Anatomy and pathology of the skull base, CT and MRI imaging

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Learning objectives

To know and understand the CT and MR anatomy of the skull base.
To analyze the different pathologies which can affect this region.

Background

SKULL BASE ANATOMY

The anatomy of the skull base is complex and its knowledge is essential for the treatment planning of the different processes that could affect this area.

The skull base is formed by two paired bones, frontal and temporal, and 3 unique, ethmoid, sphenoid and occipital. It is divided in anterior, middle and posterior cranial fossa and contains several canals of practical relevance (Fig. 1 on page 5).

ANTERIOR CRANIAL FOSSA

Formed by:

- orbital plates of the frontal bone
- ethmoid with its components: horizontal part (cribriform plate), vertical part (perpendicular plate, crista galli) and lateral masses
- lesser sphenoid wings and anterior part of sphenoid body - posterior limit of anterior cranial fossa.

MIDDLE CRANIAL FOSSA

Formed by:

- sphenoid body and its lesser wings - anterior limit of the middle cranial fossa
- petrous part of temporal bone - its superior border (with the sulcus of superior petrous sinus) and the dorsum sellae constitute the posterior limit of middle cranial fossa
- body and greater wings of sphenoid.
**Sphenoid**

- represents the fundamental structure of the skull base, situated in the centre, between the frontal, temporal and occipital bones

- contains the sella turcica and the cavernous sinuses

- it has a complex structure being a route of many neurovascular structures that connect the skull and the cervical/pharyngeal region

- it is formed by different parts: body, two greater and two lesser wings and two pterygoid processes that descend from the union of the body with the greater wings.

**Sphenoid body**

It has a cuboid form and contains the sphenoid sinuses, separated by a septum. The antero-superior part of the body, sphenoid planum o jugum, joins with the cribiform plate (spheno-ethmoid suture) and in the posterior part presents relation with the chiasmatic sulcus. Behind this groove there are situated the tuberculum sellae, the sella turcica and the dorsum sellae. The sphenoid body joins in its posterior aspect the basilar part of occipital, between them being located the spheno-occipital syncondrosis, and together forming the clivus.

**Hypophyseal fossa - borders:**

- anterior - chiasmatic sulcus, tuberculum sellae

- anterolateral - medium clinoid processes

- posterior - dorsum sellae with posterior clinoid processes

- lateral - cavernous sinuses

- inferior - superior plate of sphenoid sinuses

The pituitary fossa is covered by the diaphragma sellae, a part of duramater that inserts in the anterior and posterior clinoid processes.

**Cavernous sinus - borders:**

- anterior - superior orbital fissure

- posterior - petrous apex
- middle - sphenoid body with sphenoid sinus and pituitary fossa
- lateral - temporal uncus

Within the sinus, in the inferomedial part, it is situated the internal carotid and the sympathetic plexus, and in the immediate vicinity, the VI nerve. At this level, the III, IV, V1 and V2 nerves, in cranio-caudal order are located in the external part of the sinus (Fig. 2 on page 6).

Greater wings

They represent a superior and lateral continuation of the sphenoid body and are made up of two parts:

- lateral, divided by the infratemporal crest in the temporal surface (superior) and the infratemporal one (inferior). The first one presents insertions for the temporal muscles, and the second, together with the infratemporal crest, for the lateral pterygoid muscle.

- orbital, constitutes the posterolateral part of the orbit.

Lesser wings

They originate in the anterosuperior part of the body and connect with it by two roots: one anterior, a thin one, and the other posterior, thick, between them being the optic canal. The medial extreme of the lesser wings form the anterior clinoid process, which sometimes can join with the middle clinoid process originating the carotico-clinoid foramen.

Pterygoid processes

They originate from the union of the greater wings with the body. They have a lateral and a medial plate that join in the anterosuperior part. Between them one can find the pterygoid fossa, origin of the medial pterygoid muscle and of the tensor veli palatini; the last one has also insertions in the scaphoid fossa which is situated at the posterosuperior border of the medial plate. The root of the pterygoid process forms the posterior limit of the pterygopalatine fossa, where there is the anterior foramen of the pterygoid canal.

Lateral pterygoid lamina - anatomic relations:

- lateral - infratemporal fossa; lateral pterygoid muscle
- medial - pterygoid fossa; medial pterygoid muscle
- antero-superior - pterygo-maxillary fissure
- antero-inferior - palatine bone.

**Medial pterygoid lamina - anatomic relations:**

- lateral - pterygoid fossa
- medial - posterior nasal orifices; vomer plate
- anterior - sphenoid process of the palatine, together forming a border of the palatovaginal canal through which pass the pharyngeal branches of the maxillary artery and the pterygo-palatine ganglia.
- posterior - palatine bone; pharyngobasilar fascia
- superior - pterygoid tubercle
- inferior - superior pharyngeal constrictor muscle; uncinate process (hamulus) providing insertions for the pterygomandibular raphe and the tensor veli palatini muscle.

**POSTERIOR CRANIAL FOSSA**

**Limits:**

- anterior - dorsum sellae, posterior aspect of sphenoid body, basiocciput
- antero-lateral - petrous and mastoid parts of temporal bone, petrooccipital fissure, inferior petrous sinus
- lateral - mastoid angles of parietal, lateral part of occipital, sphenoo-occipital synchondrosis
- posterior - squamous part of occipital

The skull base contains many foramina of high clinical relevance (Table 1 on page 7).

**Images for this section:**
Fig. 1: Axials contrast-enhanced CT. Representative image of the skull base canals.
**Fig. 2:** Coronal contrast-enhanced T1WI. Representative image of the cranial nerves at the level of the cavernous sinuses.
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**Table 1:** Relevant foramina of skull base
SKULL BASE PATHOLOGY

Different entities which affect the skull base include congenital pathology, traumas, infections, inflammation and tumors.

In the followings, we present some examples of skull base pathology:

**Clinical case** - *Meningioma* of the olfactory sinus (Fig. 3 on page 11 and Fig. 4 on page 12), *neurinomas* in both internal auditory conducts (Fig. 4 on page 12) and bulbar *astrocytoma* (Fig. 3 on page 11) in a young woman with type II neurofibromatosis.

Meningioma - the most frequent intracranial extraaxial tumor, predominantly supratentorial, the peak age prevalence is between 35 and 65 years and it manifests a predilection for the feminine gender. There are demonstrated correlations with type II neurofibromatosis and with basal cells nevus syndrome. Usually it manifests by headache and seizures. If it's situated in the greater wings of the sphenoid, they have a tendency to enclose the carotid artery and the middle cerebral and to compress the optic nerve and the chiasm. CT - hyperostosis; calcifications; dural tail; erosions, mimicking schwannomas; contrast-enhancement. MR - T1 sequences are not very sensible (relaxation time similar to the cerebral tissue); in T2 it is iso- or hyperintense; presents homogeneous contrast enhancement.

Neurinoma (schwannoma) - the most affected cranial nerve is the VIII; the main symptoms there are hearing loss and tinnitus; expansion and asymmetry of the auditory canal, occupation of the pontocerebellar angle. MR is the technique of choice, they are hypointense in T1 and hyperintense in T2; they present contrast-enhancement, they have well defined borders, sometimes they show quistic parts, necrosis, and hemorrhage. They are bilateral in neurofibromatosis.

**Clinical case** - *Infiltrative mass in nasopharynx*(Fig. 5 on page 13 and Fig. 6 on page 14).

Nasopharyngeal carcinomas with skull base extensions usually have invasion of the clivus, the sphenoid sinus, the cavernous sinus, the pterygopalatine fossa, the pterygoid canal, and the foramen rotundum. They can manifest by persistent middle otitis secondary to the compromise of the Eustaquio tube.
Clinical case - *Squamous cell carcinoma of the ethmoid sinuses* (Fig. 7 on page 15, Fig. 8 on page 17 and Fig. 9 on page 19).

The carcinomas of the paranasal sinuses are not frequent processes. The main histological type is the squamous one and when it affects the ethmoid sinus it can also invade the orbit and the anterior cranial fossa. The sagittal and coronal sections are especially useful to appreciate the extension.

Clinical case - *Clivus chordoma* (Fig. 10 on page 21, Fig. 11 on page 21 and Fig. 12 on page 22).

The skull base chordomas occurs at younger ages (medium 20-40 years) than in the sacrum (40-60 years, the most frequent location). Habitually in the clivus and the sphenoccipital synchondrosis, they frequently present invasion of the nasopharynx, the nasal cavities, the maxillary sinuses and the petrous apex. CT - osseous destruction, calcifications. MR - isointense in T1, hyperintense in T2.

Clinical case - Right occipital *osteosarcoma* (Fig. 13 on page 23 and Fig. 14 on page 24).

Generally, the osteosarcoma is a osteolytic tumor which affects firstly the metaphysic parts of the extremities, with two peak ages of prevalence: one in the 2nd - 3rd decades of life and the other in the 7th decade. Rarely it affects the skull base.

Clinical case - *Jugular glomus* (Fig. 15 on page 25 and Fig. 16 on page 26).

The paraganglioma (glomus, quemodectoma) is a well vascularized tumor with a locally aggressive growth. The jugular type originates in the internal jugular vein and affects the IX, X, XI cranial nerves (at the level of jugular foramen) and the VII nerve (by extension). The tympanic type growths from the Jacobson nerve, in the mesotympanum and manifests by tinnitus and hypoacusia. CT - contrast enhancing mass with bone erosions. MR - heterogeneous aspect with lineal or punctiform signal voids ("pepper").

Clinical case - *Mycotic sinusitis* (Fig. 17 on page 27 and Fig. 18 on page 28).

It is classified in invasive and noninvasive and in acute or chronic. Mucormicosis and aspergillosis are particularly aggressive occurring usually in immunocompromised patients. They are associated to bone lesions, contrast enhancement and high tendency of intracranial spread.

Clinical case - *Otosclerosis* (Fig. 19 on page 29).
The typical patient is a young woman with bilateral hypoacusia and tinnitus. CT - otic bone resorption and, in advanced cases, osseous neoformation and sclerosis which alters the transmission of sound through the ossicular chain to the oval window.

Clinical Case - *Labyrinthitis* (Fig. 20 on page 30).

Usually it is a viral infectious process. It can be noted a decrease of the signal of the endolymph in T2 sequences and enhancement in T1.

Clinical case - *Internal carotid aneurysm*(Fig. 21 on page 31, Fig. 22 on page 32, Fig. 23 on page 33, and Fig. 24 on page 34).

The aneurysms of the intracranial segments of the ICA can manifest by headache, compression of the closed structures or rupture and bleeding. It can associate well defined bone resorption and curvilinear calcifications.

Images for this section:
Fig. 3: Sagittal contrast-enhanced T1WI. Heterogeneous enhancing tumor in cribriform plate with intracranial extension, invasion of the nasal cavity and the sphenoid sinus. Intraaxial lesion in medulla.
**Fig. 4:** Axial contrast-enhanced T1WI. Heterogeneous enhancing masses in both internal auditory canal with extension to both pontocerebellar cisterns and compression of the midbrain.
**Fig. 5:** Axial CT. Nasopharyngeal tumor which invades the skull base with destruction of the left side of the clivus and of the ipsilateral pterygoid.
**Fig. 6:** Axial T1WI with fat suppression. Nasopharyngeal tumor in the midline, infiltration of the clivus, sphenoid sinus, pterygoid process, pterygopalatine fossa and left masticator space.
Fig. 7: Sagittal T1WI. Hypointense mass in the ethmoid sinuses and nasal fossa. Secretions retention in the sphenoid sinus with high concentration of proteins (hyperintensity).
Fig. 8: Axial T2WI. Heterogeneous mass in the ethmoid cells, both nasal cavities and invasion of the sphenoid sinus and right orbit.
**Fig. 9:** Coronal, contrast-enhanced, T1WI with fat suppression. Mass with invasion of the maxillary sinus, lamina papyracea and extension to the right orbit with displacement of the rectus medialis muscle.

**Fig. 10:** Axial T2WI. Heterogeneous mass, predominantly hyperintense, in the midline and slightly to the right, with invasion of the cavernous sinus.
Fig. 11: Coronal T2WI. Lesion in the sella turcica, with invasion of the sphenoid sinus and suprasellar extension, which contacts with the optic chiasm and invades both cavernous sinuses.
**Fig. 12:** Sagittal contrast-enhanced T1WI. Heterogeneous contrast-enhancing mass in sphenoid sinus with sella turcica invasion and suprasellar extension.
**Fig. 13:** Axial T2WI. Extraaxial mass with invasion of the right petrous bone and extension to the right cerebellar hemisphere.
**Fig. 14:** Coronal contrast-enhanced T1WI. Heterogeneous enhancing lesion in both supra- and infratentorial level.
Fig. 15: Axial T2WI. Osteolytic mass in the right petrous bone with extension to the right bulbo-cerebellar cistern.
**Fig. 16:** Axial contrast-enhanced T1WI. Homogeneous contrast-enhancing mass with infiltration of the petrous bone and extension to the bulbo-cerebellar cistern.
Fig. 17: Axial CT. High-attenuating secretions in the right maxillary sinus, sphenoid sinus and right nasal fossa.
**Fig. 18:** Axial CT. Bilateral pericochlear and vestibular radiolucency.
Fig. 19: Coronal CT. High density material in the sphenoid sinus.
Fig. 20: Axial contrast-enhanced T1WI. Cochlear and vestibular enhancement (arrow).
Fig. 21: Axial CT. Extraaxial mass in the right cavernous sinus, heterogeneous with high and low density areas, and well defined borders.
Fig. 22: Axial T2WI. Lesion in the right cavernous sinus which depends on the internal carotid; central hyperintense area surrounded by a hypointense halo.
Fig. 23: Sagittal contrast-enhanced T1WI. Aneurysm thrombosed in the periphery with a permeable central zone.
**Fig. 24:** 3-D angiographic reconstruction of the aneurysm.
Conclusion

CT and MR studies provide crucial information of the skull base anatomy and of the extension of many pathologic processes contributing to a better therapeutic planning of every patient.

References


Personal Information

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