

Use of Fluid Attenuated Inversion Recovery (FLAIR) Pulse Sequences in MRI of the Brain

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Abstract: Fluid attenuated inversion recovery pulse sequences with a long echo time (TE) have been used to image the brain in one volunteer and four patients. The long inversion time used with this sequence suppresses the signal from CSF and the long TE produces very heavy T2 weighting. The marked reduction in flow artefact from CSF and the high T2 weighting enabled anatomical detail to be seen within the brain stem and produced high lesion contrast in areas close to CSF. Lesions were demonstrated with greater conspicuity than with conventional T2-weighted sequences in patients with cerebral infarction, low grade astrocytoma, and diplegia. **Index Terms:** Inversion recovery—Brain—Magnetic resonance imaging, techniques—Fluid attenuated inversion recovery (FLAIR).

In a previous paper we described the use of fluid attenuated inversion recovery (FLAIR) pulse sequences to demonstrate high signal regions in normal white matter. These sequences null or markedly reduce the signal from CSF, and long echo time (TE) versions can be used to produce heavy T2 weighting (1). In this paper we describe the use of this type of sequence in one volunteer and four patients with disease of the brain.

MATERIALS AND METHODS

All studies were performed on a Picker HPQ 1.0 T imaging system with the approval of the Royal Postgraduate Research Ethics Committee.

The initial pulse sequence previously used in these studies consisted of a nonselective 180° pulse followed by a series of slice selective excitations and spin echo (SE) acquisitions in different imaging

planes (1). This resulted in a multislice set of inversion recovery images with progressively increasing inversion times (TI). A useful range of TI was found to be approximately 1,800–3,000 ms. The same range of TI and a wider range of TE from 130 to 240 ms was used in the present study.

More conventional long TI, long TE multislice inversion recovery sequences employing slice selective inversion pulses were also implemented. These were more prone to artefacts due to CSF motion but provided a more complete and uniform examination. Artefacts were reduced by increasing the thickness of the slice that was initially inverted beyond that which was finally sampled. This was implemented by doubling the bandwidth of the initial selective inversion pulses.

The slice thickness of the FLAIR sequences was 6–8 mm, the matrix size was 128 or 192 by 256, and a single data acquisition was used in each case.

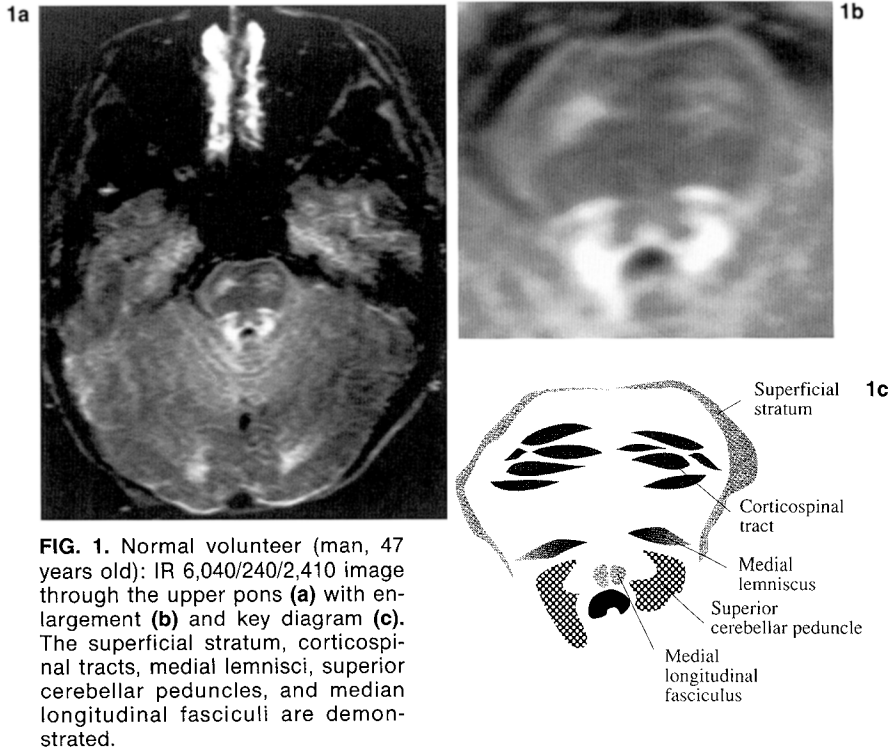
Conventional SE sequences (TE of 20 and 80 ms) and TR of ~2,500 ms were performed in all examinations. T1-weighted MRI was performed in selected cases.

RESULTS

Anatomic Observations

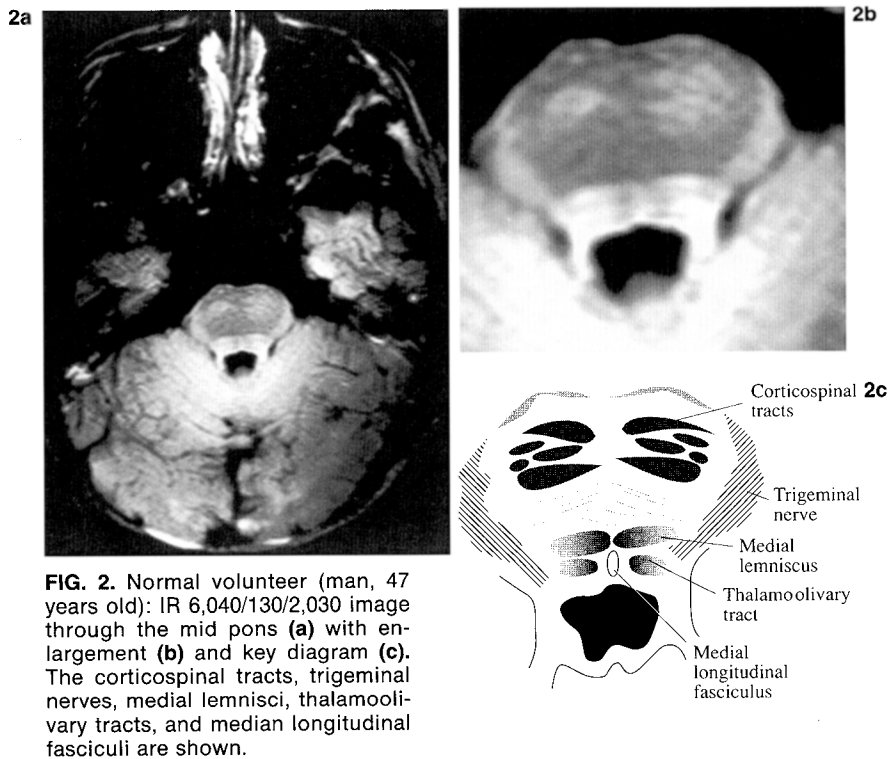
Considerable anatomical detail was seen in the cerebral hemispheres but the detail displayed within

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the brain stem was of particular interest. The corticospinal tracts, parietopontine tracts, medial lemnisci, superior cerebellar peduncles, and medial longitudinal fasciculi were readily visualised (Fig. 1) as were the trigeminal nerves (Fig. 2).

Grey matter in the periaqueductal region exhibited a relatively high signal whereas the grey matter of the substantia nigra and inferior olivary nucleus displayed a low signal. Chemical shift artefact was noted with longer TE versions of the sequence that



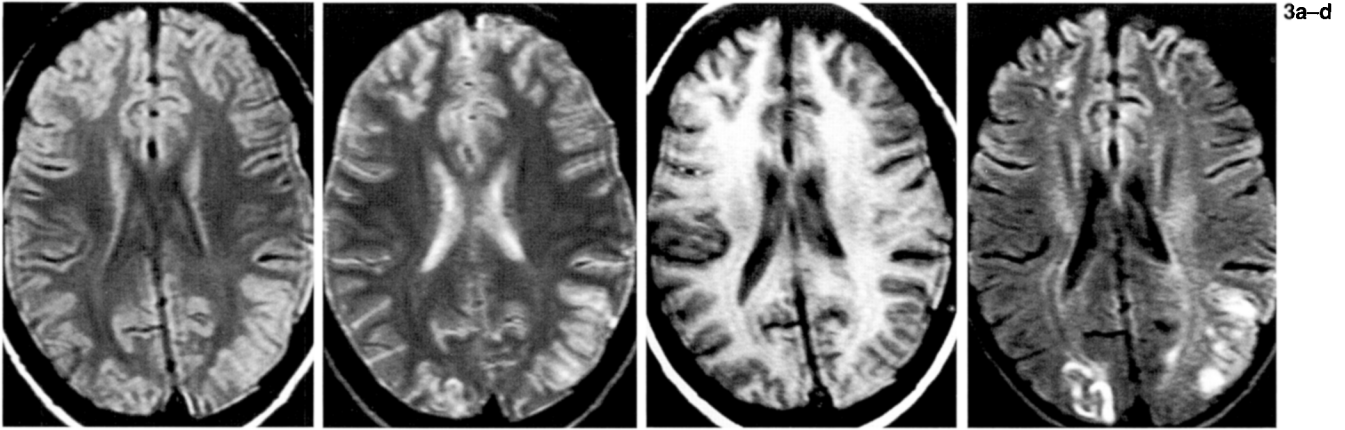


FIG. 3. Case 1. Cortical and deep white matter infarction: SE 2,700/20 (a), SE 2,700/80 (b), SE 500/20 (c), and IR 6,040/160/2,100 (d) images at mid ventricular level. Areas of infarction are highlighted in both parietal lobes and in the deep white matter in (d). Less obvious changes can be seen in (b) but not in (a) or (c).

employed a long data collection period (56 ms) but was much less obvious when shorter data collection times were used.

CLINICAL FINDINGS

Case 1

A 16-year-old girl with sickle cell disease but no neurological findings and negative CT experienced two occasions in which she appeared to lose concentration and her eyes rolled for a few seconds. Brain MRI with conventional TE = 20 and TE = 80 as well as T1-weighted SE sequences (SE 580/20) showed several ill-defined lesions. These lesions were more clearly identified with FLAIR sequences (e.g., Fig. 3). The patient showed signs of cortical infarction but the increased signal intensity expected with conventional TE = 80 sequences was partly obscured by the presence of high signal from CSF and partial volume effects between grey and white matter.

Case 2

A 42-year-old woman presented with a history of fluctuating aphasia. Angiography demonstrated a stenosed internal carotid artery on the left. The conventional TE = 20 and TE = 80 SE sequences showed an abnormal area on the left. Low signal areas within this region were better seen with the FLAIR sequence and lesions on the right were also seen with greater conspicuity. Left-sided periventricular changes were more easily recognised with the FLAIR sequence (Fig. 4).

Case 3

A 38-year-old woman with a low grade astrocytoma presented with weakness of the right arm and seizures. The TE = 80 imaging displayed a large mass (Fig. 5a), but extension of the lesion across the corpus callosum was more evident with the FLAIR sequence (Fig. 5b).

Case 4

An 8-year-old girl with a history of hypoxic ischaemic encephalopathy presented with diplegia. The TE = 20 and TE = 80 sequences were equivocal (Fig. 6a and b) but clearly abnormal areas were seen with the FLAIR sequence in the posterior centrum semiovale (Fig. 6c).

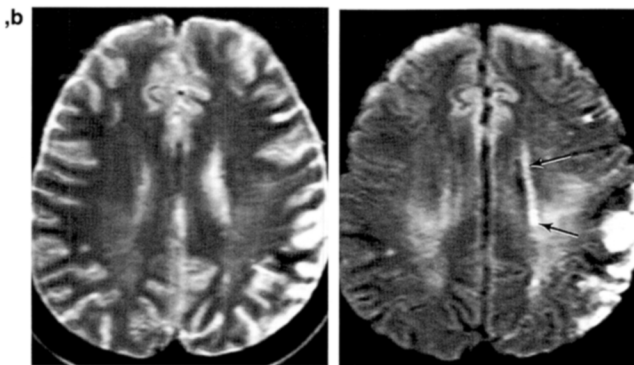


FIG. 4. Case 2. Cerebral infarction: SE 2,540/80 (a) and IR 6,710/160/2,720 (b) images. The left parietal lesions are highlighted but dark areas associated with hemorrhage are best seen in (b). The left-sided periventricular changes are better seen in (b) (arrows).

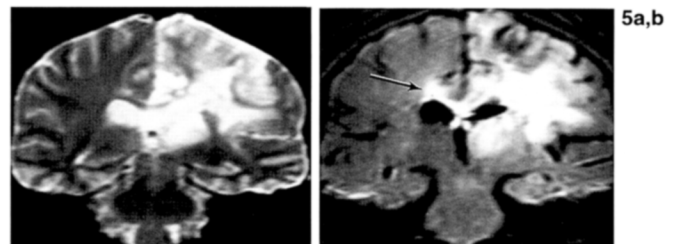


FIG. 5. Case 3. Low grade astrocytoma: SE 2,500/80 (a) and IR 6,710/160/2,520 (b) images. Extension of the lesion across the corpus callosum is shown in (b) (arrow).

6a-c

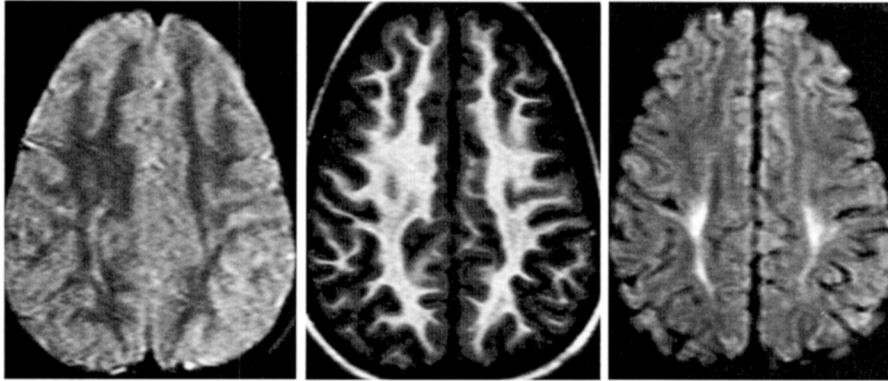


FIG. 6. Case 4. Eight-year-old girl with diplegia: SE 2,530/80 (a), IR 3,110/30/700 (b), and IR 6,040/160/1,900 (c) images. The lesions in the posterior centrum semiovale are well seen in (c) but are poorly shown in (a) and (b).

DISCUSSION

By decreasing the signal from CSF, FLAIR sequences reduce image degradation from partial volume effects and motion artefact. It is possible to combine this with a TE increased beyond that used for conventional heavy T2-weighted sequences (e.g., from 80 to 160 ms). The net result is a sequence that provides high lesion contrast against a muted background of brain and a very low signal intensity from CSF.

The technique has applications where partial volume effects from CSF are a particular problem such as with lesions at or on the surface of the brain. The low contrast between grey and white matter is useful for discriminating lesions at the grey white matter junction from partial volume effects between these two tissues.

In some cases lesions initially detected with the FLAIR sequence were subsequently identified on the TE = 20 and TE = 80 sequences. The TE = 20 sequence has a low signal from CSF that enables some lesions to be seen more clearly than on the higher contrast TE = 80 sequence, but it lacks the sensitivity gained through heavy T2 weighting. The

TE = 80 sequence has heavy T2 weighting but is also burdened by high signal from CSF.

Of particular interest is the fact that the FLAIR approach is well suited to fast imaging techniques such as rapid acquisition with relaxation enhancement (RARE) (2) and echo planar imaging (3). The multiple data acquisition during a single free induction decay employed in such techniques means that the TE is generally prolonged. If these sequences are combined with an inversion pulse designed to null or greatly reduce the signal from CSF, the advantages of the FLAIR sequence become available.

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