Neuroimaging in neuroophthalmology

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Recent advancements in the speed and accuracy of data acquisition and resolution of neuroimaging and interventional techniques have revolutionized the early anatomical and functional diagnosis, prognosis, and treatment of many neuroophthalmological disorders. The relatively new techniques include magnetic resonance (MR) spectroscopy, computed tomography angiography, positron emission tomography, and functional MR imaging. In this paper the author describes the principles of the current techniques used by neuroophthalmologists and their value in the diagnosis, localization, and treatment of various afferent and efferent visual and ocular disorders. (DOI: 10.3171/FOC-07/11/E9)

KEY WORDS • angiography • computed tomography • magnetic resonance imaging • neuroophthalmology

Neuroophthalmologist’s Role in Neuroimaging

Although modern neuroimaging modalities play a vital role in the management of many neuroophthalmological disorders, they should not be used as a substitute for an excellent and thorough clinical evaluation.

Brain MR images are an integral part of diagnostic criteria or prognostic evidence in neuroophthalmological diseases. For example, a positive MR imaging finding of a plaque lesion is both diagnostic and prognostic in patients with demyelinating optic neuritis. The Optic Neuritis Treatment Trial (ONTT study) concluded that the 10-year risk of MS following an initial episode of acute optic neuritis was significantly higher if there was a single brain MR imaging–documented lesion; higher numbers of lesions did not appreciably increase that risk.

Also, a negative neuroimaging finding is one of the criteria for making a diagnosis of pseudotumor cerebri or idiopathic intracranial hypertension. Furthermore, live 3D localization of orbital and intracranial tumors has improved the results of surgery, and functional imaging involving PET and fMR imaging has improved our understanding of the functional basis of disease.

Computed Tomography of the Orbit and Brain

The data points obtained with a CT scanner’s x-ray detector are analyzed using a computer, and the scan is represented as pixels of a numerical value resulting from the attenuation of the x-ray beams. This attenuation coefficient (Hounsfield unit; ranges from −1000 H for air, to 0 H for water, and to +1000 H for dense bone) provides a numerical matrix that helps the computer to reconstruct an image.

For neuroophthalmologists and orbital surgeons, the clinical indications for CT scanning are as follows: 1) orbital disorders (thyroid [Fig. 1], trauma, drusen, infection, and tumor), 2) sinus and lacrimal disorders, 3) calcification, 4) brain imaging evidence of acute intracranial bleeds and contraindications to MR imaging, and 5) osseous abnormalities including erosion, remodeling, hyperostosis, fractures, and calcifications. The disadvantages of CT scanning include exposure to radiation, no direct sagittal vantage, possibility of reactions to contrast agent, and dental or osseous artifacts. The x-ray dose for a standard scan is 3–5 rad and 10 rad for a high-resolution scan, which is comparable with a standard radiograph dosage. Contrast enhancement with iodinated dyes is used to detect intracranial extension of orbital tumors and to evaluate chiasmal and parachiasmal lesions. True coronal slices at intervals of 3 mm or less offer the best orientation for examining the orbital contents—to distinguish patterns of extraocular enlargement in thyroid eye disease and orbital pseudotumor, optic nerve lesions such as glioma and nerve sheath meningioma, and enlargement of the superior ophthalmic veins in arteriovenous fistulas. Computed tomography has the advantage over MR imaging of requiring less time, being less expensive, and being applicable in patients in whom MR imaging is contraindicated or in whom it cannot be performed.

Newer-generation scanners employ thinner sections (which may be as small as 1-mm thick) with less volume averaging, faster scan times, decreased motion artifact, reduced radiation exposure, more choices of position, and...
new algorithms that enable sagittal and multiplanar reconstructions. Helical or spiral scanning has reduced acquisition time further because it enables continuous data acquisition as the patient table is moved.

**Application of Ultrasonography**

In B-scan mode, ultrasonography provides a useful inexpensive, rapid, and easily tolerated adjunct to CT scanning for orbital disorders because it can distinguish solid from cystic lesions, show an enlarged superior ophthalmic vein and extraocular muscles, or demonstrate an optic nerve head drusen. Also, transcranial Doppler ultrasonography can be used to assess the patency and location of the temporal artery in patients being evaluated for temporal arthritis.

**Magnetic Resonance Tomography and MR Angiography**

When body tissue is placed in a strong magnetic field (strength of the magnet that is commercially used varies from 1–3 tesla), mobile hydrogen protons align to the magnetic field; the protons are then exposed to a brief radiofrequency pulse at a specific (Larmor) frequency that results in more protons being antiparallel and, thus, neutralizing more protons in the opposite direction. The consequence is a decrease in the longitudinal magnetization. The radiofrequency pulse can also cause the protons to precess in phase or be synchronous, resulting in a new magnetic vector called the “transverse magnetization.” Computer analysis of the frequency and phase-encoded information from each slice is converted into spatial localization, and an image is created using algorithms similar to those in CT scanning.

The common pulse sequences and techniques used in MR imaging are: spin echo, gradient echo pulse, FLAIR, diffusion weighting, and fat suppression. In FLAIR the sequences help reveal demyelination or MS plaques in the central nervous system (Fig. 2), tumors, and ischemic lesions that often are not visible on routine MR imaging. The cerebrospinal fluid signal is strongly attenuated, accentuating periventricular and extraaxial disease near the brain surface. Fat suppression is a technique that dephases the fat in the orbit, allowing visibility of small lesions in this location. Fat-suppression techniques particularly improve the detection of disease in the orbit, the pituitary gland, and around the skull base, which has fat in the bone marrow, but also may introduce artifacts, particularly in the lower aspects of the orbit. To measure the phenomenon of slow water diffusion in tissues, which generally increases in pathologic states, diffusion weighted images help in the evaluation of cytotoxic edema, demyelinating plaques, inflammation, tumors, and early brain infarction, as well as to define internal tissue architecture. Acute brain infarction is the most widely used clinical application of diffusion weighted imaging.

Magnetic resonance angiography does not simply display vascular anatomy, as in contrast angiography. Instead, it extrapolates physiological data obtained from flow characteristics of protons to demonstrate anatomy. Thus, in MR angiography, the diameter of the blood vessels sometimes may appear smaller than that shown on conventional angiograms (Fig. 3). Magnetic resonance angiography indications in neuroophthalmology include the evaluation of the extracranial circulation (carotid artery stenosis, plaques, and dissections in the evaluation of transient visual loss) and the intracranial circulation (aneurysms, AVMs, occlusive disease, and carotid artery fistulas). The limitations of MR angiography are as follows: 1) it cannot detect aneurysms < 5 mm in diameter, 2) it can yield false-positive results in tightly wound vessel loops, and 3) it has a tendency to exaggerate vessel stenosis. Conversely, MR angiography is an excellent noninvasive technique for detecting asymptomatic aneurysms > 5 mm in size.

Contrast enhancement is produced using intravenous Gd-diethylenetriamine pentaacetic acid (dose 0.1 mmol/kg), a paramagnetic material that remains extracellular, does not cross the intact blood–brain barrier, and is excreted renally. Because it shortens the T1 relaxation time, Gd typically is used for T1-weighted imaging, in which it provides a bright signal. For orbital studies, T1-weighted techniques are combined with a fat-suppression technique to enhance lesions so that they may be differentiated from the otherwise bright orbital fat signal. Hemolytic and sickle cell anemia are relative contraindications, whereas rare allergic reactions include hives, bronchospasm, headache, hypotension, or a transient rise in serum iron or bilirubin levels.

**Computed Tomography Angiography**

This is a minimally invasive technology that involves an intravenous bolus injection of iodinated contrast, followed by high-speed spiral CT scanning with computer-generated 3D images of medium- and large-sized arteries.

The advantages of CT angiography over standard MR angiography are the rapidity of examination and images of the true lumen (rather than flow within a vessel), as well as the fact that it can be performed in patients with claustrophobia, pacemakers, and older aneurysm clips. The advantages of CT angiography include detection of aneurysms as small as 1.7 mm, superior imaging of the aneurysm neck, better delineation of surgical anatomy, characterization of mural thrombi, detection of vasospasm, arterial stenosis, and carotid–cavernous fistulas, and provision of rotating 3D images. The drawbacks of CT angiography include difficult detection and delineation of cavernous sinus and posterior inferior cerebellar artery aneurysms, feeding vessels for dural carotid–cavernous fistulas, and risks involving radiation exposure and contrast agents.

**Computed Tomography Angiography or MR angiography?**

In the treatment of patients with intracranial aneurysms and especially in the evaluation of patients with painful partial cranial nerve III palsy to rule out posterior communicating artery aneurysms, the commonly asked question is which imaging modality is superior—CT angiography or MR angiography? (Table 1) Sometimes, the easy answer is that it depends on the local institutional expertise and the neuroradiologist reading the films. However, clinical data have shown that contrast-enhanced 3-tesla MR angiography was comparable in image quality with time of flight MR angiography and CT angiography. While other reports have shown that a 7-mm posterior communicating artery aneurysm was missed by brain MR imaging and MR angiography, but detected by CT angiography. Further-
more, it has been shown that CT angiography was better in detecting traumatic aneurysms in patients with skull base fractures.\textsuperscript{44} It seems that newer machines have increased in resolution enough to reliably detect aneurysms as small as 3 mm.

Conventional Catheter-Based Angiography and Angioembolization

Interventional neuroradiology, currently a fascinating field of neuroradiology, provides a relatively safe and reliable alternative to neurosurgery.\textsuperscript{43} It involves the introduction of coaxial systems of extremely flexible microcatheters, balloons, coils, chemical agents, and other devices in the cerebral vascular system for diagnostic and therapeutic purposes. Common indications are AVMs and carotid–cavernous and dural fistulas in which Guglielmi detachable coils are placed (Target Therapeutics); the risks and complications include local hematomas ([\(\leq 15\%\)) at the site of injection, commonly the femoral artery), vessel wall dissection ([\(< 1\%\)) emboli, and transient ischemic attacks or cerebral infarction (1.6%).\textsuperscript{14,30}

Conventional cerebral angiography remains the gold standard for accurate detection and localization of small intracranial aneurysms, in the presence or absence of subarachnoid hemorrhage.

Magnetic Resonance Spectroscopy and Functional Neuroimaging

Recent advances in neuroimaging technology with PET, SPECT, MR spectroscopy, and fMR imaging have permitted new understanding of the neuroanatomical basis of pathophysiological phenomena of vision. Current applications of functional imaging include detection of hypermetabolic states associated with tumor, differentiation of tumor from areas of radiation-induced necrosis, localization of seizure foci, detection of ischemic regions, evaluation of biochemical changes associated with cognitive and psychiatric abnormalities and their response to pharmaceutical intervention, and drug localization in the brain.
Magnetic Resonance Spectroscopy

Magnetic resonance spectroscopy is used for diagnostic biochemistry in vivo and is based on the same principle previously used in analytical chemistry to obtain MR spectra. With this modality, studies of cerebral ischemia are confined solely to proton (1H) and 31P because of their intrinsically higher sensitivity compared with other nuclear species. Neurospectroscopy is synonymous with proton MR spectroscopy (higher sensitivity than 31P MR spectroscopy), which provides results that are easy to interpret, uses small voxel size (1 cm$^3$), and enables the detection of compounds such as $\gamma$-acetylaspartate, creatine, choline, lactate, and inositol$^{11}$ (Fig. 5). Acquiring and interpreting spectra form the basis of a clinical report. Pathological entities documented by MR spectroscopy include brain tumor, stroke, focal cerebral lesions, MS, and intracranial hemorrhage.$^{20}$ An acutely ischemic brain produces lactate by anaerobic metabolism during the first 2–3 days after injury, which can be detected by MR spectroscopy. With the advent of MR spectroscopy and the use of multiple MR modalities (MR imaging, MR angiography, perfusion weighted MR imaging), it is now possible to evaluate extensively not only regions of cerebral injury but regions at risk of infarction, and the modalities are very useful in guiding biopsies of brain tumors.$^{38}$ Another approach to functional imaging that correlates MR imaging–delineated anatomy with magnetoencephalography, which is a mapping of the magnetic flux, is induced by the background or evoked electrical activity of the brain.

Positron Emission Tomography and SPECT

Positron emission tomography and SPECT are performed with systemically administered isotopes (such as FDG, $^{15}$NH$_3$, $^{18}$F) that emit protons to image biological processes that measure regional cerebral blood flow and glucose consumption and thus, indirectly, tissue metabolism.$^{40}$ These modalities trace the transport and phosphorylation of glucose, and the glucose-linked positron emits two photons, which strike detectors placed around the head. The greater the glucose metabolism of the tissue, the more photons are emitted. Because FDG cannot diffuse from the brain, it remains trapped intracellularly and, thus, is an excellent agent to use for cerebral metabolism imaging$^{27}$ (Fig. 6).

Tomographic images are obtained in a manner similar to those for MR imaging or CT scanning. Cerebral blood flow, oxygen utilization, and glucose utilization may be measured. For the most part, PET scanning is used for evaluation of ischemia/stroke, tumors, migraine, blepharospasm, cortical visual loss, and mapping of the visual cortex, among others.$^{18}$ The shortcoming of PET is its relatively poor resolution of 5–7 mm, high cost, and limited availability because of the requirement for proximity to a cyclotron to produce the radioisotopes.

Positron emission tomography is currently used by vision neuroscientists and researchers to study the anatomical correlates of visual function, and the neuroophthalmologists and orbital surgeons use PET imaging for functional correlates of human diseases including cancers and metastatic disease. Richter et al.$^{29}$ used PET scanning to identi-

### TABLE 1

<table>
<thead>
<tr>
<th>Pupil</th>
<th>Total</th>
<th>Partial</th>
<th>None</th>
</tr>
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<tbody>
<tr>
<td>pupil involved</td>
<td>high (MRA/CTA)</td>
<td>highest (MRA/CTA→angio)</td>
<td>little/none</td>
</tr>
<tr>
<td>normal pupil</td>
<td>lowest (?MRI)</td>
<td>low (MRA/close FU)</td>
<td>not applicable</td>
</tr>
</tbody>
</table>

* The modifier indicates the relative risk of aneurysm formation and the parenthetical information underscores the optimum detection modality. Note that the risk is highest of an aneurysm in a patient with a pupil involving partial cranial nerve III palsy. Abbreviations: angio = angiography; CTA = CT angiography; FU = follow-up; MRA = MR angiography.
ify the networks involved in the regulation of visual accommodation/vergence by contrasting the cortical functions subservient to eye–lens accommodation with those evoked by foveal fixation. Neural circuits activated selectively during the near/far response to blur cues over those during constant visual fixation occupy posterior structures that include occipital visual regions, cerebellar hemispheres and vermis, and temporal cortex. We know that color vision is processed primarily in the ventral stream. In an elegant study, the authors used PET and fMR imaging in humans to investigate whether the ventral and dorsal visual streams cooperate when active judgments about color have to be made. The visual activation sites were identified by retinotopic mapping and cortical flattening. Cortical regions involved in dimming detection and motor output included area V3A, hMT/V5+, lateral occipital sulcus, posterior dorsal intraparietal sulcus, primary motor cortex, and supplementary motor area. These experiments demonstrated that, even with color as the attribute, successive discrimination, in which a decision process has to link visual signals to motor responses, involves both ventral and dorsal visual stream areas.7

Positron emission tomography can also be useful in the study of visual pathways involved in amblyopia. It was used to study the blood flow response in the primary visual cortex (V1) to two visual stimuli: low temporal frequency (6 Hz) to activate the parvocellular system and high temporal frequency (25 Hz) to activate the magnocellular system to investigate pathophysiological mechanism of amblyopia. The experiments in humans revealed that there was a decreased activation of blood flow in the contralateral visual cortex by low temporal frequency stimuli, which supports the hypothesis that the parvocellular pathway in amblyopic eyes is depressed.25 This neuroimaging modality has found a great use in the functional evaluation of malignant tumors of the eye (malignant melanoma of the choroid, retinoblastoma, metastatic disease, and lymphomas) and brain tumors including pituitary tumors.12,26,34,39

Visual and oculomotor changes are known to occur following a stroke. The oculomotor repair during the period just after a stroke has been studied using PET.22 Positron emission tomography is also an effective tool to study the effects of pharmaceutical agents such as neuroprotectants, as well as new and evolving drugs for dementia, Alzheimer disease, and various optic neuropathies. In one such study, Bose et al.5 found that metabolic imaging with FDG–PET

![Fig. 5. Results of MR spectroscopy in a patient with a malignant brain lesion with corresponding alteration of the chemical levels. Provided courtesy of Dr. Anton Hasso.](image-url)
scans demonstrated functional changes in the primary visual cortex and visual association areas in all their patients with nonarteritic ischemic optic neuropathy. Therapy with pentoxifylline for 3 months appeared to reverse or neutralize the changes observed in the brain.

In SPECT, isotopes such as $^{123}$I-iodoamphetamine or $^{99m}$Tc are incorporated into biologically active compounds, and the CT scanner plots their distribution. The information provided by SPECT is similar to that of PET, but SPECT does not require the use of isotopes produced in a cyclotron. However, resolution is even poorer with SPECT. The future of these technologies is very bright, and with the advent of micro-PET, higher-resolution receptor and genetic imaging will provide greater understanding of the workings and abnormalities of the human brain.

**Functional MR Imaging**

Compared with PET and SPECT, fMR imaging is a more current, less invasive technology for mapping cerebral cortical activation in response to specific cognitive, sensory, or motor tasks performed by an individual. The basis for most fMR imaging today is pixel-by-pixel measurement of increases in blood oxygenation level during the performance of specific tasks (blood oxygen level–dependent imaging) (Fig. 7).

The advantage of this technique is that no injection is required. Functional MR imaging is evolving rapidly as a useful experimental and clinical tool for functional cortical mapping, psychophysical tests, brain tumor mapping, and understanding the basis of higher visual functioning. It has been recently studied to demonstrate the functional and neuroanatomical correlates of visual processing. Visual, oculomotor, and, recently, cognitive functions of the superior colliculi were studied in humans using fMR imaging. This was used to examine activity changes in the human tectum and the lateral geniculate nuclei; blood oxygen level–dependent signals in the superior colliculi were compared with activity in the inferior colliculi and lateral geniculate nuclei, and the results support a dependency of superior colliculi activity on functions beyond oculomotor control and visual processing. Recent anatomical evidence obtained in nonhuman primates indicates that cingulate

![Fig. 6. Three-dimensional surface renderings of mean differences in regional metabolic brain activity (visual cortex) of PET findings. The areas in blue represent a net decrease in regional metabolic activity compared with that noted in controls.](image)

![FIG. 7. Brain fMR imaging data obtained while the patient was observing a moving target. Note that this modality has better temporal resolution, whereas PET (Fig. 6) has superior spatial resolution.](image)
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TABLE 2

<table>
<thead>
<tr>
<th>Location</th>
<th>Clinical Condition</th>
<th>Neuroimaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>orbit</td>
<td>tumors</td>
<td>USG (solid vs. cystic), CT (noncontrast)</td>
</tr>
<tr>
<td></td>
<td>thyroid ophthalmopathy, trauma, hemorrhage, foreign body</td>
<td>MRI (soft tissue, fat suppression)</td>
</tr>
<tr>
<td></td>
<td>optic nerve tumor, orbital apex tumor</td>
<td>noncontrast CT (preferred)</td>
</tr>
<tr>
<td>cavernous sinus, chiasm,</td>
<td>aneurysm (e.g., CN III palsy)</td>
<td>Gd-enhanced, fat-suppressed MRI</td>
</tr>
<tr>
<td>parasellar region</td>
<td>aneurysm w/ bleeding</td>
<td>high-resolution contrast CT (fine cuts), MRI</td>
</tr>
<tr>
<td>retrochiasmal area &amp;</td>
<td>aneurysm or AVM w/ bleed</td>
<td>Gd-enhanced MRI, MRA, angiography</td>
</tr>
<tr>
<td>posterior fossa brain</td>
<td></td>
<td>noncontrast CT</td>
</tr>
<tr>
<td></td>
<td>intracerebral hemorrhage</td>
<td>B-scan USG (optic sheath dilation)</td>
</tr>
<tr>
<td></td>
<td>1) acute (intracellular Fe**+/metHb)</td>
<td>Gd-enhanced MRI (p/o tumors)</td>
</tr>
<tr>
<td></td>
<td>2) subacute (extracellular Fe**+/metHb)</td>
<td>MR venogram (venous thrombosis)</td>
</tr>
<tr>
<td></td>
<td>3) chronic (metHb/hemosiderin)</td>
<td>Gd-enhanced MRI, T2, FLAIR (periventricular plaques)</td>
</tr>
<tr>
<td></td>
<td>papillodema</td>
<td>carotid Doppler USG, MRA, CTA, angiography</td>
</tr>
<tr>
<td>carotid &amp; vertebral arteries</td>
<td>stenosis, dissection, plaques, evaluation of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>amaurosis</td>
<td></td>
</tr>
<tr>
<td>globe (eyeball)</td>
<td>optic disc drusen</td>
<td>B-scan USG, noncontrast CT</td>
</tr>
<tr>
<td></td>
<td>tumor, trauma, calcification</td>
<td>noncontrast CT</td>
</tr>
</tbody>
</table>

* Adapted from Bose S: Principles of Imaging in Neuro-Ophtalmology, in Yanoff M, Duker JS (eds): Ophthalmology, ed 2. St. Louis: Mosby, Inc. Abbreviations: CN = cranial nerve; Fe**+ = ferrous iron; Fe**+/metHb = iron methemoglobin; Fe**++ = ferric iron; MRV = MR venography; USG = ultrasonography.
† Modifier describes density appearance on CT scanning.
‡ Modifier describes T1-weighted signal of MR imaging.
§ Modifier describes T2-weighted signal of MR imaging.

motor areas play a substantial role in the cortical control of upper facial movement. Using fMR imaging in humans, the authors concluded that direct cortical innervation of the facial subnuclei from the cingulate motor areas might control upper face movement in humans, as previously implied in nonhuman primates. Deciding where to look is mandatory to explore the visual world. Using event-related functional MR imaging, the authors found that self-initiation of saccades, before their execution, was specifically associated with frontal lobe activation in the dorsolateral prefrontal cortex and in the right presupplementary eye field and frontal eye fields, suggesting the roles of these areas in the decision process of where to look when facing two possible visual targets. Functional neuroimaging studies of eye movement control have also been useful for investigating the interaction of cognitive and sensorimotor brain systems. Studies of antisaccades, memory-guided saccades, and predictive saccades have helped clarify how cognitive brain systems support contextually guided and internally generated action. Cognitive and sensorimotor eye movement paradigms are being used to develop a better understanding of life span changes in neurocognitive systems from childhood to late life, as well as in behavioral and systems-level brain abnormalities in neuropsychiatric disorders.

Optic neuritis is the first clinical manifestation in approximately 20% of patients with MS and is characterized by visual loss, retrobulbar pain, dyschromatopsia, decreased color and contrast sensitivity, delayed visual evoked potentials, and visual field defects. Spontaneous recovery of vision typically occurs within weeks or months after onset, depending on the resolution of inflammation, remyelination, restoration of conduction in axons that remain demyelinated, and neuronal plasticity in the cortical and subcortical visual pathways. In a study to assess where recovery occurs along the visual pathway, visual activation was studied in the lateral geniculate nucleus, the main thalamic relay nucleus in the visual pathway, and in 3 areas of the visual cortex (the lateral occipital complexes, V1, and V2) by using fMR imaging. The investigators found that early compensatory changes were established in the acute phase of optic neuritis in the lateral geniculate nucleus and that these may indicate very early plasticity of the visual pathways. Despite mapping tools for the central visual field, delineation of peripheral visual field representations in the human cortex has remained a challenge. Functional MR imaging mapping has now enabled efficient and robust retinotopic mapping of a wide visual field, which can, at low cost, be adapted to any clinical environment with visual back-projection system.

Functional MR imaging is a possible means for quantifying cortical neurodegeneration in POAG. The functional organization of the primary visual cortex (V1) and damage to the optic disc in humans with POAG was measured using the fMR imaging response to a novel method for projecting scotomas onto the flattened cortical representation. The resultant fMR imaging response was compared with interocular differences in the retinal nerve fiber layer or the mean height contour for analogous regions of the visual field. The authors demonstrated that fMR imaging respons-
es to visual stimulation were related to differences in retinal nerve fiber layer thickness or mean height contour between the eyes. Thus, cortical activity in human V1 was altered in these patients with POAG in a manner consistent with damage to the optic disc.9

Strategies of Imaging in Neuroophthalmology

General guidelines for the choice of neuroimaging modality are summarized in Table 2. Computed tomography scanning is useful for the evaluation of patients with orbital disease (tumor, trauma, and thyroid) and in those with acute intracranial bleeding. It is important to remember that head CT scans should not be used to interpret orbital disease, and separate orbital scans should be obtained. Orbital scans require negative angulations, parallel to the orbital floor, whereas head scans require positive angulations. Also, the neuroophthalmologist should specifically order coronal views of orbits (as preferred to reconstructions) in addition to standard axial views for orbital CT scans. Gadolinium-enhanced, fat-suppression MR imaging generally best demonstrates diseases of the optic nerve, which include tumors (such as glioma, meningioma, and hemangioma), radiation-induced damage, demyelinating disease, and inflammatory damage (such as sarcoidosis). Papilledema can be evaluated using B-scan ultrasonography to look for a dilated optic nerve sheath and confirmed by a decrease in the diameter of the sheath with abduction (or adduction) of the eye by 30°. Brain MR imaging in cases of papilledema will show slit ventricles, and a different sequence for the veins (MR venogram) may reveal a venous thrombosis. Optic nerve drusen, often calcified, may be seen with B-scan ultrasonography, CT, MR imaging, or autofluorescence imaging. For most sellar and parasellar lesions, MR imaging usually is the study of choice. The Optic Neuritis Treatment Trial and the Controlled High-Risk Avonex Multiple Sclerosis study have found MR imaging changes to be of diagnostic and predictive value.1

Combining an understanding of neuroophthalmological anatomy with proper imaging techniques provides a powerful method to detect lesions involving the afferent and efferent visual pathways. Precise documentation of the extent of injury within the nervous system is becoming increasingly important to assess and monitor the effect of neurological therapies.10 On the contrary, the diagnostic yield of neuroimaging in patients with normal examination findings and isolated, unilateral eye/facial pain referred to a neuroophthalmologist is low.16 Modern advances in speed and resolution will continue to amaze us as is seen in the 12-tesla MR imaging picture of the postmortem human optic nerve that resembles a histopathological section (Fig. 8).31

References


Fig. 8. An imaging “section” of the optic nerve seen using a 12-tesla ultra–high resolution MR imaging system. The arrows point to the location of the lamina cribrosa.
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