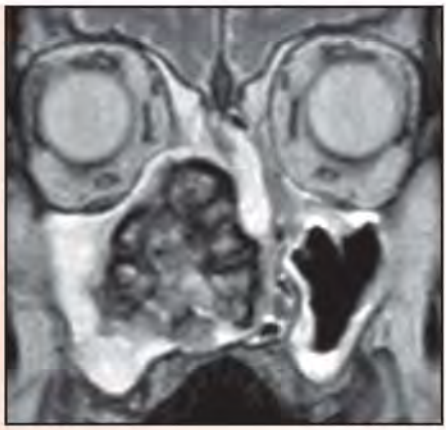
Clinico Radiological Series

SINONASAL IMAGING



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Sinonasal Anatomy: Structure-wise

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INTRODUCTION

Sinonasal cavity includes the nose, nasal cavity and paranasal sinuses including frontal, ethmoid, maxillary and sphenoid sinuses.

- *Nose* refers to the part projecting above the mouth, containing the nostrils, and used for breathing and smelling.
- *Nasal cavity* refers to is a large air filled space above and behind the *nose* in the middle of the face.

- *Paranasal sinuses* are mucosa-lined air filled spaces located within the facial/calvarial bones.
- Mucosa from the sinuses drains into the nasal cavity. Sinuses have numerous functions which include decreasing the weight of the head and humidifying and warming the air inhaled through nose. Sinuses also increase the resonance of speech.
- There are four sets of sinuses: (1) frontal, (2) ethmoid, (3) maxillary, and (4) sphenoid. Surface anatomy of the nose is depicted on 3D volume rendered image (Fig. 2.1).

ANATOMY OF NASAL CAVITY

- Its superior boundary is the cribriform plate and inferior boundary is formed by hard and soft palate (Fig. 2.2).
  - Midline nasal septum separates the nasal cavities on the two sides (Fig. 2.3). It comprises of an anterior cartilaginous and posterior bony part formed by vomer and perpendicular plate of ethmoid.
- The lateral wall bears the nasal turbinates
  - Three turbinates on the lateral wall—superior, middle, inferior (Fig. 2.4)
  - Occasionally there is a fourth/supreme turbinate
  - The middle turbinate has an anterior vertical attachment to skull base lateral to medial lamella of cribriform plate; and then a more posterior oblique attachment (also called basal lamella) to lamina papyracea and further posterior horizontal attachment to medial wall of maxillary sinuses (Figs. 2.5A to C)
- Meati refers to passages of the nasal cavity
  - There are three meati—superior, middle and inferior, each beneath the corresponding turbinate
  - A fourth supreme meatus may be there beneath the supreme turbinate, if present
  - Sphenoid and posterior ethmoid air cells drain into superior meatus

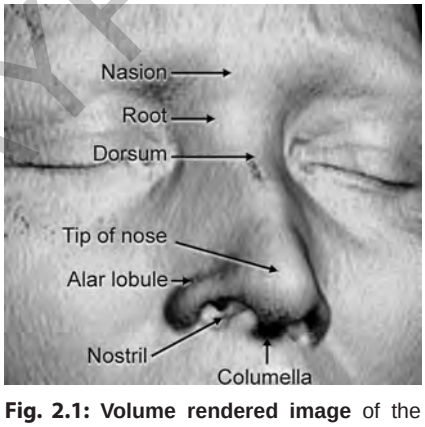


Fig. 2.1: Volume rendered image of the nose.

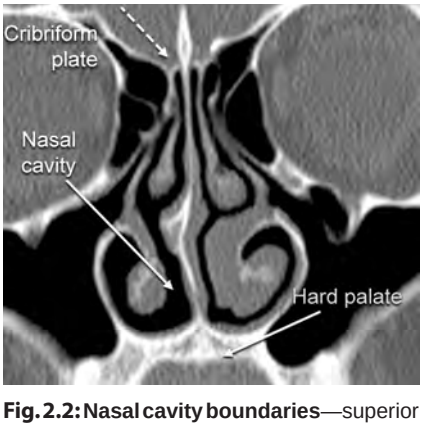


Fig. 2.2: Nasal cavity boundaries—superior cribriform plate and inferior hard palate.

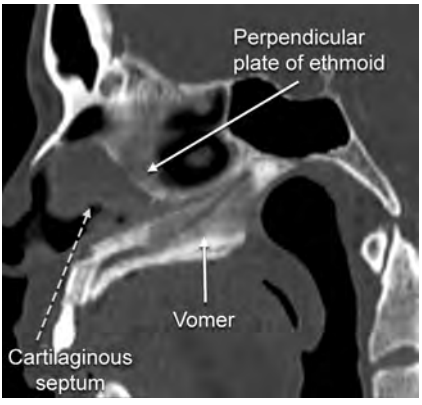


Fig. 2.3: Nasal septum parts—anteriorly cartilaginous part and posteriorly bony part (perpendicular plate of ethmoid and Vomer).

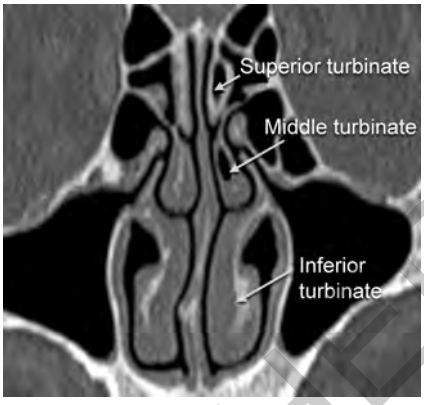
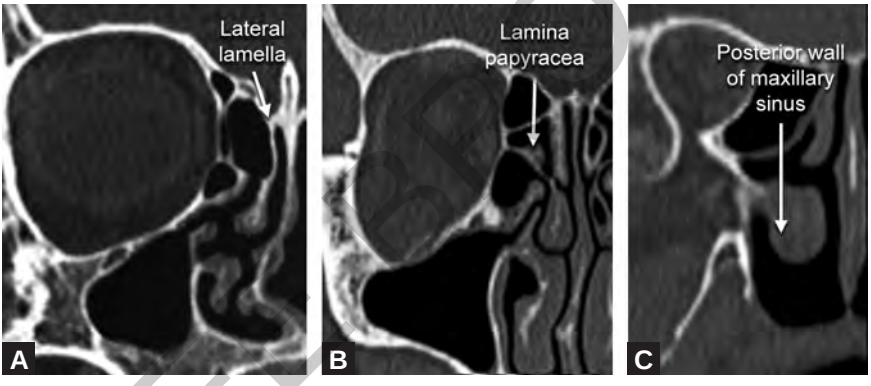


Fig. 2.4: Lateral wall of nasal cavity. Meati are beneath the corresponding turbinates.



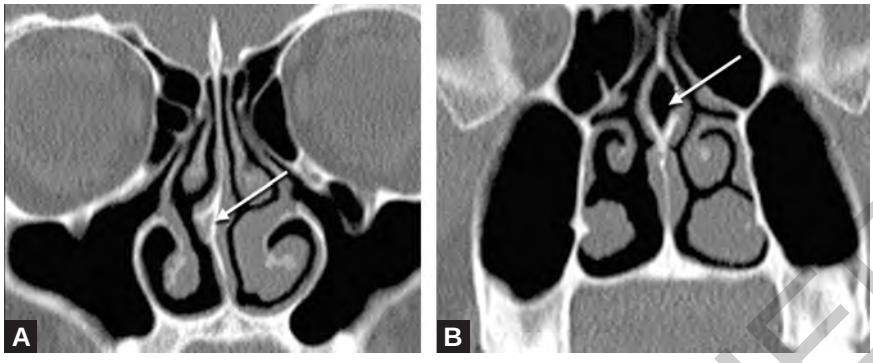
Figs. 2.5A to C: Middle turbinate attachments. (A) Anteriorly to lateral lamella superiorly; (B) Then obliquely to lamina papyracea; and (C) posteriorly to medial wall of maxillary sinus.

- Frontal, maxillary and anterior ethmoidal cells drain into middle meatus
- Nasolacrimal duct drains into inferior meatus.

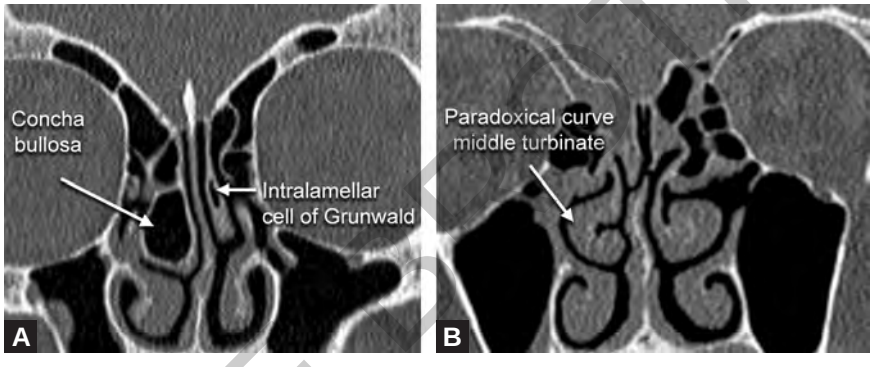
ANATOMICAL VARIANTS OF NASAL CAVITY

Nasal Septum

- *Septal Deviation (Figs. 2.6A and B)*
  - Most common at chondrovomeral junction
  - Can narrow middle meatus and impair access to the meatus during functional endoscopic sinus surgery (FESS)
  - Septal deviation can be either S-shaped deviation to either side of midline, or septal spur



Figs. 2.6A and B: (A) **Nasal septal deviation with spur** (arrow); (B) **Posterior septal pneumatization** (arrow).



Figs. 2.7A and B: (A) Right sided **concha bullosa** and left sided **intralamellar cell of Grunwald**. (B) **Paradoxical curvature** of right sided middle turbinate.

- *Septal spurs* (Figs. 2.6A and B) are often seen with septal deviation. It can narrow middle meatus and ethmoid infundibulum

- *Septal Pneumatization (Figs. 2.6A and B)*
  - Anteriorly (from crista galli) or posteriorly (from sphenoid sinus)
  - Posteriorly pneumatized septum can impair access to sphenoid ostium during FESS.

Nasal Turbinates

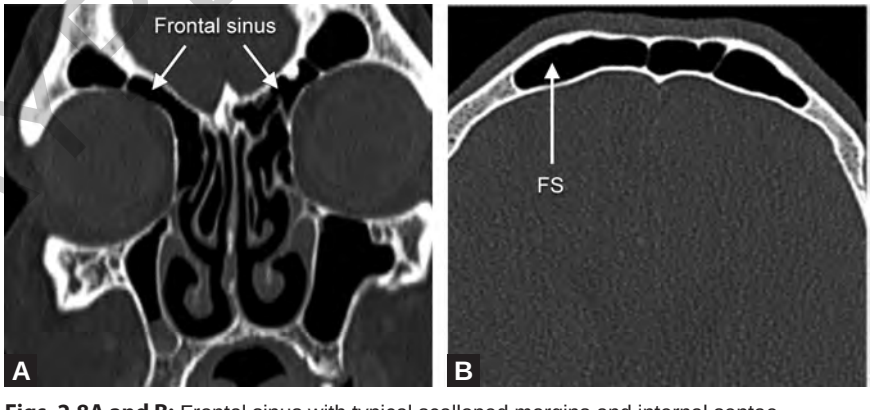
- Superior and inferior turbinates do not show any functionally significant variant.
- Middle turbinate variants are commonly significant. These include:
  - Concha bullosa (Fig. 2.7A): It is pneumatization of bulbous portion of middle turbinate. It is often bilateral, associated with septal deviation; and can obstruct the infundibulum if large
  - Intralamellar cell of Grunwald/conchal neck air cell/lamellar bulla (Fig. 2.7A): It refers to pneumatization above level of OMU involving vertical lamella; and does not have any impact on sinonasal physiology.

- Paradoxical curvature (Fig. 2.7B) refers to turbinate with lateral convexity which can impede access to OMU, if significant sized
- Turbinate sinus is deep invagination produced by sharp folding of middle turbinate on itself
- Pneumatized basal lamella is significant as it can be confused as an ethmoid air cell.

ANATOMY OF FRONTAL AND ANTERIOR ETHMOIDAL SINUSES

Frontal Sinus

- Frontal sinuses (FS) are located in the frontal bone superomedial to the orbit.
- These are formed by upward migration of the ethmoid cells after the age of 2 years. These are last sinuses to be pneumatized.
- Frontal sinuses are paired structures separated by a septum.
- FS has a thicker anterior wall, and a thinner posterior wall which abuts the anterior cranial fossa.
- On CT, Frontal sinuses have scalloped margins with internal septae typically (Figs. 2.8A and B).
- Each frontal sinus is funnel shaped with an ostium located in its inferior which drains through the frontal sinus drainage pathway (FSDP) into the middle meatus.
- Underdeveloped frontal sinus can result in intracranial penetration during intervention (Fig. 2.9).
- FSDP is surrounded by several frontoethmoidal and anterior ethmoidal air cells.
- The terminology used in the description of FSDP and the associated air cells is confusing and has been classified/modified by several authors



Figs. 2.8A and B: Frontal sinus with typical scalloped margins and internal septae.

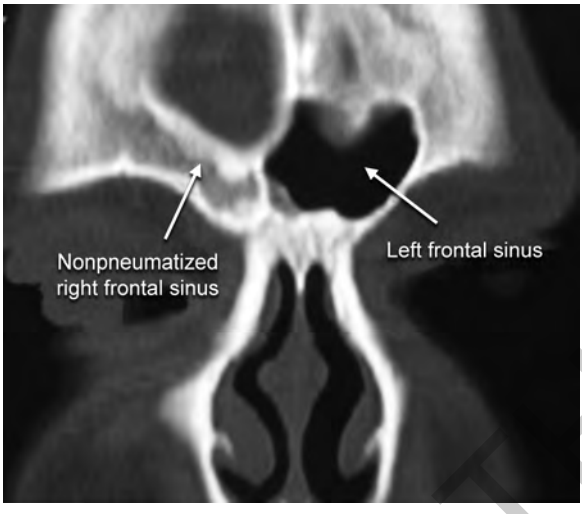


Fig. 2.9: Nonpneumatized frontal sinus.

(Aleya, Kuhn, Wormald).[1-3] A recent classification has been proposed by Wormald et al. as an international consensus statement.[3] In this chapter we attempt to amalgamate some of this content.

Frontal Sinus Ostium

- Transition zone between the frontal sinus and frontal recess.
- It is the narrowest part located at the level of the frontal beak.

Frontal Beak or Frontonasal Process of Maxilla

- It corresponds to level of frontal ostium (Fig. 2.10)
  - Thicker the frontal beak, narrower is the ostium
  - Above the frontal beak is the frontal sinus and below it is the FSDP.

Frontal Recess

- Frontal recess is below the ostium, and is the space into which the FS drains.

Frontal Sinus Drainage Pathway

- Frontal sinus drainage pathway (FSDP) can be evaluated in coronal images but is best evaluated in parasagittal images.
- It is inverted funnel shaped with apex at frontal ostium.
- FSDP has superior and inferior compartments.
- The superior compartment communicates with the frontal ostium above and inferior compartment below. It is located at the junction

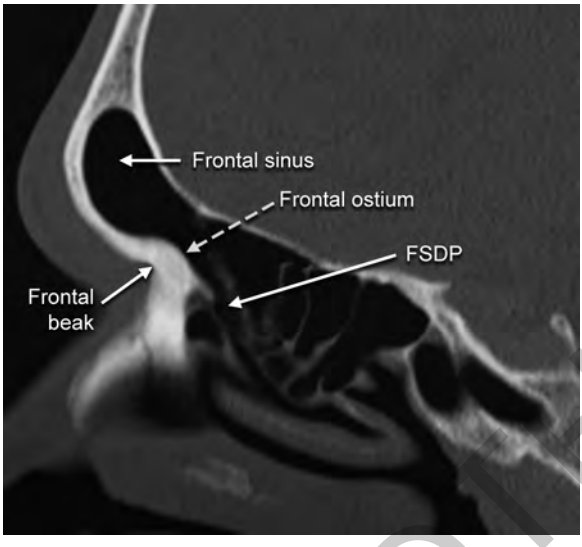


Fig. 2.10: Frontal beak at the level of frontal ostium. Above the frontal beak is the frontal sinus and below is the frontal sinus drainage pathway (FSDP).

of air spaces of the frontal and ethmoidal bones and is bordered by the *"frontoethmoidal air cells"*. The variable anatomy of these air cells governs the shape and size of FSDP.

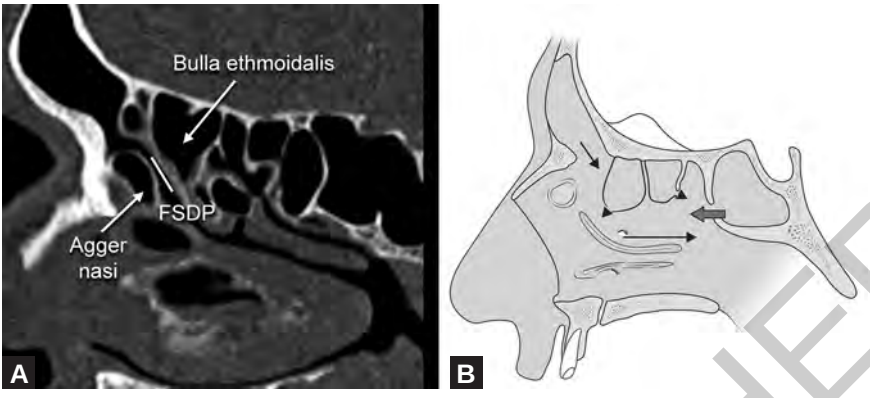
- The inferior compartment is a narrow passage formed by the ethmoid infundibulum or the middle meatus, depending on the attachment of the uncinate process.
- Variants of inferior compartment are discussed later in the chapter.
- Anterior to FSDP is agger nasi air cell, posteriorly lies the ethmoidal bulla, laterally is lamina papyracea and medially the lateral wall of olfactory fossa and middle turbinate, superiorly lies the fovea ethmoidalis (Figs. 2.11A and B).

Frontoethmoidal Cells

- Also known as Kuhn cells after the name of the researcher who first described them. These have variable anatomy and are clinically important as they have an impact on FSDP.
- Frontoethmoidal cells (FES) lie superior to agger nasi cell (ANC).
- Several classification systems are described.
- A recent modification of International Frontal Sinus Anatomy Classification 2016 is described in Table 2.1.

International Frontal Sinus Anatomy Classification[3]

- Wormald modified classification is also used frequently and classified FES into the following types (Figs. 2.13A to F):
  - Type 1: Single cell above ANC and below frontal beak

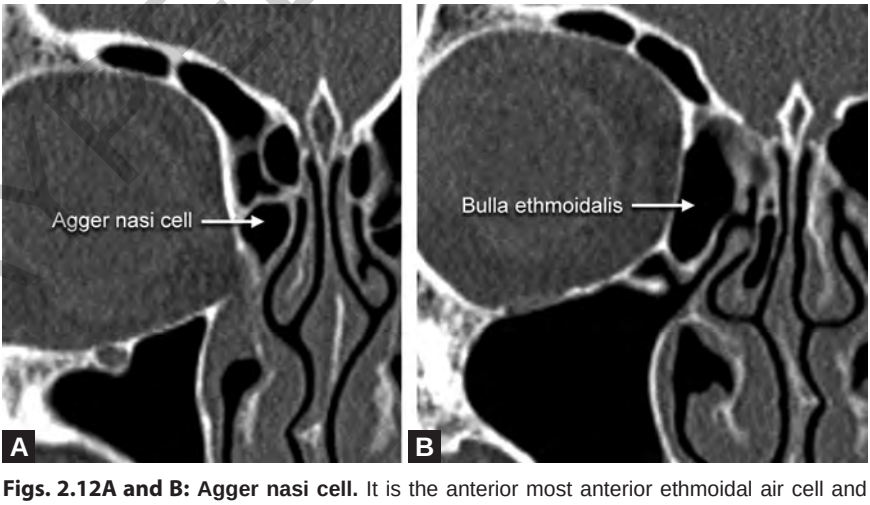


Figs. 2.11A and B: Frontal sinus drainage pathway (FSDP). (A) Agger nasi cell anterior to FSDP and bulla ethmoidalis posterior to FSDP. (B) Diagrammatic representation of drainage pathways of frontal sinus (arrow), maxillary ostium (long arrow), anterior ethmoidal (arrowheads) and sphenoid sinuses (block arrow). *Courtesy:* Dr Arvind K Kairo.

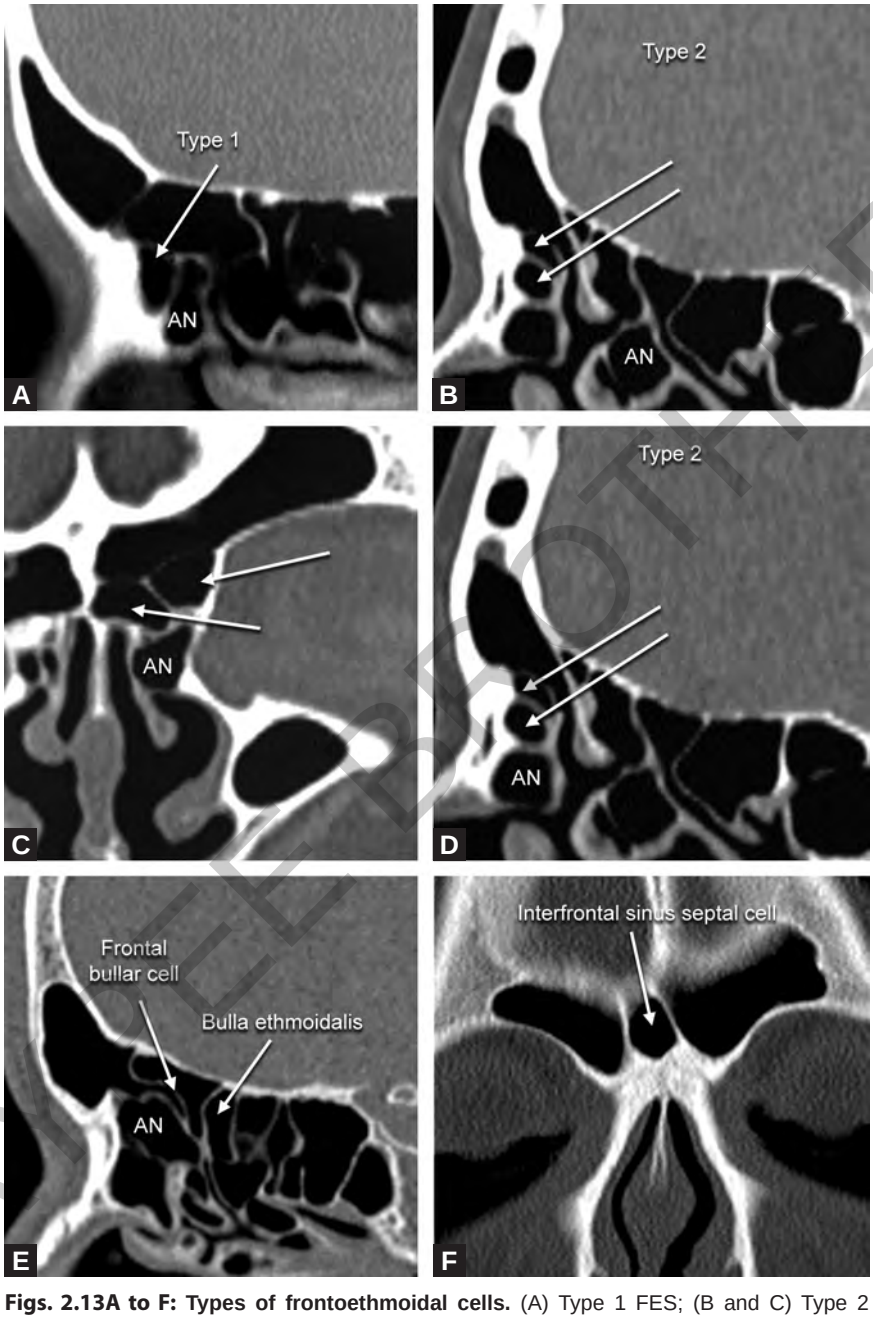
Table 2.1: The International Frontal Sinus Anatomy Classification (IFAC) modified classification of frontoethmoidal cells (FES).[3]

Anterior cells (push FSDP posteriorly, medially or posteromedially)	• Agger nasi cell (Figs. 2.12A and B) • Supra agger cell • Supra agger frontal cell
Posterior cells (push FSDP anteriorly)	• Suprabulla cell • Suprabullar frontal cell • Supraorbital ethmoidal cell
Medial cells (push FSDP laterally)	• Frontal septal cell

(FSDP: Frontal sinus drainage pathway).



Figs. 2.12A and B: Agger nasi cell. It is the anterior most anterior ethmoidal air cell and anteroinferior to FSDP. Bulla ethmoidalis is the largest cell of the anterior ethmoidal cells and is posterior to FSDP.



Figs. 2.13A to F: Types of frontoethmoidal cells. (A) Type 1 FES; (B and C) Type 2 FES. (D) Type 3 FES; (E and F) Types of frontoethmoidal air cells—frontal bullar cell and interfrontal sinus septal cell. This is seen in between frontal sinuses. (AN: Agger nasi cell).

- Type 2: Two or more cells above ANC and below frontal beak
- Type 3: Single cell above ANC and extending into frontal sinus not exceeding 50% height of frontal sinus

- Type 4: Single cell above ANC and extending into frontal sinus exceeding 50% of vertical height of frontal sinus or completely contained within frontal sinus
- Frontal bullar cell—single cell above bulla ethmoidalis along the undersurface of skull base and anteriorly extending into frontal sinus
- Interfrontal sinus septal cell—cell within the septum and may compromise the frontal ostium.

Ethmoid Sinuses

- Ethmoid sinuses (ES) are composed of numerous air cells located in the lateral mass of the ethmoid bone, between the two orbits.
- At birth, these cells are fluid filled and pneumatize over time, up to the age of 12 years.
- ES are bordered by the medial orbital wall (lamina papyracea) laterally, and the middle turbinate medially.
- Superiorly ES abuts the anterior skull base (ASB). The roof of ES is formed by the sphenoid bone and orbital process of the frontal bone. ASB is discussed subsequently in this chapter.
- The ES, however, has variable number and size of cells (from 3 to 18 in number) separated by thin bony septae. ES may extend above the orbits and frontal sinuses, posteriorly these can go posterior and lateral to sphenoid sinus, and inferolaterally into the roof of the maxillary sinuses.
- Broadly these are divided into anterior and posterior air cells, being divided by the basal lamella (attachment of the middle portion of middle turbinate to the lamina papyracea).
- The anterior group of cells drains into the middle meatus, while the posterior cells drain into the superior meatus.
- As the anterior cells abut the FS and the FSDP, these are considered together in the "frontoethmoidal anatomy". Located anterior to basal or ground lamella which demarcates anterior from posterior ethmoidal air cells.
- The anterior ethmoid cells drain via the bulla, ethmoid infundibulum, then hiatus semilunaris and into the middle meatus.
- There are several named AE cells that surround/form part of FSDP, and the ostiomeatal complex.

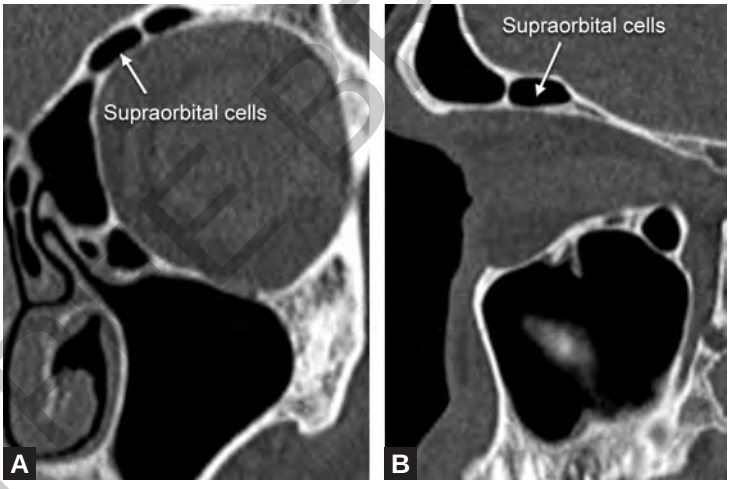
Anterior Ethmoidal Air Cells

- Largest cell in this group is bulla ethmoidalis which is a key surgical landmark (*see* Figs. 2.12A and B).
- Hiatus semilunaris is the gap between uncinate process and anterior wall of bulla ethmoidalis and opens into ethmoidal infundibulum.
- Agger nasi air cell is the most anterior extramural ethmoidal air cell and is located anteroinferior to FSDP (*see* Figs. 2.12A and B). Access to ANC needs to be carried out prior to FSDP surgery
  - If ANC small, then frontal beak is thicker with narrow ostium

- If ANC large, then frontal beak is small with wider ostium but large ANC can still obstruct FSDP albeit more inferiorly
- ANC also is closely related to nasolacrimal duct, can result in spread of infection from one structure to another.

OTHER ANATOMIC VARIANTS IN FRONTAL AND ETHMOIDAL SINUS CELLS[3,4]

- Suprabullar recess between superior wall of bulla ethmoidalis and roof of ethmoid sinus. Can form supraorbital cells laterally (Figs. 2.14A and B)
  - May displace anterior ethmoidal artery bony canal posteriorly
- Retrobullar recess
  - Between bulla ethmoidalis and basal lamella, if bulla does not reach the basal lamella posteriorly.
- Haller cells (Fig. 2.15).
  - Anterior ethmoidal cells along floor of orbits lateral to the plane of lamina papyracea
  - Can narrow maxillary ostium.



Figs. 2.14A and B: Supraorbital cells. Anterior ethmoidal cells seen to extend into the orbital plate of frontal bone.

ANATOMY OF MAXILLARY SINUS

- Located in the maxillary bone, this is the largest paranasal sinus and is first to pneumatize.
- Being fluid filled at birth, pneumatization in the horizontal posterolateral direction occurs up to 3 years of age, and then expansion inferiorly occurs from 6 years to 12 years.

Fig. 2.15: Haller cells. Anterior ethmoidal cells along the floor of orbit lateral to plane of lamina papyracea (dotted line).

- MS is in the shape of a pyramid with the apex directed laterally, and base along the lateral nasal wall.
- It extends from orbital floor superiorly to alveolar process of maxilla inferiorly..
- Inferior orbital nerve (branch of maxillary division of trigeminal nerve) runs along the roof of the maxillary sinus (Fig. 2.16).
- Inferior orbital nerve exits through the anterior MS wall into the cheek. Anterior wall is thinnest in the region of canine fossa, providing an entry point for intervention.
- Critical structures are located posterior to the MS. Pterygopalatine fossa is located behind the posteromedial wall, while the infratemporal fossa is behind the posterolateral wall.

ANATOMICAL VARIANTS OF MAXILLARY SINUS

- Sinus hypoplasia: Risk of orbital penetration during FESS.
- Septae (Fig. 2.17) can be fibrous/bony. These often extend from infraorbital nerve canal to lateral wall and can impede drainage of sinus.
- Dehiscent bony canal of infraorbital nerve may put this nerve at risk of involvement in cases of sinus disease (Fig. 2.18).

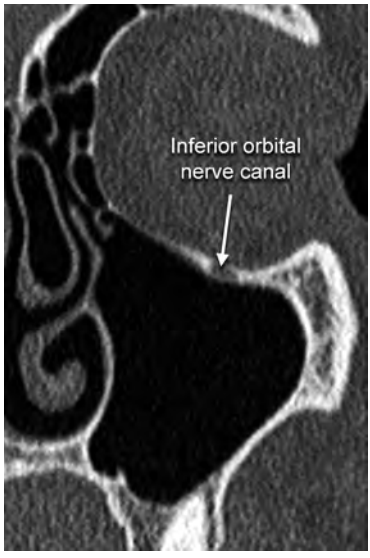


Fig. 2.16: Inferior orbital nerve canal. This runs along the superior wall of maxillary sinus.

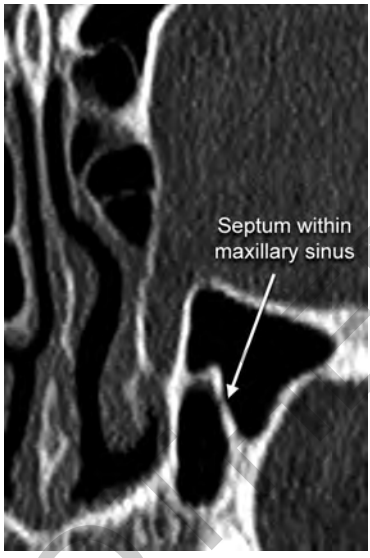


Fig. 2.17: Bony septum within left maxillary sinus.

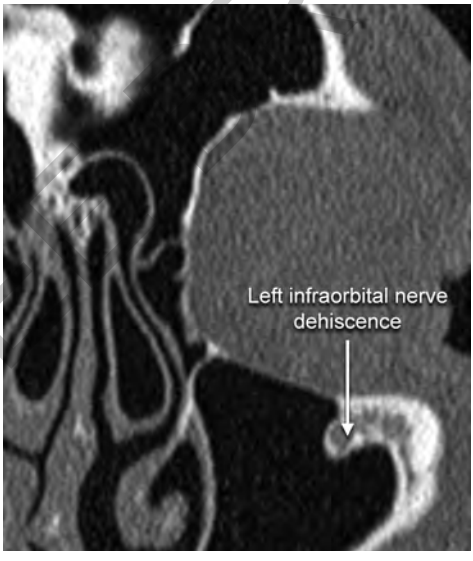


Fig. 2.18: Dehiscent infraorbital canal. Inferior orbital nerve canal projecting into the left maxillary sinus.

ANATOMY OF OSTEOMEATAL UNIT (OMU)

- It is a three dimensional space which is the drainage unit of frontal, anterior ethmoidal and maxillary sinuses.
- Comprises of maxillary ostium, ethmoidal infundibulum, middle meatus, bulla ethmoidalis, uncinate process and hiatus semilunaris (Figs. 2.19A and B)

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SINONASAL IMAGING

Salient Features

- This book focusses on core imaging and management issues in sinonasal diseases
- Complex topic presented in a simple and lucid manner
- Extensive coverage of newer classification and terminology
- Unique arrangement of sections having a combined clinical and radiological perspective of the disease
- Chapters contributed by reputed experts from Radiology, Otorhinolaryngology and Pathology.
- High quality images and illustrations with detailed description of the disease entities
- Illustrative cases: a unique feature of this book which will act as a ready guide to the radiologists in practice on how to approach and report in a specific situation
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