Specialty Corner

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'A FLAIR for T1'

By Mala Modi and Shawn Halpin

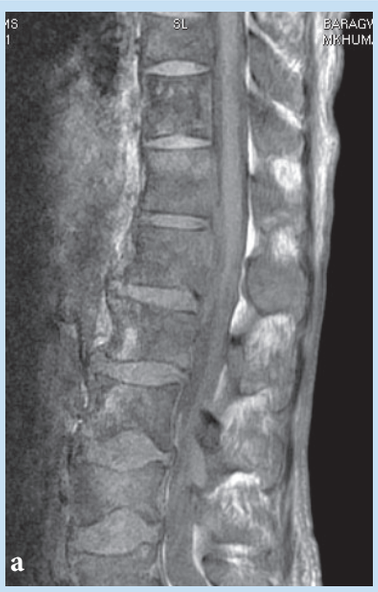
We are at present performing T1 FLAIR (fluid-attenuated inversion recovery) sequences for some brain and spinal imaging. It enhances the differentiation between grey and white matter, providing better anatomical definition. T1 FLAIR further suppresses any signal from the CSF which then appears black, rather than dark grey.

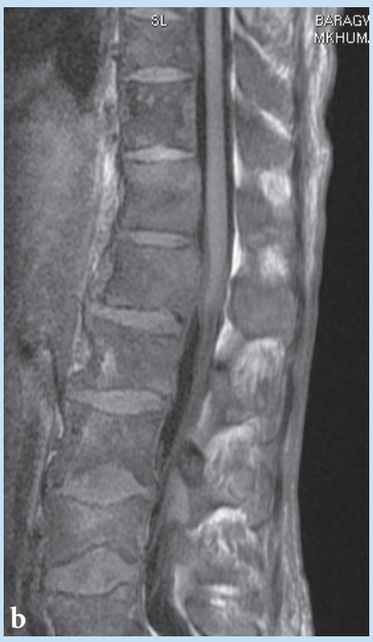
Indications for using the T1 FLAIR sequence in the brain would include imaging for mesial temporal sclerosis, grey matter heterotopia, and primary epilepsy.

Spinal imaging using T1 FLAIR is proving to be very helpful in assessing cord size; and separating cord from CSF, CSF pulsation artefact, and epi- and extradural pathology.

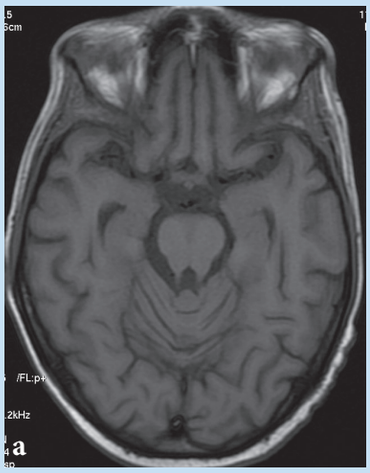
The disadvantage is that the T1 FLAIR sequences do take longer, and it is not recommended for use with T1 contrast imaging.

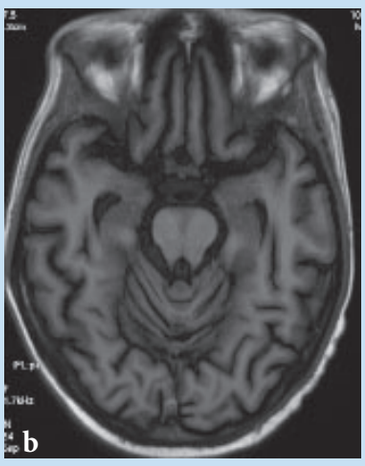
At present the scanning parameters we are using are a TR of 2000, a TE of 20, and a TI of 760.



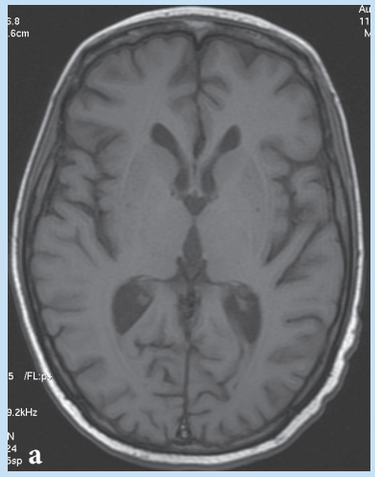


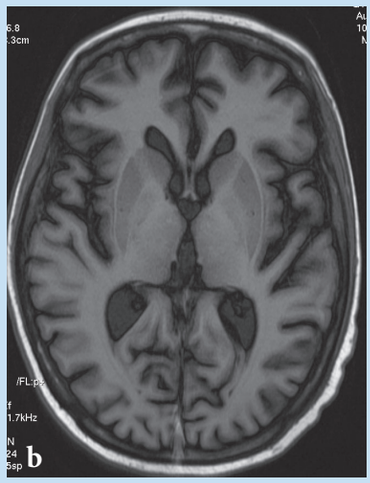
Figs 1 a and b: T1 and T1 FLAIR images of the L-spine.





Figs 2 a and b: T1 and T1 FLAIR images of the midbrain and hippocampus.





Figs 3 a and b: T1 and T1 FLAIR images of the basal ganglia.

Education exhibit - journal review

Bitar R, Leung G, Perng R, *et al.*
MR pulse sequences: what every radiologist wants to know but is afraid to ask.
Radiographics 2006; **26:**513-537

On paging through the latest *Radiographics*, the above article caught my attention for obvious reasons. As mentioned in the article the use of magnetic resonance (MR) imaging is increasing exponentially, and as such it is not limited to senior residents, and it is being introduced to residents in their first and second years of training. MR physics is necessary for the Part 1 of the radiology exam anyhow – therefore this article is highly recommended to all radiologists and radiologists-in-training.

Pearls

1. Tissue contrast

↓ TR → T1 weighting (TR affects T1 contrast)

↑ TE → T2 weighting (TE affects T2 contrast)

↑TR/↓TE = proton density (T1 and T2 effects are minimised, and signal is predominantly due to differences in proton density)

2. Pulse sequences

Two fundamental types: SPIN ECHO and GRADIENT ECHO.

Spin Echo (SE)

90° RF pulse followed by a 180° RF rephasing pulse (at ½ TE) to minimise magnetic field inhomogeneity

SE sequences

FSE-Fast/turbo = single 90° RF pulse followed by multiple 180° RF rephrasing pulses

(All echos together = echo train, the total 180° RF pulses + echos = echo train length)

Conventional inversion recovery sequence = a preparatory 180° pulse being applied to flip the net magnetisation vector thereby nullify the signal from a particular tissue, e.g. water, the 90° pulse is applied when the transverse plane is passed (null point for a particular tissue).

Uses: STIR = short IR sequence used to nullify the signal from fat

FLAIR = fluid attenuated IR sequence used to nullify the signal from water

Gradient Echo (GRE)

Small (variable) angle RF pulse followed by gradients and not RF pulses (positive/rephasing or negative/dephasing gradients). GRE sequences are sensitive to magnetic field inhomogeneity (T2* signal decay) as there are no rephasing pulses. This feature is exploited for the detection of haemorrhage, for use in cerebral perfusion studies, for BOLD (blood oxygen-level dependant) imaging in brain function mapping and cardiac imaging.

GRE sequences

Partially refocused, fully refocused and spoiled

3. Echo-planar imaging (EPI)

A single echo train is used to collect data from all lines of k-space during one TR (single-shot EPI), or from multiple TRs (multishot EPI).

It can be used with SE or GRE sequences.

4. Diffusion-weighted imaging (DWI)

DWI facilitates the differentiation of restricted diffusion from unrestricted diffusion.

EPI or fast GRE is used. Two equal gradient pulses (on either side of 180° pulse) are applied (dephasing and rephasing), if there is no net movement → ↑ signal; if there is net movement (i.e. undergoing dephasing but not rephasing or vice versa) → ↓ signal.

Apparent diffusion coefficient (ADC) maps are usually applied with DWI sequences.

Two sets of images are necessary to calculate ADC maps – one without a diffusion gradient (~T2 W image) and one with a diffusion gradient.

Area of restricted diffusion (eg. acute stroke)

No diffusion gradient – arbitrary signal value = 10

Diffusion gradient – arbitrary signal value = 5 (some but not profound signal loss)

Ratio = 0.5 (negative log of 0.5 = 0.7)

Area of normal brain

No diffusion gradient – arbitrary signal value = 10

Diffusion gradient – arbitrary signal value = 2
Ratio = 0.2 (negative log of 0.2 = 1.6)
Therefore areas of restricted diffusion appear darker on ADC maps, and unrestricted diffusion appears bright.

5. MR angiography (MRA) TOF and MOTSA

In time-of-flight (TOF) imaging and multiple overlapping thin-slab acquisitions (MOTSA) stationary tissue signal is suppressed by repetitive RF pulses, but inflowing blood is unaffected and appears hyperintense. It can be in 2D or 3D. MOTSA = hybrid of 2D and 3D.

Phase contrast imaging

Information about the phase (or direction) and of flow and velocity (or magnitude of flow) is provided. It requires two measurements that are sensitised to flow in equal and opposite directions thereby eliminating any signal not arising from flow or motion. It can be in 2D or 3D.

Contrast-enhanced angiography

An intravenous agent that shortens the T1 (hastening longitudinal recovery) of blood is used, so that there is a higher net magnetisation vector that can result in a high signal on T1W imaging. It can be in 2D or 3D.

6. Fat-related imaging techniques - fat signal suppression

Fat has a high signal on T1 as it has a short TR. There are many ways to suppress this high signal (to evaluate other tissues better).

First – an RF pulse at the beginning of any sequence is applied followed immediately by a gradient that shifts the net magnetisation vector of fat so that it has no longitudinal magnetisation at the start of the image acquisition. As no transverse magnetisation from fat is generated, there is no signal from fat.

Second – an inversion recovery pulse sequence is used to nullify the signal from fat (e.g. STIR).

Third – a water-excitation technique is applied so that only tissues containing water have transverse magnetisation. As no transverse magnetisation from fat is generated, there is no signal from fat.

7. In-phase and out-of-phase imaging

Hydrogen in fat and hydrogen in water have different chemical environments, they precess at different rates. A spoiled GRE sequence is used. Fat and water are imaged when their H nuclei are spinning in phase and out of phase with each other by using a TEs of 4.2 and 2.1 msec at 1.5T respectively. If microscopic fat is present (e.g. adrenal adenoma versus carcinoma), its signal is nullified on the out-of-phase images.

8. Specific absorption rate (SAR)

The RF pulse that flips the net magnetisation vector into the transverse plane is an energy pulse that is deposited in the patient. SAR is a measure of the rate at which the RF energy (measured in watts) is dissipated in tissue, per unit of tissue mass (measured in kilograms). SAR is proportional to $B^2 \propto^2 D$ where B = field strength, $\propto$ = flip angle, and D = duty cycle (or TR). Therefore if the field strength is doubled (1.5T to 3T) the SAR increases fourfold, if the flip angle is doubled (15° vs 30°) the SAR increases fourfold, and if the TR is halved, the SAR is doubled.

The above is just a short, select summary of the above article.

1. Enterline DS. Pre-filled syringes: applications in CT imaging. Applied Radiology 2001; 30(suppl): 1-14.