MR IMAGING OF THE CAVERNOUS SINUS

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I. INTRODUCTION

Due to its unique location lateral to the pituitary fossa, inferior to the optic chiasm, and encasing cranial nerves III, IV, V1, V2, and VI, the cavernous sinus region has held great interest to the neuro-ophthalmologist. Recent advances in neurosurgical technique allowing microsurgical dissection within the sinus itself make identification and exact location of lesions increasingly important. While dynamic CT scanning has added significantly to the non-invasive evaluation of the cavernous sinus, MR imaging promises to further enhance our ability to accurately image the cavernous sinus and its contents. MRI has several obvious advantages, including the absence of radiation, direct multiplanar imaging, the absence of bone and dental artifact, and the avoidance of iodinated contrast.

II. TECHNIQUE

A conventional head coil is routinely used in evaluating the cavernous sinus, as the structures are too deep to derive any added benefit from surface coils. The greatest anatomic detail is obtained from T1 weighted spin-echo images, utilizing a short TR/TE. Most centers use a TR less than 800 and a TE less than 25 milliseconds, utilizing a 256 x 256 matrix with 3 mm cuts and two excitations. While anatomic detail is greater with T1 weighted images, T2 weighting with a long TR/TE helps characterize tissues, and may cause some tumors to stand out more boldly from the background. Higher signal to noise ratios also add to the increased sensitivity of MR. A higher signal to noise ratio may be obtained by increasing the field strength of the magnet, and by increasing the number of excitations. A recent paper by Daniels indicates that using both spin-echo T1 weighted images, and a gradient recalled echo sequence, they were better able to characterize masses within the cavernous sinus. He used a gradient recalled echo sequence with a TR of 100, TE of 15, with four excitations, with a 256 x 256 matrix, 90 degree flip angle, and 3 mm slices. They felt that this combination of sequences enabled them to differentiate the normal cavernous sinus venous spaces from tumor, as well as visualizing the intracavernous sinus contents. Since this paper appeared one year ago, further literature has not been forthcoming, and this has not been utilized as a routine protocol in most centers.

On T1 weighted spin-echo images, cranial nerve signal is equal to that of corpus collosum. Cranial nerves III and IV are usually seen as a single structure. Meckel's cave is best seen with T1 weighted images, and shows a signal that is slightly increased from that of cerebrospinal fluid. The lateral wall of the cavernous sinus is always seen, and appears as a low intensity signal. The medial wall of the cavernous sinus which separates the pituitary fossa from the cavernous sinus border is rarely seen, and therefore of limited diagnostic utility. On MRI the normal cavernous sinus usually appears as a symmetric structure with several venous spaces. The venous spaces include a constant large space, inferolateral to the horizontal portion of the cavernous carotid artery, a space that is often asymmetric and inconsistently seen medial to the artery, and a space between the artery and the sphenoid bone. The venous spaces appear as an area of low intensity on T1 weighted sequences due to the flow of blood. There may be significant variability in the intensity of the images in different subjects depending on the actual flow rate.

Gadolinium-DPTA has added much to the sensitivity and specificity of MR imaging. Gadolinium leads to moderate enhancement of the venous spaces of the cavernous sinus, pituitary stalk and gland, and the cavernous portion of the cranial nerves and adjacent dura on T1 weighted images. On occasion this may lead to obscuration of a lesion when using gadolinium that may be better seen without gadolinium. Scanning twenty to thirty minutes after the infusion of gadolinium may lead to continued enhancement of a mass lesion with washout of normal cavernous sinus enhancement. For highest yield in cavernous sinus imaging, scans should be obtained pre- and post-gadolinium infusion.

Different Information may be obtained through imaging in the coronal, axial, and parasagittal planes. Coronal views add the most information at this time, showing the clearcut anatomic relationship between a cavernous sinus lesion and the pituitary, optic chiasm, sphenoid sinus, Meckel's cave, and medial-temporal lobe. The coronal plane also allows inspection of the lateral cavernous sinus wall, the cranial nerves, venous compartments, and offers comparison with the contralateral cavernous sinus. The axial view allows a view of the lateral wall, as well as the anatomic relationship to the orbital apex and canal, clivus, and brain stem. While parasagittal views are not routinely obtained, they allow a more detailed view of Meckel's cave, the pterygopalatine fossa, and foramen rotundum and ovale. Most centers do routine axial and high resolution coronal imaging, leaving parasagittal views for special situations.

III. MR IMAGING OF CAVERNOUS SINUS PATHOLOGY

A. MR Signs of Cavernous Sinus Involvement

Compression of the intracavernous carotid artery is a highly specific sign of intracavernous involvement. Displacement of the artery may indicate intracavernous pa-
Intracavernous lesions are common, and their diagnosis can be challenging. High-field MRI is the procedure of choice for imaging the cavernous sinus, with some problems remaining. Pituitary tumors, meningiomas, and aneurysms are the most commonly encountered lesions of the cavernous sinus. As other lesions are rare, no studies other than single case reports are available. Several reports on trigeminal neuromas and neuromas of the cranial nerves have shown that MR imaging with gadolinium offers major advantages over CT scanning and is currently the procedure of choice.

**IV. PITFALLS IN Cavernous Sinus MR Imaging**

While MR imaging is the procedure of choice for imaging the cavernous sinus, some problems remain. Small meningiomas within the cavernous sinus may be missed, even with gadolinium. In addition, hyperostotic changes, especially when subtle, are easily missed on MRI. Small extension of tumor, especially with the use of gadolinium. As the lateral wall of the cavernous sinus is virtually always seen, bulging at the wall can be differentiated from tumor penetrating the wall.

While retrospective analysis of MRI scans in patients with hyperostosis usually reveals an abnormality, hyperostotic changes are much more easily seen with CT scanning. When the suspicion for a cavernous sinus lesion is high and the MR is not diagnostic, CT scanning still has a role.
aneurysms less than 1 cm within the cavernous sinus may also be confused with a tortuous carotid artery. On occasion it may be difficult to differentiate partially thrombosed aneurysms from hemorrhagic neoplasms, and completely thrombosed aneurysms from solid neoplasms. In addition, flow rate variations within the cavernous sinus venous spaces may give a wide spectrum of signal characteristics, leading to a wide range of normal. It also may be difficult to differentiate compression of the cavernous sinus from invasion, especially with pituitary tumors. Despite some of these pitfalls, MR imaging of the cavernous sinus with and without gadolinium-DTPA remains the best single technique for imaging this difficult region.

V. THE FUTURE

MR angiography takes advantage of the flow void sign seen with rapidly flowing blood. By taking 1 mm cuts in three dimensions and reconstructing them with the computer, one is able to obtain a three dimensional view of the intracranial vasculature. MR angiography is now becoming available at most major academic centers, and some large community imaging centers. The current quality is similar to that of venous digital subtraction angiography. As the images improve, as they undoubtedly will, MR angiography could potentially replace routine angiography.

Three dimensional reconstruction is now also becoming available on many MR software packages. This enables the viewer to rotate an image around 360 degrees to look at it from all sides. In addition, three dimensional reconstruction allows for slicing the image in any plane to look inside the three dimensional box. Both of the above-mentioned techniques are sure to enhance the neuroophthalmologist's ability to diagnose disease by less invasive means.

VI. SUMMARY

High field, high resolution MR imaging of the cavernous sinus with and without gadolinium allows a detailed view of the cavernous sinus, its contents, and surrounding region. MRI has a high sensitivity with moderate specificity. MR imaging provides the most sensitive means of detecting intracavernous sinus disease, and determining the extent of involvement. MR easily differentiates neoplasm from aneurysm, and can detect thrombus in both an aneurysm, or within the cavernous sinus itself. MR shows excellent vascular detail, and is readily able to determine tumor margins. MRI angiography is now able to show us intracranial vasculature, and with software improvements may potentially replace routine angiography. Currently, MR Imaging is the best method for imaging the cavernous sinus and its surrounding structures.

REFERENCES
