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# Fast Fluid-Attenuated Inversion-Recovery MR of Intracranial Infections

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**PURPOSE:** To assess the usefulness of fast fluid-attenuated inversion-recovery (FLAIR) MR sequences in the diagnosis of intracranial infectious diseases. **METHODS** We compared fast FLAIR images with conventional spin-echo images (T1- and T2-weighted) obtained in 20 patients with infectious diseases (six with encephalitis, five with brain abscesses, three with meningitis, two with meningoencephalitis, two with Creutzfeldt-Jakob disease, one with epidural empyema, and one with cysticercosis). Two neuroradiologists independently reviewed the FLAIR images and compared them with the conventional spin-echo images, obtaining agreement in all patients. **RESULTS:** FLAIR images of diagnostic quality were obtained in 18 patients. In two patients, FLAIR images were degraded by motion. Lesions in the patients with encephalitis and meningoencephalitis were better delineated on FLAIR images than on spin-echo images. FLAIR images clearly depicted lesions in the basal ganglia in both patients with Creutzfeldt-Jakob disease. In patients with brain abscess, meningitis, cysticercosis, and epidural empyema, FLAIR images provided no more information than conventional spin-echo images, and the lesions were seen better on postcontrast T1-weighted spin-echo images. **CONCLUSION:** Fast FLAIR images showed pathologic changes in intracranial infectious diseases better than or as well as conventional T2- and proton density-weighted spin-echo sequences. However, postcontrast T1-weighted spin-echo sequences resulted in better visibility of abscess, meningitis, cysticercosis, and epidural empyema than did FLAIR images.

**Index terms:** Brain, infection; Brain, magnetic resonance

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The fluid-attenuated inversion recovery (FLAIR) sequence is a T2-weighted imaging technique that generates heavily T2-weighted and cerebrospinal fluid (CSF)-nulled MR images (1-5). Because these sequences are modified inversion-recovery sequences, their use has been limited by long scanning times. However, by combining a fast or turbo spin-echo sequence with an inversion-recovery sequence (fast or turbo FLAIR), scanning time can be greatly reduced (6).

Use of FLAIR imaging in infectious disorders

and in other inflammatory processes, such as sarcoidosis, has shown promising results (1, 4, 5, 7). In these reports, FLAIR imaging was stated to be more sensitive than T2-weighted spin-echo imaging in a limited number of patients. We therefore determined to assess the utility of fast FLAIR sequences as compared with conventional spin-echo sequences, including postcontrast T1-weighted spin-echo imaging, in the diagnosis of intracranial infections.

## Materials and Methods

The subjects consisted of 20 patients (12 male and eight female, 5 to 78 years old) with a variety of intracranial infectious diseases. These included three patients with herpes simplex encephalitis, three with encephalitis caused by other viruses, five with brain abscess, three with meningitis (one tuberculous and two pyogenic), two with meningoencephalitis caused by an unknown organism, two with Creutzfeldt-Jakob disease, and one patient each with epidural empyema and cysticercosis. The diagnosis

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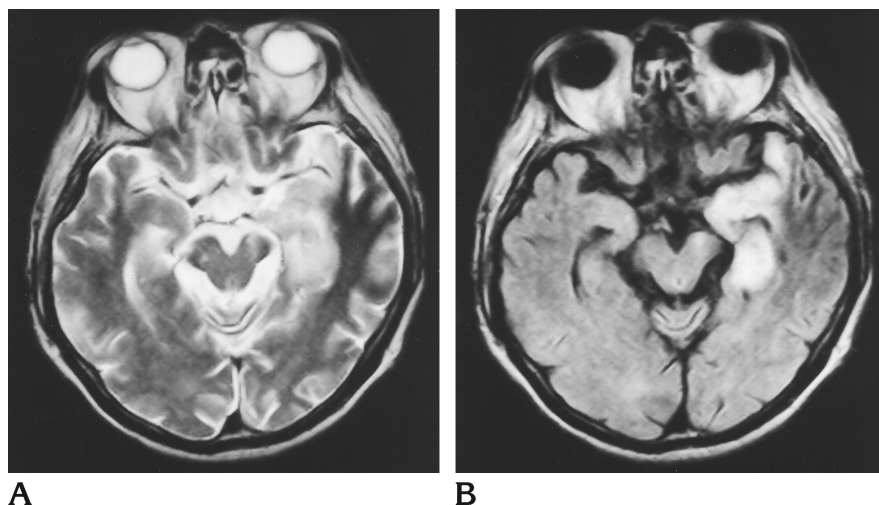
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Fig 1. Herpes simplex encephalitis.

A, T2-weighted fast spin-echo image (4000/120/1) at 0.5 T shows a hyperintense lesion in the left temporal lobe.

B, Fast FLAIR image (6000/120/2, inversion time of 1700) shows the lesion far better.



was confirmed by surgery in six patients with brain abscesses or epidural empyema. In the remaining 14 patients, the diagnosis was made on the basis of clinical, imaging, and laboratory findings and the patients' response to antibiotic therapy.

We used 1.5-T and 0.5-T MR units. In 17 patients examined on a 1.5-T unit, we used FLAIR imaging sequences with parameters of 6000/9000/119/1 (repetition time/echo time/excitations) and an inversion time of 2060 or 2200. For one patient, we used another 1.5-T unit and a different FLAIR sequence (9980/160/1) with an inversion time of 2000. In the remaining two patients, we used two 0.5-T units and FLAIR sequences of 6000/88,120/2 with an inversion time of 1700. Other imaging parameters were as follows: imaging matrix, 98–256 × 192–256; section thickness, 5 to 10 mm; and field of view, 15–23 × 20–23 cm. Scanning time ranged from 2 minutes to 6 minutes 24 seconds.

Two neuroradiologists blinded to the clinical data assessed the FLAIR images, comparing them with conventional spin-echo images, which included T2- and proton density-weighted fast spin-echo images and precontrast and postcontrast T1-weighted spin-echo images. They rated the FLAIR images as superior, equal, or inferior to the spin-echo images. The assessment resulted in agreement between the two neuroradiologists in all patients.

## Results

The FLAIR images were degraded by motion artifacts in one patient with encephalitis and in another with Creutzfeldt-Jakob disease, but we obtained images of diagnostic quality in the others.

The lesions in the patients with encephalitis or meningoencephalitis were seen better on the FLAIR images than on the T2- or proton density-weighted spin-echo images (Fig 1). Involvement of the gray matter tended to be well de-

picted on FLAIR images, with good contrast with CSF. In the patients with Creutzfeldt-Jakob disease, both of whom were in the early stage, the FLAIR images showed the lesions in the basal ganglia slightly better than did the T2- or proton density-weighted spin-echo images, although the images of one of them were degraded by motion (Fig 2). In two of five patients with brain abscesses, FLAIR images were judged superior to T2- or proton density-weighted spin-echo images in showing hypointensity of the capsule. However, in all patients with brain abscesses, postcontrast T1-weighted spin-echo images delineated the capsule better than any other sequence (Fig 3). Likewise, in patients with meningitis, cysticercosis, and epidural empyema, FLAIR images provided no more information than conventional spin-echo images, including the postcontrast T1-weighted spin-echo images. However, it was noteworthy that the cisternal lesions in the patient with tuberculous meningitis were more conspicuous on FLAIR images than on T2- or proton density-weighted images, as they appeared hyperintense relative to CSF on FLAIR images (Fig 4). In eight patients, hyperintensity due to hydrocephalus and/or perifocal edema was better depicted on FLAIR images than on T2- or proton density-weighted images.

## Discussion

The FLAIR technique is a recently developed method of obtaining T2-weighted images with nulling of the CSF signal (1–5). This technique is an inversion-recovery sequence that reduces the signal from CSF and attains heavy T2

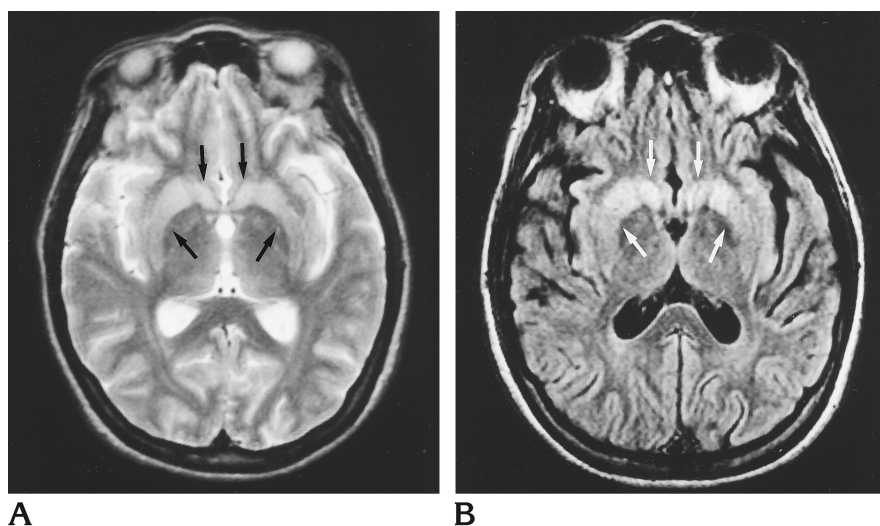


Fig 2. Creutzfeldt-Jakob disease in a 50-year-old woman whose images were not degraded by motion.

A, T2-weighted fast spin-echo image (4000/90/1) at 1.5 T shows hyperintense lesions in the bilateral basal ganglia (arrows).

B, The lesions, which probably represent gliosis and/or spongiform changes, are seen better on fast FLAIR image (9000/119/1, inversion time of 2200) (arrows).

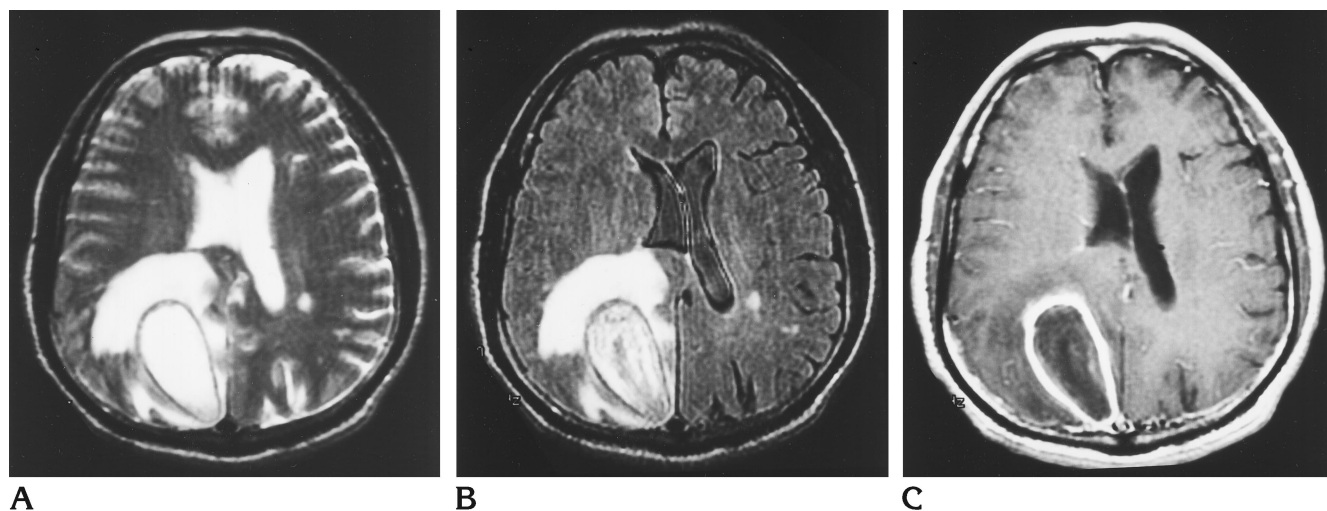


Fig 3. Brain abscess.

A, T2-weighted fast spin-echo image (3500/102/1) at 1.5 T shows a right parietooccipital abscess.

B, Both the hypointensity of the capsule and the hyperintensity of surrounding edema are clearer on fast FLAIR image (9980/160/1, inversion time of 2000).

C, Postcontrast T1-weighted spin-echo image (500/19/2) depicts the capsule best—note the thick enhancing dura adjacent to the abscess.

weighting with the use of a long echo time. The clinical utility of FLAIR images has been assessed in several intracranial conditions (1, 2, 4, 6, 8–13). FLAIR imaging has proved to be useful in head injury, multiple sclerosis, acute subarachnoid hemorrhage, carbon monoxide poisoning, tuberous sclerosis, and mesial temporal sclerosis (8–13), but its usefulness has been reported to be limited in the diagnosis of intracranial tumors (6). The use of FLAIR sequences in the diagnosis of intracranial infectious diseases has been reported in a limited number of patients (1, 5, 7).

In our series, FLAIR images delineated le-

sions related to encephalitis and Creutzfeldt-Jakob disease more clearly than on T2- and proton density-weighted images. FLAIR images yielded particularly high lesion contrast in encephalitic lesions. Encephalitis frequently involves the gray matter. Because artifacts from CSF motion and CSF volume averaging with the brain parenchyma are minimized and because the signal from CSF is reduced, FLAIR images result in better visibility of gray matter lesions. Our experience with cysternal lesions in a patient with tuberculous meningitis may be similarly explained (Fig 4). In addition, although not essential in the diagnosis of these diseases,

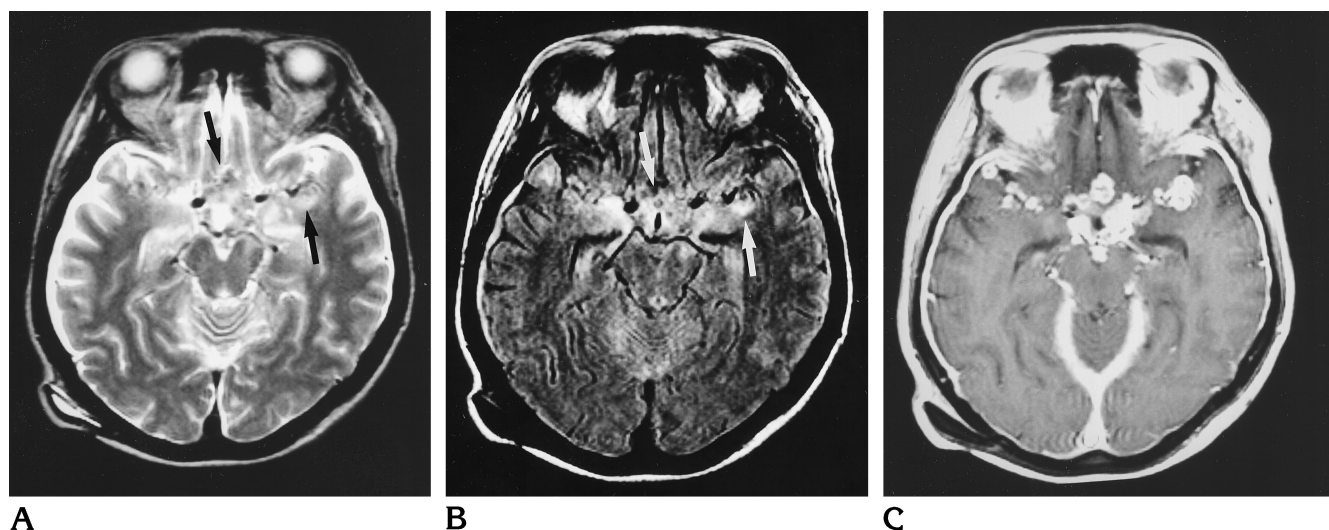


Fig 4. Tuberculous meningitis.

A, T2-weighted fast spin-echo image (4000/90/1) at 1.5 T shows lesions isointense with CSF in the suprasellar cistern and left sylvian fissure (arrows).

B, Fast FLAIR image (9000/119/1, inversion time of 2200) shows the lesions as slightly hyperintense relative to CSF (arrows).

C, Postcontrast T1-weighted spin-echo image (500/19/2) depicts the lesions best, since they show apparent contrast enhancement—note the thick enhancement of the convexity dura and tentorium cerebelli.

FLAIR images showed hyperintensity due to hydrocephalus and/or perifocal edema better than did the T2- or proton density-weighted images.

The usefulness of postcontrast MR imaging has been widely accepted in the evaluation of intracranial infectious diseases (14–16). Our results indicate that postcontrast T1-weighted spin-echo images are superior to FLAIR images in delineating enhancing lesions, such as the capsules in brain abscess, cysticercosis, and epidural empyema. Similarly, cisternal or meningeal abnormalities associated with meningitis were more clearly depicted on postcontrast T1-weighted spin-echo images than on FLAIR images. Enhancing lesions on postcontrast T1-weighted spin-echo images reportedly also show enhancement on postcontrast FLAIR images (6). So far, we have had no experience with postcontrast FLAIR images in patients with meningitis.

Although patients with intracranial infectious diseases are frequently uncooperative, we were able to obtain FLAIR images of diagnostic quality in all but two patients in this series. We applied an inversion pulse to multiple fast spin-echo radio-frequency signal complexes in a relatively long inversion time. This greatly contributed to the short scanning time and the increase in number of sections obtained per one scan. Recently, it has become possible to acquire

FLAIR images by using echo-planar sequences in a shorter scanning time. We are in the process of investigating the usefulness of this technique for imaging patients with infectious brain disorders.

We encountered several difficulties with FLAIR images. First, there were various types of artifacts. Hyperintense artifacts related to CSF flow motion were frequently noted near the foramen of Monro, aqueduct, posterior fossa cisterns, and fourth ventricle, and we also encountered artifactual hyperintensity lining the wall of the lateral ventricles. Fortunately, the former did little to hinder us in formulating a diagnosis. The latter, however, may simulate the pathologic hyperintensity seen with ventriculitis; therefore, postcontrast T1-weighted images may be required to make the correct diagnosis. Second, because FLAIR images are T2-weighted, the same as long-repetition-time spin-echo images, the findings were not always specific. For example, perifocal edema could not be definitely differentiated from encephalitis. Third, in our experience, lesions in the brain stem (eg, lacunar infarcts) tend to be inadequately depicted as compared with supratentorial lesions on FLAIR images. Therefore, although not a problem in our series, the diagnostic utility of FLAIR imaging for brain stem lesions may be limited.

In conclusion, fast FLAIR images showed pathologic changes in several intracranial infectious diseases better than conventional T2- and proton density-weighted spin-echo sequences. Its short scanning time was advantageous in examining patients with these diseases, since many of them are uncooperative and clinically unstable. The postcontrast T1-weighted spin-echo sequence, however, remains indispensable in some conditions, such as brain abscess, meningitis, cysticercosis, and epidural empyema.

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