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The caverno-apical triangle: anatomic-pathological considerations and pictorial review

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ABSTRACT

Background: The caverno-apical triangle (CAT) is defined from the components that define its contours: the cavernous sinus and the orbital apex. A wide range of pathologies arise from the space between the cavernous sinus and the orbital apex.
Object: To better define radiologically this critical anatomic landmark and establish an organized approach for image analysis to help generate focused differential diagnoses and accurately characterize lesions found on imaging.
Conclusion: We have identified common imaging characteristics of frequently encountered lesions and divided them into specific categories to facilitate creation of logical and focused differential diagnoses.

1. Introduction

The caverno-apical triangle (CAT) is defined from its shape and the components that delineate its contours: the cavernous sinus and the orbital apex. A wide range of pathologies may arise from the space between the cavernous sinus and the orbital apex. Detection and appropriate characterization of pathology at the CAT remains vital as pathology can affect critically important structures often progressing intracranially and within the orbit. Moreover, this region remains a challenging location for operative biopsy and the procurement of tissue diagnosis. Accordingly, the informed radiologist can guide clinical management by alerting clinicians to the involvement of local anatomic structures and by generating an appropriate differential diagnosis. Despite this, the CAT has not been previously described in the literature as a distinct anatomic landmark, and because of its small size, it can be readily overlooked on imaging.

Clinical findings of CAT lesions are variable including orbital apex and cavernous sinus syndromes but these lesions can also be asymptomatic. Moreover, the clinically important anatomic relations in this area may result in high morbidity. Computed tomography (CT) and magnetic resonance imaging (MRI) are complementary in formulating limited differential and sometimes precise diagnoses and in defining the relationship with adjacent neurovascular structures to guide the surgical approach. As a broad range of lesions can occur here, our purpose is to better define radiologically this critical anatomic landmark and establish an organized approach for image analysis to help generate focused differential diagnoses and accurately characterize lesions found on imaging.

2. Normal anatomy and contents

The CAT forms part of the anteromedial aspect of the middle cranial fossa. Its name is defined from the components that define its contours: the cavernous sinus and the orbital apex. This triangular-shaped region is formed by the cavernous sinus anterior to Meckel's cave and extends to the superior orbital fissure (SOF) where the III, IV, Vi, and VI cranial nerves enter the orbital apex superolateral to optic nerve (Fig. 1).

The bony confines of the CAT are formed by the greater and lesser wings of the sphenoid bone that project transversely from the sphenoid corpus, bending superiorly in their anterior portion, and contain foramina through which the cranial nerves exit. The lesser wings are two thin triangular plates of bone arising from the anterior aspect of the sphenoid bone. The inferior surface constitutes a portion of the superior wall of the orbit and overhangs the SOF, the elongated opening between the wings. The posterior CAT is formed at the anterior cavernous sinus in the plane of the caroticoclinoid foramen (Henle) [1]. The posterior roof of the CAT is formed by the surgical carotico-oculomotor triangle at the level of the anterior clinoid process [2].

More noteworthy is an understanding of the anatomic relationships between the anterior cavernous sinus and its connecting foramina that serve as neurovascular channels to the orbit and thus permit egress of pathology along natural anatomic conduits. The SOF is situated between the greater and lesser wings and body of the sphenoid bone. At the fissure, the dura covering the middle fossa and cavernous sinus blends into the periorbita of the orbital apex and the annular tendon of Zinn from which the extraocular muscles arise [3]. The lateral margin of the

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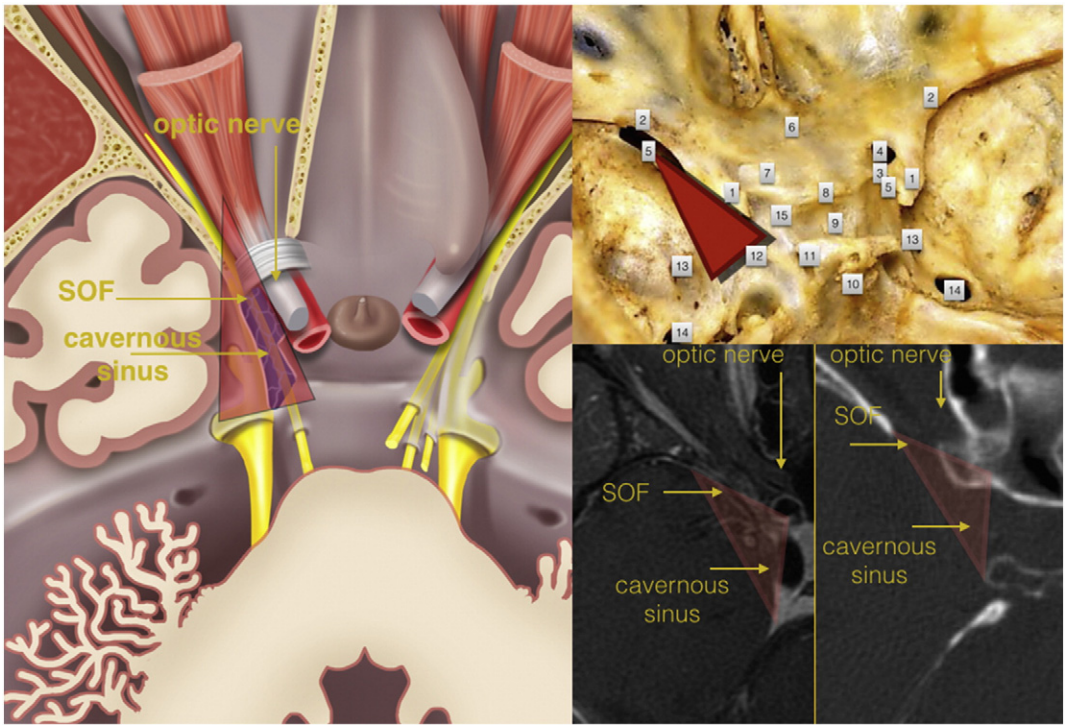

Fig. 1. Anatomy of the CAT. *Left*, illustration of the right CAT (red triangle) that includes the anterior cavernous sinus (blue) and the orbital apex. *Upper right*, labeled ex vivo skull base, superolateral view. *(1) Anterior clinoid, (2) sphenoid ridge, (3) optic strut, (4) optic canal, (5) superior orbital fissure, (6) planum sphenoidale, (7) chiasmatic sulcus, (8) tuberculum sellae, (9) pituitary fossa, (10) dorsum sellae, (11) posterior clinoid, (12) carotid sulcus, (13) foramen rotundum, (14) foramen ovale, and (15) middle clinoid. Lower right*, axial postcontrast T1 MR; *lower left*, axial noncontrast CT illustrating the CAT. The CAT forms part of the anteromedial aspect of the middle cranial fossa. Its name is defined from its shape and the components that define its contours: the cavernous sinus and the orbital apex. This triangular-shaped region is formed by the cavernous sinus anterior to Meckel's cave and extends to the SOF where cranial nerves 3, 4, 5[1], and 6 enter the orbital apex, superolateral to the optic nerve.

SOF and CAT, sometimes referred to as the horizontal meningeal limb, is covered by the frontotemporal dural fold [4]. It is important to note, however, that the foramen for the ophthalmomeningeal vein (Hyrtl) is situated in the greater wing and may form the lateral CAT, usually connecting the lateral half of the orbit with cerebral veins and cavernous sinus. A meningolacrimal artery may also pass through this foramen and supply lacrimal territory [5]. The anterior CAT is formed as an osseous tunnel for the numerous neurovascular structures entering the orbital apex and associated with the annulus of Zinn and posterior muscle cone [6].

3. Clinical presentation of lesions

Symptoms associated with CAT lesions are myriad but can be absent as well. Involvement of the anterior cavernous sinus can produce cranial neuropathies equivalent to the cavernous sinus syndrome. Various combinations of Horner's syndromes, oculomotor palsy, and facial sensory loss can be seen [7]. Similarly, the orbital apex syndrome has been described wherein ophthalmoplegia is combined with optic nerve dysfunction [8]. All such symptoms may be accompanied by ophthalmologic red flags pointing to a retrobulbar lesion [9].

4. Materials and methods

A database of exemplary lesions is maintained by the University of California, San Francisco (UCSF) Department of Radiology and Biomedical Imaging as a collaborative effort between Laboratory for Radiological Informatics and AGFA Medical Imaging, *UCSF Digital Teaching File*. Subsequent to query of this database, electronic medical records of patients presenting to the tertiary referral center, UCSF, and the San Francisco General Hospital were reviewed. This study qualified for exempt/waived requirement for informed consent under UCSF institutional review board guidelines.

5. Range of pathological lesions of the CAT

From our collection of cases from three hospitals and on review of the available literature, we created an imaging guide to creating a differential diagnosis of the common and unusual CAT lesion (Table 1). The table may be of value for reminding radiologists of the varied pathologies and specific features of each.

Table 1
Differentiating features of CAT lesions by CT and MR

Lesion	CN III, IV, V, VI involvement	Cavernous sinus involvement	Enhancement	Bony changes on CT	Extra-CAT abnormality	Lesional T2 signal intensity
Meningioma	Uninvolved	Variable	Homogenous	Hyperostotic	Dural tail	Iso
Schwannoma	Involved	Variable	Peripheral/Target	Smooth lytic	Extension to orbit	Variable
PNTS	Involved	Involved	Homogenous	Absent	Primary site	Iso
IOI[a]	Involved	Involved	Homogenous	None	EOM/Sclera	Iso
GPA[b]	Uninvolved	Variable	Homogeneous	None	Face	Low
Sarcoid	Variable	Variable	Homogeneous	None	Lacrimal/Uveal	Low
AVM	Uninvolved	Variable	Serpentine	None	Vascular pouch	Low

[a] Idiopathic orbital inflammation (formerly orbital pseudotumor).
[b] GPA (formerly Wegener's granulomatosis).