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The Cavernous Sinus: A Computed Tomographic Study

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Evaluation of over 255 patients with sellar and parasellar lesions allowed study of the computed tomographic (CT) appearance of the cavernous sinus. Optimal visualization of the cavernous sinus was obtained with continuous contrast enhancement of both axial and coronal tomograms. The coronal projection provided imaging of cranial nerves within the cavernous sinus. The intracavernous carotid artery was seen only if it were calcified or encased by tumor extending into or invading the sinus. CT criteria suggesting an abnormal cavernous sinus are: (1) asymmetry of size, (2) asymmetry of shape, particularly the lateral wall, and (3) focal areas of abnormal density within the sinus. The neurovascular anatomy of the cavernous sinus is reviewed and correlated with CT findings. Discrepancies between anatomic and CT appearance are discussed.

The cavernous sinus is a unique component of the cranial vascular system, having direct or indirect connections with the cerebrum, cerebellum, brainstem, face, eye, orbit, nasopharynx, mastoid, and middle ear [1]. In the past, radiographic examination has been limited; angiography and venography have delineated only the vascular components. However, high resolution computed tomography (CT) now provides imaging of cranial nerves within the cavernous sinus and accurate definition of its dural boundaries. This report discusses the CT appearance of the cavernous sinus, illustrating its normal contents and configuration and its appearance when affected by a variety of pathologic processes.

Neurovascular Anatomy of the Cavernous Sinus

The cavernous sinus is a venous channel extending from the superior orbital fissure to the dorsum sella. Covered by dura superiorly and laterally, the sinus receives tributaries from the superior and inferior ophthalmic veins, the central retinal vein, the middle and inferior cerebral veins, and the middle meningeal veins. It also communicates posteriorly with the superior and inferior petrosal sinuses, inferiorly with the pterygoid plexus, and with the contralateral cavernous sinus through anterior and posterior connections. While the contours and contents of the cavernous sinus are better described with pictures than with words (fig. 1), a brief summary of the neurovascular composition of the cavernous sinus is presented [1-3].

The major arterial structure within the cavernous sinus is the internal carotid artery. There is individual variation in the curvature of the intracavernous carotid, but in general the artery bends to form an "S" in the sagittal plane and another more tightly coiled "S" in the coronal plane. The intracavernous carotid is about 2 cm long and lies an average of 2-3 mm lateral to the pituitary gland. However, in some instances it may course more medially and indent the pituitary gland. The S-shaped segment of the carotid is firmly anchored at its points of entrance and exit, but lies unsupported in the intervening cavernous sinus.

The neural structures within the cavernous sinus include the sympathetic

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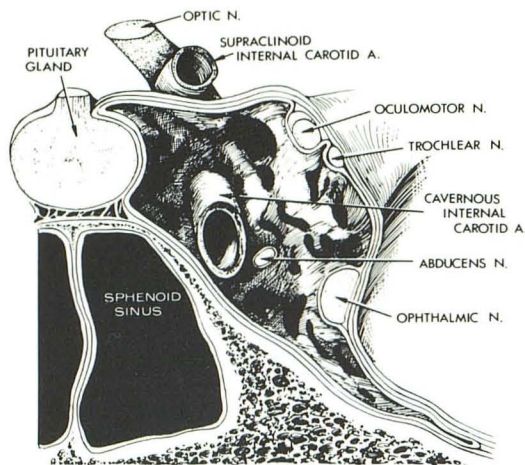


Fig. 1.—Coronal section of right cavernous sinus viewed posteriorly. (Reprinted from [3].)

carotid plexus and four cranial nerves. The location of these nerves in superior to inferior order are the oculomotor, trochlear, abducens, and ophthalmic division of the trigeminal (fig. 1). Coursing parallel to the free edge of the tentorium, the oculomotor nerve pierces the dura of the cavernous sinus slightly anterior and lateral to the dorsum sella, at a point inferior and medial to the ridge of the free tentorial edge. Running superiorly in the lateral sinus wall, beneath the anterior clinoid, the oculomotor nerve enters the orbit through the superior orbital fissure.

The trochlear nerve is located slightly below the free edge of the tentorium and, on reaching the ridge of the free tentorial edge, it enters the dura of the cavernous sinus behind the entrance of the oculomotor nerve. Once within the wall of the sinus, the oculomotor and trochlear nerves lie within a common dural tunnel, separated by thin fibrous tissue. On exiting the cavernous sinus, the trochlear nerve passes through the superior orbital fissure into the orbit.

The abducens nerve ascends from the lower pons enclosed in the dura of the clivus, and passes beneath the petroclinoid (Gruber) ligament within Dorello canal. Piercing the dura of the cavernous sinus about 2 cm below the posterior clinoid, the abducens nerve lies freely within the sinus closely adherent to the lateral side of the intracavernous carotid, and travels through the superior orbital fissure, beneath the oculomotor and trochlear nerves, into the orbit.

All of the divisions of the trigeminal nerve do not course through the cavernous sinus. The frontal, lacrimal, and nasociliary nerves exiting from the orbit through the superior orbital fissure form the ophthalmic division. Within the cavernous sinus the ophthalmic nerve maintains an inferior position in the lateral sinus wall. Exiting the sinus posteriorly, the ophthalmic nerve runs to the gasserian ganglion, which lies within two folds of dura of Meckel cave on the petrous apex. Entering the skull through foramen rotundum, the course of the maxillary division of the trigeminal nerve remains controversial. While it has been described as traversing the posterior aspect of the cavernous sinus prior to joining the gasserian ganglion [4], there is evidence dem-

onstrating that the maxillary nerve is embedded in the dura of the middle fossa just lateral to the cavernous sinus, rather than within the wall of the sinus [5]. On entering the skull through foramen ovale, the mandibular division of the trigeminal nerve runs to the gasserian ganglion without ever reaching the cavernous sinus.

Materials and Methods

Over 255 patients with sellar and parasellar lesions were evaluated at University Hospital, Birmingham, Ala. and Jackson Memorial Hospital, University of Miami, Miami, Fla. Using the General Electric CT/T 8800 Scanner, scans were obtained axially and coronally. The axial tomograms were obtained parallel to the orbitomeatal line, and patients were then placed in the "hanging head" position for coronal CT. A lateral digital localizer image was used to select the optimal scan levels and gantry angles to avoid the potential artifacts induced by dental fillings. When direct coronal scanning could not be done, coronal images were reconstructed. Both noncontrast and contrast-enhanced CT images were obtained of 5 or 1.5 mm thick slices. In most cases, contrast enhancement was accomplished by the rapid intravenous administration of 18–36 g of iodinated contrast medium before initiating of scanning, and the continuous administration of another 42 g during the procedure.

Observations

Normal Cavernous Sinus

Scanned coronally with contrast enhancement, the cavernous sinus appeared as an area of increased attenuation lateral to the sella turcica. Within the cavernous sinus were low attenuation structures representing cranial nerves. In visualizing these structures and the boundaries of the cavernous sinus, 5 mm tomographic slices proved superior to those of 1.5 mm. The thinner tomographic sections frequently were noisier resulting in decreased spatial and attenuation resolution of soft tissue [6]. Three contiguous coronal sections provided visualization of structures within and adjacent to the cavernous sinus.

Anteriorly, at the level of the anterior clinoids, the oculomotor nerves could be reliably visualized immediately beneath the clinoid processes (fig. 2). Less consistently, the abducens nerve was seen running inferiorly in the sinus (fig. 2). At the midsellar level, the oculomotor nerve was seen superiorly in the lateral dural sinus wall, under the ridge of the free edge of the tentorium (fig. 3). The ophthalmic division of the trigeminal nerve was visualized inferiorly in the lateral sinus wall, and at times its point of separation from the maxillary nerve could be seen (fig. 3). It was the most consistently imaged structure within the cavernous sinus. In the most posterior coronal CT section of the cavernous sinus, at the level of the dorsum sella, the gasserian ganglion was seen (fig. 4). The trochlear nerve was not visualized separately from the oculomotor nerve because of the proximity of the two nerves. The low attenuation referred to as the oculomotor nerve may represent both the oculomotor and the trochlear nerves. The intravenous carotid artery was imaged only if it were calcified or encased by tumor extending into or invading the sinus (see below).

After contrast enhancement, the cavernous sinus was visualized in the axial projection as well. Occupying the parasellar region, it was characterized by a straight or slightly concave lateral wall (fig. 5A). While normal intracavernous structures were not seen consistently with axial CT, the gasserian ganglion could be visualized (fig. 5B).

Symmetry of size and contour was of critical importance in assessing the cavernous sinus. Except for the lateral boundary, its contours are determined by related structures, that is, superiorly by anterior and posterior clinoids, posteriorly by the dorsum sellae, anteriorly by the superior orbital fissure, inferiorly by the base of the skull and related foramina, and medially by parts of the sphenoid bone and pituitary gland. Therefore, the lateral wall of the cavernous sinus was a sensitive indicator of pathologic involvement. Careful examination with oscilloscopic review of the CT image of the lateral sinus wall was of utmost importance in both axial and coronal views.

Although patients were scanned both axially and coronally, in our experience the coronal projection allowed optimum evaluation of the cavernous sinus; contrast enhancement was distinctly advantageous. In addition, direct coronal scanning provided much better visualization of the cavernous sinus than did reconstructed coronal images.

Pathologic Cavernous Sinus

CT criteria suggesting an abnormal cavernous sinus are: (1) asymmetry of size, (2) asymmetry of shape, particularly the lateral wall, and (3) focal areas of abnormal density within the sinus. Several pathologic processes provide illustrative examples.

Tumorous involvement of the cavernous sinus may be due to local extension or metastatic spread. A 68-year-old woman had a painless, right oculomotor nerve palsy for 7 months. Contrast-enhanced coronal CT revealed a pituitary tumor extending into the right cavernous sinus (fig. 6). A 72-year-old man with progressive, bilateral visual loss and a left oculomotor nerve palsy was found to have a pituitary adenoma. Because of calcification and tumor encasement, both intracavernous carotid arteries were seen on CT (fig. 7). Tumor compression of the cavernous sinus led to right painful ophthalmoplegia in another patient, a 46-year-old man. CT documented a low density, lobulated lesion, compressing the right cavernous sinus (fig. 8), which proved to be an extradural epidermoid. A 71-year-old woman had severe facial pain in the distribution of the ophthalmic and maxillary divisions of the left trigeminal nerve. She underwent surgery 3 years before for breast carcinoma, and evaluation now revealed widespread metastatic disease, including the cavernous sinus (fig. 9).

High resolution coronal CT is of great assistance in evaluating vascular lesions of the cavernous sinus. Intracavernous carotid artery aneurysm typically produces a slowly progressive unilateral ophthalmoplegia, occasionally painful. In these cases, contrast-enhanced CT usually discloses an enlarged cavernous sinus of normal attenuation with a smooth, bulging lateral wall (fig. 10). A carotid-cavernous sinus fistula is illustrated in figure 11. Once again, with

contrast enhancement, CT revealed an enlarged cavernous sinus with a bulging, yet smooth, lateral wall. In addition to having different clinical presentations, intracavernous carotid artery aneurysm and carotid-cavernous fistula require cerebral angiography for definitive radiologic diagnosis.

Rarely, structural abnormalities may involve only neural tissue of the cavernous sinus. An 8-year-old female with neurofibromatosis was found to have plexiform neuromas involving both orbits, sphenoid bone dysplasia, and a right optic nerve and chiasmal glioma. Although facial sensation was normal, CT demonstrated a trigeminal neurinoma of the posterior left cavernous sinus (fig. 12).

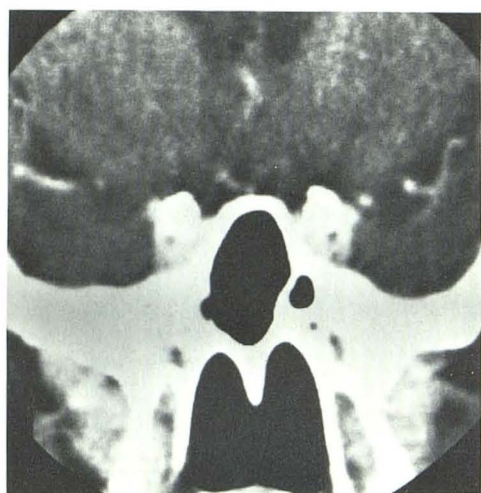
Discussion

While all patients were examined in the axial plane, and most scanned coronally as well, we found the coronal projection to be superior in visualizing the boundaries and contents of the cavernous sinus. Supplemented with high-dose continuous contrast infusion, the cavernous sinus is seen as an enhancing parasellar structure, with a well defined straight lateral border, containing low attenuation structures representing cranial nerves. Nevertheless, the axial tomogram does provide complementary information, and we routinely obtained both projections.

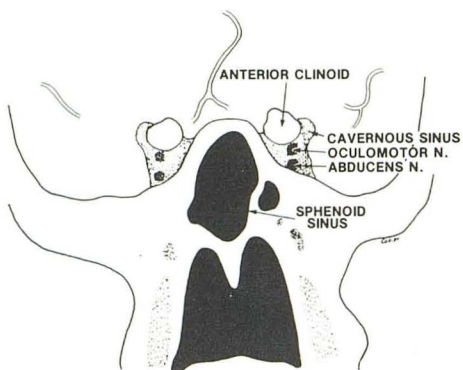
It is important to point out that we did not perform "true" coronal tomograms, that is, sections perpendicular to the orbitomeatal line. Alterations of the coronal plane were necessary for the many patients who could not assume a "true" coronal position or to avoid artifacts induced by metallic dental fillings. Therefore, modified (i.e., "oblique") coronal CT sections were scanned. For this reason, the gasserian ganglion and maxillary nerve appeared to merge with structures within the cavernous sinus (figs. 3 and 4). In his anatomic studies of the maxillary nerve, Henderson [5] emphasized the importance of the plane section: "Diagrams showing the maxillary nerve in the wall of the cavernous sinus were probably based on 'obliquely coronal' sections . . . and therefore show the cavernous sinus apparently extending laterally to beyond the maxillary nerve." Nevertheless, the present generation of high resolution CT allows visualization in the coronal projection of neural structures within the cavernous sinus.

The intracavernous carotid artery proved more elusive. This is due to the fact that, after contrast enhancement, attenuation coefficients are the same for the intracavernous carotid and surrounding venous sinus. Either calcification within the arterial wall or tumorous encasement was necessary to see this part of the carotid artery (figs. 6 and 7).

Asymmetry of size of the cavernous sinus signified pathologic involvement. In most cases the abnormal sinus was enlarged, but occasionally it was compressed (fig. 8). Altered contour of the sinus was another critical factor in evaluation. For reasons discussed above, the lateral sinus boundary was a sensitive indicator of abnormality. The bulging lateral sinus wall tended to maintain a smooth contour in more benign conditions such as "invasive" pituitary tumor (figs. 6 and 7), intracavernous aneurysm (fig. 10),

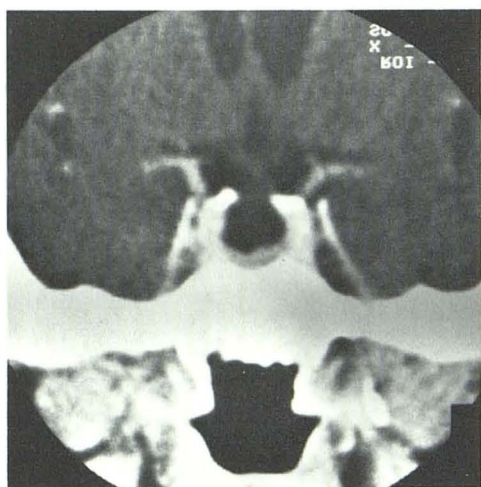


A

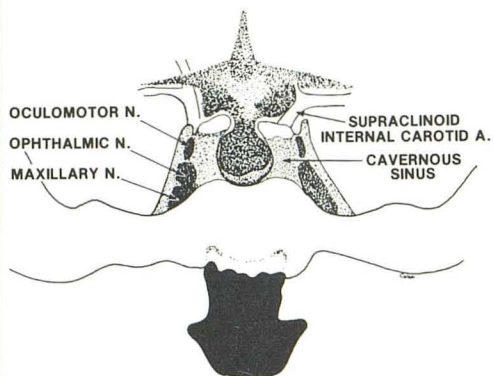


B

Fig. 2.—Normal cavernous sinus, contrast-enhanced coronal scan, at level of anterior clinoid processes.

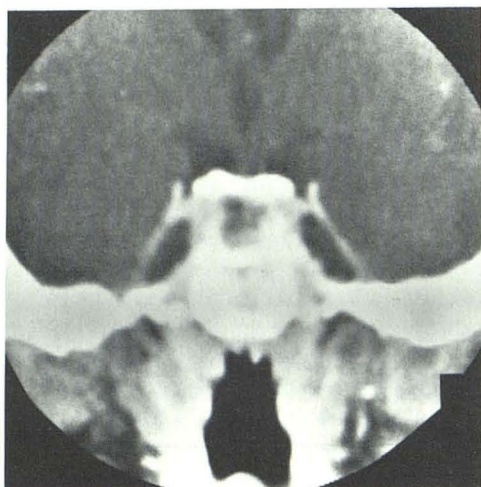


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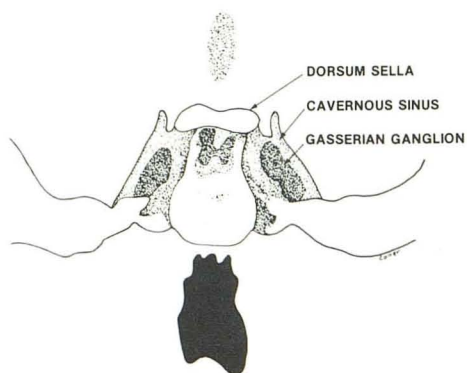


B

Fig. 3.—Normal cavernous sinus, contrast-enhanced coronal scan, mid-sellar region in case of empty sella syndrome.



A



B

Fig. 4.—Normal cavernous sinus, contrast-enhanced coronal scan, at level of dorsum sellae.

Fig. 5.—Normal cavernous sinus, contrast-enhanced axial scans. **A**, Lateral wall is straight or slightly concave. **B**, Gasserian ganglion (arrows).

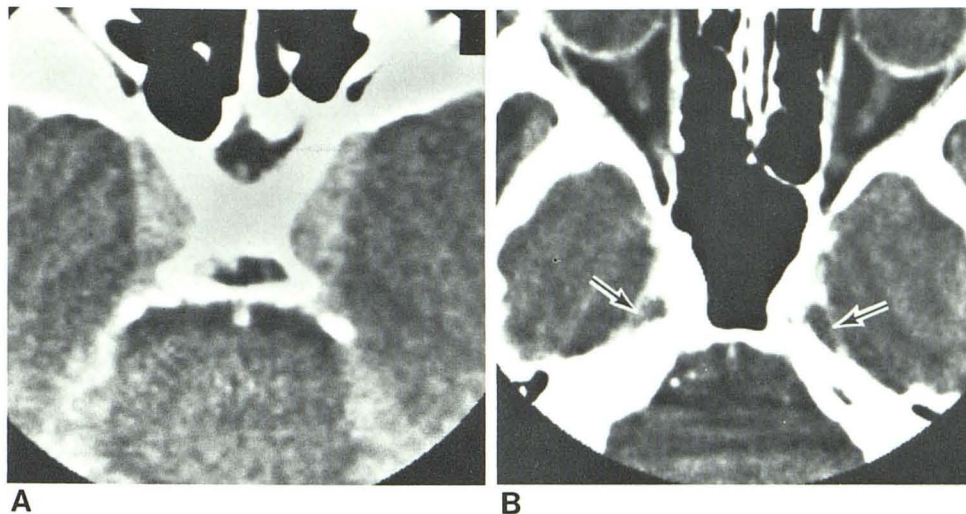


Fig. 6.—Pituitary adenoma. Contrast-enhanced coronal CT scans. **A**, At level of anterior clinoids. Extension of pituitary adenoma into right cavernous sinus, with bulging lateral wall (arrows). **B**, At mid-sellar level. Calcified intracavernous carotid arteries (arrows).

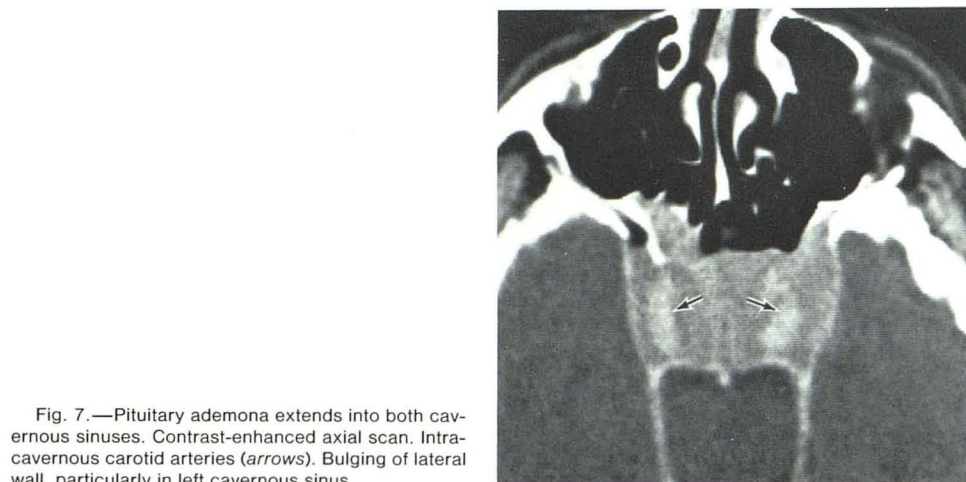
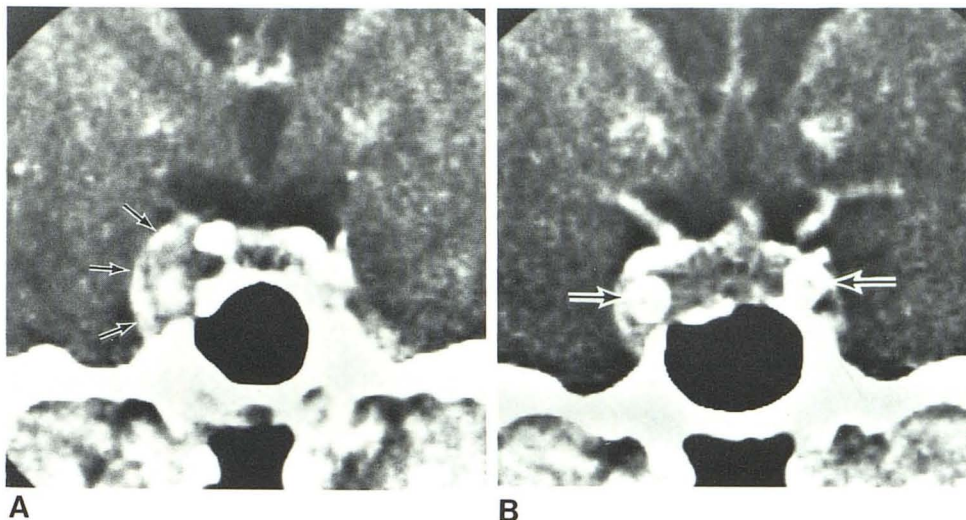


Fig. 7.—Pituitary adenoma extends into both cavernous sinuses. Contrast-enhanced axial scan. Intra-cavernous carotid arteries (arrows). Bulging of lateral wall, particularly in left cavernous sinus.

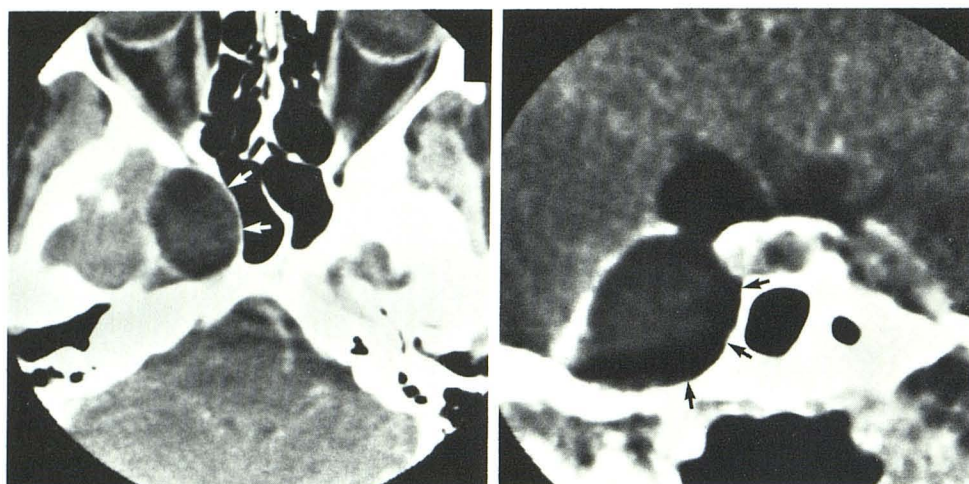


Fig. 8.—Extradural parasellar epidermoid. **A**, Axial scan. Right parasellar lesion of low attenuation. **B**, Coronal projection. Lobulated lesion compresses right cavernous sinus. Both views demonstrate remodeling of sphenoid bone (arrows). (Reprinted from [7].)

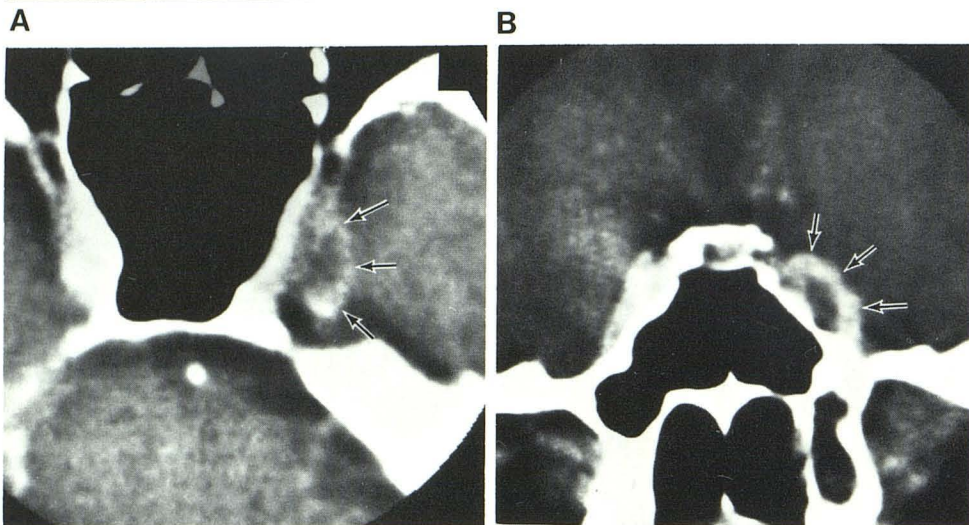


Fig. 9.—Metastatic breast carcinoma. Axial (**A**) and coronal (**B**) contrast-enhanced scans. Left cavernous sinus appears enlarged, contains a low attenuation density, and has a bulging, irregular lateral wall (arrows).

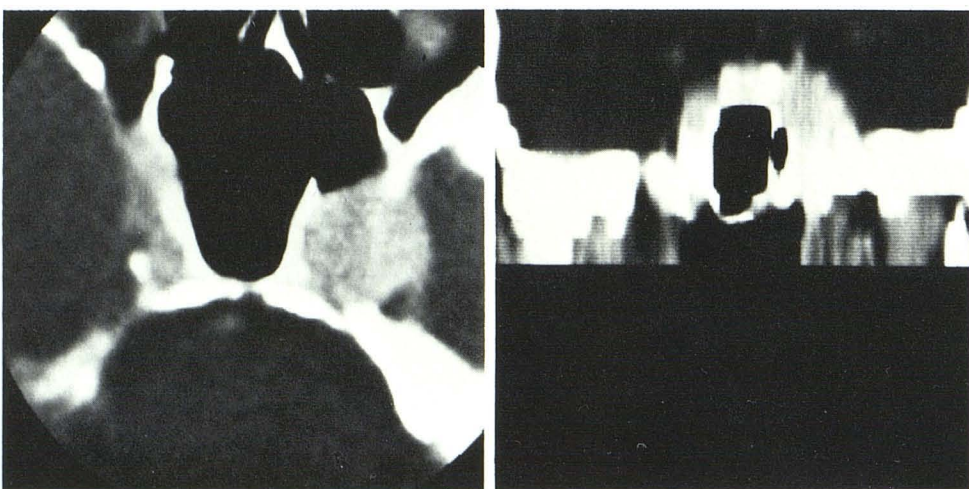


Fig. 10.—Intracavernous carotid artery aneurysm. Axial (**A**) and reconstructed coronal (**B**) scans after contrast enhancement. Homogeneous enlargement of left cavernous sinus.

Fig. 11.—Carotid-cavernous fistula. Axial (A) and coronal scans (B) after contrast enhancement. Subtle enlargement with bulging of lateral wall of left cavernous sinus (arrows).

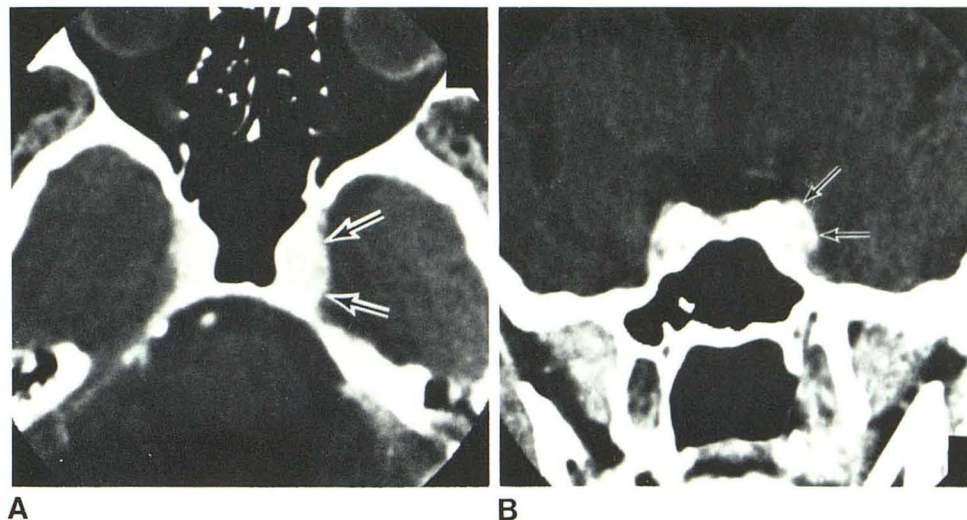
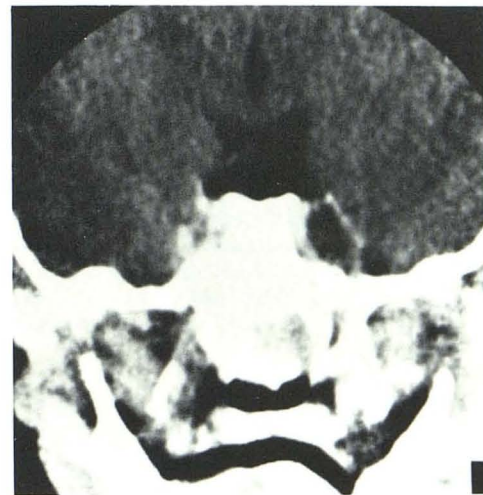


Fig. 12.—Coronal scan of left trigeminal neurinoma in patient with neurofibromatosis.



carotid-cavernous fistula (fig. 11), and trigeminal neurinoma (fig. 12). In contrast, metastatic malignant disease produced a more irregular lobulated lateral boundary, as illustrated in a case of metastatic breast carcinoma (fig. 9). Areas of abnormal attenuation within the cavernous sinus served as a third indicator of pathologic involvement. This altered attenuation may be increased or decreased, as in pituitary tumor extending into the cavernous sinus (figs. 6 and 7) or metastatic carcinoma (fig. 9), respectively.

While the value of CT in assessing the sella turcica and suprasellar region has been emphasized, relatively little attention has been given to the cavernous sinus. Our report demonstrates that the current generation of CT scanning, with high spatial and contrast resolution, provides visualization of the cavernous sinus, in both health and disease.

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