AJNR

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AJNR Am J Neuroradiol 1985, 6 (1) 77-84
http://www.ajnr.org/content/6/1/77.citation

Pictorial Essay

Anatomy of the Ethmoid: CT, Endoscopic, and Macroscopic

F. Terrier,[1] W. Weber,[2] D. Ruefenacht,[1] and B. Porcellini[1]

Many operations have been devised and are performed for the surgical treatment of severe chronic inflammatory disease and polyposis of the ethmoid. Although internal transnasal ethmoidectomy was discredited for many years because of possibly severe complications, it is now regaining in popularity and is preferred over external transmaxillary and transfacial procedures [1-3].

This is the result of recent more conservative operative techniques based on endoscopic control and the use of angle optics allowing enhanced visualization of the surgical field. However, transnasal ethmoidectomy is still difficult and dangerous. The ethmoidal labyrinth has great anatomic variability and few landmarks. Furthermore, the upper paranasal sinuses are close to important organs and structures.

Penetration beyond one of the walls into the eye laterally or the brain superiorly may entail very serious complications [4]. A detailed radiologic preoperative evaluation of the topographic relations is therefore essential for planning and executing this procedure. High-resolution thin-section computed tomography (CT), capable of accurately depicting the thin bony septa of the ethmoid bone and the superior paranasal sinuses, even in the presence of severe inflammatory soft-tissue changes, may provide a method for precise preoperative surgical mapping.

We illustrate the normal CT anatomy of the ethmoid region and correlate it with the endoscopic and macroscopic anatomy to define landmarks that can be recognized on CT and during endoscopically controlled transnasal ethmoidectomy.

TABLE 1: **Key to Numeric Labels in Figures 1-7**

Label	Anatomic Landmark
1	Ethmoidal labyrinth
1a	Anterior ethmoidal cell(s)
1b	Middle ethmoidal cell(s)
1c	Posterior ethmoidal cell(s)
2	Frontal sinus
3	Maxillary sinus
4	Sphenoidal sinus
5	Crista galli
6	Perpendicular plate
7	Nasal septum
8	Cribriform plate
9	Inferior turbinate
10	Middle turbinate
10a	Anterior part with vertical attachment
10b	Posterior part with horizontal attachment
10c	Basal lamella (intraethmoidal root of the middle turbinate)
11	Superior turbinate
12	Supreme turbinate
13	Unciform process
14	Ethmoidal bulla
15	Sphenoethmoidal recess
16	Medial ethmoidal wall
17	Medial orbital wall
18	Nasolacrimal duct
19	Accessory ostium of the maxillary sinus
20	Agger nasi, cell of the agger nasi

Materials and Methods

Two embalmed cadaver heads (specimens A and B) were used for this study. Contiguous axial, coronal, and sagittal high-resolution 2-mm-thick CT sectons of the middle face were obtained with a Somatom SR or a Somatom DR2 scanner (Siemens, West Germany). After craniotomy and removal of the brain, selected anterior and posterior ethmoidal cells as well as the frontal sinus were punctured successively with a butterfly needle through the anterioir skull base

This article appears in the January/February 1985 issue of *AJNR* and the March 1985 issue of *AJR*.
Received October 26, 1983; accepted after revision June 11, 1984.
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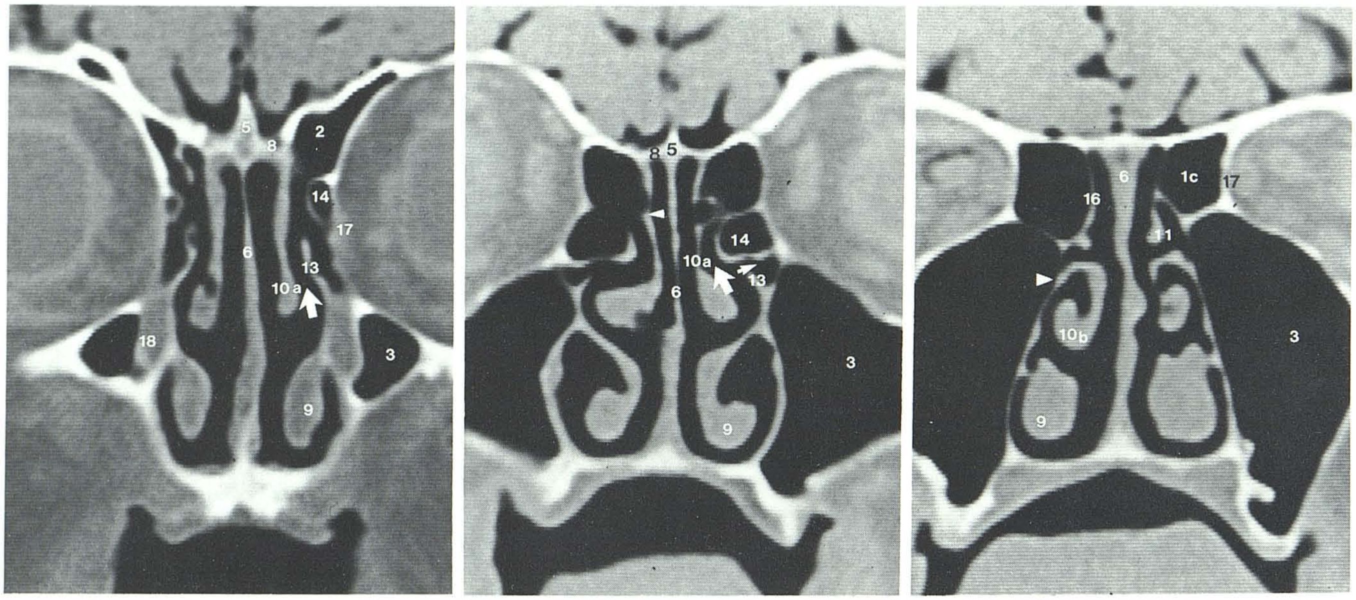


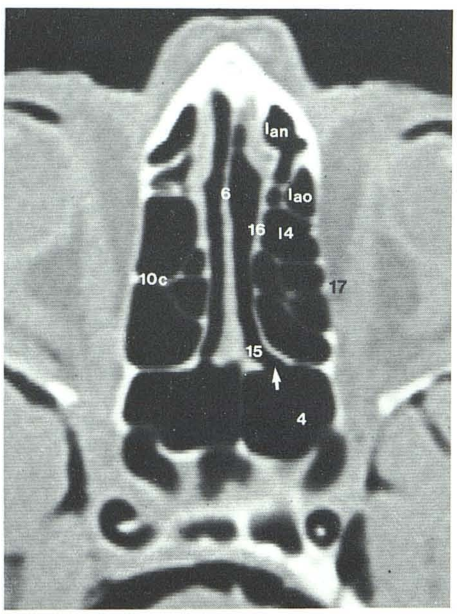
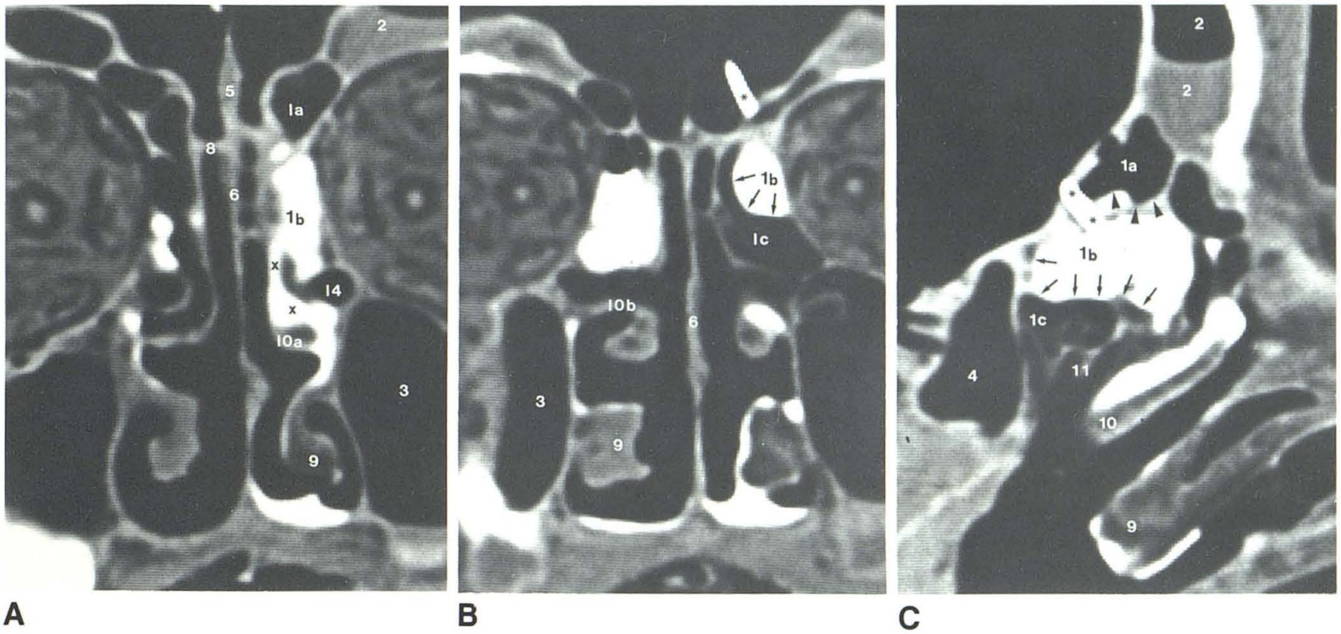


Fig. 1.—General CT anatomy of ethmoid with landmarks. **A**, Anterior coronal scan. Middle turbinate (10a) and unciform process (13) forming premeatal groove (*arrow*). **B**, Midline coronal scan. Ethmoidal bulla (14) between middle turbinate (10a) and unciform process (13). Unciform groove (*small arrow*) and retrobullar groove (*large arrow*). Attachment (*arrowhead*) of middle turbinate (10a). **C**, Posterior coronal scan. Posterior part of middle meatus roofed by horizontal attachment (*arrowhead*) of middle turbinate (10b). **D**, Axial scan. Sphenoethmoidal recess (15) with ostium of sphenoidal sinus (*arrow*). Medial ethmoidal wall (16) parallel to perpendicular plate (6).

and filled with dilute barium sulfate (E-Z-Cat). After each injection, CT scanning was repeated. Endoscopic examination of the nasal cavity and the middle meatus was carried out by using 30° and 70° angle optics (Storz, West Germany). The maxillary sinus was inspected after trepanation of the inferior meatus. In each specimen, an intranasal endoscopic dissection of the ethmoidal labyrinth was then performed on one side. At first, the ethmoidal bulla and the anterior ethmoidal cells were opened with forceps. In the next step, exenteration of the posterior ethmoidal cells was achieved. Finally, the sphenoidal cavity was entered and its anterior wall punched down. At the end of the procedure, there was a single broadly opened ethmoidal cavity communicating with the nasal cavity and the sphenoidal sinus. Afterward, each specimen was sawed through in the middle sagittal plane for macroscopic analysis of its intact side. The posterior ethmoidal cells were first displayed after resection of the superior and supreme turbinates. The middle turbinate was then removed to expose the middle meatus, the ethmoidal bulla, and the anterior ethmoidal cells. The nasofrontal duct too was dissected. Finally, the maxillary sinus was fenestrated after the inferior turbinate had been cut off.

Results

The anatomic landmarks corresponding to the labels used in figures 1–7 are identified in table 1.



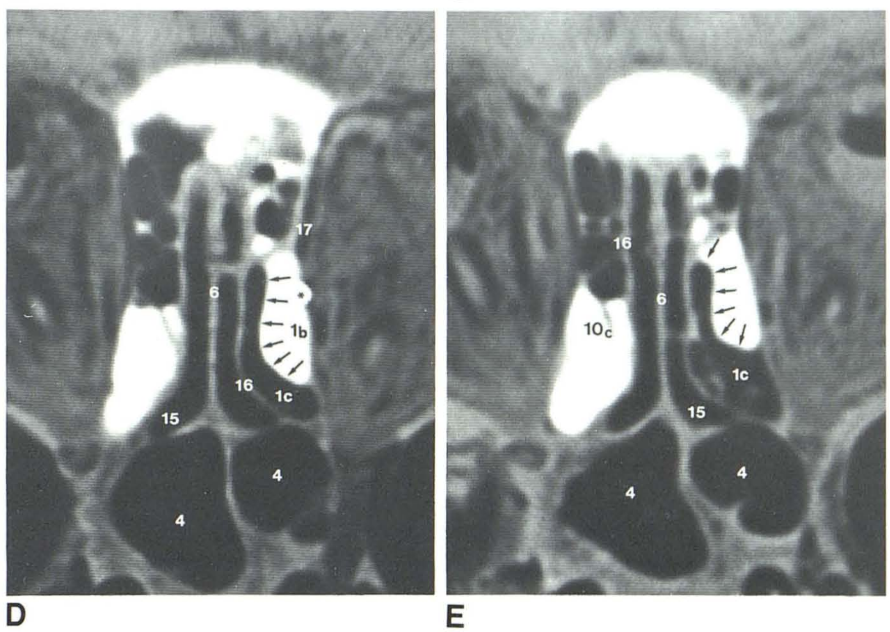
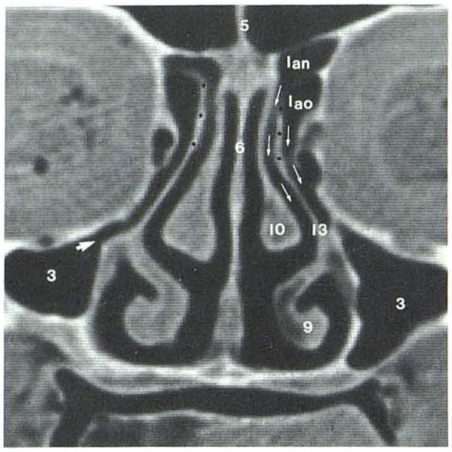


Fig. 2.—Basal lamella separating middle from posterior ethmoidal cells in specimen A after intraethmoidal injection of dilute barium sulfate. Contrast medium in middle ethmoidal cell on left side and in both middle and posterior ethmoidal cell on either side of basal lamella (10c) on right side. Needle (*). **A**, Anterior coronal scan. Contrast medium flowing from middle ethmoidal cell (1b) into middle meatus (x) around ethmoidal bulla (14) on left side. Aerated anterior ethmoidal cell (1a). **B**, Posterior coronal scan. Opacified middle ethmoidal cell (1b) separated from aerated posterior ethmoidal cell (1c) by basal lamella (*arrows*) on left side. On right side, basal lamella is seen as fine filling defect between opacified middle ethmoidal cell (1b) superiad and posterior ethmoidal cell (1c) inferiad. **C**, Sagittal scan, left side. Posterior extent of middle ethmoidal cell (1b) in its cranial aspect is demonstrated well. Anteriorly, this cell is separated from aerated anterior ethmoidal cells (1a) by transverse bony wall (*arrowheads*). Posterior ethmoidal cells (1c), fluid-filled frontal sinus (2), sphenoidal sinus (4). **D**, Cranial axial scan. On left side, opacified middle cell (1b) extends far posteriad. As a result, basal lamella (*arrows*) shows S-shaped configuration. **E**, More caudad. Middle ethmoidal cell does not reach so far posteriad.

General Anatomy

In coronal sections, the ethmoid bone has the shape of a Latin cross (figs. 1A–1C). The sagittal part above the horizontal bar (cribriform plate) is the crista galli and the part below, the perpendicular plate. At each end of the cribriform plate are two air cell cavities, the right and the left ethmoidal labyrinth or lateral mass. On the macroscopically dissected side of both specimens, seven and 10 cells, respectively, were counted, some of them incompletely divided by bony septa. The roof of the ethmoidal labyrinth is mainly formed by the orbital part of the frontal bone, which separates the ethmoidal cells from the anterior fossa and its contents (figs. 1A and 1B). It is adjacent internally to the cribriform plate and rises like a dome above it. It is most prominent at the anterior ethmoid. Medially and inferiorly, the ethmoidal roof is continuous with the medial wall of the ethmoidal labyrinth beyond the level of the cribriform plate. This wall attaches to the middle, superior, and supreme turbinates (figs. 1A and 1B). The lateral wall of the ethmoidal labyrinth forms part of the inner wall of the orbit, which is mostly the lamina papyracea. On axial sections, the ethmoidal labyrinth is trapezoidal or quadrangular in shape (fig. 1D). The apex points anteriad, and the base abuts the sphenoid. The posterior wall of the last ethmoidal cell (cell of Onodi) forms a common wall with the anterior wall of the sphenoidal sinus.



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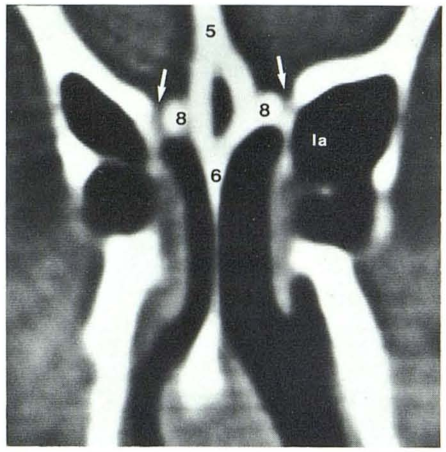

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Fig. 3.—Boundary (*) between orbital and nasal anterior ethmoidal cells. Bony wall is continuous below with unciform process (13). Nasal ethmoidal cell (1an) draining directly into middle meatus. Orbital ethmoidal cell (1ao) draining into unciform groove. Maxillary sinus with ostium (3).

Fig. 4.—Nasal split (*arrows*) in anterior part of cribriform plate for passage of nasal branch of anterior ethmoidal artery and nerve into nasal cavity.

Middle Turbinate

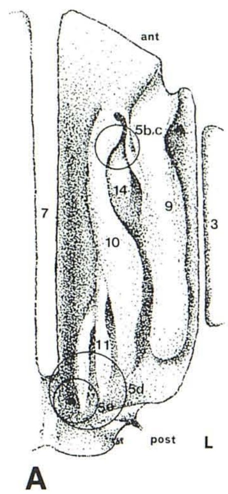
All of the turbinate bones of the nose, with the exception of the inferior, are part of the ethmoid. The principal turbinate is the middle. Anteriorly, it hangs down from the ethmoidal roof and lies both medially and inferiorly to the anterior ethmoidal cells (figs. 1A and 1B). Posteriorly, however, its insertion turns laterad behind the ethmoidal bulla and forms a thick horizontal bony plate, the roof of the middle meatus (fig. 1C). Coronal CT scans show this prominent bony landmark particularly well. At endoscopy, visualization of its superior side requires the opening of the ethmoidal bulla (fig. 5C). Macroscopically it is best seen after the superior turbinate has been removed and the posterior ethmoidal cells exenterated (figs. 6B–6D).

Basal Lamella

The ethmoidal labyrinth is internally divided into anterior and posterior parts by an ethmoidal lamella, the so-called basal lamella [5]. Being the intraethmoidal root of the middle turbinate, this basal lamella runs outward to the lamina papyracea and upward to the roof of the labyrinth. All cells in front of the attachment of this basal lamella are called anterior cells and drain into the middle meatus. All cells posterior to it are classed as posterior and drain into the superior or supreme meatus. By means of injection of contrast medium into anterior and posterior ethmoidal cells and subsequent CT scanning, the configuration of this important anatomic boundary was shown to be quite complicated in both studied specimens (fig. 2). On axial sections, it appeared as an S-shaped line. As a result, the last anterior ethmoidal cell (middle ethmoidal cell) was seen to extend far posteriad along the medial orbital wall. On sagittal sections, this bony septum was shown to run obliquely from both anterior and inferior to posterior and superior. On coronal sections, it was also recognized, separating the last anterior ethmoidal cell from the posterior half of the labyrinth. Macroscopically, this border between the anterior and posterior ethmoidal cells was well demonstrated (figs. 6C and 7C). At endoscopic dissection, however, it was not easily recognized.

Middle Meatus and Unciform Process

The middle meatus lies beneath the middle turbinate. Three key landmarks are seen at endoscopy and also can be localized easily with CT: the ethmoidal bulla, the unciform process, and the middle turbinate itself (figs. 1B and 5B). The blisterlike ethmoidal bulla, which lies under the cover of the middle turbinate, is the most accessible part of the labyrinth anteriorly and inferiorly (figs. 6C, 6D, 7A, and 7B). It may vary considerably in size. It consisted of a single cell draining into the middle meatus in one specimen and into the superior meatus in the other. The unciform process of the ethmoid is a slender bony plate projecting from the lateral wall in the ventral part of the middle meatus (figs. 1A, 6C, 6D, 7A, and 7B). Anteriorly, it is adherent to a ridge of the ascending process of the maxilla, called the agger nasi (agger = mound) (fig. 6). Here a cell may be developed, known as the cell of the agger nasi (a cell that also belongs to the group of the unciform process). Such a cell was observed in one of the two specimens, draining directly into the maxillary canal (fig. 6D). Posteriorly, the unciform process curves downward, first in front of the bulla and then below it. The gutterlike slit between the bulla and the unciform process is the unciform groove (also called the unci-bullar or lateroinferior groove) (figs. 1B, 5B, 6C, and 6D). Anteriorly, the groove ended in an ethmoidal cell in one specimen and extended into a large ethmoidal cell communicating with the frontal sinus in the other. A second gutter is formed between the bulla and the middle turbinate: the retrobullar groove (bulloturbinal or mediosuperior groove). The most anterior part of the middle turbinate ridges across the unciform process to gain attachment to the inner surface of the ascending process of the maxilla. In this way, the tip of the middle turbinate and the unciform process combine to form a narrow slit in front of the bulla. This is the opening of the middle meatus or premeatal groove (fig. 1A) [6]. Posterior to the ethmoidal bulla, the middle



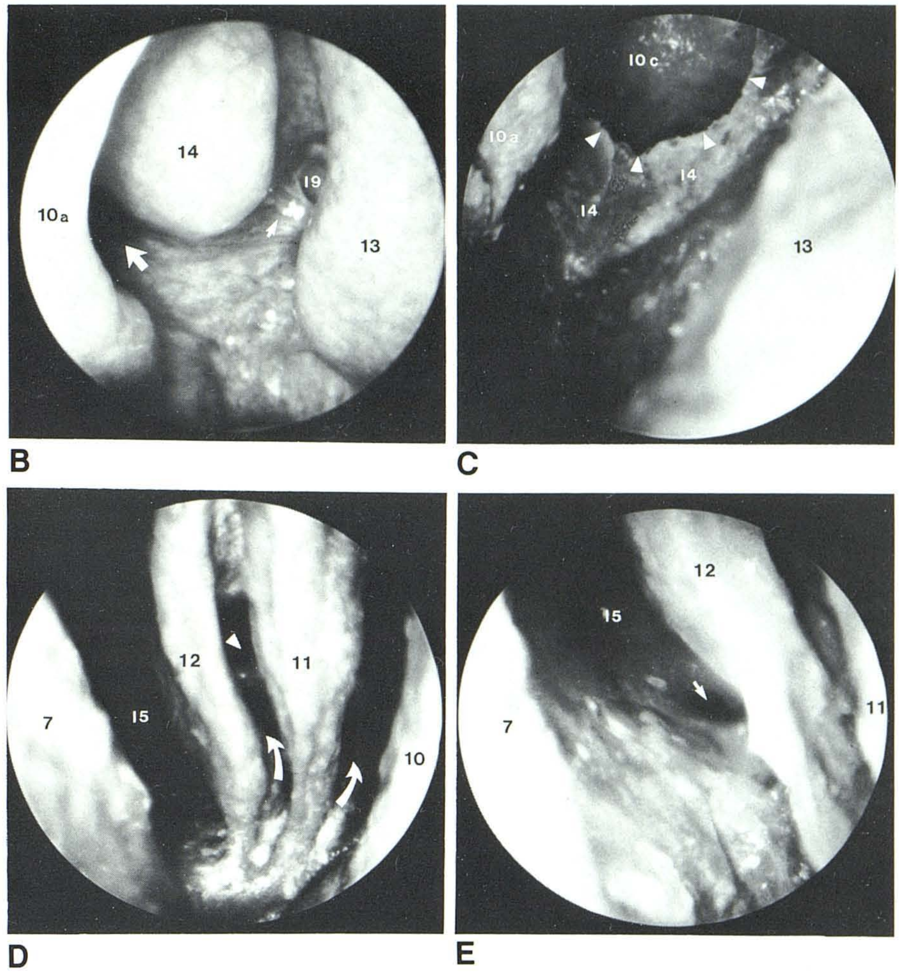


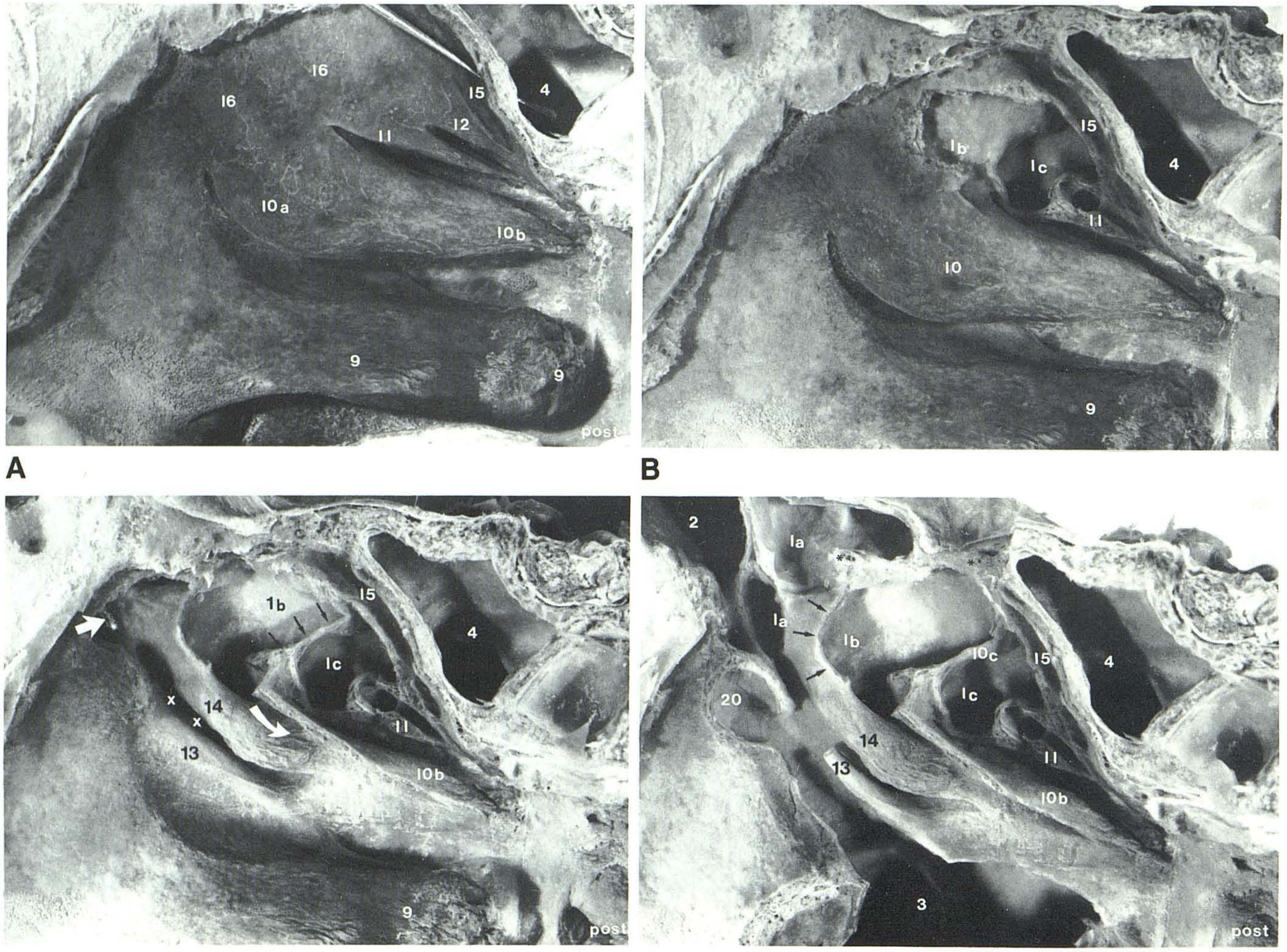
Fig. 5.—Endoscopic anatomy of ethmoid with landmarks. Left side of specimen B. **A**, Left nasal cavity seen from floor. Circles indicate details of **B–D** photographed through endoscope. **B**, Anterior rhinoscopy. Ethmoidal bulla (14) between middle turbinate (10a) and unciform process (13). Unciform groove (*small arrow*) and retrobullar groove (*large arrow*). (Cf. fig. 1B.) **C**, Anterior rhinoscopy. Ethmoidal bulla (14), opened, best demonstrating basal lamella (intraethmoidal root of middle turbinate) (10a). (Cf. fig. 2C.) **D**, Posterior rhinoscopy. Posterior ethmoid with supreme and superior meatus (*arrows*) between supreme (12) and superior (11) or superior and middle (10) turbinate, respectively. Sphenoethmoidal recess (15). Ostium of posterior ethmoidal cell (*arrowhead*) drains into supreme meatus. **E**, Sphenoethmoidal recess (15) with ostium of sphenoidal sinus (*arrow*).

turbinate is roofed by the horizontal bony plate, which gives insertion to the middle turbinate (fig. 1C).

Anterior Ethmoidal Cells; Frontal and Maxillary Sinus

Two bony septa divide the anterior ethmoidal labyrinth into three cell groups: the cells of the unciform process, the cells of the middle meatus, and the cells of the ethmoidal bulla [7]. The first of these septa lies about in the sagittal plane and attaches caudally to the unciform process (figs. 1D and 7A). It delimits the cells of the unciform process laterally from the cells of the middle meatus medially. The second bony plane is transverse and is continuous below with the ethmoidal bulla. It separates the cells of the bulla posteriorly from the other two cell groups anteriorly (figs. 2C and 6D). The cells of the unciform process abut laterally and anteriorly on the lacrimal bone and the ascending process of the maxilla. They drain into the unciform groove. The cells of the middle meatus lie medially and drain directly into the middle meatus or the premeatal groove (figs. 3 and 7A). With regard to their topographic relations, the cells of these two last groups can also be called orbital and nasal anterior cells, respectively. Their ostia were well imaged during endoscopic examination of the middle meatus in both specimens. The cells of the ethmoidal bulla are clustered above the bulla and open into the retrobullar groove (figs. 6C, 6D, 7B, and 7C). They are known also as middle ethmoidal cells. On CT, the exact arrangement of the anterior ethmoidal cells could only be identified retrospectively after macroscopic dissection. In one of the two specimens, the group of the middle meatus was not developed, while in the other, the three cell groups could be defined.

The frontal sinus originates embryologically from an anterior ethmoidal cell that may belong to any of the three cell groups [7]. This accounts for the great variability of its orifice at the nasal end of the nasofrontal duct. In one specimen, the frontal sinus was the only cell of the group of the middle meatus, and the nasofrontal duct was situated medially along the middle turbinate. Its lower opening was found above the unciform groove draining directly into the middle meatus (fig. 6C). This is the most frequently encountered disposition, according to Sieur and Jacob [8]. However, barium sulfate injected into the sinus cavity readily flowed into the unciform groove. In the other specimen, the sinus arose from the



C D

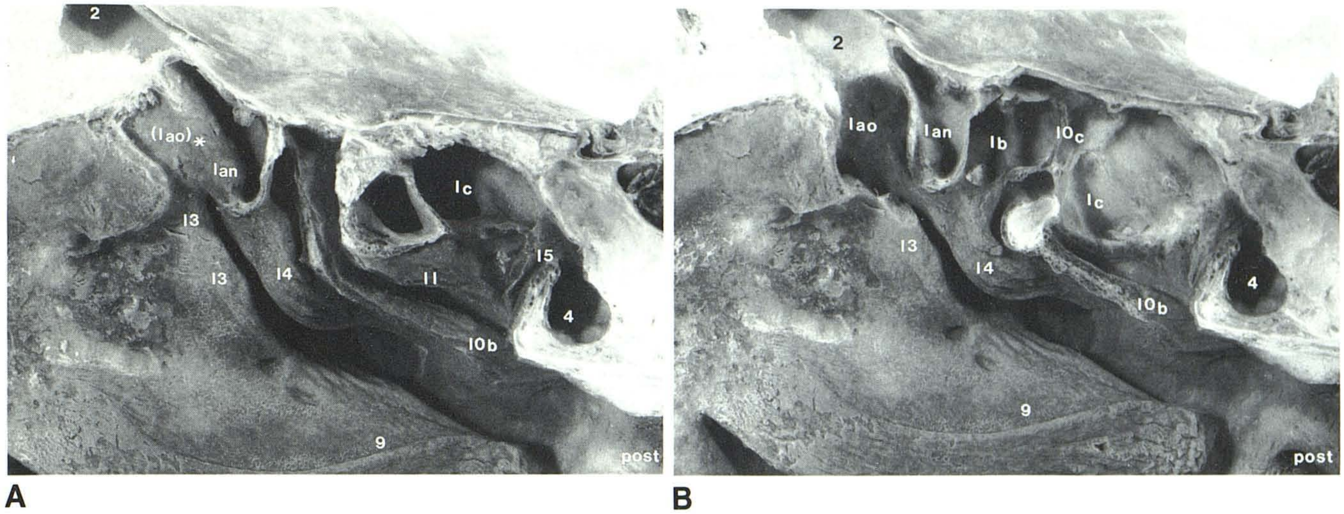
Fig. 6.—Macroscopic anatomy of ethmoid with landmarks. Left side of specimen A as seen during dissection from medial to lateral. **A**, Intact medial ethmoidal wall (16) and turbinate (10a and 10b). Probe in ostium of sphenoidal sinus. **B**, Posterior ethmoidal cells after resection of medial ethmoidal wall posteriorly. Sphenoethmoidal recess (15) well demonstrated. Intact middle ethmoidal cell (1b) in depth above middle turbinate (10). **C**, Middle meatus with unciform process (13), and ethmoidal bulla (14) between unciform groove (x) and retrobullar groove (*curved arrow*). Basal lamella (*black arrows*) separating middle (1b) from posterior (1c) ethmoidal labyrinth. Probe in nasofrontal duct (*large straight arrow*), which is contiguous with unciform groove, but drains directly into middle meatus. **D**, Anterior ethmoidal cells, frontal and maxillary sinus after complete dissection. Bony septum (*arrows*) between anterior (1a) and middle (1b) ethmoidal cells continuous below with anterior wall of ethmoidal bulla (14). Anterior and posterior ethmoidal vessels (*) in roof of ethmoid.

unciform process group and the nasofrontal duct opened into a large ethmoidal cell (infundibulum), which was in line with the unciform groove (fig. 7B).

The ostium of the maxillary sinus is located anterosuperiorly on the medial antral wall and opens constantly into the unciform groove. At endoscopy, while its maxillary antral side was very well demonstrated after trepanation of the inferior meatus and introduction of the scope into the sinus cavity, the nasal opening of the orifice, hidden under the cover of the unciform process, could not be imaged easily. On CT it is best depicted on coronal sections (fig. 3). In one of the specimens, an accessory ostium was observed on CT, endoscopy, and macroscopic dissection (figs. 5B and 7C).

Posterior Ethmoidal Cells and Sphenoidal Sinus

The posterior ethmoidal cells are larger and less numerous than the anterior cells. They drain either into the superior or the supreme meatus, which is developed in 62% of cases [5]. A supreme turbinate was found in both specimens (figs. 6 and 7). The sphenoidal sinus drains into the sphenoethmoidal recess, also called juxtaseptal meatus [6]. This is a laterodorsal blind pouch of the nasal cavity between the rostral wall of the sphenoidal sinus and behind the superior and supreme turbinates. Posterocaudally, it opens toward the choana (fig. 6B). On CT it is best seen on axial sections (fig. 1D). It is also well demonstrated by endoscopy (fig. 5E).



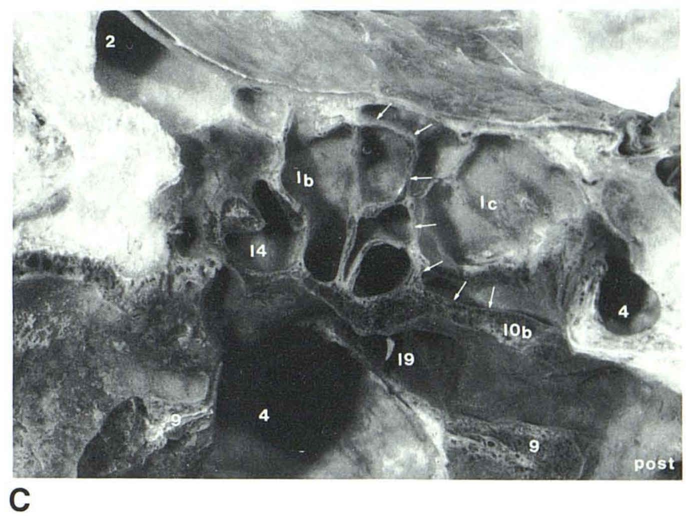


Fig. 7.—Macroscopic anatomy of ethmoid, particularly anterior labyrinth. Left side of specimen B during dissection from medial to lateral. **A**, Bony wall (*) between anterior ethmoidal cells of middle meatus (nasal cells) (1an) and cells of unciform process (orbital cells) (1ao). This wall is continuous below with anterior part of unciform process (13). **B**, Orbital cell (1ao) opened after resection of bony wall. This cell drains frontal sinus (2) and consequently acts as infundibulum. **C**, All paranasal sinuses opened at end of dissection. Maxillary sinus (4) fenestrated. Accessory ostium of maxillary sinus (19). Basal lamella (intraethmoidal root of middle turbinate) (*arrows*) between middle (1b) and posterior (1c) ethmoidal cells.

Lateral to this recess, the last ethmoidal cell (cell of Onodi) and the sphenoidal sinus share a common wall.

Cribriform Plate

The cribriform plate forms the narrow roof of the nasal cavities and is the lowest part of the anterior base of the skull. It lies between the medial wall of each ethmoidal labyrinth. Posteriorly, it abuts the body of the sphenoid. On coronal CT sections, just lateral to the crista galli, there may appear a discontinuity of its most anterior part, which is the nasal slit, the point where the nasal branch of the anterior ethmoidal artery and nerve enters the nasal cavity (fig. 4) [9].

Discussion

The paranasal sinuses are divided into two anatomic and functional entities [7]. The air cavities of the first group, that is, the anterior ethmoidal cells and the intimately related frontal and maxillary sinus, all open into the middle meatus, around the ethmoidal bulla, which is at the crossroads of their drainage system. The posterior ethmoidal cells and the sphenoidal sinus belong to the second group, which opens above the middle turbinate and which is affected less often by chronic inflammatory disease and polyposis [10]. CT and endoscopy are complementary methods for the examination of the ethmoid and the paranasal sinuses and together allow a detailed evaluation of the anatomic relations and the pathologic changes. The ethmoidal labyrinth can be thoroughly investigated only by CT. On the other hand, endoscopy provides morphologic, histologic, and bacteriologic information about the state of the nasal cavities, and particularly the middle meatus [6]. Endoscopic examination of the maxillary sinus is also performed easily after trepanation through the inferior meatus. The topography of the ethmoidal labyrinth and the upper paranasal sinuses is very intricate and fraught with great individual variability. Even some asymmetry between the two sides is the rule. The boundaries between the anterior and posterior ethmoidal labyrinth (basal lamella) or between the different groups of anterior ethmoidal cells are rarely identified precisely by CT despite high-resolution thin-section imaging. Indeed, the spatial arrangement of the ethmoidal sinuses defines their anatomic grouping much less than does the exact location of their ostia. Unfortunately, these openings cannot be accurately traced on CT scans. However, while it may be interesting to classify the ethmoidal cells anatomically, the surgeon is primarily concerned with the topographic relations, particularly laterally to the orbit and superiorly to the anterior fossa [5]. A common wall separates the ethmoidal labyrinth from the orbit. Two-thirds of this surface is the lamina papyracea. The lacrimal bone forms the anterior third. The anterior ethmoidal cells, therefore, are in relation to the lacrimal sac and the orbit. The posterior ethmoidal cells too have an extensive relation to the orbit. At times, the optic nerve is very close to the most posterior ethmoidal cell and elevates its superior outer angle [5]. Consequently, the nerve may be easily injured during posterior ethmoidectomy. The superior surface is the second dangerous area of the ethmoidal labyrinth. The cribriform plate, which lies to the inside of the ethmoidal labyrinth, is not a particularly critical structure, as it cannot be injured as long as the surgeon's instrument remains within the medial wall of the labyrinth [11]. The most hazardous structure is the ethmoidal roof, which is a very thin bony wall sometimes having dehiscences [12]. Therefore, it is prone to injury during intranasal ethmoidectomy. Such damage will result in leakage of cerebrospinal fluid and a high risk of intracranial infection.

High-resolution CT provides a means of precisely evaluating the topographic relations of the external and superior confines of the ethmoidal labyrinth. Furthermore, despite the great variability of its cellular arrangement, the ethmoid has some constant and prominent landmarks, which may be used as reliable guides during endoscopically controlled intranasal ethmoidectomy: the ethmoidal bulla, the unciform process, the medial ethmoidal wall with the related middle turbinate, and the sphenoethmoidal recess. These landmarks are accurately demonstrated by biplanar axial and coronal high-resolution CT. The spatial relations of normal or diseased ethmoidal cells to these important reference structures can therefore be clarified very well by this technique. It is hoped that a routinely performed preoperative CT study of the ethmoid and the upper paranasal sinuses may help avoid severe complications of intranasal ethmoidectomy resulting from unsuspected anatomic relations.

ACKNOWLEDGMENT

We thank G. Terrier, Department of Oto-Rhino-Laryngology, University of Lausanne, Lausanne, Switzerland, for inspiration.

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