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.


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**
   \[ \begin{align*}
   & \downarrow \text{TR} \rightarrow \text{T1 weighting (TR affects T1 contrast)} \\
   & \uparrow \text{TE} \rightarrow \text{T2 weighting (TE affects T2 contrast)} \\
   & \uparrow \text{TR/TE} = \text{proton density (T1 and T2 effects are minimised, and signal is predominantly due to differences in proton density)}
   \end{align*} \]

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 \( \frac{1}{2} \) 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.

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 \( \rightarrow \uparrow \) signal; if there is net movement (i.e. undergoing dephasing but not rephasing or vice versa) \( \rightarrow \downarrow \) 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

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**Schedule 2**


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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)

5.1 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 (fastening longitudinal recovery) of
blood is used, so that there is a higher net
magnetisation vector that can result in a
high signal on TIW 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 \[ B^2 \propto \frac{\alpha}{D} \]
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.