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Preliminary Evaluation of Fluid-Attenuated Inversion-Recovery MR in the Diagnosis of Intracranial Tumors

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PURPOSE: To report our preliminary results in the application of a turbo fluid-attenuated inversion-recovery (FLAIR) MR technique to the diagnosis of intracranial tumors and to assess the clinical usefulness of this technique. **METHODS:** Thirty-four patients with various intracranial tumors were studied with MR imaging, including a turbo FLAIR sequence. FLAIR images were compared with images obtained with conventional spin-echo sequences. **RESULTS:** Except for 2 lesions in 1 patient, tumor signal intensities on FLAIR images were consistent with those shown on T2-weighted spin-echo images. FLAIR images showed peritumoral edema more clearly than T2-weighted and proton density-weighted images when the tumor itself was not hyperintense. In 8 of 23 patients in whom edema was associated with tumor, FLAIR images provided better definition between edema and tumor than did T2-weighted and proton density-weighted images. In 5 patients, FLAIR images depicted different signal intensity between cerebrospinal fluid and a cystic or necrotic component. In 20 of 22 patients, postcontrast FLAIR images showed contrast enhancement comparable to that seen on postcontrast T1-weighted images. **CONCLUSION:** Turbo FLAIR images can supplement conventional spin-echo images in the diagnosis of intracranial tumors.

Index terms: Brain neoplasms, magnetic resonance; Magnetic resonance, technique

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The fluid-attenuated inversion-recovery (FLAIR) sequence produces heavily T2-weighted and cerebrospinal fluid (CSF)-nulled magnetic resonance (MR) images. Its clinical usefulness in neuroimaging has been described in regard to several conditions (1-7). As this sequence is a modification of inversion-recovery sequences, its long scanning time has been problematic. However, the combining of a turbo or fast spin-echo sequence with an inversion-recovery sequence (turbo or fast FLAIR) has greatly reduced the scanning time. We present our experience in applying turbo FLAIR sequences to the diagnosis of intracranial tumors and discuss the clinical utility of this technique.

Subjects and Methods

Our study group consisted of 34 patients with various surgically proved or clinically diagnosed intracranial tumors. There were 20 female and 14 male subjects, 9 to 80 years old (mean, 56 years), including 9 patients with meningioma, 8 with multiple metastases, 7 with glioma, 2 with acoustic neuroma, and 8 with other tumors of miscellaneous origin.

MR imaging was performed on a 1.5-T system. Scanning parameters for turbo FLAIR sequences were as follows: 9000/119/1 (repetition time/echo time/excitations); inversion time, 2200; imaging matrix, 168 to 224 × 256; and section thickness, 5 mm. In this series, we used a sequence called *interleaved multisection mode*. The sequence applies an inversion pulse to multiple turbo spin-echo radio frequency signal complexes in a relatively long inversion time. This made it possible to obtain the same number of FLAIR images as T1-weighted, T2-weighted, and proton density-weighted spin-echo images in one scan (eg, 15 sections with an intersection gap of 2.5 mm). The scanning time depended on such technical factors as a rectangular field of view and use of oversampling. Practically, it ranged from 3 minutes 45 seconds to 5 minutes 51 seconds. Of 34 examinations, precontrast and postcontrast (0.1 mmol/kg gadopentetate dimeglumine) FLAIR images were obtained in 24, and only precontrast images were obtained in the remaining 10.

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Two neuroradiologists blinded to the pathologic disorder independently reviewed the MR images and reached a consensus in all patients. They compared the FLAIR images with a set of T2-weighted, proton density-weighted, and precontrast and postcontrast T1-weighted images. T2-weighted and proton density-weighted images were obtained in the double-echo manner using turbo spin-echo sequences. For patients whose postcontrast FLAIR images were available, the images were compared with precontrast FLAIR and postcontrast T1-weighted images. In 23 patients in whom tumor was associated with edema, the delineation of edema on precontrast FLAIR images was compared with that on T2-weighted and proton density-weighted images. Similar assessments were made for 8 patients in whom the tumor was found to contain a cystic or necrotic component at surgery. In the evaluation of edema, special attention was directed toward the distinction of edema from tumor.

Results

Signal Intensity

We identified a total of 72 lesions in this series. Tumors on precontrast FLAIR images were either isointense (34 lesions) or hyperintense (38 lesions) relative to white matter. Their signal intensity usually coincided with that on T2-weighted spin-echo images. However, two lung cancer metastases in one patient showed isointensity on FLAIR images and hyperintensity on T2-weighted spin-echo images. When a tumor was hyperintense and accompanied by edema, the tumor-edema interface was unclear because the edema was also hyperintense, as described below. One patient had a preopine epidermoid tumor, which was isointense with CSF on conventional spin-echo images but was hyperintense relative to CSF on FLAIR images (Fig 1). Before surgery, the lesion was thus considered unlikely to be an arachnoid cyst.

Peritumoral Edema

In 23 patients in whom the tumor was associated with peritumoral edema, the edema was seen much better on FLAIR images as an area of hyperintensity than on T2-weighted or proton density-weighted spin-echo images. As to the ability to distinguish edema from tumor, FLAIR images were better than T2-weighted and proton density-weighted images in 8 patients, whereas FLAIR, T2-weighted, and proton density-weighted images were equal in the remaining 15 patients (Fig 2). In 7 of the latter 15

patients, tumor and edema were not differentiated, as both were equally hyperintense.

Contrast Enhancement on Postcontrast FLAIR Images

Both precontrast and postcontrast FLAIR images were obtained in 22 patients, among whom postcontrast FLAIR images showed contrast enhancement of the tumors in 20. The enhancement made lesions more obvious than on precontrast images in 14 patients. However, in 4 patients, the tumor and surrounding edema became difficult to discriminate owing to contrast enhancement (Fig 3). In 2 lesions (1 glioma and a metastatic lesion), enhancement on postcontrast FLAIR images was not noted, although both were enhanced on postcontrast T1-weighted spin-echo images.

Other Findings

In 10 patients, FLAIR images incidentally demonstrated coexistent infarcts and/or periventricular abnormal intensity better than T2-weighted and proton density-weighted images did. In 3 of the 8 patients whose tumor contained a cystic or necrotic component, T2-weighted and proton density-weighted images provided better distinction between tumor and a cystic or necrotic component than did the FLAIR images. In the remaining 5 patients, FLAIR, T2-weighted, and proton density-weighted images were almost equal. However, in another group of 5 patients among these 8, FLAIR images were better at depicting different signal intensity between CSF and a cystic or necrotic component than were T2-weighted and proton density-weighted images (Fig 4). Postcontrast FLAIR images showed subarachnoid dissemination better than postcontrast T1-weighted spin-echo images did in 2 patients, 1 with glioblastoma and the other with lung cancer metastasis. Ultimately, FLAIR images provided no additional information on any of our patients.

Discussion

It has been accepted that T2-weighted sequences are the most sensitive for detecting intracranial lesions with MR imaging. This is because, although both T1 and T2 signal are prolonged in many pathologic conditions, re-

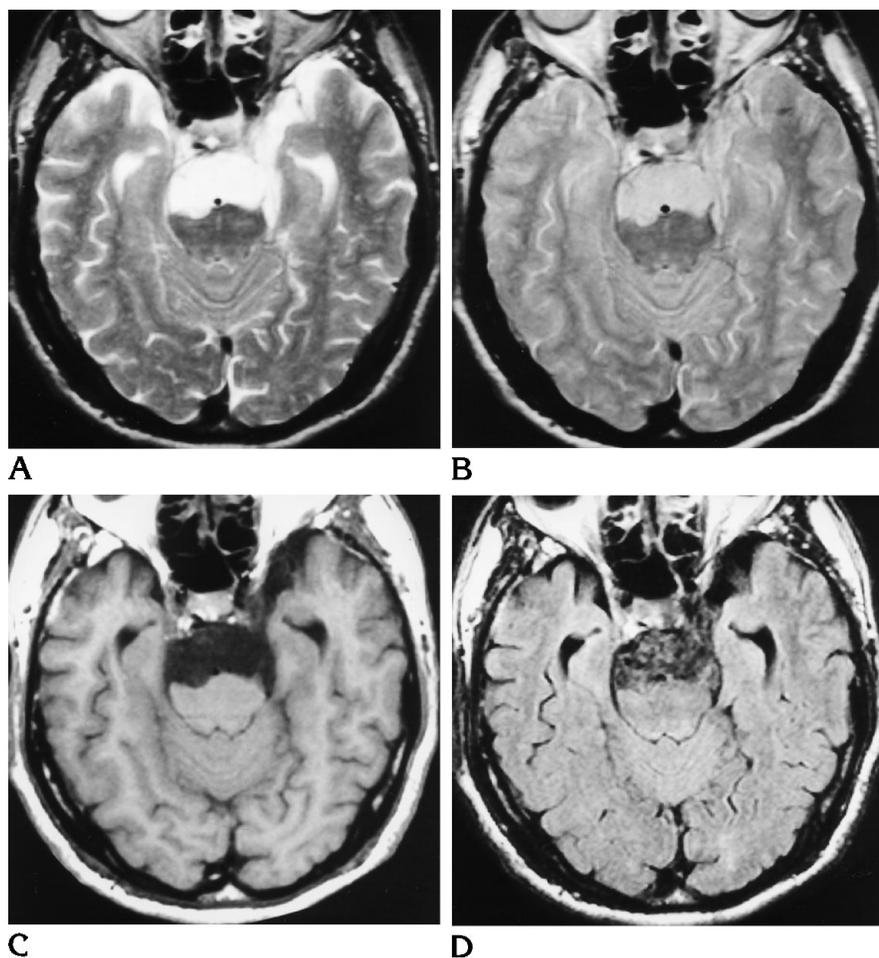


Fig 1. Surgically proved preopontine epidermoid in a 67-year-old man. T2-weighted turbo spin-echo image (4000/90/1) (A), proton density-weighted turbo spin-echo image (4000/22/1) (B), and T1-weighted spin-echo image (500/14/2) (C) all show the mass to be isointense with CSF. However, precontrast FLAIR image (9000/119/1, inversion time of 2200) (D) shows the mass to be hyperintense relative to CSF.

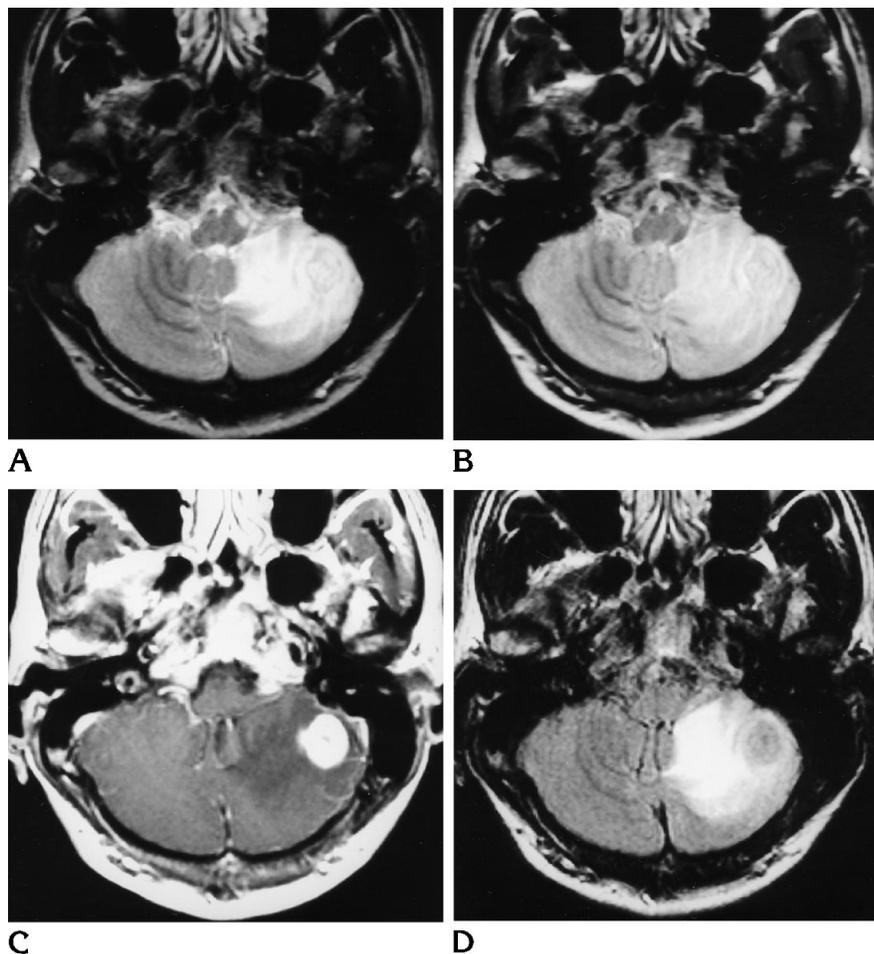
sultant lesion contrast is most conspicuous on T2-weighted images. The diagnostic value of T2-weighted spin-echo images has, therefore, been completely established. The FLAIR technique is a method of obtaining T2-weighted images that has been described by a group from Hammersmith Hospital (1-3, 8). The FLAIR sequence is an inversion-recovery pulse sequence designed to reduce greatly the signal from CSF. With this sequence, CSF artifacts are reduced and heavily T2-weighted images are attained with a long echo time (7).

Descriptions of the clinical application of the FLAIR technique to cerebral infarction, demyelinating diseases, inflammatory diseases, cerebral trauma, and subarachnoid hemorrhage have been reported (1, 5-7); however, its use in the diagnosis of intracranial tumors has been less widely recounted and has not been thoroughly investigated (1, 2, 5). With the sequence used in this study, the same number of sections can be obtained as with other routine sequences

in a reasonably short scanning time. These attributes motivated us to carry out this study.

Our results demonstrate that the signal intensities of tumors are usually similar to those on T2-weighted spin-echo images. In seven patients, neither FLAIR, T2-weighted, or proton density-weighted imaging was able to discriminate surrounding edema from a tumor. This is to be expected, as FLAIR is essentially a T2-weighted technique. On the other hand, many lesions in this series showed contrast enhancement on postcontrast FLAIR images. We speculate that signal intensity on FLAIR images is at least partially T1-dependent and that the enhancement was due to T1 shortening caused by administration of contrast material. However, in two patients, contrast enhancement was not seen on postcontrast FLAIR images that were obtained before the postcontrast T1-weighted images. We speculate that the time lag may have caused the so-called delayed enhancement. Meanwhile, in many patients, this en-

Fig 2. Clinically diagnosed cerebellar metastasis from lung cancer in a 46-year-old man. On T2-weighted turbo spin-echo image (4000/90/1) (A) and proton density-weighted turbo spin-echo image (4000/22/1) (B), the demarcation of edema from tumor is indistinct. Postcontrast T1-weighted spin-echo image (500/14/2) (C) clearly depicts the tumor; and precontrast FLAIR image (9000/119/1, inversion time of 2200) (D) differentiates tumor from edema, as the tumor is isointense.



hancement resulted in better delineation of tumors than that seen on precontrast images. Conversely, in some patients, this enhancement made it difficult to discriminate tumors from edema (Fig 3). We advocate further studies to determine whether contrast medium is useful in the diagnosis of intracranial tumors using FLAIR sequences.

Cerebral edema, which has conventionally been evaluated on T2-weighted and proton density-weighted spin-echo images, was more clearly seen on FLAIR images than on either of these other two sequences in our 23 patients in whom edema was associated with tumor. Additionally, in 8 patients, FLAIR images were better at differentiating edema from tumor. Furthermore, FLAIR images clearly showed edema even if it extended into the cerebral cortex. We regard as noteworthy the clear demonstration of peritumoral edema on FLAIR images because its precise evaluation is important in the differential diagnosis and treatment of intracranial

tumors. FLAIR images may also be useful in influencing patient treatment, as they clearly depict coexistent infarcts or abnormal periventricular signal intensities in hydrocephalus.

In patients whose tumors had a cystic or necrotic component, the signal intensities of such areas were different from that of CSF on FLAIR images (Fig 4). Similar findings were noted in a patient with an epidermoid tumor (Fig 1). Thus, in terms of the contents of cystic or cavitory components, we may be able to obtain more information on FLAIR images than on conventional spin-echo images.

Artifacts related to CSF flow motion are frequently noted near the foramen of Monro, fourth ventricle, and aqueduct on FLAIR images. In addition, we also encountered artifactual hyperintensity lining the wall of the lateral ventricles. Indeed, in the two patients with subarachnoid tumor seeding (glioblastoma and lung cancer), abnormal periventricular hyperintensity simulated this artifact.

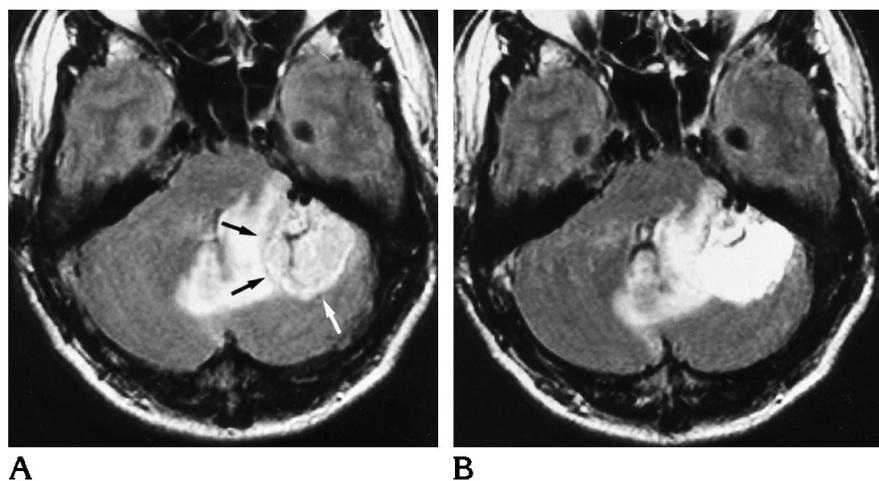


Fig 3. Surgically proved solid heman-gioblastoma in a 43-year-old man. Pre-contrast FLAIR image (9000/119/1, inversion time of 2200) (A) shows a slightly hyperintense tumor (arrows) surrounded by edema. Postcontrast FLAIR image (9000/119/1, inversion time of 2200) (B) shows enhancement of the tumor, resulting in poor delineation of the tumor from surrounding edema.

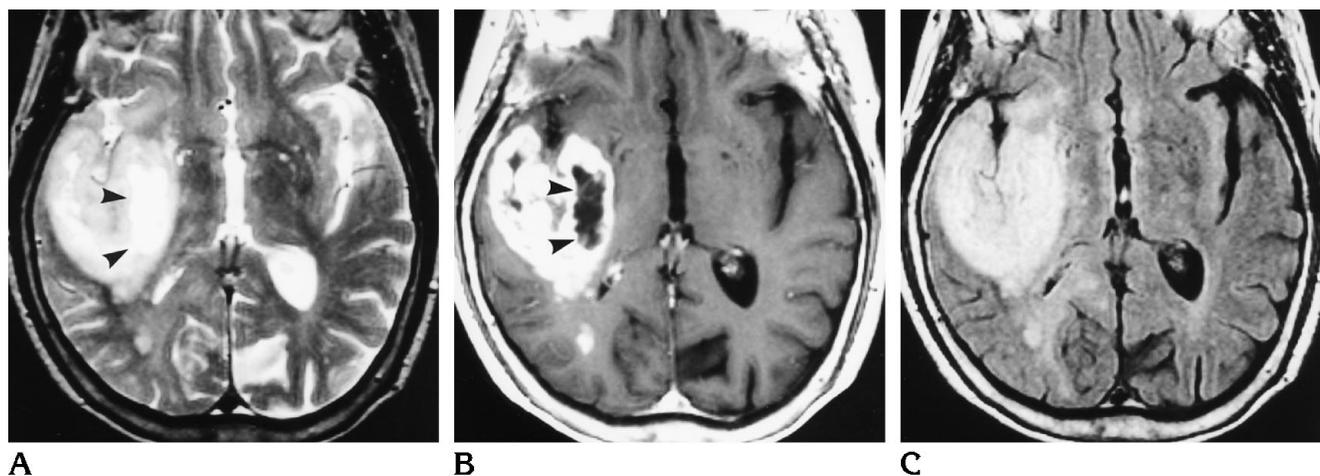


Fig 4. Surgically proved glioblastoma in a 76-year-old woman. T2-weighted turbo spin-echo image (4000/90/1) (A) shows histologically proved necrotic component to be isointense with CSF (arrowheads), which was similar to appearance on proton density-weighted image (not shown). Postcontrast T1-weighted spin-echo image (500/14/2) (B) clearly depicts the necrotic part of the tumor (arrowheads). Precontrast FLAIR image (9000/119/1, inversion time of 220) (C) shows necrotic component to be hyperintense relative to CSF and almost isointense with solid part of tumor.

In summary, FLAIR images did not provide any information on our patients that was not available on conventional T2-weighted or proton density-weighted spin-echo images. However, peritumoral edema was clearly demonstrated, and the FLAIR images often delineated edema from tumor, and distinguished CSF from a cystic or necrotic component, better than T2-weighted and proton density-weighted images did. From a clinical perspective, we note the advantage of a short scanning time and the availability of a number of sections with one scan that this technique provides. We thus agree with Rydberg et al (9) that the turbo

FLAIR technique may be used as an adjunct to T2-weighted or proton density-weighted spin-echo imaging and may even replace proton density-weighted imaging. However, further study is needed before the usefulness of this technique can be established in the diagnosis of intracranial tumors.

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