



EXPLORING THE FRONTAL RECESS: SPECIMENS, ENDOSCOPY, AND CT PERSPECTIVES

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Abstract

The frontal sinus, situated between the external and internal plates of the frontal bone, posterior to the brow ridges, is the most superior and complex structure within the paranasal sinuses. The frontal sinus outflow tract encompasses two parts: the frontal ostium superiorly and the frontal recess inferiorly, collectively forming the frontal sinus drainage pathway. The frontal recess represents the most anterosuperior portion of the ethmoid. Pneumatization of this area can extend from the agger nasi cell anteriorly to the ethmoidal bulla posteriorly. This recess is bounded by the orbital plate of the ethmoid laterally and the middle nasal concha ('middle turbinate') medially. The detailed understanding of frontal sinus anatomy is indispensable for medical professionals, including surgeons, otolaryngologists, rhinologists, and radiologists. The frontal recess is clinically important, especially in the diagnosis and management of various medical conditions, particularly sinusitis. Surgeons often need to navigate this intricate area. Radiological imaging, such as computed tomography (CT) scans, is frequently employed to evaluate the frontal sinus and its drainage pathway, enabling clinicians to identify abnormalities such as tumors, polyps, or foreign bodies. In this study, we investigated the anatomical intricacies of the frontal recess using specimens, CT scans, and endoscopic imagery sourced from didactic and clinical settings.

Running title: Anatomical insights into the frontal recess

Keywords: frontal recess, frontal sinus, frontal sinus drainage pathway, frontal sinus outflow tract, human anatomy, clinical anatomy

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Introduction

The frontal sinuses are the most superior and complex structures among the paranasal sinuses due to their location, anatomical variations, and clinical manifestations [1]. The frontal sinus is an air-filled cavity situated behind the brow ridges within the frontal bone. It consists of bilateral sinuses separated by a bony septum [2]. Typically, the frontal sinus is larger in males, contributing to the noticeable frontal bossing observed in many men, although this sinus varies greatly in size. In most cases, the right sinus is larger than the left one in both sexes. Unlike the other paranasal sinuses, the frontal sinus is absent at birth and develops after the age of 2 years. Growth of this sinus increases at the age of 6 years. Therefore, these sinuses are often not visible radiographically before this age.

The frontal sinuses are located between the external and internal plates of the frontal bone, posterior to the superciliary arches, and are lined with a moist mucosal membrane that acts as a humidifier. They drain into the lateral wall of the middle nasal meatus through the frontal sinus drainage pathway, which is also known as the frontal sinus outflow tract, that penetrates the ethmoidal labyrinth and continues as the ethmoidal infundibulum at the front end of the semilunar hiatus. The frontal sinus drainage pathway can be divided into two segments: the frontal ostium superiorly and the frontal recess inferiorly [3]. The frontal ostium is bounded anteriorly by the agger nasi cell, posteriorly by the roof of the ethmoidal bulla, laterally by the orbital plate of the ethmoid bone (*lamina papyracea*), and medially by the basal lamella of the middle nasal concha. The frontal recess

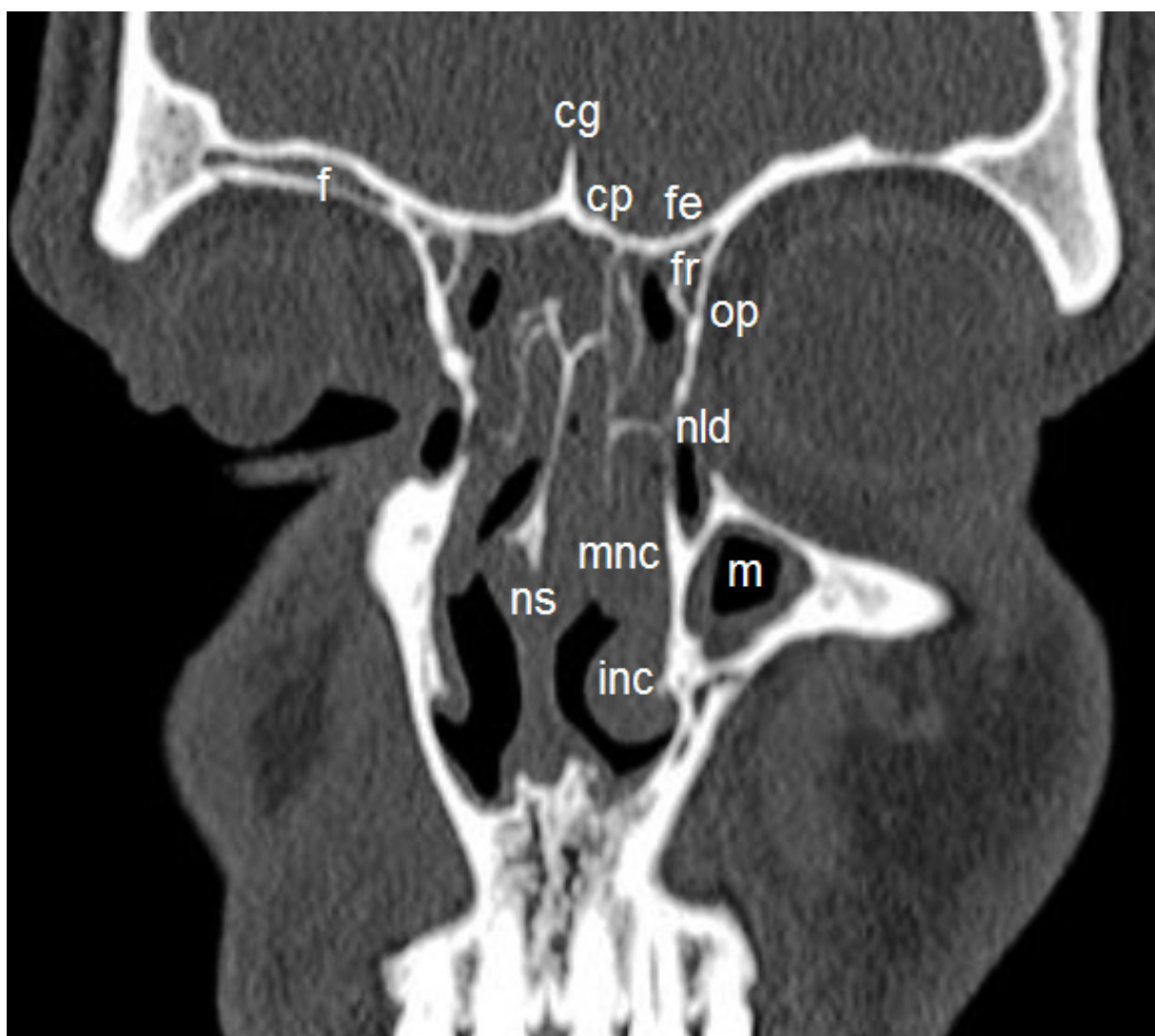


FIGURE 1 Coronal CT scan of the paranasal sinuses at the level of the nasolacrimal duct: crista galli (cg), cribriform plate of the ethmoid (cp), frontal sinus (f), fovea ethmoidalis (fe), frontal recess (fr), orbital plate of the ethmoid (op), nasolacrimal duct (nld), middle nasal concha (mnc), inferior nasal concha (inc), nasal septum (ns), and maxillary sinus (m). The figure was generated by the authors

connects the frontal sinus and the middle nasal meatus and is bounded by the agger nasi cells anteriorly, the ethmoidal bulla posteriorly, the cranial base superiorly, the orbital plate of the ethmoid bone laterally, and the middle nasal concha medially. Despite its clinical significance, the frontal recess has been omitted by leading anatomical atlases, textbooks, and lexicons. Surprisingly, the Terminologia Anatomica has never acknowledged its existence [3-6].

In this work, we investigated the anatomy of the frontal recess utilizing specimens and endoscopic images, including computed tomography (CT) scans, sourced from didactic and clinical settings.

Materials and methods

Three distinct sources were employed for the purpose of this analysis: (1) CT scans, (2) adult specimens without evident pathologies or surgical procedures in the examined area were sourced from the Dissecting Room at the Department of Anatomy, and (3) preoperative endoscopic images from the clinics were employed for analyzing specific anatomical features of the frontal recess and its adjacent structures.

The integration of specimen inspection and endoscopic images facilitated a comprehensive examination of the frontal sinus drainage pathway and the preparation of pertinent illustrations based upon the obtained views.

Results

The frontal recess was identified in all examined individuals (100%). CT scans revealed that the frontal recess is bounded by the orbital plate of the ethmoid bone (*lamina papyracea*) and the lacrimal bone laterally and the vertical portion of the middle nasal concha ('middle nasal turbinate') medially (**Fig. 1**). Furthermore, it was demonstrated that its inferior boundary depends on the attachment of the uncinate process. In all specimens, the frontal recess was consistently present behind the anterior ethmoidal air cells (agger nasi cells) and the frontal beak, just anterior and inferior to the ethmoidal bulla and the skull base (**Fig. 2**).

Preoperative endoscopic images of the frontal recess revealed its complex and intricate anatomy with six boundaries and various anatomical and surgical landmarks (**Fig. 3**). The anterior ethmoidal air cells were situated anterior and inferior to the frontal recess, draining into the ethmoidal infundibulum. The union of the agger nasi and the uncinate process forms the vertical bar, that is, the medial lamella of the uncinate process, which is often used as an important landmark for reaching the frontal recess during endoscopic procedures. Superiorly, the frontal recess communicates with the hourglass-shaped frontal ostium, which is the narrowest dimension between the frontal beak and the skull base.

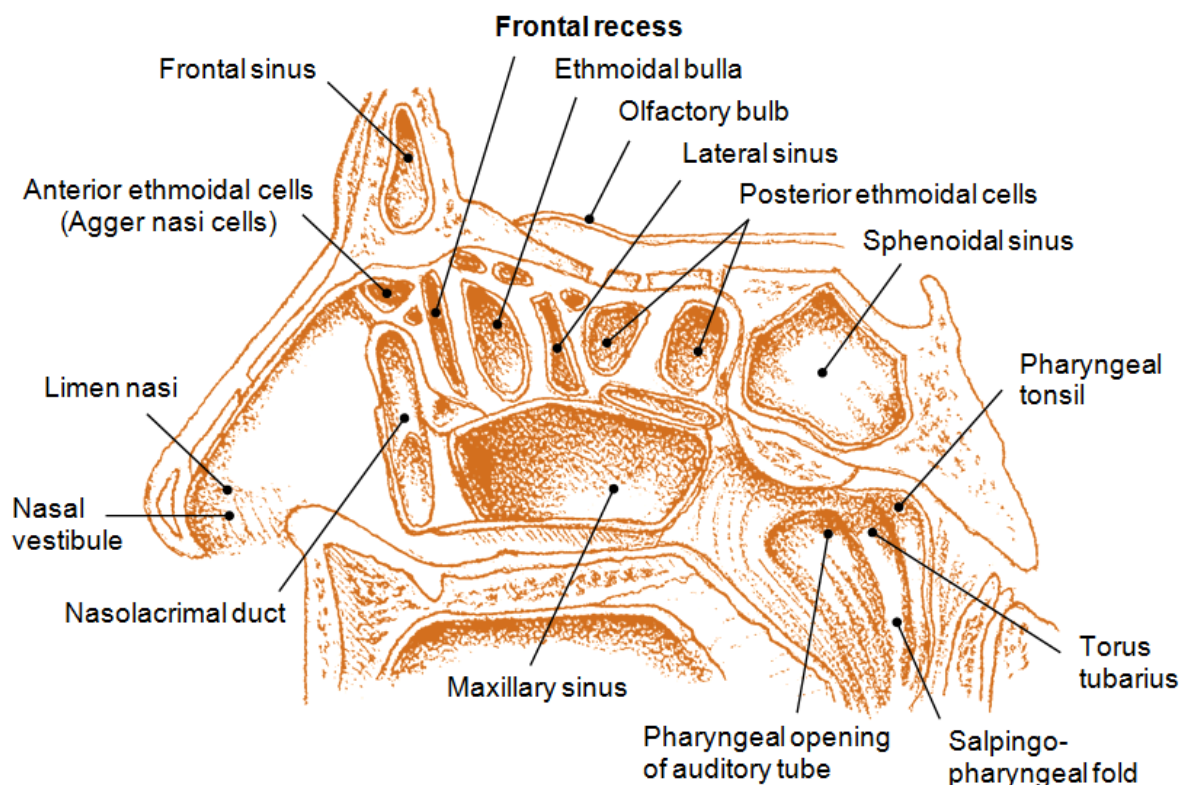


FIGURE 2 Sagittal section of the lateral nasal wall with the conchae removed to allow the visualization of the frontal recess and lateral sinus. Adapted and modified from [3]

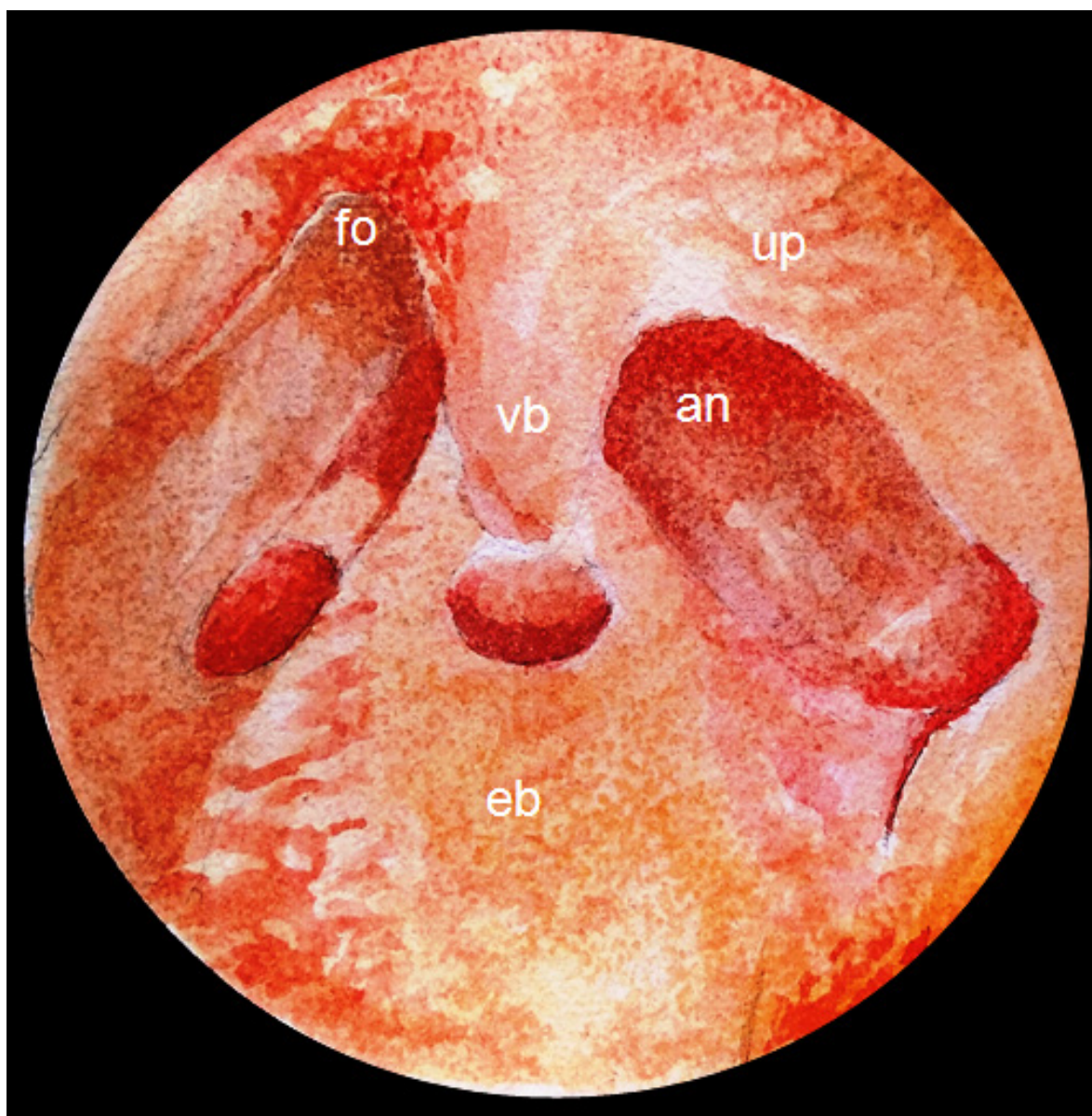


FIGURE 3 Endoscopic anatomy of the left frontal recess: frontal ostium (fo), vertical bar (vb), uncinate process (up), aggr nasi (an), ethmoidal bulla (eb). Adapted and modified from [3]

Discussion

The frontal recess (*recessus frontalis* in Latin) represents the lower portion of the frontal sinus drainage pathway [1,3] and the upper portion of the ethmoidal infundibulum [4]. This recess was first described by a German laryngologist, Gustav Killian in 1903. The current study was aimed at exploring the clinical significance and anatomy of the frontal recess, utilizing CT scans, anatomic preparations, and endoscopic images. It has been shown that the frontal recess is a constantly present structure. Considering that the frontal recess is clinically significant, it may come as a surprise that the Terminologia Anatomica has never recognized its existence [5,6]. Due to its intricate architecture, the frontal recess ranks among the most

complex anatomical structures found within the paranasal sinuses, warranting recognition in future editions of the international standardized anatomical nomenclature [3,4].

In 1994, Bent and associates [7] defined the frontal cells as air cells derived from the anterior portion of the ethmoidal sinus behind and above the aggr nasi cell. These authors excluded aggr nasi, supraorbital ethmoid, and intersinus septal cell from the frontal recess and divided the frontal cells into four groups based on coronal cuts of the CT scans [8]. In 2014, the European Position Paper (EPOS) defined the frontal recess as the most anterosuperior part of the ethmoid, located inferior to the frontal sinus opening [9]. It was demonstrated that the pneumatization of the frontal recess can

extend from the agger nasi, ethmoidal bulla or the terminal recess of the ethmoidal infundibulum. The cells located outside the frontal recess were termed the anterior ethmoidal cells, whereas the cells located within this recess were termed the frontoethmoidal cells. These cells were classified as the anterior, posterior, medial, and lateral groups of cells, with respect to the frontal recess or the inner walls of the frontal sinus. The agger nasi cell is an easily identifiable landmark when approaching the frontal sinus [10]. According to Pend and associates [11], the frontal recess cells have an extremely intricate anatomical structure and can be divided into agger nasi, suprabullar, supra agger, supra agger frontal, supraorbital ethmoidal, frontal septal, and suprabullar frontal cells. In cases where the frontal recess is extensively pneumatized or when the attachment of the basal lamella protrudes, this recess takes on a tubular shape. This is why the frontal sinus drainage pathways is often described as the frontonasal duct (*ductus frontonasalis*).

The frontal sinus outflow tract is clinically important for a number of reasons. One of the most common clinical issues associated with the frontal recess is rhinosinusitis [12,13]. When the frontal sinus drainage pathway becomes blocked due to swelling or mucous thickening, the frontal sinusitis may develop [14,15]. This condition can cause symptoms such as frontal headache, pressure, nasal congestions, and purulent nasal discharge. If left untreated, the serious complications can occur, including orbital abscess or frank frontal lobe abscess [16]. Surgical procedures involving the frontal sinus and its outflow tract, such as endoscopic sinus surgery, often necessitate a detailed understanding of the intricate anatomy of the frontal recess. During endoscopic sinus surgery, which is a common procedure to treat chronic sinusitis, the frontal recess is approached. Surgeons often need to access and clear the narrow passage to reach the frontal sinus and remove diseased tissue. Proper surgical techniques in the region are crucial to avoid complications such as injury to the eye and surrounding structures. In clinical practice, radiological imaging, such as CT scans, is often employed to evaluate the frontal sinus and the frontal recess [1]. Abnormalities, such as the presence of tumors, cysts, or foreign bodies, can easily be identified through these scans, guiding clinicians in diagnosing and planning treatment.

Conclusions

To conclude, the frontal recess is clinically important in the diagnosis and management of various medical conditions, particularly sinusitis and surgi-

cal procedures involving the frontal sinus drainage pathway or the nasal cavity. A clear understanding of the anatomy and function of this area is essential for otolaryngologists, radiologists, and other medical professionals. Further research in this area might uncover new insights into the diagnosis and treatment of sinus-related conditions, promising improved outcomes for patients.

Ethical approval

The study did not require the approval of the local Ethics Committee.

Acknowledgments

Not applicable.

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Conflict of interest

The authors declare no conflict of interest.

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