ORIGINAL ARTICLE
RHINOLOGY
DOI: 10.5152/B-ENT.2020.20230

Analysis of type IV frontal cell on an embryological basis

Zeynep Onerci Altunay[1], Tevfik Metin Onerci[2]

[1]Department of Otorhinolaryngology, Haseki Research and Training Hospital, Istanbul, Turkey
[2]Department Otorhinolaryngology, Hacettepe University School of Medcine, Ankara, Turkey

Cite this article as: Onerci Altunay Z, Onerci TM. Analysis of type IV frontal cell on an embryological basis. B-ENT 2020; 16(3): 153-7.

ABSTRACT

Objective: To analyse the frontal recess in three planes simultaneously and by changing the angle and to discuss the type IV frontal cell on an embryological basis.

Methods: A total number of 200 patients (400 sides) who had a cone-beam computed tomography (CT) for various reasons were included in this retrospective study. Patients who had previous nasal or paranasal sinus surgery or were having a history of head or facial trauma, sinonasal tumors, sinonasal polyposis, or fibrous dysplasia, or were with acute or chronic sinusitis were excluded from the study. Type IV frontal cells were analyzed on three planes.

Results: Of 200 paranasal CT scans, only three type IV frontal cells were found. On sagittal CTs, two of these cases were the extension of ethmoid cells. In one CT, by changing the angle of the CT, it was found that the lower cell had continuous aeration with agger nasi cell and the upper cell had continuous aeration with the ethmoid cell system.

Conclusion: If a type IV frontal cell is seen on a coronal CT scan, the sagittal view should be examined. An isolated cell in the frontal sinus that does not seem to have any contact with the agger nasi is supposed not to be the frontal cell and should be evaluated on the sagittal section to identify the origin of the aeration. If the continuity of the ethmoturbinal system cannot be established, the continuity of the so-called type IV intrafrontal isolated cell can be established with either agger nasi cell or ethmoid cell system by giving different angles to the CT scan

Keywords: Anatomy, cone-beam CT, embryology, frontal sinus, Type IV frontal cell

Introduction

The most challenging part of endoscopic sinus surgery is frontal sinus and recess surgery. Because the frontal cells are the main cause of the obstruction of the frontal recess outflow track, it is very important to understand the anatomy of the frontal cells. Computed tomography (CT) is the gold standard in the evaluation of frontal recess, and multiplanar reconstruction is now routinely used to evaluate frontal cells. Cone-beam CT (CBCT), which has been used more commonly in recent years, gives more detailed anatomical information with a lower dose of radiation (1, 2). CBCT allows the evaluation of the frontal recess on coronal, sagittal, and axial planes at the same time and gives the chance to change the angle and view the anatomy from different perspectives. There are different classification systems of the frontal cells. The purpose of this study is to analyze the frontal recess, outflow tract, and frontal cells in three planes simultaneously and by changing the angle of the CT sections. The terminologies and the classification systems will be discussed on an embryological basis.

Methods

A total number of 200 patients (400 sides) who had paranasal CT for various reasons were included in this retrospective study. CT examinations were performed by using the Genoray three-dimensional CBCT unit. The imaging parameters were voxel size (75-400 μm), tube voltage (60-90 kV), tube current (4-12 mA), line voltage (220 V, 50/60 Hz), pixel pitch (100x100 μm), and focal spot (0.5 mm). Patients who had previous nasal or paranasal sinus surgery or were having a history of head or facial trauma, sinonasal tumors, sinonasal polyposis, or fibrous dysplasia, or were with acute or chronic sinusitis were excluded from the study. The evaluation of the paranasal CTs was performed by the authors. Since this is a

Corresponding Author: Tevfik Metin Onerci, monerci@gmail.com
Received: December 10, 2020 **Accepted:** January 11, 2021
Available online at www.b-ent.be

retrospective study on CT scans there is no need for ethic committee approval.

Results

Of the 200 paranasal CT scans (400 sides), only three type IV frontal cells were found. On sagittal CT sections, two of the cases were the extension of ethmoid cells (Figure 1a and b). In one CT, by changing the angle of the CT, it was found that of two cells, one cell (the lower one) belonged to the anterior group, which had continuous aeration with agger nasi cell, and the other (the upper one) belonged to the posterior group, which had continuous aeration with the posterior group (Figure 2a and b).

Figure 1. (a) Coronal section, a type IV frontal cell. (b) The sagittal section shows that this cell is an extension of the anterior ethmoid cell.

Main Points:

- Frontoethmoid cells play a very important role in functional endoscopic sinus surgery.
- The frontoethmoid cells are pneumatized through either maxilloturbinal or ethmoturbinal complex.
- The cells pneumatized through the maxilloturbinal complex form the anterior group of cells, whereas the cells pneumatized through the ethmoturbinal complex form the posterior group of cells.
- There is no isolated type IV frontal cell. The so-called type IV frontal cells are found to be continuous with the posterior group of cells.
- The cone-beam computed tomography (CT) allows to analyze the frontal cells by changing the angles of the CT scan.

Discussion

After the introduction of the endoscopes into paranasal sinus surgery, frontal recess, frontal cells, frontal ostium, and frontal sinus have become the center of discussion. The presence of various cells in the outflow space narrows the passage and obstructs the drainage pathway. Surgery in the frontal recess is challenging because it is a narrow area and any trauma to the mucosal lining of this area may cause scarring and postop-

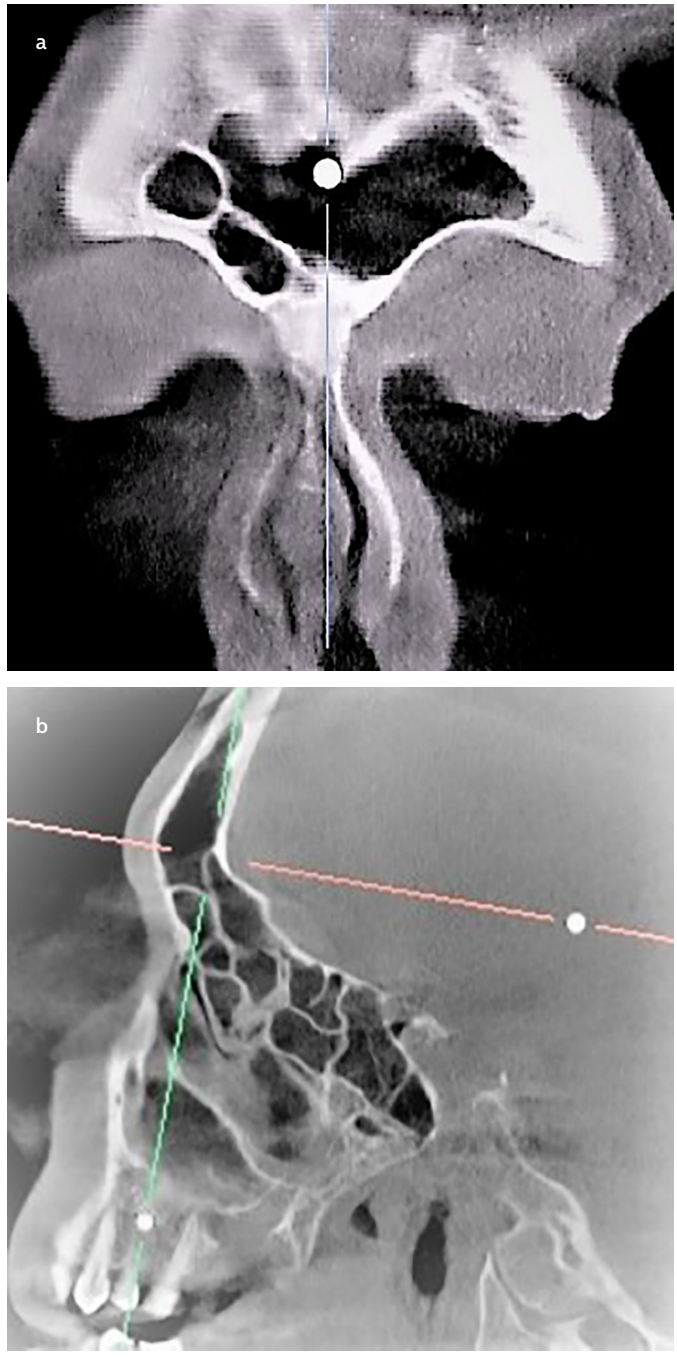

Figure 2. (a) Coronal section: a type IV frontal cell. (b) Sagittal section: changing the angle demonstrates the continuity of the aeration with agger nasi for the lower frontal cell, which proves that it belongs to the anterior cell system, whereas the continuity of the aeration for the upper cell was established with the ethmoid cells (posterior cell system) on sagittal CT by changing the angle of the CT scan. CT, computed tomography.

erative obstruction. The basic frontal recess surgery changed more to frontal cell surgery (3). The success of the surgery lies in the opening of these cells completely without traumatizing the mucosa. Thorough anatomy of these cells has been studied, and various classification systems were proposed to understand the anatomy better and to have uniformity about the classification systems and the surgical approaches. Therefore, the understanding of the frontal cells is of great importance.

Frontal recess was described as the space in the upper part of the ethmoid infundibulum just below the frontal sinus ostium into which the frontal sinus drains (1, 2). Although Schaeffer in 1916 (4) described this area as the nasofrontal region, a detailed description was made by van Alyea (5, 6). He named this area the frontal recess area. Frontal recess is surrounded by vertical lamella of the middle turbinate medially, lamina papyracea and lacrimal bone laterally, posterior wall of agger nasi anteriorly, and ethmoid suprabullar air cells posteriorly. Van Alyea (4, 5) defined the frontal cell as a cell encroaching on the

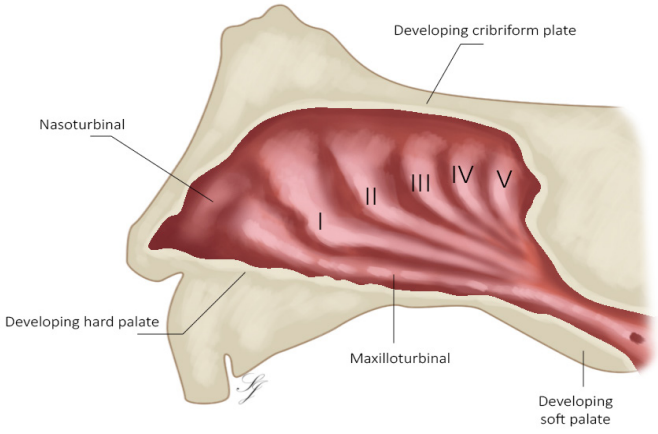

Figure 3. Several soft-tissue folds appear on the lateral wall of each nasal cavity. The maxilloturbinal develops first and then is followed by five ethmoturbinals.

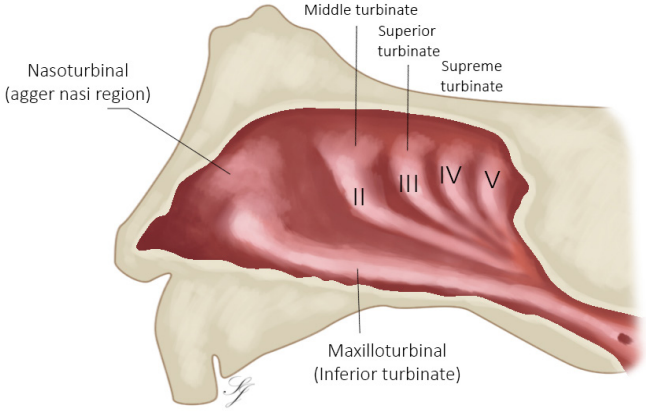

Figure 4. An additional rudimentary nasoturbinal arises anteriorly, appearing later as a slight elevation, the agger nasi. By the eighth week, the inferior and middle turbinates start forming. Their development is by the proliferation of mesenchymal cells and hypertrophy of the overlying epithelium.

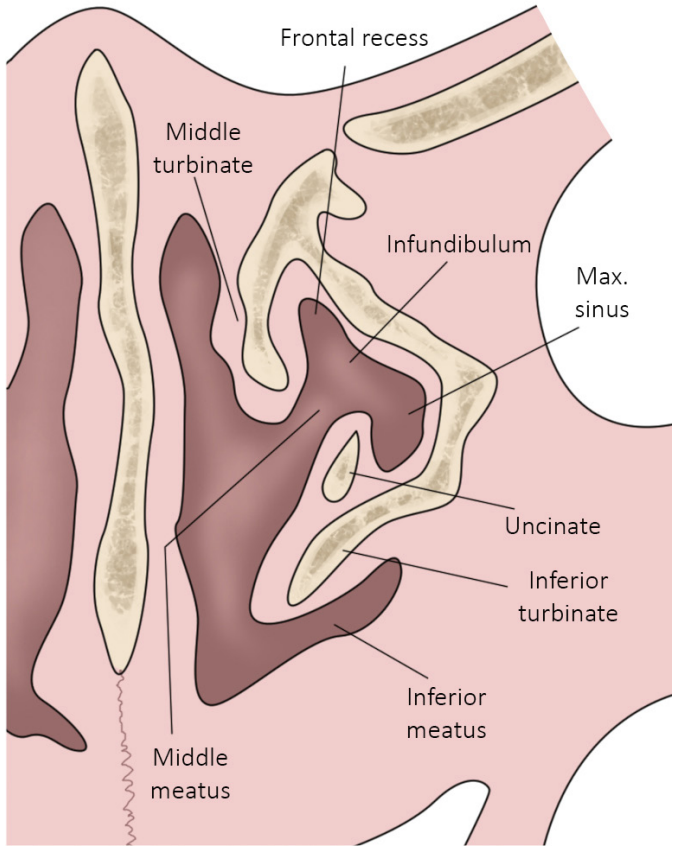

Figure 5. A furrow progressively develops into the lateral wall of the primitive choana, forming the primitive infundibulum by 10-11 weeks. This infundibulum forms the frontal recess and the frontal sinus. The prominences later form the middle turbinate, inferior turbinate, and uncinate process. The infundibulum, maxillary sinus, and frontal recess are seen as small blind recesses or pockets within the middle meatus. The infundibular cells are divided according to their location to the infundibulum, forming two different systems: maxilloturbinal and ethmoturbinal complexes. The cells aerated with the uncinate process and the inferior turbinate belong to the maxilloturbinal complex and form the frontal cells continuous with agger nasi. Posterior and lateral cells belong to the ethmoturbinal complex. They form the anterior and posterior ethmoid cells.

Table 1. Modified Kuhn and Brent frontal cell classification

Type	Description
Type I	The frontal cell represents a single air cell above the agger nasi.
Type II	The frontal cells correspond to a series of small cells above the agger nasi, within the frontal recess, but below the orbital roof.
Type III	The frontal cells are defined as a single cell arising above the agger nasi pneumatizing into the frontal sinus and remain contiguous with the agger nasi cell.
Type IV	The cell corresponds to a completely isolated frontal cell (not contiguous with the agger nasi cell) within the frontal sinus cavity without an obvious connection to the frontal recess.

frontal recess or frontal sinus; in other words, he limited cells to the frontal recess. He considered all cells, including ethmoid cells, pneumatizing in the frontal recess area as frontal cells. These cells were called either the frontal cells or the frontoethmoid cells. Jankowski in 2013 (7) in his book and Jankowski et al. in 2016 (8) in their article wrote about the evolution of species and embryological development trying to explain the complex anatomy of the human nose, the holoprosencephalic spectrum of facial malformations, and suggesting the phylontogenic theory on nose and sinus diseases. However, their evo-devo theory was more related to the olfactory fascia, which unites the cartilages of the nose to the olfactory mucosa, trying to explain nose and sinus diseases. In 2014, Lund et al. (9), in their supplement "European position paper on the anatomical terminology of the internal nose and paranasal sinuses," suggested using the term frontoethmoidal cells for the cells extending into the frontal sinus. Their suggestion was to classify these cells as anterior or posterior and medial or lateral, concerning the frontal recess/inner walls of the frontal sinus. They considered an intersinus septal cell a medial frontoethmoidal cell. This classification makes sense in classifying the frontal cells into anterior and posterior but does not give any clues about the structure and degree of frontal cells.

In 1991, Kuhn and Bent (10) proposed a classification system for frontal cells (Table 1). According to this system, they described four types of cells. The first three cells are continuous with agger nasi cells, whereas the type IV cell is an isolated cell. According to Kuhn, the type IV cell is a completely isolated frontal cell (not contiguous with the agger nasi cell) within the frontal sinus cavity without an obvious connection to the frontal recess. Kountakis et al. (11) defined the type 4 cell as a sinus cell located within the frontal sinus that drains within the frontal sinus itself. All these classifications were based mainly on two-dimensional radiological views.

To understand frontal cells, the embryology of this region should be reviewed. All of the turbinates and the paranasal sinuses arise from the cartilaginous nasal capsule. Several soft-tissue folds appear on the lateral wall of each nasal cavity (12-14). The maxilloturbinal develops first and then is followed by five ethmoturbinals (Figure 3). An additional rudimentary nasoturbinal arises anteriorly, appearing later as a slight elevation, the agger nasi. By the eighth week, the inferior and middle turbinates start forming (Figure 4). Their development is by the proliferation of mesenchymal cells and hypertrophy of the overlying epithelium. The uncinate process arises from the cartilaginous capsule at 10 weeks (12, 13). A furrow then progressively develops laterally to the uncinate process. This represents the primitive infundibulum by 10-11 weeks. From the superior margin, the frontal recess develops. Because this infundibulum forms the frontal recess and the frontal sinus, the infundibular cells are divided anteriorly and posteriorly according to their location to the infundibulum, forming two different systems. Anterior cells aerated anteriorly to the infundibulum belong to the maxilloturbinal complex and form the frontal cells. Posterior cells that are posterior to the infundibulum belong to the ethmoturbinal complex. They form the anterior and posterior ethmoid cells (Figure 5).

Because the aeration of the agger nasi and the frontal cells belong to the same system, they are supposed to be related and contiguous. If a cell is isolated and seems to have no connection with an agger nasi cell, sagittal sections should be evaluated. If no relation is found with the agger nasi, it is supposed to have a connection with the ethmoid cells. Therefore, type IV cell, an isolated cell, which is not contiguous with agger nasi cell, is difficult to explain according to the embryological development (12-14).

The introduction of CBCT gave the chance to get detailed anatomical information of frontal recess in three planes at the same time with a lower dose of radiation. It also allowed to change the angle and view the anatomy from different perspectives and to examine the continuity of aeration of these cells as seen in Figure 2.

The incidence of type IV frontal cells is reported as around 2-4%. The incidence may be higher because it is possible not to visualize the frontal cell owing to its thin walls. The incidence of frontal type IV cells was found to be 3.1 by Del Gaudio (15), 3.1 by Meyer (16), and 3.3 by Shruti et al. (2). In our study, of 200 CTs (400 sides), only three type IV frontal cells were found, corresponding to 0.75%. But on the sagittal sections, all these cells were aerated from the ethmoidal cells posteriorly (Figure 1a and b). These cells mainly belong to the ethmoid system. When the ethmoid cells are aerated into the frontal sinus extensively, they are seen as isolated frontal cells on coronal sections. These isolated cells in the frontal sinus drain posterior to the infundibulum, which shows the development of the cell posterior to the infundibulum, that is, from the ethmoturbinal system (11). In one CT, although the continuity of the aeration with agger nasi was found for the lower frontal cell, which proves that it belongs to the anterior cell system, the continuity of the aeration for the upper cell was established with the ethmoid cells (posterior cell system) on sagittal CT by changing the angle of the CT scan (Figure 2a and b).

Therefore, the definition of type IV cell as an isolated intrafrontal sinus cell may not be correct. They are not isolated even if they seem so. The frontoethmoid cells pneumatize either through the maxilloturbinal complex (forming the anterior group of cells) or through the ethmoturbinal complex (forming the posterior group of cells). They should always have a connection either with the ethmoid (posterior) or agger nasi cell (anterior) system to be aerated. Regarding the classification system, the cells should be classified either as anterior frontal celss or as posterior frontoethmoid cells if they pneumatize into the frontal sinus. There is not isolated type IV frontal cell. The so-called type IV frontal cells were found to be continuous with the posterior group of cells in this study.

If a type IV frontal cell is identified on a coronal CT scan, the sagittal view should be examined. An isolated cell in the frontal sinus that does not seem to have any contact with the agger nasi should be evaluated on the sagittal section to identify the origin of the aeration. The continuity of aeration of the so-called type IV intrafrontal isolated cell through the maxilloturbinal system or the ethmoturbinal system should be tried to be established. This continuity can be established by changing the angles of the CBCT sections on sagittal views. Bent and Kuhn's frontal cell classification system should be revised.

Ethics Committee Approval: Ethics Committee Approval is not necessary due to the retrospective nature of this study.

Informed Consent: Informed consent is not necessary due to the retrospective nature of this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision – T.M.Ö.; Design – Z.Ö.A., T.M.Ö.; Supervision – T.M.Ö.; Resources –T.M.Ö.; Materials – Z.Ö.A., T.M.Ö.; Data Collection and/or Processing – Z.Ö.A., T.M.Ö.; Analysis and/or Interpretation – Z.Ö.A., T.M.Ö.; Literature Search – Z.Ö.A., T.M.Ö.; Writing Manuscript – Z.Ö.A., T.M.Ö.; Critical Review – T.M.Ö.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

References

1. Minni A, Messıneo D, Attanasıo G, Pıanura E, D'ambrosıo F. Cone-beam (CBCT) in the evaluation of frontal recess: findings in youth population European Review for Medical and Pharmacological Sciences 2012; 16: 912-8.
2. Dhingra Shruti, Agarwal AK, Passey JC, Kaul JM. Anatomical analysis of the frontal recess cells in endoscopic sinus surgery-an ındian perspective. Clin Rhinol: An Int J 2009; 2: 15-9. [CrossRef]
3. Eweiss AZ, Khalil HS. The prevalence of frontal cells and their relation to frontal sinusitis: a radiological study of the frontal recess area. ISRN Otolaryngol. 2013; 24: 1-4. [CrossRef]
4. Schaeffer JP. Further observatıons on the anatomy of the sinus frontalis in man. Ann Surg 1916; 64: 665-71. [CrossRef]
5. Van Alyea OE. Ethmoid labyrinth: anatomic study, with consideration of the clinical significance of its structural characteristics. Arch Otolaryngol Head Neck Surg 1939; 29: 881-902. [CrossRef]
6. Van Alyea OE. Frontal cells: an anatomic study of these cells with consideration of their clinical significance. Arch Otolaryngol Head Neck Surg 1941; 34: 11-23. [CrossRef]
7. Jankowski R. The Evo-Devo Origin of the Nose, Anterior Skull Base and Midface. 1st ed. France: Springer Verlag. 2013. [CrossRef]
8. Jankowski R, Rumeau C, de Saint Hilaire T, et al. The olfactory fascia: an evo-devo concept of the fibrocartilaginous nose. Surg Radiol Anat 2016; 38: 1161-8. [CrossRef]
9. Lund VJ, Stammberger H, Fokkens WJ, et al. European position paper on the anatomical terminology of the internal nose and paranasal sinuses. Rhinol Suppl 2014; 24: 1-34.
10. Bent JP, Cuilty-Siller C, Kuhn FA. The frontal cell as a cause of frontal sinus obstruction. Am J Rhinol 1994; 8: 185-91. [CrossRef]
11. Maeso PA, Deal RT, Kountakis SE. Combined endoscopic and mini-trephination techniques in the surgical management of frontal sinus type IV cell disease. Am J Otolaryngol 2009; 30: 337-9. [CrossRef]
12. Som PM, Naidich TP. Illustrated review of the embryology and development of the facial region, part 1: Early face and lateral nasal cavities. Am J Neuroradiol 2013, 34: 2233-40. [CrossRef]
13. Arredondo de Arreola G1, López Serna N, de Hoyos Parra R, Arreola Salinas MA. Morphogenesis of the lateral nasal wall from 6 to 36 weeks Otolaryngol Head Neck Surg 1996; 114: 54-60. [CrossRef]
14. Bingham B, Wang RG, Hawke M, Kwok P. The embryonic development of the lateral nasal wall from 8 to 24 weeks. Laryngoscope 1991; 101: 992-97. [CrossRef]
15. DelGaudio JM, Hudgins PA, Venkatraman G, Beningfield A. Multiplanar computed tomographic analysis of frontal recess cells: effect on frontal isthmus size and frontal sinusitis. Arch Otolaryngol Head Neck Surg 2005; 131: 230-5. [CrossRef]
16. Meyer TK, Kocak M, Smith MM, Smith TL. Coronal computed tomography analysis of frontal cells. Am J Rhinol 2003; 17: 163-8. [CrossRef]