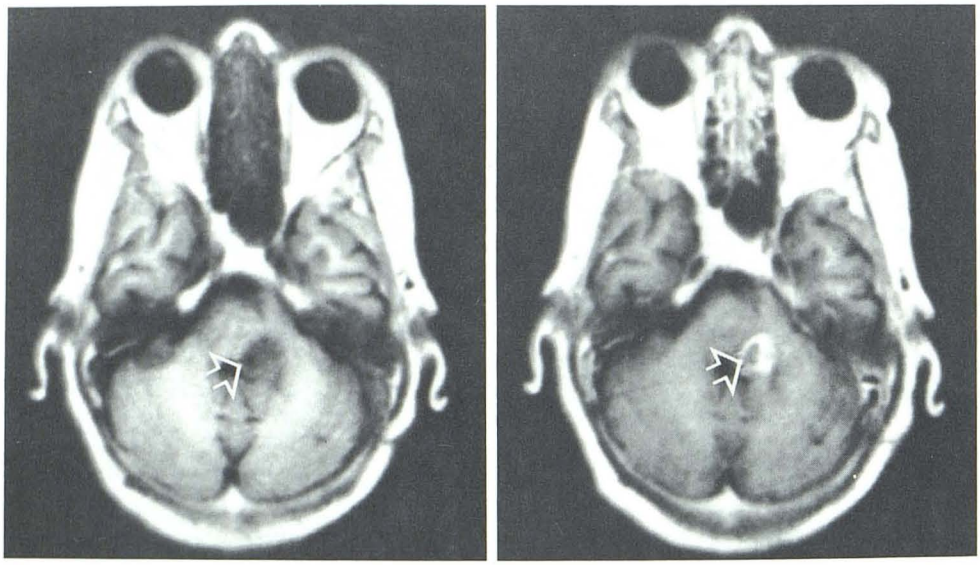
Discussion

In the initial stage of development of MR imaging, machines were slow and were often located in factories or other clinically inconvenient sites. This created considerable difficulty in examining seriously ill patients, and few patients with CNS infections were studied until recently. Despite these difficulties, MR imaging may prove to have a significant application in the study of CNS infections because of the importance of early diagnosis in instituting effective treatment.

The lesions of an active, nonhemorrhagic, infectious process of the brain are characterized by increased T1 and T2 relaxation times in most instances, although decreased T1 and increased T2 relaxation times may indicate hemorrhage. One patient with evidence of a normal T1 on IR scan had a long T2 lesion on the SE sequence, suggesting that this latter sequence may be the most sensitive technique for the detection of the primary cerebral focus.

Liquid pus has a very long T1. Because of the influence of T1 on SE pulse sequences, fluid may appear dark unless longer values of TR are used. The surrounding inflammatory brain response and edema will also have increased values of T1 and T2, but this is usually less than liquid pus.

The myelination process can be followed with MR [8], and



A B

Fig. 8.—69-year-old woman with postoperative retained cotton gauze swabs. IR 1500/500/44 scans. **A**, Before Gd-DTPA. Long T1 lesion displaces fourth ventricle (*arrow*). **B**, Ring enhancement after administration of Gd-DTPA (*arrow*).

it was possible to observe disturbance of myelination in three patients. In all instances the brain appeared to be that of a younger child. No cause and effect relation was provided with respect to etiology (*T. gondii*, *D. pneumoniae*, and unknown), location of disease (one encephalitis and two meningitis), gender (two boys and one girl), or age (1–22 months).

The pial-ependymal line of increased T1, which was observed in both subdural and intracerebral lesions, has not been seen in other pathologic conditions of the brain on MR images at our institution, and a report of its observation elsewhere has not been found. Because all of these patients (six) survived, pathologic correlation was not available. All were adults (28–71 years) of both genders with varied infections (tuberculous, viral, and bacterial causes). Whether this sign is specific for inflammatory disease or not awaits further observation.

Focal distribution of lesions may be characteristic of certain viruses, as shown in figure 7. However, not all viruses produce this characteristic distribution. When present, this pattern suggests a viral etiology, but its absence has no particular etiologic significance.

Gadolinium-DTPA is a paramagnetic material that reduces T1 (increases signal intensity). When given intravenously it concentrates in areas of blood-brain barrier damage similar to that observed with iodinated contrast media in CT. This occurred in both patients examined, and the agent may prove valuable once it is fully evaluated.

REFERENCES

1. Bloch F, Hansen WW, Packard ME. Nuclear induction. *Phys Rev* **1946**;69:127
2. Purcell EM, Torrey HC, Pound RV. Resonance absorption by nuclear magnetic moments in a solid. *Phys Rev* **1946**;69:37
3. Damadian R. Tumor detection by nuclear magnetic resonance. *Science* **1971**;171:1151–1153
4. Lauterbur P. Image formation by induced local interactions: examples employing nuclear magnetic resonance. *Nature* **1973**;242:190–191
5. Bydder GM, Steiner RE, Young IR, et al. Clinical NMR imaging of the brain: 140 cases. *AJNR* **1982**;3:459–480, *AJR* **1982**;139:216–235
6. Modic WT, Weinstein MA, Pavlicek W, et al. NMR imaging of the spine. *Radiology* **1983**;148:757–762
7. Carr DH, Brown J, Bydder GM, et al. Intravenous chelated gadolinium as a contrast agent in NMR imaging of cerebral tumors. *Lancet* **1984**:484–486
8. Johnson MA, Pennock JM, Bydder GM, et al. Clinical NMR imaging of the brain in children: normal and neurologic disease. *AJNR* **1983**;4:1013–1026, *AJR* **1983**;141:1005–1018