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Nasosinusal Endoscopic Anatomy and Physiology

Anatomia e fisiologia da endoscópica nasossinusal

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Abstract

The present article focuses on the analysis of the nasal cavity's anatomy succinctly and descriptively. This essay was carried out through a bibliographic review, directed to the detailed anatomy of the nasal cavity, and the structures that form its sinuses. We have identified the need for more studies directed to the related anatomical area so that the improved knowledge of this region ensures a nasoendoscopic treatment with better effectiveness and no complications.

Keywords
- anatomy
- nasal cavity
- nasoendoscopy
- neurosurgery

Resumo

O presente artigo foca na análise da anatomia da cavidade nasal de forma sucinta e descritiva. Esse trabalho foi realizado através de uma revisão bibliográfica, direcionada à anatomia detalhada da cavidade nasal, e às estruturas que formam seus seios. Constatamos a necessidade de mais estudos direcionados à área anatômica relacionada para que o conhecimento aprimorado desta região possa garantir um tratamento nasoendoscópico de melhor efetividade e sem complicações.

Palavras-chave
- anatomia
- cavidade nasal
- nasoendoscopia
- neurocirurgia

Introduction

In the areas of otorhinolaryngology and neurosurgery, endoscopic surgery has evolved significantly in the last decades. This happened due to improvements in endoscopy, such as the development of instruments for endonasal use, bipolar coagulation, and neuronavigation by image, which enabled better visualization of the nasosinusal region anatomy and the skull base.[1]

Tumors of the nasal cavity and paranasal sinus tend to be diagnosed at a late stage since their symptoms are usually attributed to more common etiologies. Nasal lesions include sinonasal papilloma, hemangioma, malignant fibrous histiocytoma, fibromatosis, leiomyoma, ameloblastoma, myxoma, hemangiopericytoma, fibroma, bone and bone-fibrous lesions, such as fibrous dysplasia, ossifying fibroma, and osteoma. Intracranial tissues can extend to the nasal area and present as encephaloceles, meningoceles, and pituitary tumors.[2]

Currently, transnasal, and especially transsphenoidal, approaches have been performed jointly by neurosurgeons and otorhinolaryngologists, which allowed a better transsphenoidal endonasal access to the skull base, avoiding extensive and traumatic dissections of the nose and, possibly, the oral region. These approaches, performed with the

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use of a rigid nasal endoscope, provide excellent visualization, allowing the surgeon to perform a precise and meticulous dissection with greater nose anatomy and function. These characteristics represent a great advance, especially for the sphenoid sinus surgery, which is the main gateway for the treatment of injuries that affect the skull base.[1]

Therefore, the goal of the present study was to explain in detail the anatomical components of the nasal cavity in order to enable an efficient approach in neurosurgical treatments.

Methodology

The methodology concerns a bibliographic review on physiology and nasosinusal endoscopic anatomy. The research was carried out from already prepared material, comprised of books and scientific articles. The research started in November 2019, extending until April 2020. The bibliographic survey contained in the current study was obtained through research in book and scientific articles, found in the Medline virtual databases via PUBMED, SCIELO, and Virtual Library, using the descriptors: *anatomy*, *nasal cavity*, *nasoendoscopy*, and *neurosurgery*.

Initially, the selected material was read using the inclusion criterion, with a 13-year time frame, from 2006 to 2019. After this selection, four books and fice articles were compiled. Articles whose topic was not relevant to the research and were outside of the delimited time frame were excluded.

Then, we started the descriptive analysis of the theme, according to the survey of pertinent information from the respective studies and, finally, the elaboration of the conclusion obtained through the analysis of the compiled texts.

Discussion

Paranasal Sinuses

The paranasal sinuses include the sphenoidal, ethmoidal, maxillary, and frontal sinuses (►**Fig. 1**). The lateral nasal part includes the inferior, middle, superior, and supreme turbinates, as well as the ostiomeatal complex and the nasolacrimal duct and orifices, which are highly vascularized.[2] The paranasal sinuses are extensions, filled with air, from the nasal cavity respiratory part of the following skull bones: frontal, ethmoid, sphenoid, and maxilla.[3]

Ethmoid Bone

The ethmoid bone is located between the orbital cavities and is part of the upper half of the nasal skeleton.[4]

This bone has four main components: the crista galli, the cribriform plaque, the perpendicular plaque, and the bilateral ethmoidal labyrinths, the last of which are formed from the lateral, medial, posterior, superior, and antero-inferior regions.[5]

Located on both sides of the ethmoid bone lateral region, these portions merge and remain joined by the crusty laminae, forming a continuous horizontal plate. In the medial fusion region between the two blades, there is a perpendicular plate called the crista galli.[5]

Medially, the ethmoid bone is limited by three conchae. The middle or first concha, the upper or second concha, and the supreme or third ethmoidal concha.[5] The second concha is located in the upper third of the nasal cavity, with its anterior portion opposite the medial central tendon (►**Fig. 2**).[4]

In the posterior part, the anterior wall of the sphenoid sinus delimits the ethmoidal cells. Anteroinferiorly, the ethmoidal cells undergo an opening to the ethmoidal infundibulum and posterior nasal cavity and choanae. The upper region is then formed by the frontal bone through the ethmoidal fovea.[5]

Finally, it is very important to mention the ethmoidal labyrinth. It is inserted in the crusty plate and has its own bone limits. The lateral part is formed by the lamina papyracea that separates the orbit from the ethmoid labyrinth. This anatomical region is of clinical relevance when thinking about the cases in which the lamina papyracea is dehiscent, as in these cases a pathway for the spread of inflammatory processes to the orbit becomes possible.[5]

Ethmoidal Cells

The ethmoidal cells are located between the orbit and the nasal cavity. These cells are the middle- and upper-nasal mucous membranes, small meatus invaginations for the ethmoid.[3]

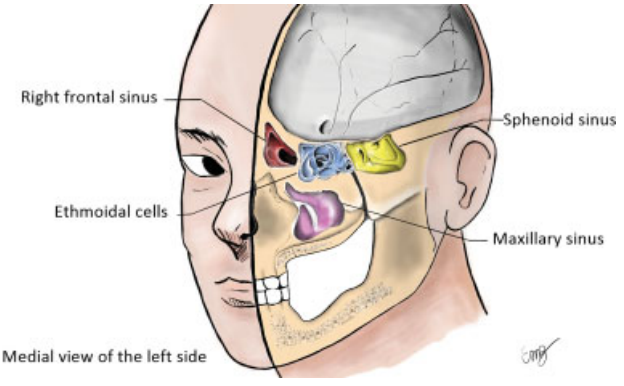

Fig. 1 The paranasal sinuses are composed of the frontal, maxillary, ethmoidal, and sphenoid sinuses. They are filled with air and extensions from the nasal cavity to the skull bones. (Source: Estevan Martin Portela Júnior).

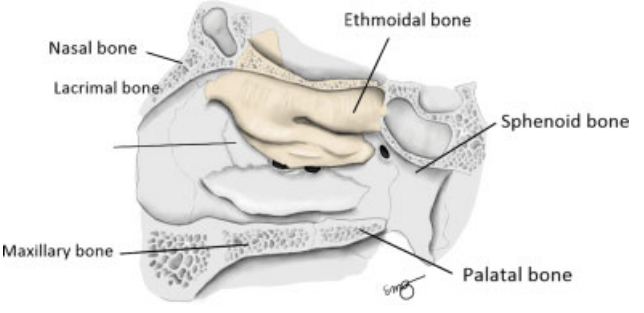

Fig. 2 The ethmoidal bone is located between the orbital cavities, and it is composed by the crista galli, cribriform plaque, perpendicular plaque, and bilateral ethmoidal labyrinths. Medially, it is limited by three conchae, the superior, medium, and inferior conchae. (Source: Estevan Martin Portela Júnior).

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Such cells are divided into anterior, middle, and posterior ethmoidal cells. The anterior ones drain into the middle nasal meatus through the ethmoidal infundibulum, both directly and indirectly. The middle ethmoidal cells—also called bullous cells—open directly in the middle meatus. The posterior ethmoidal cells open in the upper meatus. All of these cells are innervated by the nasociliary nerves' anterior and posterior branches.[3]

Lamellae of the Ethmoidal Labyrinth

Bone gills are thin, flattened structures that are usually found very close to each other. The spaces that are formed between the lamellae are called meatus.[3] During the embryonic development, the ethmoid labyrinth lamellae are externalized through the ethmoid on the nose's lateral wall, thus being called basal lamellae. There are five lamellae found in this region: the upper and supreme conchae, which we may or may not have, the middle concha basal lamella, the ethmoidal bulla, and the uncinate process.[5]

1- Uncinate Process

It is a thin bony structure that is located in the anterosuperior to posteroinferior direction. In the super posterior direction, the border is concave and parallel to the ethmoidal bulla's anterior surface. Anteroposteriorly, it is inserted in the middle concha, forming the agger nasi inferior-medial wall. In the lower portion, the uncinate process is inserted in the lower concha and in the palatine bone.[5]

Between the ethmoidal bulla and the uncinate process, at its free edge, is the lower semilunar hiatus, a slit that corresponds to the passage to the ethmoidal infundibulum.[3]

Finally, the uppermost portion is not visible; it can, however, can have three different types of insertion[5]:

- Laterally, it is inserted in the lamina papyracea. Consequently, the infundibulum is closed superiorly in a blind bottom, denominated the terminal recess. In this case, the ethmoidal infundibulum and the frontal recess are separated. Therefore, the frontal recess opens in the middle meatus between the infundibulum and the middle concha;
- Skull base, in the region of the superior ethmoid;
- Middle concha.

In the possibilities of the skull base and middle concha, the frontal recess and frontal sinus drain directly into the ethmoidal infundibulum. Thus, the chance of simultaneous involvement of the maxillary and frontal sinuses is greater since the drains from both sinuses have a common route.[5]

2- Ethmoidal bulla (Second lamella)

The ethmoidal bulla corresponds to the largest anterior ethmoidal cell. It is formed by bullar- lamella pneumatization. Laterally, it comes in contact with the lamina papyracea. Subsequently, it may present variable distances from the middle concha basal lamella and the middle concha diagonal portion. The medial limit is the middle concha's vertical portion. When there is a three-dimensional space between the bulla and the middle concha basal lamella, it is called the retrobulbar recess or lateral sinus, and the entrance to this space is called the upper semilunar hiatus.[5]

3- Middle concha (diagonal portion of the third, or basal, lamella)

To guarantee the stabilization of this lamella, the middle concha has three insertion parts[5]:

- Anterior (vertical portion);
- Average (diagonal portion);
- Posterior (horizontal portion).

Anteriorly, it is inserted in a sagittal direction into the lateral portion of the crusty lamina. Medially, the insertion is in the lamina papyracea and/or in the medial wall of the maxillary sinus, forming the middle meatus' most posterior roof.[5]

It is the middle concha's basal lamella that separates the ethmoidal cells in anterior and posterior. The upper meatus may extend anteriorly and inferiorly, thus causing a bulging anteriorly. The basal lamina's middle third may present irregularities with anterior and posterior bulging. This happens due to the extension of posterior and anterior ethmoidal cells.[5]

The middle concha's posterior portion borders the palatal bone's perpendicular-process ethmoidal crest. Immediately after the insertion of this portion, it meets the local sphenopalatine foramen, which passes the sphenopalatine arteries and veins and the posterior and superior nasal nerves.[5]

Lower Conchae and Meatus

The inferior nasal concha is formed by an independent bone, and it is covered by a mucous membrane that contains large vascular spaces that increase and control the nasal cavity caliber.[3]

The inferior concha is a thin bony blade curved at its free edge, and it inserts on the maxilla nasal surface and the palatal bone's perpendicular blade. Embryologically, it has a different origin from other conchae. The inferior concha results from the endochondral and maxillary region's bony infiltration.[3]

There are three prominences that protrude from the lower concha. The most anterior prominence corresponds to the lacrimal process that connects to the lacrimal bone and the nasolacrimal duct's ostium. The most median prominence, the inferior concha ethmoidal process, connects to the uncinate process and separates the anterior from the posterior fontanelle. The posterior prominence, which is the maxillary process, forms the maxillary sinus medial part.[5]

The inferior nasal meatus is a horizontal passage located in an inferolateral position to the inferior nasal concha. The nasolacrimal duct, which drains tears from the lacrimal sac, opens at the bottom of this meatus[3] (►**Fig. 3**).

Turbinates and Superior Meatus

Super posterior to the ethmoid's medium process is the spheno-ethmoidal recess, which receives the sphenoidal sinus opening.[5]

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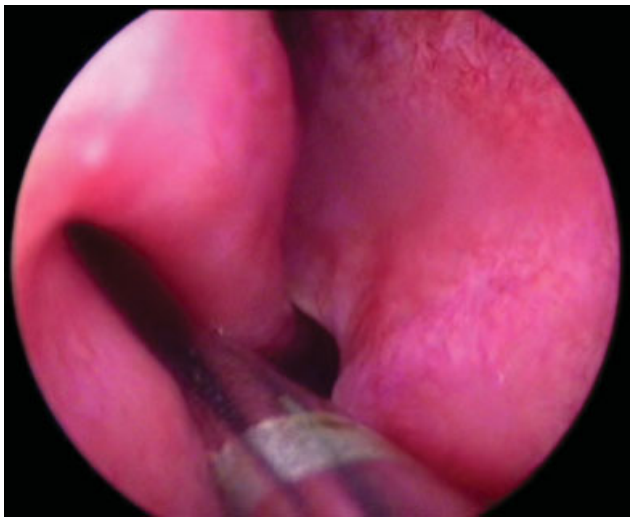

Fig. 3 Inferolateral position to passage the inferior nasal meatus; the nasolacrimal duct opens at the bottom of this meatus. (Personal archive of Dr Marcelo Nery Silva).

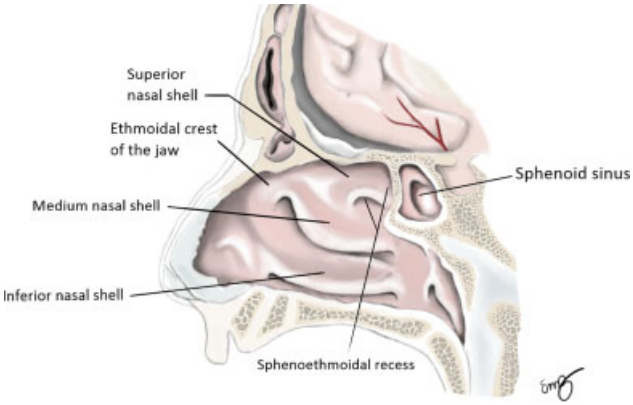

Fig. 4 The superior-posterior part of the ethmoid is the sphenoethmoidal recess, which receives the opening of the sphenoidal sinus. The ethmoidal sinuses open through one or more hole of the upper nasal meatus in which is a narrow passage between the upper and middle nasal turbinates. (Source: Estevan Martin Portela Júnior).

The upper nasal meatus is a narrow passage between the upper and middle nasal turbinates, in which the posterior ethmoidal sinuses open through one or more holes.[3] (►**Fig. 4**). There may even be a fourth or fifth (supreme) turbinate.[5]

Nose Sidewalls Spaces

Semilunar Hiatus

The semilunar hiatus is involved superiorly by the ethmoidal bulla, laterally by the orbit, inferiorly by the uncinate process, and, medially, it communicates with the middle meatus. Laterally and inferiorly, the semilunar hiatus communicates with the infundibulum. The ethmoidal bulla generally consists of a single aerated cell, which projects inferior-medially over the semilunar hiatus.[6]

The lower semilunar hiatus corresponds to a two-dimensional cleft that is located between the posterior margin of the uncinate process and the anterior wall of the ethmoidal bulla. It gives access to a space (therefore, three-dimensional) called the ethmoidal infundibulum.[6]

Fig. 5 The lower semilunar hiatus is a two-dimensional space that represents the entrance to the ethmoidal infundibulum. In this endoscopic image, the lower semilunar hiatus is found between the posterior free edge of the uncinate process and the anterior portion of the ethmoidal bulla. (Personal archive of Dr Marcelo Nery Silva).

The upper semilunar hiatus is the two-dimensional structure located between the ethmoidal bulla and the basal lamella, which communicates the retrobullar recess with the middle meatus[5] (►**Fig. 5**).

Ethmoidal Infundibulum

Through the lower semilunar hiatus, there is a three-dimensional space called the ethmoidal infundibulum. Its limits are:

1. Medial wall: uncinate process;
2. Lateral wall: lamina papyracea;
3. Anterior wall: formed by the uncinate process junction with the structures that form the infundibulum lateral wall;
4. Posterior wall: ethmoidal bulla.

The ethmoidal infundibulum connects the ostium maxillary and ethmoidal sinuses to the semilunar hiatus. The greater the uncinated process, the narrower the ethmoidal infundibulum becomes.[5]

Frontal Recess

The frontal recess is a narrowing between the frontal sinus and the anterior middle meatus, usually located in the infundibulum anterosuperior portion. It proceeds through the semilunar hiatus to the middle meatus anterior portion, where it joins the ipsilateral maxillary sinus flow.[6]

Its limits are generally:

1. Anterior: agger nasi and frontal cells;
2. Posterior: variable according to the ethmoidal bulla;
3. Lateral: lamina papyracea;
4. Medial: middle turbinate's most anterior and upper portions. The olfactory fossa, which is the anterior cranial

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fossa's most anterior portion, is located superiorly to the middle turbinate insertion;
5. Superior: frontal and ethmoid bone.

Depending on the uncinate process insertion, it can be part of the frontal recess medial or lateral walls, and the frontal recess can open in the middle meatus or in the ethmoidal infundibulum.[5]

Suprabullar and Retrobullar Recess

Located superior and medially to the bullar lamella and the ethmoidal bulla. It is limited superiorly by the roof of the ethmoid, inferiorly by the roof of the ethmoidal bulla, laterally by the lamina papyracea, and posteriorly by the middle turbinate basal lamella. Anteriorly, the suprabular recess is separated from the frontal recess only when the bullar lamella is inserted in the skull base.[5]

The retrobullar recess is the space located in the posterior region of the anterior ethmoidal cells. Its limits are the lamina papyracea, laterally; the ethmoid roof, superiorly; the middle turbinate, posteriorly;-and the basal lamella, antero-inferiorly by the roof and ethmoidal bulla's posterior wall.[5]

Ethmoid Roof and Anterior Ethmoidal Artery

The ethmoid boné is superiorly opened in the two anterior thirds. Because of this, the frontal bone forms the ethmoid roof in this region.[5]

The anterior ethmoidal artery (AEA) is an important anatomical point used to locate the frontal sinus and the anterior skull base. Its injury during an endonasal procedure can cause serious complications, such as profuse bleeding, rhinoliquorrhea, artery retraction to the intraorbital region, and, consequently, orbital hematoma and even brain infections.[7]

In its intranasal path, the anterior ethmoidal artery is found in a bone canal called the anterior-ethmoidal canal. It departs from the orbit through the anterior ethmoidal foramen. This artery is responsible for the anterior ethmoidal cells and frontal sinus irrigation. It emits meningeal vessels in its pathway in the olfactory fossa and goes down to the nasal fossa, where it irrigates the septum anterior third and the adjacent nose lateral wall (►**Fig. 6**). It runs through the ethmoidal roof in a posteroanterior direction, and the spot where it penetrates the skull (cribriform union plate with the olfactory fossa's lateral lamella) is the most fragile and susceptible to lesions.[7]

Sphenoid Sinus

The sphenoid sinus has variable size and shape. It is divided into two asymmetrical parts by an irregular septum. When the sphenoid sinus is well developed, its thin and slender lateral wall forms the cavernous sinus medial wall. The internal carotid artery's intracavernous portion is the cavernous sinus' most medial structure, and, in well-developed sphenoid sinuses, it produces a bony elevation in its lateral

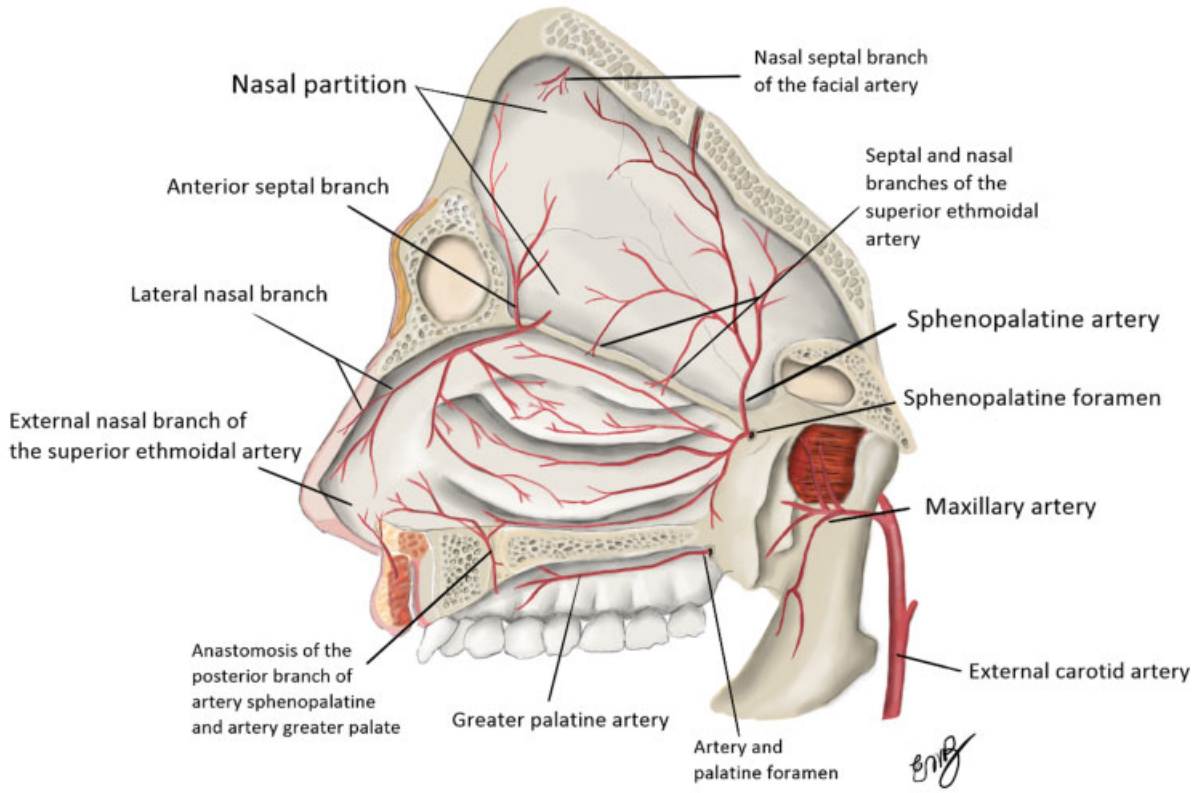

Fig. 6 Mirror image showing the main arterial irrigation of the nose. The anterior-septal branch irrigates the anterior-third of the septum and the lateral wall of the adjacent nose. (Source: Estevan Martin Portela Júnior).

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wall, called carotid prominence. This prominence is divided into three segments: presellar, infrasellar, and rectosellar. The presellar segment corresponds to the anterior vertical segment and the internal carotid artery intracavernous portion's anterior curvature. The infrasellar segment corresponds to the carotid artery's short horizontal portion, and the posterior curvature and posterior vertical segment forms the rectosellar segment.[1]

With relative frequency, the optical channel is partially surrounded by the sphenoid sinus, producing a bony protuberance in the anterosuperior portion of its lateral wall. The bone depression is called an opticocarotid recess, and it is located between the optical channel and the carotid prominence presellar segment. The sphenoid sinus's lateral bone wall is usually very thin and may be absent in some areas. It is located over the internal carotid artery and the optic nerve.[1]

The sella turcica and the optical chiasm are located superiorly, inside the roof.[2] Just below the sella's tuberculum, the carotid arteries are closer together, with an average distance of 13.9 mm (range: 10–17 mm). In the anterior wall of the saddle, there is a 20-mm gap between the carotid arteries (range 13–26,5 mm), and, at the level of the clivus, the distance between them is 17.4 mm (range 10.5–26.5 mm).[1]

The pneumatization degree of the sphenoid sinus varies considerably, reaching other structures, such as the clivus and foramen lacerum. Previously, pneumatization may involve the septum and, anterolaterally, the pterygoid-process base.[5] Due to this substantial pneumatization, the sphenoid body is fragile.[3]

Maxillary Sinuses

The maxillary sinuses are the largest paranasal sinuses.[3] They are limited superiorly by the orbital floor, inferiorly by the alveolar and maxilla-palatine processes, and medially by the nose's lateral wall.[5]

Usually bilateral, they occupy the maxillary bone's body. The natural ostium is located deep in the ethmoidal infundibulum, and, in 88% of cases, it is hidden by the uncinate process' lower third internal mucosa. The visualization of the ostium in the middle meatus' endoscopic examination, with a 0° endoscope generally corresponds to an accessory ostium presence[5] (►**Fig. 7**).

The maxillary sinuses' arterial irrigation proceeds mainly from the maxillary artery's upper alveolar branches; however, the descending and greater palatine artery branches irrigate the sinus floor.[3]

They drain into the middle meatus and are later limited by the pterygopalatine and infratemporal fossae.[2] The maxillary sinuses innervation is performed by the anterior, middle, and posterior-superior alveolar nerves, which are maxillary nerve branches.[3]

Frontal Sinus

The frontal sinus goes through the frontal bone pneumatization from the frontal recess.[5] The right and left frontal sinuses are located between the frontal-external and internal blades, after the superciliary arches and the nose root. The

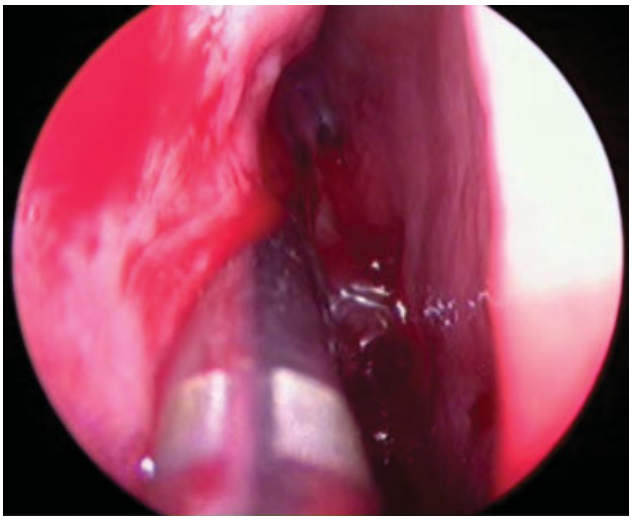

Fig. 7 The accessory maxillary sinus ostium. In 88% of cases, the maxillary sinus' natural ostium is hidden by the internal mucosa of the uncinate process. (Personal archive of Dr Marcelo Nery Silva).

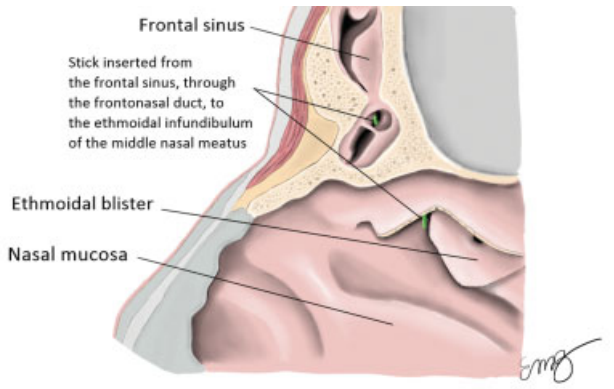

Fig. 8 Sagittal image showing the anatomical relationship between the frontal sinus and the nasal cavity. The frontal sinus drains into the middle meatus. (Source: Estevan Martin Portela Júnior).

asymmetrical air cavities in the frontal bone drain into the nasal cavity through the frontal recess.[2]

The frontal sinus recess can be occupied by several cells, and its anatomical variability is big. In a simplified way, the recess's anterior limit is the agger nasi (when present) and the posterior is the ethmoidal bulla. The uncinate process is the recess's lateral and lower limit when it is inserted in the lamina papyracea, forming the terminal recess.[5] Depending on the uncinate process' anterosuperior insertion, the frontal recess and frontal sinus may drain into the middle meatus or the ethmoidal infundibulum[5] (►**Fig. 8**).

Posterior Ethmoid

The posterior ethmoidal cells open directly into the upper meatus.[3]

They are found posteriorly to the middle turbinate basal lamella, being numbered from one to five. The posterior ethmoid is delimited superiorly by the skull base, laterally by

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the lamina papyracea, medially by the middle and upper turbinates' horizontal portion, and later by the sphenoid sinus' anterior wall. All cells and slits belonging to the posterior ethmoid open posteriorly and above the basal lamella, in the upper meatus.[5]

Pterygopalatine Fossa and Sphenopalatine Artery

The pterygopalatine fossa is an elongated pyramidal space below the orbit. Its upper end opens at the lower orbital fissure. Its lower end is closed, except for the sphenopalatine foramen. Laterally, it opens into the infratemporal fossa. It is located between the sphenoid bone's pterygoid process. Posteriorly, it is delimited by the palatal bone's vertical lamina; medially and anteriorly by the maxillary bone posterior wall. The maxilla is located at the front, and its roof is formed by the sphenoid's larger wing. It communicates laterally with the infratemporal fossa through the pterygomaxillary fissure, medially with the nasal cavity through the sphenopalatine foramen, and posterior superiorly with the skull's middle fossa through the round foramen.[5]

The main source of blood in the nasal cavity comes from the sphenopalatine artery, an external carotid system branch. Located in the nasal cavity's posterior region, this artery is responsible for the most severe episodes of epistaxis.[8]

The maxillary artery, a branch of the external carotid artery, originates from the sphenopalatine artery, that passes through the sphenopalatine foramen and provides branches that irrigate the lateral and septal nasal wall mucosa.[5]

Conclusion

Knowledge of the nasal cavity anatomy is essential for the performance of correct and efficient neurosurgeries. There is also a need for more studies and scientific publications on this topic to understand the nasal cavity's anatomy and, therefore, major neurosurgical approaches frequency, like greater security due to the mastery of the studied anatomy.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

Conflict of Interests

The authors have no conflict of interests to declare.

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