Figure 1. An axial image of the cortex from a 61-year-old woman that shows differentiation of gray and white matter (A) and a detail of leptomeningeal vessels (black arrow) as signal voids perpendicular to the sulcus (B). (FOV = 20 x 20 cm; slice thickness = 2.0 mm; TR = 750 msec; TE = 9.2 ms; matrix 1024 x 1024).
Figure 2. Axial GE images showing details of deep brain structures and microvasculature from a 40-year-old woman. 1 = substantia nigra, 2 = red nucleus, 3 = aqueduct, 4 = internal cerebral veins, 5 = superior colliculus, 6 = mammillary bodies, 7 = globus pallidus, 8 = anterior thalamic vein, 9 = sup. thalamic vein, 10 = transmedullary veins. (GE: FOV = 20 x 20.0 cm, slice thickness = 2.3 mm, TR = 603, TE = 10.0, matrix 1024 x 1024.)
CHAPTER 13 — Clinical Promise: Clinical Imaging at Ultra High Field

Figure 3. Comparisons of brainstem imaging at 8 (A) and 1.5 T (B) with a histological specimen (C). Panel A shows axial gradient echo 8T image from a healthy volunteer (GE: TR = 1000 msec, TE = 7 msec, FOV = 20 cm, matrix 512 x 512 points, slice thickness = 2 mm, receiver bandwidth = 72 kHz). Panel B shows an axial image at 1.5 T with similar parameters (FSE: TR = 750 ms, TE = 8 ms, FOV = 22 cm, slice thickness = 3 mm, receiver bandwidth = 32 kHz). Panel C shows a Lugol-stained histological specimen.

Figure 4. High-resolution axial 8T RARE images at the levels of the ventricles (A, B, C) show high signal intensity confluent white matter changes (white empty arrows) and punctuate white matter lesions in basal ganglia and periventricular white matter (white arrows). 8T GE images (D, E, F) at the level of the ventricles show normal-appearing medullary veins as signal voids. Microvessels with high signal intensity are seen distally to the normal vasculature (white arrows). (GE: BW = 69.4 kHz, FOV = 20 x 20 cm, slice thickness = 2.3 mm, TR = 600 ms, TE = 10 ms, matrix 1024 x 1024; RARE: BW = 69.4 kHz, FOV = 20 x 20 cm², slice thickness 2 mm, TR = 3000 ms, TE = 22 ms, matrix 512 x 512, RARE factor 4.)
Figure 5. 8T GE sagittal image at midline (A) and axial images of the cortex (B) that show calcium and fat deposits within the falx cerebri (white arrow) as prominent areas of low signal intensity and a prominent venous draining of the posterior sagittal sinus in a 52-year-old man with right parietal stroke (black arrow). (GE: BW = 50.0 kHz, FOV = 20 x 20 cm, slice thickness = 5.0 mm, TR = 504.3 ms, TE = 7.0 ms, matrix = 512 x 512.)

(GE: BW = 50.0 kHz, FOV = 20 x 20 cm, slice thickness = 2.3 and 5.0 mm, TE = 12 ms, matrix = 512 x 512 and 1024 x 1024, producing an in-plane pixel size of 390 and 195 microns, respectively. TR = 800 ms was selected to maintain a reasonable imaging time of up to 13 minutes with adequate signal-to-noise ratio. To increase the degree of contrast and $T_2^*$ weighting, the nutation angle was set to approximately 20º and the echo time (TE) was set to 12 ms. RARE: slice thickness = 5 mm, number of echoes (N) = 4, TR = 5000 ms, TE = 18 ms, and matrix size 256 x 256.

1.5T parameters: $T_1$: slice thickness = 5 mm, TR = 500 ms, TE = 14 ms, FOV = 22 x 22 cm, matrix 256 x 192, N = 16; $T_2$: slice thickness 5 mm, TR = 7000 ms, TE = 105 ms, FOV = 22 x 16 cm, matrix 128 x 128, N = 16; FLAIR: slice thickness = 5 mm, TR = 10000 ms, TE = 140 ms, inversion time, TI, = 2200, matrix = 192 x 256, N = 16.)
Figure 7. Comparisons of high-resolution axial 8 T GE (A) and RARE (C) cortical images and corresponding 1.5 T FSE (B) and FLAIR (D) images that show three cortical white matter lesions (black and white arrows, respectively). Panel C also shows prominent perivascular Virchow-spaces (white empty arrow). 8T GE: BW = 69.4 kHz, FOV = 20.0 x 20.0 cm, slice thickness = 2.2 mm, TE = 10.8, TR = 600 ms, matrix 512 x 512. 8T RARE: BW = 50.0 kHz, FOV = 20.0 x 20.0 cm, slice thickness = 3.0 mm, TR = 2500 ms, TE = 30 ms, matrix = 512 x 512, N = 12, flip angle = 60º, RARE factor = 4.
Figure 8. In-vivo MR images through a WHO classification grade III astrocytoma. Panel A: 8T RARE; 512 x 512 matrix; B: 1.5T FSE $T_2$; 256 x 256 matrix; C: 8T GRE; 1024 x 1024 matrix; D: 1.5T GRE; 512 x 512 matrix; E: magnification from box depicted on C. No significant differences were identified on extent of signal abnormality between 8 and 1.5 T. E: High-resolution details of tumor site; arrows and arrowheads indicate microvessels and increased vascular density.
**Figure 9.** Coronal in-situ cadaver image acquired (a) at 8 T with a 2D gradient echo sequence using TR/TE 500/9, flip angle <20°, FOV = 24 cm, 1024 x 1024 matrix size, and 2 mm slice thickness. Not shown are corresponding 1.5T gradient echo images acquired with TR/TE 500/30, flip angle 15°, FOV = 24 cm, 256 x 192 matrix size, and 2 mm slice thickness. Image signal was measured for CSF, white matter, and vessels for the regions indicated on the image.

**Signal intensities**
- Brain = 65-85 (white arrow head)
- CSF = 168 +/- 11 (black arrow)
- Vessel: 10-13 (black arrow head)
- Noise st. dev. = 2-4
- \( \text{SNR} = \frac{S(0)}{\text{SD(noise)}} \)
- CSF: 42.3-84  Brain: 16.4-2 Vessel: 2.5-6.5
- \( \text{CNR} = \frac{S(0)-S(a)}{\text{SD(noise)}} \)
- CSF – vessel: 38-79  Brain-Vessel: 13-37

**Figure 10.** 8T GE axial image, 1024 x 1024, 20-cm FOV, TR = 600 msec, TE = 12 msec, approximately 20° flip angle. GE 8T image of a cadaver in-situ study of patient with a known glioblastoma that involves the splenium of the corpus callosum. Hematoxylin and eosin (H&E) histologic stains of representative specimens were obtained from the corresponding foci depicted by the arrows.
Figure 11. Corresponding FSE $T_2$ 1.5T images (A), post-gadolinium $T_1$ 1.5T (B), cerebral volume map obtained at 1.5T (C), time-intensity curves (D), and GE 8T (E) with magnification (F) of region within white square on 11E. Arrows indicate microvasculature.
Figure 12. 8 Tesla GE images from the same patient depicted in Fig. 11 obtained 3 months later postmortem with a 1024 x 1024 matrix size (A) and a 2048 x 2048 matrix size (B) with corresponding magnification from boxed regions (C and D). Note the improved delineation of the microvasculature (arrows) with the higher matrix size. Additionally, notice that the area surrounding the visualized microvascul arity has a lower signal than the adjacent tumor bed. This loss of signal may be attributed to deoxyhemoglobin within microvessels beyond the resolution of these exams.
Figure 13. Pre- (A) and post- (B) intravenous USPIO administration GE 8T MRI of a Fisher rat bearing an F98 glioma. Note the improved delineation of microvascularity (arrows) in the post-contrast images compared with the non-contrast study.