Central Skull Base lesions: a challenge for a radiologist

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Learning objectives

The central skull base has a complex anatomy and a singular embryology. Both aspects are determinant to make it a location with a wide spectrum of pathologies, including some exclusives entities. We can find neoplastic and non-neoplastic lesions. Any lesion at the central skull base is a challenge for a radiologist. Our objectives are:

- Review the embryology and anatomy of the central skull base.
- Expose and classify the wide spectrum of lesions that can be found at this location and some of their most important aspects.
- Propose a protocol to study these lesions with the combining CT and MR images.
Background

EMBRYOLOGY:

The bones of the skull base are derived from cartilaginous precursors, and those are derived from the mesenchyme around the 6th week of gestation.

The notochord becomes enclosed by the bodies of the upper cervical vertebrae and passes into the basiocciput. Here it lies directly in contact with the endoderm of the embryonic pharynx. The notochord terminates in the body of the sphenoid (Fig. 1).

Up to 15 separate endochondral and intramembranous ossification centers constitute the sphenoid bone.

The pharyngohypophyseal track (of the Rathke pouch), which gives rise to the anterior lobe of the pituitary gland, is obliterated by the postsphenoid ossification centers. A persistent craniopharyngeal canal forms the basis of congenital craniopharyngeal tumors.

The sphenoooccipital synchondrosis, the last one to fuse, is primarily responsible for the growth of the skull base in the postnatal period. The sphenoid and occipital bones are completely fused by the 25th year

ANATOMY

1. Bone structures:

Sphenoid bone:

- **Body:** Block-like structure hollowed out by the sphenoidal sinus. The superior surface is divided in the jugum, the sella turcica and the sphenoidal part of the clivus.

- **Wings:** the lesser wings form part of the floor of the anterior cranial fossa and contain the anterior clinoid process and the optic canals, and are the superior margin of the superior orbital fissure; the greater wings are the inferior part of the superior orbital fissure, form part of the central cranial fossa and contain from medial to lateral the foramen rotundum, foramen ovale and foramen spinosum.
Occipital bone:

- **Clivus**: occipital part of the clivus is immediately posterior to the sphenocipital syncondrosis

2. Soft tissue intracranial structures:

Cavernous sinus:

- Venous sinusoid located on either side of the pituitary fossa and body of the sphenoid bone between the two layers of the dura. The syphon of the internal carotid passes through the sinus as the abducens nerve (VI). The oculomotor and trochlear nerves and ophtalmic (V1) and maxillary (V2) branches of the trigeminus pass along the lateral wall of the sinus (Fig. 2).

Meckel’s cave:

- Cerebrospinal fluid-containing arachnoidal pouch, situated at the posterolateral aspect of the cavernous sinus on either side of the sphenoid bone that houses the trigeminal ganglion.

PATHOLOGY:

1. Neoplastic:

- **Chordoma**: Less than 1% of all intracranial tumors and 3%-4% of all primary bone tumors. These tumors are histologically benign, although they are regionally invasive and have a poor prognosis, with an almost 100% recurrence rate despite radical surgery. More than one-third occur in the clivus between the ages of 20 and 40 years. They commonly contain areas of calcification and bone fragments, this is best demonstrated on CT. They have a dominant soft-tissue component that may enhance. On MRI the majority of chordomas appear isointense relative to brain parenchyma on T1 and hyperintense on T2, although some tumors can appear inhomogeneously hyperintense on T1.

- **Chondrosarcoma**: These tumors arise from bone or cartilage and represent the 6% of skull base tumors. They grow in the various synchondroses that remain after ossification between the fourth and fifth decade. Almost all skull-base chondrosarcomas are well or moderately differentiated. On CT there is a significant soft tissue component with high attenuation with a variable calcification, and enhances in some degree (Fig. 3). On MRI
they have intermediate T1 and fairly high T2 signal intensity with detectable enhancement. (Fig. 4)

- **Juvenile Nasopharyngeal Angiofibromas (JNA):** Benign tumors arising adjacent to the sphenopalatine foramen. They occur in adolescent males in most of the cases. The JNA are very vascular and locally invasive. They can extend to any extracranial space, or to an intracranial location through the foramina. On CT and MRI they enhance intensely. On MRI they have intermediate signal intensity on T1 weighted images, and hyperintense on T2 sequences, with flow voids representing the high-flow vessels.

- **Meningioma:** Benign tumors that arises from the arachnoidal cells of the meninges, with a peak of incidence between 20-60 years. The skull base menigioma is not very common and can arise along every part of the sphenoid bone and the wall of the cavernous sinus. On CT they show as a soft tissue mass with intense enhancement and we can find calcifications. On MRI they are isointense with the brain, they enhance intensely, and sometimes there is a visible "dural tail" (Fig. 5).

- **Neurogenic tumors:** Neurogenic tumors can arise along the course of any cranial nerve, in the cisterns or through the foramina. Schwannomas are the most frequent entity, and the trigeminal is the most commonly affected in the central skull base. They are solid but can have cystic component. The cortex of the adjacent bone structures is intact, but they can expand de foramen ovale. On MRI they have intermediate signal on T1 and high T2, with intense enhancement (Figs. 6 and 7).

- **Craniopharyngioma:** Benign slow growing tumors with infiltrative character that arise from remnants of the Rathke's pouch. They occur most commonly in a suprasellar location, but they can appear in the sella turcica and rarely in the sphenoid bone. Well encapsulated lesion, mainly cystic with isolated solid focus and calcified debris. On CT we find a lobulated mass in suprasellar location with cystic regions, with rim-like or conglomerate calcifications and a variable attenuation. On MRI they have variable intensity on T1, and high on T2, and wall and solid portions enhancement (Figs. 8 and 9).

- **Pituitary adenoma:** Benign neoplasias arising in the pituitary gland. They are called macroadenomas when they are bigger than 1 cm in diameter. If they break through the sella floor or grow into the cavernous sinuses, it is considered infiltrative pituitary adenoma. They can be very destructive and may surround the carotid. On MRI they are usually isointense on T1 images, moderately hyperintense on T2 and hypointense in relation to the surrounding enhancing normal pituitary tissue (Fig. 10).

- **Hemangioma:** Primary intraosseous cavernous hemangioma of the skull base and clivus are extremely rare benign neoplasm. CT scan shows an
intraosseous mass with a honeycomb or sunburst pattern. Lesions tend to have a variable signal intensity on T1-WI depending on the fatty content, and high signal intensity on T2-WI (Fig. 11).

2. Non neoplastic:

-Congenital:

- Cephalocele: Protrusion of intracranial contents through a congenital defect in the skull. Basal encephaloceles are a rare condition and most of them usually pass into the nose or the nasopharynx. The outer layers depend on the structures it passes through. They are commonly classified into four groups: trans-sphenoidal, sphenoethmoidal, sphenoorbital, and transethmoidal. The petroclival cephalocele is a very uncommon entity. On CT the leak in the bone is more evident, but MR shows the protrusion of the intracranial content (Figs. 12 and 13)

-Bone lesions:

- Fibrous Dysplasia: Abnormal development of the bone and its mineralization. The bone is enlarged with a variety of appearances on CT from fairly lucent to densely calcified. The classic CT pattern is the "ground glass" medullary. On MRI has low T1 and low T2 signal intensity (Fig. 14).

- Paget Disease: This is a process with abnormal osteoclastic activity and the subsequent osteoblastic response of indefinite cause. The normal bone is replaced with an abnormal matrix. It shows thicker, more sclerotic but softer bone

-Vascular:

- Aneurysm: They arise from the intracavernous segment of the carotid. Most of them are spontaneous, but some occur after a trauma. A big aneurysm enlarges the cavernous sinus and bows its lateral wall. They can be detected with conventional CT or MRI but CT angiograms and MRA are very useful (Fig. 15).

-Miscellanea:

- Eccordosis Physaliphora: Benign intradural mass of soft tissue located along the surface of the clivus. It is considered to be a remnant of the primitive notochord, found in 2% of individuals in autopsy series. On CT a bony irregularity of the superior surface of the clivus is evident (Fig. 16).

- Rathke’s Pouch Cyst: Cystic remnant of Rathke’s pouch that arises in the anterior part of the sella or suprasellar cistern and rarely in the sphenoidal...
bone. It is a cyst with a single layer of epithelial cells with low mucoid content. On MRI it can show low or intermedium T1 signal intensity and high T2 and no enhancement (Fig. 17).

• **Mucocoele**: Airless mucus-filled expanded sphenoid sinus cavity, consequence of an obstruction of the sphenoid sinus ostium.
Fig. 4: Axial postcontrast T1-weighted image with fat saturation shows same left petroclival chondrosarcoma. The tumor has a moderate expansive character and intense enhancement.

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**Fig. 1:** Drawing of the midsagittal section. Course of the notochord and anatomic references: Embryonic Nasopharynx (EN), Sella Turcica (ST), Notochord (N), Notochordal Termination (Nt), Odontoid Process (OP) and Clivus (C).

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Fig. 13: Axial T2-weighted image of a petroclival cephalocele. An expansile lesion with smooth margins and cystic content is noted in the left petrous apex and petrooccipital fissure.

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**Fig. 12:** Sagital T2-weighted image of a sphenoeptmoidal encephalocele containing brain tissue, extending into the nasal cavity. The connection can be followed through the anterior sella and anterior sphenoid.

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Fig. 9: Axial FLAIR image of the same craniopharyngioma shows a suprasellar mass with high signal.

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Fig. 17: Coronal T2-weighted image of a cyst of Rathke’s pouch. It shows a well-circumscribed cystic structure arising within the sella turcica with mild suprasellar extension.

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Fig. 5: Axial postcontrast T1-weighted image. Meningioma of the left petroclival region that fills the region of the cavernous sinus. The carotid artery is not narrowed.

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Fig. 10: Coronal postcontrast T1-weighted image. Right side macroadenoma with intermediate enhancement. It extends into the cavernous sinus, wrapping around the carotid.

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**Fig. 11:** Axial CT bone scan of an intraosseous hemangioma of the clivus. It shows the tipical image of hemangioma, a well-circumscribed non-expansile lesion with thickened vertical trabeculae.

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Fig. 16: Axial CT bone scan of echordosis physaliphora shows a bony irregularity of the dorsal surface. The erosion is corticated and of long standing.

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**Fig. 14:** Fibrous dysplasia of the sphenoid. Axial CT bone scan shows a typical "ground glass" appearance that fills and expands most of the body and the left major wing.

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Fig. 8: Axial CT without contrast of a craniopharyngioma shows a suprasellar mass with a significant cystic component, and with areas of calcification in the periphery.

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Fig. 6: Coronal T2-weighted image. Left trigeminal schwannoma expanding the cavernous sinus and obscuring the Meckel's cave. The carotid artery is pushed medially.

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Fig. 3: CT bone scan of a chondrosarcoma arising in the left petrooccipital fissure. It shows a soft tissue mass with a non-sclerotic abrupt margin and with several calcification in it.

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**Fig. 7:** Axial postcontrast T1-weighted image. Left trigeminal schwannoma expanding the cavernous sinus and obscuring the Meckel's cave. The tumor has both a posterior fossa and a middle cranial fossa component that. The carotid artery is pushed medially.

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**Fig. 15:** MR angiography time-of-flight sequence shows an aneurysm of the cavernous carotid with flow extending into the sella and expanding the cavernous sinous.
Fig. 2: Drawing of a coronal section of the cavernous sinuses. Cranial nerves (III, IV, V1, V2 y VI) and internal carotid arteries.

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Imaging findings OR Procedure details

We used a 1.5 Tesla MR to perform the exams.

Our protocol includes a scan of the whole brain: sagittal T1 spin echo, coronal T2 spin echo, axial FLAIR and DWI. In the area of the central skull base we use a coronal 4 mm-thick T2 spin echo, and axial and coronal 3mm-thick section for T1 pre and post contrast.

We consider that combining MR with CT scan is very helpful. Multidetector multislice CT: an axial acquisition to create a three-dimensional volume data set.
Conclusion

Central skull base lesions are always a challenge for a radiologist. The knowledge of their embryology and anatomy is an essential key, not only to understand the broad spectrum of pathologies, but to be able to describe the nervous and vascular structures that may be affected. An appropriate protocol that combines CT and MRI techniques is important for an accurate diagnosis.


