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Uncinate Process Variations and Their Relationship with Ostiomeatal Complex: A Pictorial Essay of Multidedector Computed Tomography (MDCT) Findings

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A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Summary

The ostiomeatal complex (OMC) is a key area for the drainage and ventilation of the paranasal sinuses. Stenosis created by inflammation and anatomic variations in this region causes an ideal ground for parasanal sinus infections, by preventing the drainage and ventilation of the sinuses. In today's diagnostics of paranasal sinus infections, the role of evaluation of OMC anatomical variations and soft tissue pathology has increased.. Knowing the anatomical details is important in terms of directing both medical and surgical treatment. The uncinate process (UP) constitutes the most important structure of the ostiomeatal complex, playing a role in mucociliary activity. UP variations can cause mucociliary drainage and ventilation problems, causing complications during surgery. Therefore, knowing and identifying their appearances in multidetector computed tomography (MDCT), the most frequently used radiological imaging method for these variations, becomes a very important consideration.

MeSH Keywords: Anatomic Variation • Multidetector Computed Tomography • Paranasal Sinuses

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Background

The bulla ethmoidalis and the uncinate process are stable structures situated on the lateral walls of the nasal cavity. However, despite being stable and continuous structures, their anatomical role and function have not been fully explained yet. It is likely that they are involved in ventilatory processes, preventing the non-sterile inspired air from contacting the sinus surfaces, while directing the sterile expired air towards the sinuses [1]. When treating patients, it is both necessary and important to take into consideration the possible functions of these structures, as well as the clinical and surgical relevance of variations in their structures. Computed tomography (CT) imaging is the preferred technique for examining the paranasal sinuses, with OMC being best visualized in the coronal plane [2]. In this study we evaluated the different features associated with uncinate process variations, such as the bifid UP, curved UP, atelectatic UP, the variations of the superior attachment of the uncinate process, ethmoid variations (e.g. the giant ethmoid bulla), and the uncinate bulla. We then examined the relationship of these different features with OMC. The current study aimed to assess the functional roles of the uncinate process and to evaluate the importance that the variations found in the CT findings have on surgery.

Anatomical Overview

Uncinate process

The uncinate process, which is the most important structure of OMC, both prevents the direct contact of the inspired air with the maxillary sinus, acting like a shield, and plays a role in mucociliary activity [3]. The UP is not a simple vestigial structure; it actually plays a role in the ventilatory mechanisms within the nasal cavity [1]. Being a key component of the ostiomeatal unit, UP is a thin, semi-circular bony process of variable length and covered with the mucosa. The UP can be located either frontally and inferiorly, or anteriorly and superiorly to the inferior

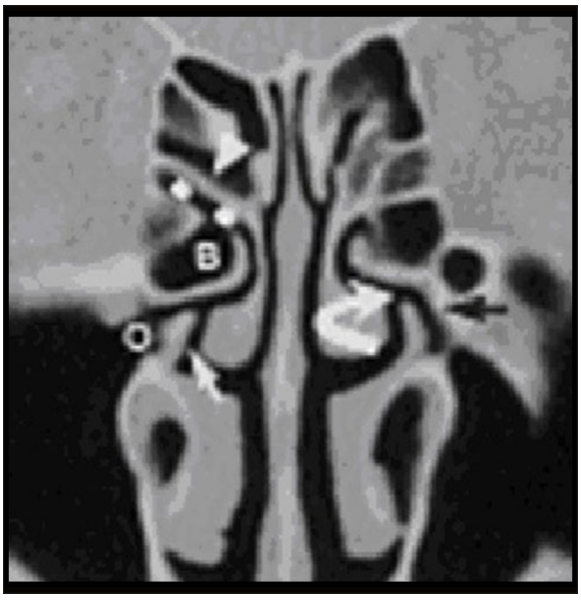

Figure 1. Ostiomeatal unit. Coronal CT scan demonstrates the right maxillary sinus ostium (O), ethmoid bulla (B), uncinate process (white arrow), basal lamella (arrowhead) and sinus lateralis (asteriks). Left ethmoid infundibulum (black arrow) and hiatus semilunaris (curved arrow) which is the gap in between the ethmoid bulla and the tip of the UP, are also demonstrated [8].

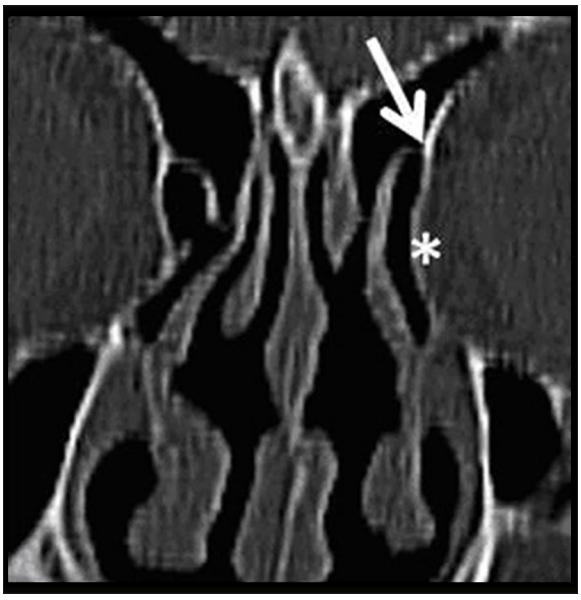

Figure 2. A 20-year-old male with type 1 UP insertion. Coronal CT scan shows that UP is attached (straight arrow) to the laminae papyracea (asteriks) on the left.

turbinate's ethmoidal process. On its posterior side, the uncinate bone has a superior edge forming the lower margin of the hiatus semilunaris (while the ethmoid bulla forms the upper margin of the hiatus semilunaris) [4]. The UP serves as a barrier that helps protect the anterior sinuses from bacteria and allergens by preventing the non-sterile/contaminated inspired air from reaching the sinus surfaces. It is likely that UP also assists ventilation and the passage through the sinuses during expiration. The UP thus appears to be a protective structure which directs the non-sterile inspired air (which potentially harbors allergens and undesirable microorganisms) away from the sinus surfaces, and then directs the sterile expired air towards the sinuses. Consequently, the inadvertent and ill-judged removal of UP would potentially result in greater exposure of the mucosa to non-sterile/contaminated air – especially in patients with allergic rhinosinusitis [1]. It is known that in the event that some of the uncinate process variations cannot be determined before surgery, they can cause crucial complications, and some also constitute a predisposition to ventilation problems and mucosiliary drainage.

Ostiomeatal unit (OMU)

The ostiomeatal complex is not the name of a certain anatomical structure but it is used to mean the formation of

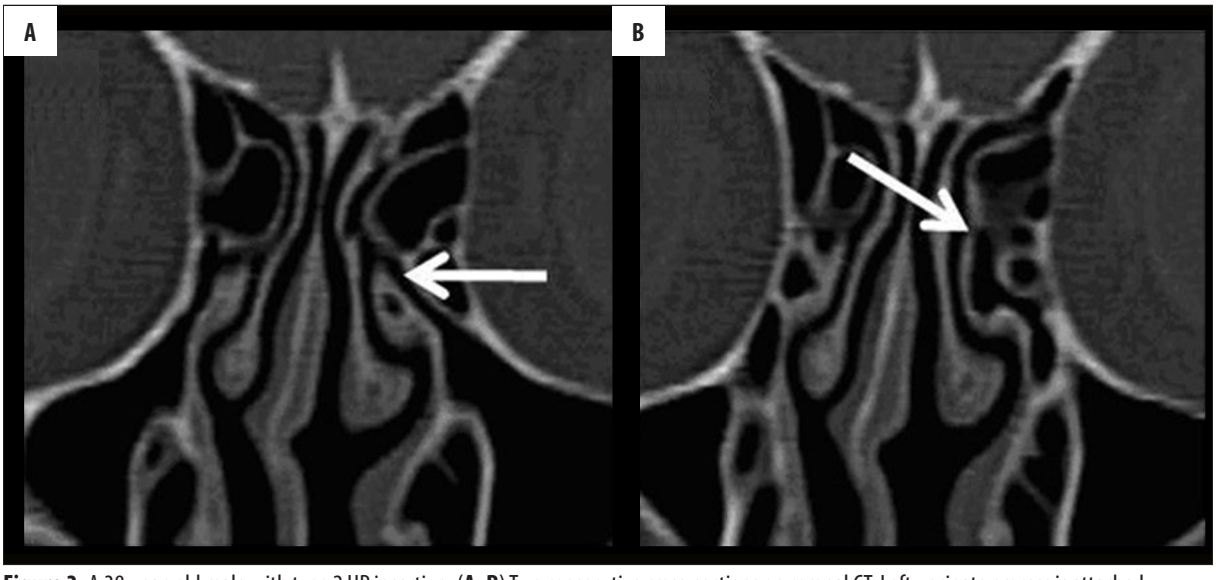

Figure 3. A 38-year-old male with type 2 UP insertion. (**A, B**) Two consecutive cross-sections on coronal CT. Left uncinate process is attached (**A**, arrow) to the posterior agger nasi cell (**B**, arrow)

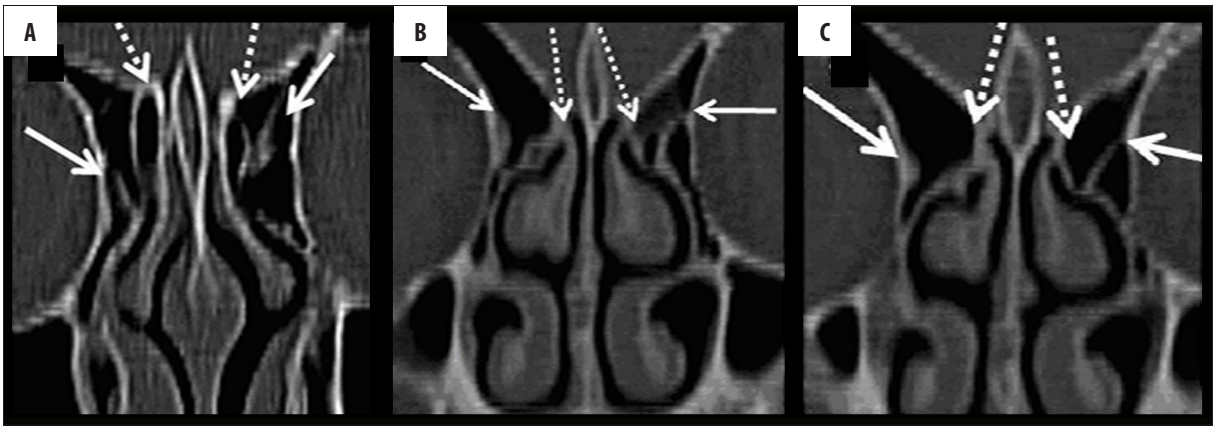

Figure 4. A 34-year-old female with type 3 UP insertion. (**A–C**) Consecutive cross-sections on coronal CT. Both uncinate processes are attached to the lamina papyracea (straight arrow) and junction of the middle turbinate with the cribriform plate (dotted arrow).

Figure 5. A 30-year-old male with type 4 UP insertion. Coronal CT demonstrates that the right UP is attached to the junction of the middle turbinate with cribriform plate (straight arrow).

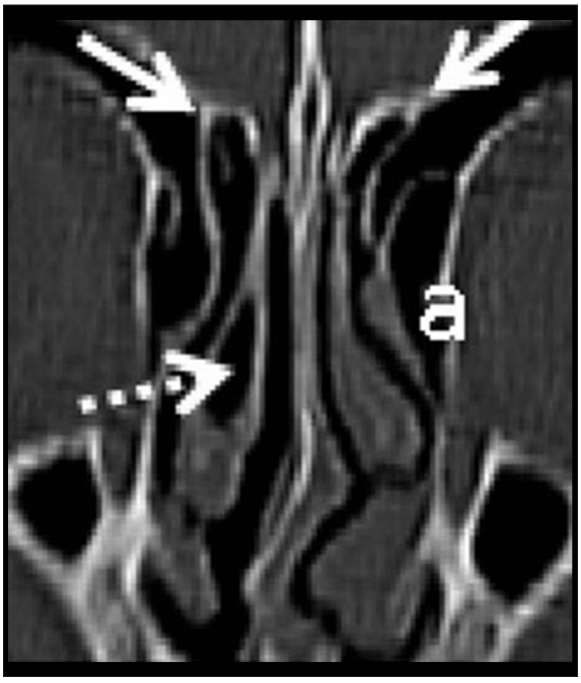

Figure 6. A 29-year-old male with type 5 UP insertion. Coronal CT reveals that both UPs are attached to the skull base (straight arrow). Note the right concha bullosa variation as well (dotted arrow).

several middle meatuses acting in cooperation [5]. The middle concha is covered in medial, the lamina papricea is covered in lateral, the basal lamina of the middle concha is covered in the upper and middle, the UP is covered in front and fovea ethmoidalis is covered on top [6]. The anterior OMU is a key component for the drainage (frontal, anterior ethmoidal and maxillary) of the anterior sinuses. The sphenoethmoidal recess, also called the posterior OMU, drains the posterior sinuses (posterior ethmoidal and sphenoid). The anterior OMU contains the maxillary sinus ostium and ethmoidal infundibulum, hiatus semilunar, middle meatus, anterior ethmoidal cells and frontal recess [4,7] (Figure 1).

Ethmoid bulla

The ethmoid bulla is formed by pneumatization of the bulla lamella in 92% of cases but may not always be pneumatized. If the ethmoidal lamella is not pneumatized, it cannot be named as the ethmoidal bulla [8]. Its appearance can be quite varied, depending on the degree/extent of pneumatization [9,10].

Imaging with Computed Tomography

CT is the most useful imaging method to show the anatomy and pathology of paranasal sinuses at the highest level, and is used most commonly, providing the gold standard for the evaluation of a patient prior endoscopic sinus surgery [11,12]. During the examination, axial and coronal sections are taken. A normal OMC is visualized on two or three, 3-mm-thick, coronal CT sections [13]. In recent years, with the widespread use of multislice CT, coronal and sagittal images can be obtained using indirect reconstructions from thin sections received from single and axial images. Sagittal reconstructions can be useful for morphological

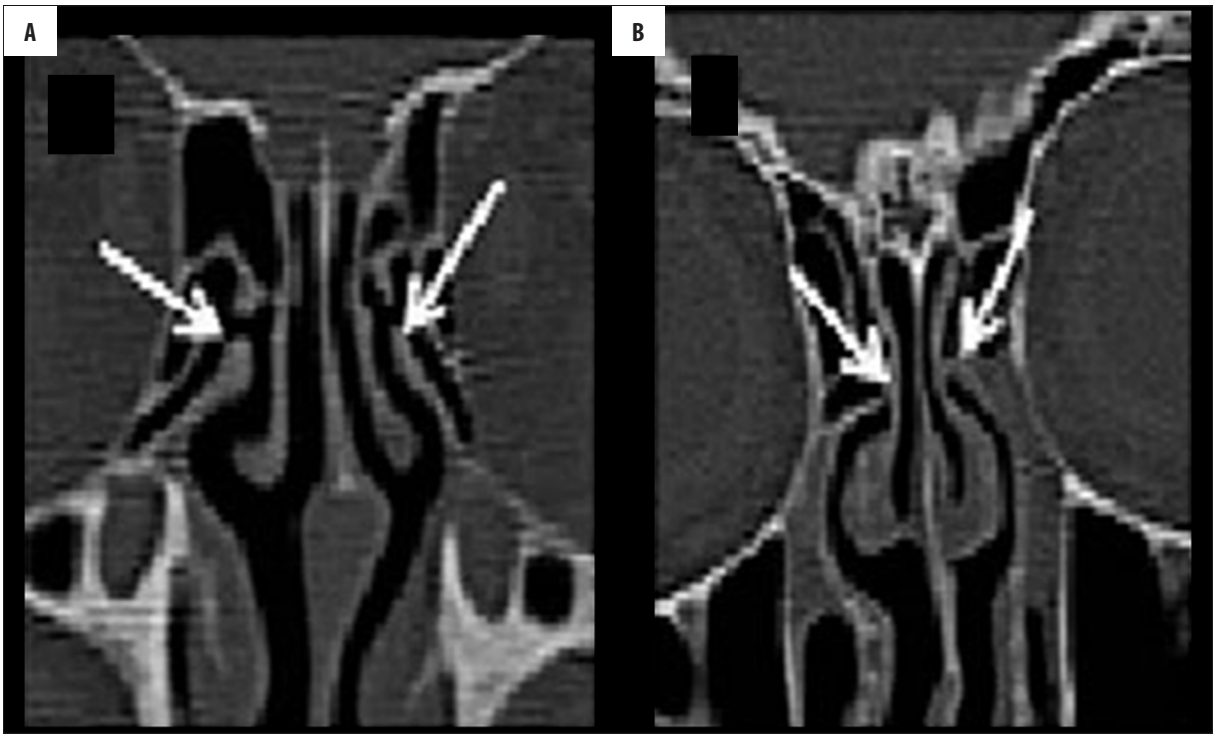

Figure 7. A 60-year-old female with type 6 UP insertion. (**A, B**) Two consecutive cross-sections on coronal CT. Uncinate processes (**A**, arrow) are attached to the middle turbinate (**B**, arrows).

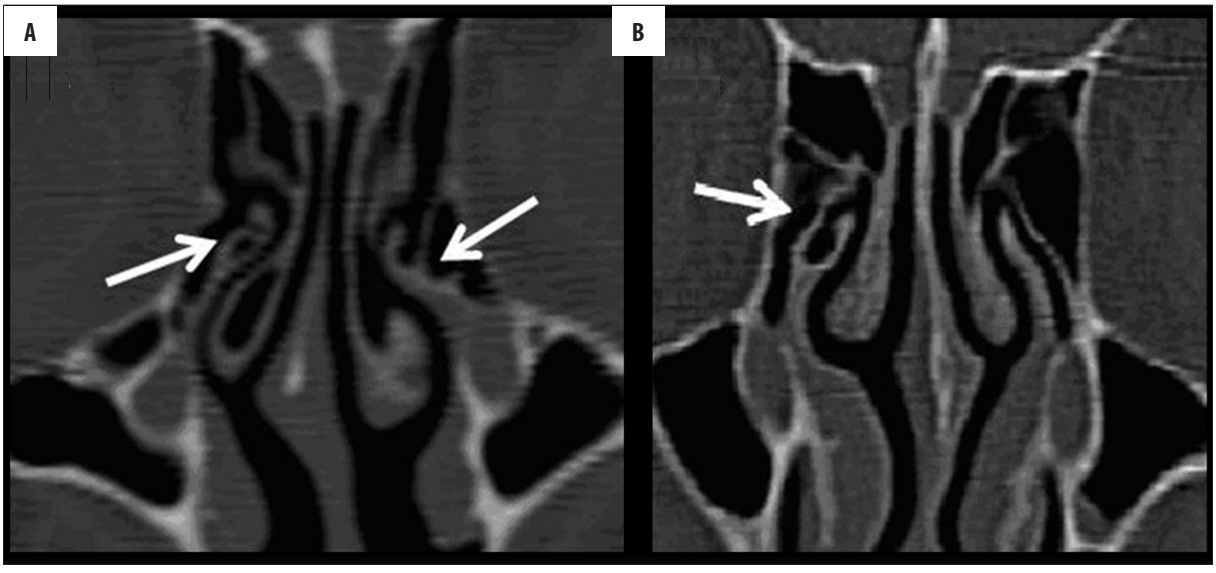

Figure 8. A 23-year-old male with bifid uncinate process. Coronal CT demonstrates (**A**) bilateral and (**B**) right-sided bifid UP (straight arrow) in different cases.

orientation [14]. Using CT effectively is convenient particularly in determining the treatment protocol and pathologies, understanding the normal anatomy and, if available, in understanding the anatomic variations prior to surgery [11].

Uncinate Process Variations

Variations of the superior attachment of the uncinate process

The position of the superior attachment of UP was originally suggested by Stammberger and Hawke in 1991 [15]. These researchers described 3 possible extensions of UP: lamina paprisea, skull base or middle concha. However, they did not mention other possible variations and combinations. Friedman et al. placed emphasis on the position of the superior attachment of UP for adequate exposition of the frontal sinus and appropriate dissection during the frontal recess [16]. Landsberg and Friedman described six different types related to the position of the superior attachment of UP and presented more detailed information relating to the superior attachment, by an imaging technique [17,18].

Figure 9. A 44-year-old female with uncinate bulla. (**A**) Coronal CT image shows that both uncinate processes are pneumatized (straight arrow). (**B**) In a different case, bilateral uncinate bulla variation (straight arrow) causes significant narrowing in the ostiomeatal unit.

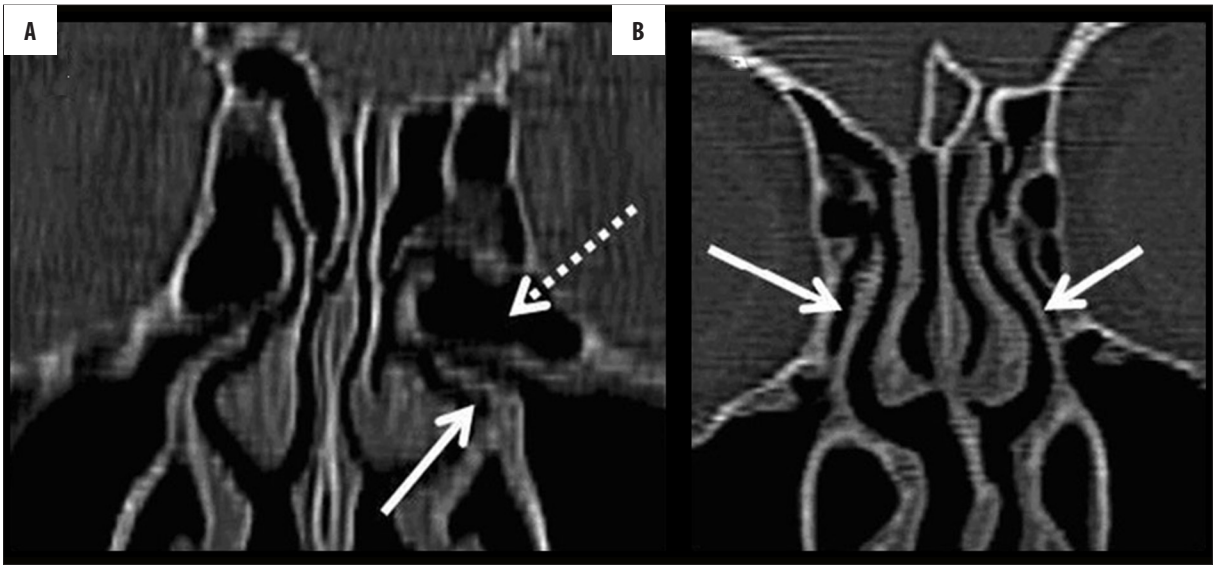

Figure 10. A 41-year-old female with horizontal and vertical UP. (**A**) The horizontal orientation of the left uncinate process (straight arrow) is accompanied by a large ethmoid bulla (dotted arrow) on the coronal CT. (**B**) In a different case, both uncinate processes seem to be localized vertically.

The variability of the UP's anterosuperior attachment affects the drainage of the frontal recess. UP generally attaches to the lamina paprisea and the agger nasi air cell anteriorly and the frontal recess is drained into the middle meatus [4]. The ethmoid infundibulum can be closed from the upper side by a blind pouch known as the "resessus terminalis" [18,19]. This explains why the ethmoid infundibulum inflammation does not cause frontal sinusitis [4,18]. UP can be replaced by a large agger nasi and can be attached to the middle concha. This causes the frontal recess to move toward the agger nasi posteriorly. In this situation, it can be reached by damaging the back wall of the agger nasi during endoscopy for the frontal drainage path [4].

Rarely the skull base can be reached in superior without touching UP agger nasi and the frontal recess can be drained into the ethmoid infundibulum. In this situation, the ethmoid infundibulum can cause frontal, ethmoid and maxillary sinuses to be involved in the process by affecting the occlusion and also the frontal sinus [4,18]. Moreover, due to variable attachment sites, unsinectomy may result in damage to the skull base and lamina papyracea [4] (Figures 2–7).

Bifid UP

The case of bifid UP is mentioned very rarely in literature [20] (Figure 8).

Uncinate bulla

The aeration of UP is called uncinate bulla [21] (Figure 9). Even though the mechanism of occurrence is not

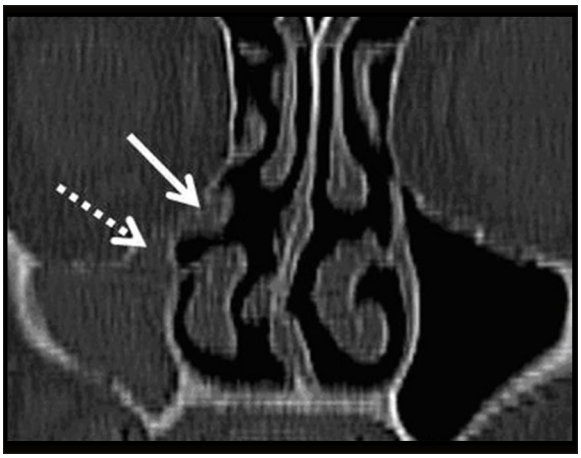

Figure 11. A 52-year-old male with atelectatic uncinate process. Opacified hypoplastic maxillary sinus antrum (dotted arrow) is shown together with UP (straight arrow) attached to the inferomedial orbital wall on coronal CT image.

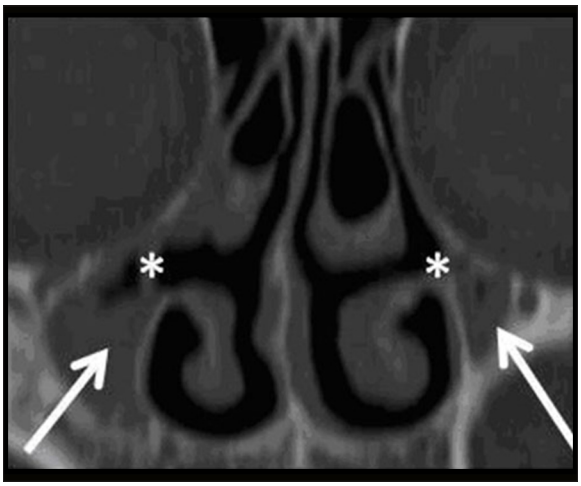

Figure 12. A 38-year-old male with maxillary sinus hypoplasia. Coronal CT image demostrates bilateral hypoplastic maxillary sinus (straight arrows) and atelectatic UP (asteriks).

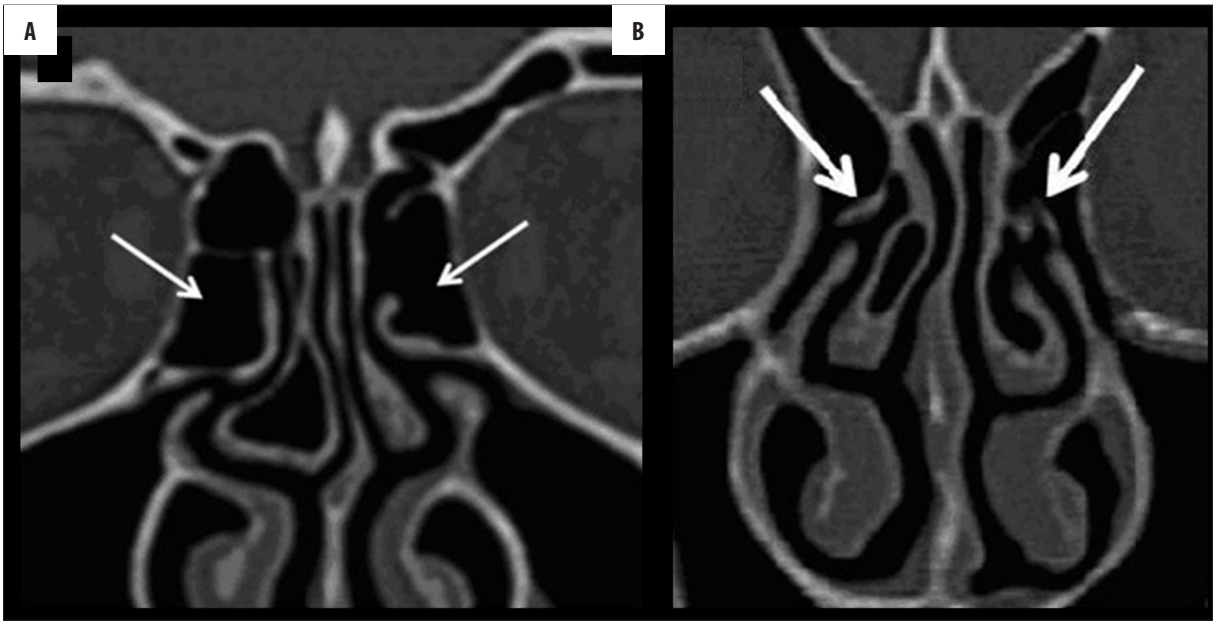

Figure 13. A 20-year-old female with ethmoid bulla. In two different cases, bilateral wide ethmoid bulla (**A**, arrows) and bilateral persistent, non-pneumatized second basal lamella (torus ethmoidalis) (**B**, arrows) are seen on coronal CT images.

sufficiently known, it is predicted that the agger nasi cells stem from the growth of the UP's frontmost and uppermost section towards the inside [22,23]. The uncinate bulla are considered to be a variation that can alter the ventilation through the infidibulum, anterior ethmoid cells and frontal recess. This variation increases the wideness of the uncinate, so it constitutes to be potentially dangerous for the infundibulum. Narrowness in the infundibulum is of clinical significance, since it can disrupt ventilation in the frontal ethmoid cells and the frontal recess region [21,23]. It can cause significant deterioration in OMU function by acting functionally like a concha bullosa or a widened ethmoid bulla. As it is in the uncinate bulla and haller cells, the pathological effect should be considered in cases where the number of combinations of anatomical variations is higher [24].

Deviation of the tip of the uncinate

The UP can show lateral deviation, obstructing infundibulum and/or semilunar hiatus or medial deviation, affecting the middle meatus. More rarely, the UP can be spiral, occluding the middle meatus [25].

Curved UP

The UP can show a set of rotation and attachment variations. The most commonly observed variation is a medially oriented UP. If it moves anteriorly and exits from the middle meatus, it is called 'Kaufmann's double middle turbinate' [3,8,26]. The horizontal and vertical orientation of UP is determined by adjacent structures: ethmoid bulla is the nasal septum affecting frontal OMU drainage and middle

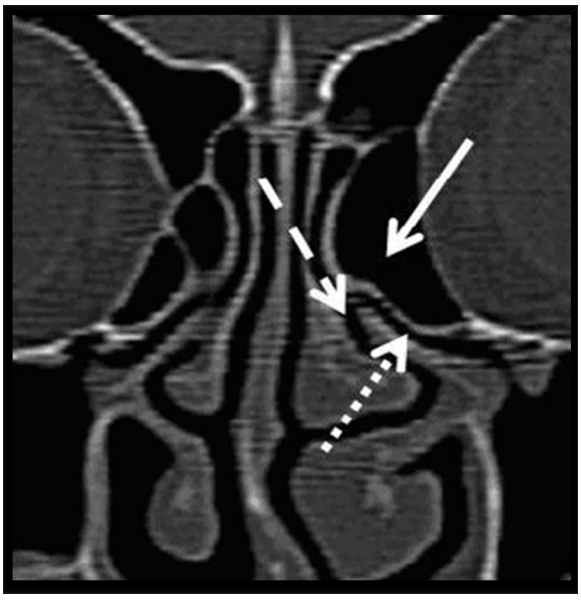

Figure 14. A 21-year-old female with a giant ethmoid bulla. Coronal CT demonstrates that left excessively pneumatized ethmoid bulla (straight arrow) narrows the middle meatus (dashed arrow) and infundibulum (dotted arrow) on the left.

Table 1. Types of ostiomeatal complex abnormalities [13].

Types of OMC	Uncinate process orientation	Ethmoid bulla appearance
1	Vertical	Enlarged or prolapsed
2	Vertical	Normal
3	Vertical	Absent or hypoplastic
4	Horizantal	Enlarged or prolapsed
5	Horizantal	Normal
6	Horizantal	Absent or hypoplastic

concha. Horizontal UP is always related to an enlarged ethmoid bulla. The UP can also take the form of a hook or can be pneumatized [4] (Figure 10).

Atelectatic UP

Sometimes, UP's free end shows hypoplastic development and attaches to orbita medial wall or inferior section of lamina paprisea. This condition is called atelectatic UP (Figure 11). Generally, it is seen together with an opacified hypoplastic maxillary sinus [27–30] (Figure 12). This variation is very important in the cases where anterior endoscopic sinus surgery is applied. If it is not defined radiologically, it can cause important complications posing a great danger for the orbital and optic nerve during unsinectomy. This variation and any accompanying hypoplastic sinus must be identified by a radiologist [26,28].

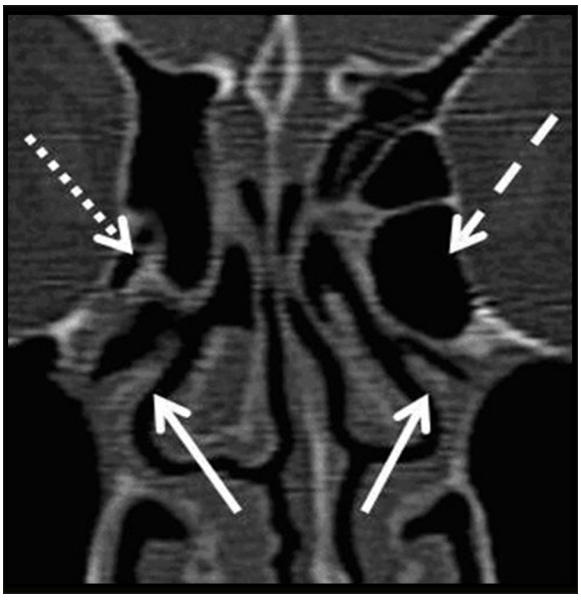

Figure 15. A 35-year-old male with OMC type 4 and type 6. Coronal CT reveals right hypoplastic ethmoid bulla (dotted arrow) and horizontal UP (straight arrow) (OMC type 6, the least common), left enlarged ethmoid bulla (dashed arrow) and horizontal UP (straight arrow) (OMC type 4, the most common).

Appearance of the ethmoid bulla

Ethmoid bulla is large anterior ethmoid air cells found in many people;they are clearly identified. The degree of pneumatization may be highly variable, from a giant ethmoid bulla that pushes the UP medially to torus ethmoidalis without pneumatization [8] (Figure 13). Enlarged ethmoid bulla includes cells that grow up to the ethmoid ceiling superiorly, basal lamella of the middle concha posteriorly, and lamina paprisea laterally [26,31]. The relationship of ethmoid bulla with lamina paprisea and lateral, and the relationship of frontal cranial fossa in superior with base should be clarified in preoperative CT. Ethmoid bulla is a reliable surgery marker point because it is the highest and the most constant anterior ethmoid cell.

The giant ethmoid bulla may enlarge to narrow or obstruct the middle meatus and infundibulum [23, 28] (Figure 14).

Abnormalities of the ostiomeatal unit

Narrowness in OMC, due to anatomic variations, can increase the likelihood of a full blockage and obstruction during inflammation. Such anatomic variations can be associated with both intrinsic structures – such as the uncinate process or ethmoid bulla – and extrinsic structures – such as middle turbinate enlargement, Haller cells, septal deviation, or a combination of these. Based on the ethmoid bulla's configuration and size and the orientation of the uncinated process, the abnormalities in OMC are classified into six types (Table 1). Earwaker defined that as follows: type 1: vertical UP orientation and enlarged or prolapsed ethmoid bulla, type 2: vertical UP orientation and normal ethmoid bulla, type 3: vertical UP orientation and absent or hypoplastic ethmoid bulla, type 4: horizantal

UP orientation and enlarged or prolapsed ethmoid bulla, type 5: horizantal UP orientation and normal ethmoid bulla, type 6: horizantal UP orientation and absent or hypoplastic ethmoid bulla [13] (Figure 15).

Conclusions

The UP constitutes the most important structure of OMC and has an important role in mucocilliary drainage and ventilation. UP variations are clinically and surgically significant, and it is important for the physician to be aware of the relevance and consequences of these variations. CT is an imaging method accepted as a gold standard and used routinely for determining the anatomy and pathology of this region. Therefore, CT is absolutely essential for the evaluation of patients considered for surgery.

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