

Specialty Corner

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The dumbo guide to diffusion-weighted imaging (DWI)

DWI definition: MRI sequences made sensitive to the diffusion of molecules – usually water.

DWI provides

- Measure of the cellular function by assessing the metabolic state of cells.
- Structural images representing the integrity and direction of white matter tracts.¹

How diffusion gives the signal

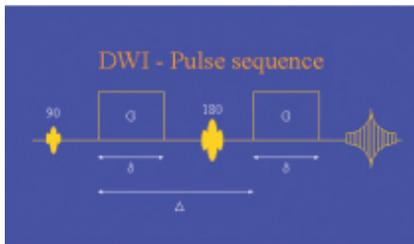
Two gradient pulses:

- The first labels the position of the water molecules.
- The second 'reads' the final position of the molecules after they have had time to diffuse.

If the molecules changed position the MRI signal is not refocused properly by the second gradient pulse and image intensity is reduced.

The basic sequences

Makes use of EPI (echoplanar imaging). Single echo-train is used to collect data from all lines of k-space during one TR. < 100 ms, i.e. 16.5 mm slices in 6 s and therefore very sensitive to motion. Either echoplanar SE or a fast GRE.²



Parameters affecting the signal

- 'b'-value: The degree of diffusion sensitivity.
- High b-values = high degree of diffusion sensitivity.

By increasing either the gradient timing, time of separation between gradient pulses or gradient strength, we can increase diffusion weighting.

- TE and TR are generally long in DWI. DWI therefore inherently has some degree of T2-weighting.
- T2 changes will also change the appearance of DWI: T2 shine-through effect.

How do I read the DWI

What we get in practice (Figs 1 a – e)

- b0 - T2-weighted images
- b500 - in 3 directions
- b1000 - in 3 directions
- ADC MAP

B1000 and ADC MAP read in conjunction to eliminate T2 shine-through effects. The 3 directions are denoted by 's', 'p', or 'r', respectively indicating 'slice encoding direction', 'phase

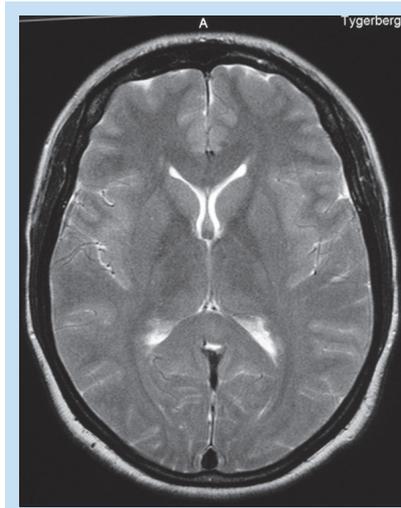


Fig. 1a. Axial T2WI of the brain.

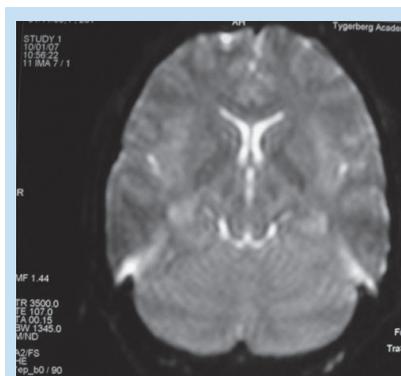


Fig. 1b. Axial 'DWI' with b value = 0 which is in reality a T2WI, the initial series of a diffusion-weighted sequence.

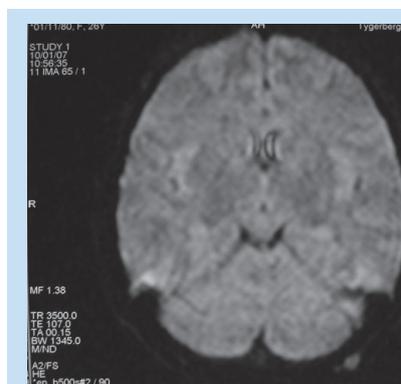


Fig. 1c. DWI with b value = 500, in the 'p' direction – phase encoding gradient or y-axis.

encoding direction' and 'readout gradient direction'.

Getting rid of T2 shine-through and allowing diffusion to affect the signal

- Two sets of images with (b = 800/1000) and without (b = 0) are acquired. Post processing subsequently calculates an image that reflects diffusion only, called the ADC MAP.
- ADC is calculated from the signal intensities of images acquired with varying magnitudes of diffusion sensitivity (b-values) and represented as an image (Figs 2 a - c).

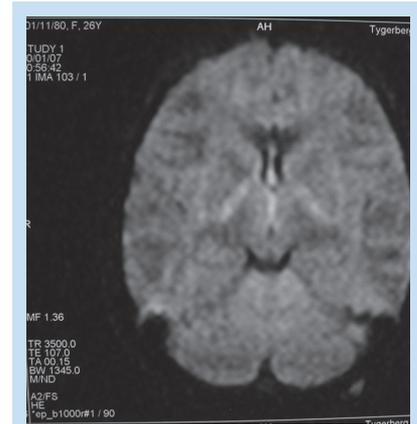


Fig. 1d. DWI with b value = 1000, in the 'r' or read out direction – frequency encoding gradient, or x-axis.

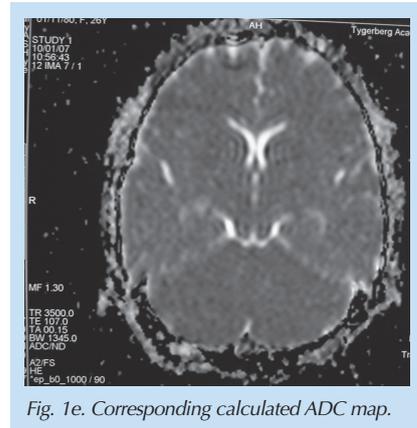


Fig. 1e. Corresponding calculated ADC map.

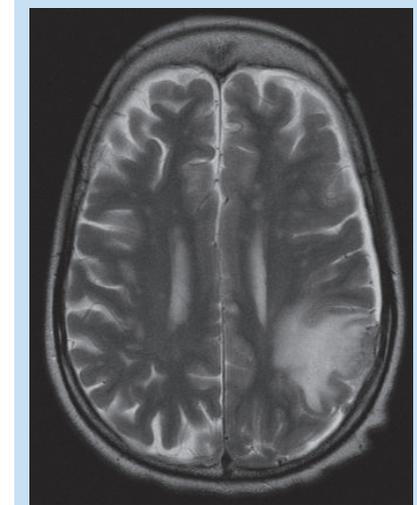


Fig. 2 a. Axial T2WI of a patient with a focal meningoencephalitis and associated vasogenic oedema L posterior parietal as T2 high signal.

When do I use it?

Routine: High speed acquisition sequence and can therefore be incorporated easily into routine MRI protocol.

Specific:

- Cellular metabolism – infarcts. Area of ischaemia ↑DWI and ↓ADC map (Fig. 3 a - c).
- Discrimination of acute (↓ADC map) versus chronic (↑DWI) lesions.
- Epidermoid (↓ADC map) v. arachnoid cyst

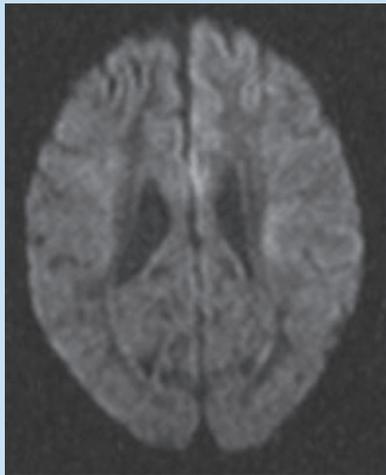


Fig. 2b. DWI ($b = 1000$) demonstrates subtle high signal in the same region.

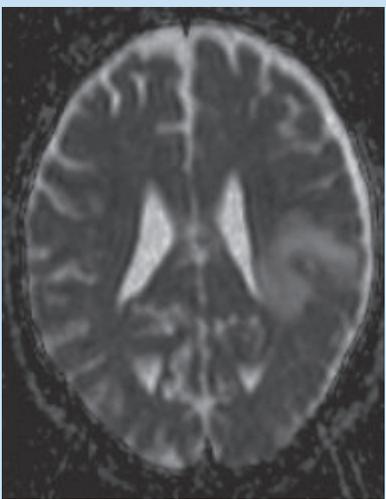


Fig. 2c. On the corresponding ADC map there is no restricted diffusion (white) confirming the T2 shine-through effect.

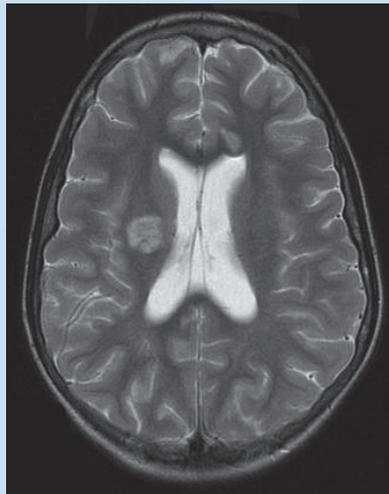


Fig. 3a. Axial T2WI with focal high signal right periventricular, in the centrum semi-ovale representing an acute infarct in a patient with TBM.

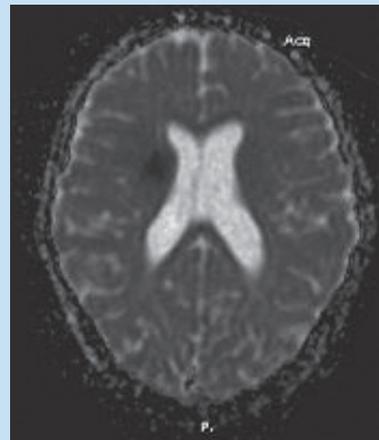
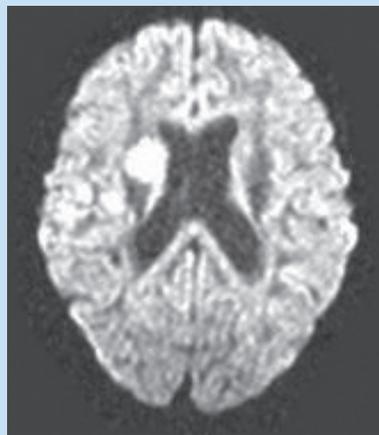


Fig. 3b and c. Corresponding DWI ($b = 1000$) the same lesion appears hyperintense (b), with restricted diffusion demonstrated on the ADC map (black) (c).

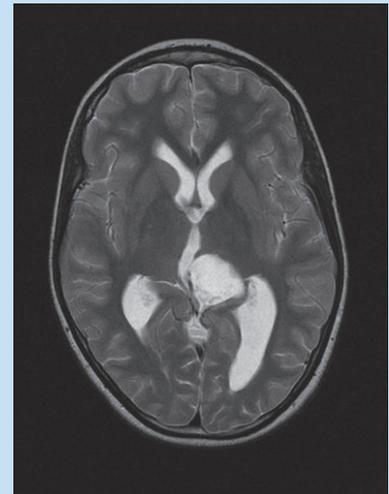


Fig. 4a. Axial T2WI with a well-circumscribed, hyperintense mass lesion in the region of the L quadrigeminal plate cistern.

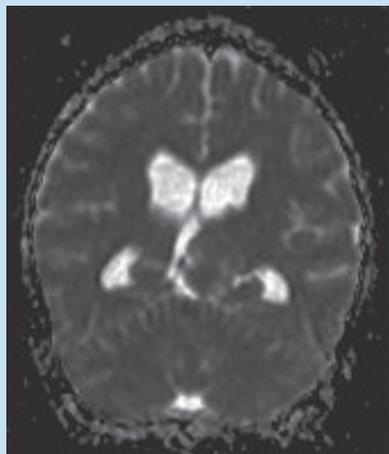
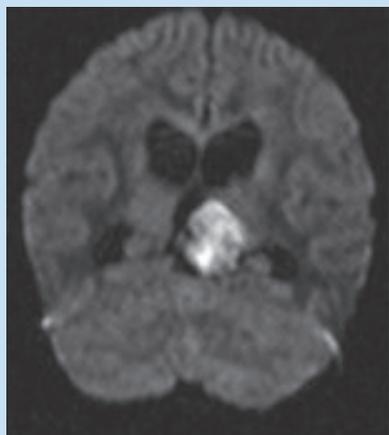


Fig. 4b and c. DWI ($b = 1000$) shows the same lesion to be hyperintense (b), the corresponding ADC map indicates reduced ADC values confirming the suspicion of an epidermoid.

(no restricted diffusion) (Fig. 4 a – c).

- Brain abscess (\uparrow DWI, \downarrow ADC map) v. cystic tumours (usually no restricted diffusion).

Children

- HIE
- Monitoring development of WM tracts in neonates.
- Assessing WM damage as a result of an insult, i.e. infections, inherited metabolic diseases.

Other

- MS – improves specificity of MR on characterising lesions and detects lesions on normal appearing T2WI (\uparrow ADC).
- Neurodegenerative diseases (i.e. Alzheimer's, Huntington's) \uparrow ADC.
- Ischaemic leukoencephalopathy \uparrow ADC.

DTI = Diffusion tensor imaging

- Problem with DWI : dependence on the direction along which D is measured. If regions of anisotropic diffusion are present, DWI / ADC maps can vary considerably depending on the direction of diffusion gradients.
- Anisotropic = D different in various direc-

tions. Isotropic = D the same in various directions.

- These anisotropic 'artefacts' can be eliminated by acquiring the diffusion tensor.
- This basically means measuring diffusion along a large number of directions (> 6).
- Postprocessing of the DTI images can result in both maps in which ischaemic lesions are better delineated - trace ADC maps

and maps in which white matter tracts are highlighted- fractional anisotropy maps.

1. Beaulieu C, D'Arceuil H, Hedehus M, De Crespigny A, Kastrup A, Moseley ME. Diffusion-weighted magnetic resonance imaging: Theory and potential applications to child neurology. *Semin Pediatr Neurol* 1999; 6:87-100.
2. Bitar R, Leung G, Perrng R, et al. MR pulse sequences: What every radiologist wants to know but is afraid to ask. *Radiographics*