26 T1, T2, and Proton Density

MRI offers multiple variables that may be assessed to obtain distinct tissue contrasts based on T1/T2 relaxation times, proton density (PD), magnetization transfer (Chapter 33), susceptibility (Chapter 57), fat (hepatic fat quantification, Chapter 60), incoherent motion (diffusion, Chapter 76), coherent macroscopic motion (blood flow, Chapter 64), blood oxygen level (Chapter 78), proton spectroscopy (Chapter 80), and temperature, amongst others.

The tissue contrast mechanisms discussed in this chapter include PD, T1 relaxation time, and T2 relaxation time. Images are usually acquired for which the contrast is weighted more toward one of these parameters. The key word here is "weighted." Tissue contrast in the image has contributions from each of the various intrinsic contrast mechanisms, but is "weighted" more toward one than the others. In this context, weighting simply means the amount of contribution made to the image contrast associated with the difference between tissues on the basis of the parameter of interest (PD, T1, or T2). This weighting is accomplished by the selection of the timing parameters of the pulse sequence (set prior to scan acquisition). For spin echo sequences, these are the TR (repetition time) and the TE (echo time).

TR primarily controls the amount of T1-weighting, whereas TE primarily controls the amount of T2-weighting. If one wishes to obtain images in which the contrast is weighted more toward T1 (using spin echo or fast spin echo sequences), then a relatively short TR is selected. There is no exact "best" TR, but rather a range to produce T1-weighted images. The range depends on the tissues being imaged as well as the field strength of the MR system. T1 relaxation times lengthen (increase) as field strength increases. At 1.5 T, when acquiring T1-weighted images of the brain, the TR is usually between 400 and 550 msec. Raising the TR will not make the image more T2-weighted, but rather simply reduce the T1-weighting.

A word of caution is warranted, given the previous statements. If scan techniques other than spin echo or fast spin echo are used to produce T1- (or T2-) weighting, the choice of TR and TE will be quite different. For example, the T1-weighted image depicted in **Fig. 26.1a** was performed at 3 T using a gradient echo technique, with TR = 250 msec in this instance. The remainder of the discussion is specifically in reference to spin echo and fast spin echo techniques.

As previously mentioned, TE primarily controls the amount of T2-weighting in an MR image. If one desires a T1-weighted image, a relatively short TE is selected. Often, one selects the shortest TE possible. For spin echo images, short is 25 msec or less. If one desires a T2-weighted image, then the TR is increased to reduce the amount of T1-weighting (usually 2500 msec or higher), and a long TE is selected. For spin echo, this is usually 80 to 120 msec. **Fig. 26.1b** is an example of a T2-weighted spin echo image (long TR/long TE).

To obtain PD-weighted images (**Fig. 26.1c**), one increases the TR to reduce the T1-weighting (again to ≥ 2500 msec) and reduces the TE (to 25 msec or less) to reduce the T2-weighting. Although one may choose to acquire PD-weighted images, in clinical practice T2-weighted fluid-attenuated inversion recovery (FLAIR) sequences (**Fig. 26.1d**) have supplanted PD-weighted scans for imaging of the brain. Indeed there are few remaining clinical applications, outside the musculoskeletal system, for PD-weighted imaging today.

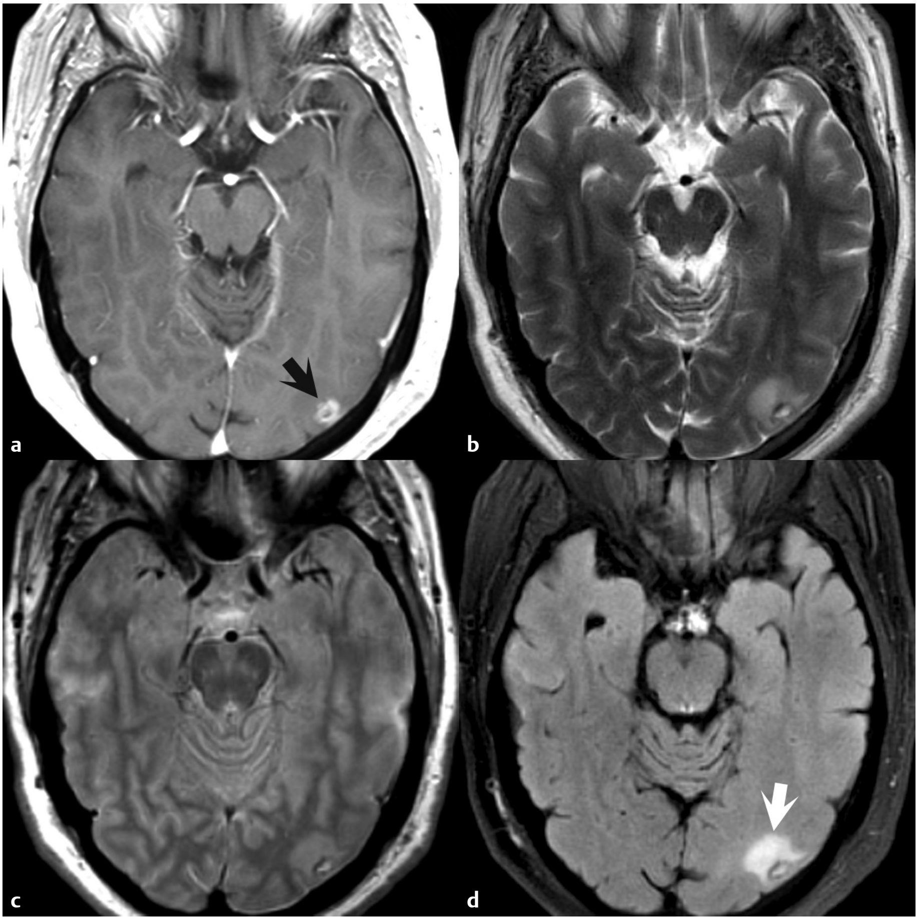

Fig. 26.1

The images presented in **Fig. 26.1** also illustrate the general applicability of the different parameter weightings discussed. T1-weighted scans (**Fig. 26.1a**) find application for depiction of detailed anatomy and detection of contrast enhancement, the latter using a gadolinium chelate (the most commonly employed intravenous MR contrast agent). Fat is high signal intensity, CSF low signal intensity, and white matter is higher signal intensity than gray matter. Depicted well in **Fig. 26.1a** is a metastatic lesion (arrow) from lung carcinoma, due to enhancement on this post-contrast image. Heavily T2-weighted images, such as that illustrated in **Fig. 26.1b**, find application for visualization of fluid (such as CSF) and to a lesser extent edema. Anatomic detail may also be high, depending on the specific technique used. CSF is high signal intensity and the gray–white matter signal intensity ratio is reversed as compared with T1-weighted images. PD-weighted images, illustrated in **Fig. 26.1c**, are no longer used in the brain due to poor contrast between tissues. FLAIR, illustrated in **Fig. 26.1d**, depicts extremely well edema within the brain (with high signal intensity, arrow), being specifically a T2-weighted scan with CSF suppression.