TABLE 440e-4 COMMON CONTRAINDICATIONS TO MAGNETIC RESONANCE IMAGING

Cardiac pacemaker or permanent pacemaker leads
Internal defibrillatory device
Cochlear prostheses
Bone growth stimulators
Spinal cord stimulators
Electronic infusion devices
Intracranial aneurysm clips (some but not all)
Ocular implants (some) or ocular metallic foreign body
McGee stapedectomy piston prosthesis
Duraphase penile implant
Swan-Ganz catheter
Magnetic stoma plugs
Magnetic dental implants
Magnetic sphincters
Ferromagnetic inferior vena cava filters, coils, stents—safe 6 weeks after implantation
Tattooed eyeliner (contains ferromagnetic material and may irritate eyes)

Note: See also *http://www.mrisafety.com*.

contrast-enhanced MRA has become the standard for extracranial vascular MRA. This technique entails rapid imaging using coronal three-dimensional TOF sequences during a bolus infusion of gadolinium contrast agent. Proper technique and timing of acquisition relative to bolus arrival are critical for success.

MRA has lower spatial resolution compared with conventional film-based angiography, and therefore the detection of small-vessel abnormalities, such as vasculitis and distal vasospasm, is problematic. MRA is also less sensitive to slowly flowing blood and thus may not reliably differentiate complete from near-complete occlusions. Motion, either by the patient or by anatomic structures, may distort the MRA images, creating artifacts. These limitations notwithstanding, MRA has proved useful in evaluation of the extracranial carotid and vertebral circulation as well as of larger-caliber intracranial arteries and dural sinuses. It has also proved useful in the noninvasive detection of intracranial aneurysms and vascular malformations.

ECHO-PLANAR MRI

Recent improvements in gradients, software, and high-speed computer processors now permit extremely rapid MRI of the brain. With echo-planar MRI (EPI), fast gradients are switched on and off at high speeds to create the information used to form an image. In routine spin echo imaging, images of the brain can be obtained in 5–10 min. With EPI, all of the information required for processing an image is accumulated in milliseconds, and the information for the entire brain can be obtained in less than 1–2 min, depending on the degree of resolution required or desired. Fast MRI reduces patient and organ motion and is the basis of perfusion imaging during contrast infusion and kinematic motion studies. EPI is also the sequence used to obtain diffusion imaging and tractography, as well as fMRI and arterial spin-labeled studies **(Figs. 440e-2*H*,** 440e-3, **440e-4*C*, and 440e-6;** and **see Fig. 446-16)**.

Perfusion and diffusion imaging are EPI techniques that are useful in early detection of ischemic injury of the brain and may be useful together to demonstrate infarcted tissue as well as ischemic but potentially viable tissue at risk of infarction (e.g., the ischemic penumbra). Diffusion-weighted imaging (DWI) assesses microscopic motion of water; abnormal restriction of motion appears as relative high-signal intensity on diffusion-weighted images. Infarcted tissue reduces the water motion within cells and in the interstitial tissues, resulting in high signal on DWI. DWI is the most sensitive technique for detection of acute cerebral infarction of <7 days in duration (Fig. 440e-2*H*). It is also quite sensitive for detecting dying or dead brain tissue secondary to encephalitis, as well as abscess formation (Fig. 440e-3*B*).

Perfusion MRI involves the acquisition of fast echo planar gradient images during a rapid intravenous bolus of gadolinium contrast material. Relative cerebral blood volume, mean transit time, and cerebral blood flow maps are then derived. Delay in mean transit time and reduction in cerebral blood volume and cerebral blood flow are typical of infarction. In the setting of reduced blood flow, a prolonged mean transit time of contrast but normal or elevated cerebral blood volume may indicate tissue supplied by collateral flow that is at risk of infarction. Perfusion MRI imaging can also be used in the assessment of brain tumors to differentiate intraaxial primary tumors, whose BBB is relatively intact, from extraaxial tumors or metastases, which demonstrate a relatively more permeable BBB.

Diffusion tensor imaging is derived from diffusion MRI imaging sequences, which assesses the direction of microscopic motion of water along white matter tracts. This technique has great potential in the assessment of brain maturation as well as disease entities that undermine the integrity of the white matter architecture. It has proven valuable in preoperative assessment of subcortical white matter tract anatomy prior to brain tumor surgery (Fig. 440e-6).

fMRI of the brain is an EPI technique that localizes regions of activity in the brain following task activation. Neuronal activity elicits a slight increase in the delivery of oxygenated blood flow to a specific region of activated brain. This results in an alteration in the balance of oxyhemoglobin and deoxyhemoglobin, which yields a 2–3% increase in signal intensity within veins and local capillaries. Further studies will determine whether these techniques are cost effective or clinically useful, but currently, preoperative somatosensory and auditory cortex localization is possible. This technique has proved useful to neuroscientists interested in interrogating the localization of certain brain functions.

ARTERIAL SPIN LABELING

ASL is a quantitative noninvasive MR technique that measures cerebral blood flow. Blood traversing in the neck is labeled by an MR pulse and then imaged in the brain after a short delay. The signal in the brain is reflective of blood flow. ASL is an especially important technique for patients with kidney failure and for pediatric patients in whom the use of radioactive tracers or exogenous contrast agents is contraindicated. Increased cerebral flow is more easily identified than slow flow, which can be sometimes difficult to quantify. This technique has also been shown useful in detecting arterial venous shunting in arteriovenous malformations and arteriovenous fistulas.

MAGNETIC RESONANCE NEUROGRAPHY

MRN is a T2W MR technique that shows promise in detecting increased signal in irritated, inflamed, or infiltrated peripheral nerves. Images are obtained with fat-suppressed fast spin echo imaging or short inversion recovery sequences. Irritated or infiltrated nerves will demonstrate high signal on T2W imaging. This is indicated in patients with radiculopathy whose conventional MR studies of the spine are normal, or in those suspected of peripheral nerve entrapment or trauma.

POSITRON EMISSION TOMOGRAPHY

PET relies on the detection of positrons emitted during the decay of a radionuclide that has been injected into a patient. The most frequently used moiety is 2-[^{18}F]fluoro-2-deoxy-D-glucose (FDG), which is an analogue of glucose and is taken up by cells competitively with 2-deoxyglucose. Multiple images of glucose uptake activity are formed after 45–60 min. Images reveal differences in regional glucose activity among normal and pathologic brain structures. FDG-PET is used primarily for the detection of extracranial metastatic disease; however, a lower activity of FDG in the parietal lobes is associated with Alzheimer's disease, a finding that may simply reflect atrophy that occurs in the later stages of the disease. Combination PET-CT scanners, in which both CT and PET are obtained at one sitting, have largely replaced PET scans alone for most clinical indications. MR-PET scanners have also