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Surgical anatomy of the frontal recess – is there a benefit in multiplanar CT-reconstruction?*

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SUMMARY

Anatomical variations in the sinus region are not necessarily pathological, but they may complicate the anatomy of the lateral nasal wall and contribute to the occurrence or persistence of chronic inflammatory diseases. In this study the interpretations of initial coronal CT scans were significantly altered following multiplanar CT-reconstruction. Assuming that a multiplanar analysis includes coronal views, we may conclude that imaging in three planes yields more information and provides a substantial benefit in the planning and performance of a surgical procedure on the paranasal sinuses.

Key words: frontal recess, surgical anatomy, CT-scan, multiplanar CT, diagnosis

INTRODUCTION

Surgical procedures on the paranasal sinuses are among the most frequent operations in otorhinolaryngology. Anatomical variants in this region are common [1-10]. They may significantly hamper surgical procedures and occasionally require the use of specialized techniques and instruments.

The current gold standard for preoperative diagnosis is computed tomography (CT). This modality has largely replaced conventional radiographs in recent years [11-13] and can provide sectional images less than 1 mm thick. CT is an efficient means of identifying anatomical variants that may predispose to chronic rhinosinusitis (CRS) [14]. High-resolution imaging of the paranasal sinuses can be carried out within a few seconds. Additionally, the primary scans provide data sets for the computer generation of reconstructed image planes called multiplanar reconstructions (MPRs). Coronal slices can thus be supplemented by axial and sagittal image planes. This is particularly advantageous in the frontal recess and frontal sinus where the anatomy is complex and variable. Surgical anatomy can be accurately evaluated in three dimensions as an aid to preoperative planning [7;15-17].

Another advantage of MPRs is the elimination of metallic artifacts. In primary coronal CT, artifacts from metal dental restorations are visible over the entire image field. In axial spiral scans however, these artifacts are confined to the axial plane. Despite these advantages, multiplanar imaging of the paranasal sinuses has not become a standard tool in preoperative investigations. Usually only the coronal plane is imaged in 3-mm slices, despite the fact that sagittal and axial images could be reconstructed without subjecting the patient to additional radiation exposure. The object of this study was to quantify the benefit of MPRs compared with coronal imaging alone.

MATERIALS AND METHODS

CT-scans

The study was based on 162 CT examinations of the paranasal sinuses performed at the Munich-Pasing Radiology Center during the period from August 2, 2004, to October 29, 2004. Scan parameter were as follows: 120 kV, slice thickness 1.25 mm, pitch 1, 0° tilt, triplanar computer evaluation with 1-mm overlapping slices. The eFilm software package (version 1.8.3, Merge eMed, Milwaukee, WI) was used for the image reconstructions.

Image interpretation

The images were interpreted by two independent readers: a surgically experienced otorhinolaryngologist, and a resident in otorhinolaryngology training. The 3-mm coronal slices were evaluated first. Anatomical variants of the frontoethmoid complex were analyzed and tabulated. Three months later, both readers re-evaluated the same cases based on an analysis of multiplanar images reconstructed in three planes with a 1-mm slice thickness. The results of the multiplanar analysis were tabulated and compared with the results of the coronal analysis.

Agger nasi cells (ANCs) are the most common anatomical variants in the anterior ethmoid (Figure 1). They result from pneumatization of the agger nasi (Latin: “ridge of the nose”). The agger nasi is the rudiment of the anterior turbinate that is present in infants. While these cells are found in up to 98% of patients based on current data [3,9,10,18], they have no pathologic

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Table 1. The Kuhn classification of frontoethmoid cells.

Kuhn type 1 (K1 cell)	- Single cell above an agger nasi cell
Kuhn type 2 (K2 cell) (Figure 2)	- Two or more cells above and directly behind an agger nasi cell
Kuhn type 3 (K3 cell) (Figure 3)	- Single large cell above an agger nasi cell - Pneumatized into the frontal sinus (< 50% the height of the frontal sinus)
Kuhn type 4 (K4 cell) (Figure 4)	- Single large cell above an agger nasi cell - Pneumatized into the frontal sinus (> 50% the height of the frontal sinus)

significance in the absence of clinical symptoms. But when ANCs are very large or coexist with other frontoethmoid cells, they can significantly hamper the ventilation and drainage of the frontal sinus and may predispose to CRS.
Agger nasi cells may be mistaken for a terminal recess when viewed in the coronal plane. The terminal recess is formed by a lateral attachment of the uncinate process to the lamina papyracea [19,20]. Unlike agger nasi cells, however, the terminal recess is open inferiorly to form a "blind pouch" rather than a closed cell.

The frontoethmoid cells (Kuhn cells) pneumatize upward from the anterior ethmoid and the agger nasi region. Four different types of frontoethmoid cells are distinguished in the Kuhn classification [9,21] as shown in Table 1.

The frontoethmoid cells have one feature in common: their posterior wall is the anterior boundary of the frontal recess. Much like agger nasi cells, they may narrow the frontal recess from the anterior side (Figures 2, 3, 4). The anterior wall of the frontoethmoid cells also forms the anterior wall of the frontal sinus.

Frontal bullae are cells that pneumatize from the anterior ethmoid into the frontal sinus. Two features distinguish a frontal bulla from a K3 cell:
- It is pneumatized from the region above the ethmoid bulla and along the skull base into the frontal sinus.
- Its posterior wall is formed by the skull base. Its anterior wall directly faces the interior of the frontal sinus.

Frontal bullae may narrow the frontal recess from the posterior side. When combined with agger nasi and Kuhn cells, they may contribute to the obstruction of ventilation and drainage. Frontal bullae are usually indistinguishable from K3 cells on coronal CT scans which is illustrated in Figure 5. By using additional saggital and axial planes (Figures 6,7) the pneumatisation along the skull base upward from the anterior ethmoid can be visualized.

Cells of the interfrontal septum may develop from the agger nasi into the frontal sinus or may occur as isolated cells in the sinus. They are characterized by their close contact with the interfrontal septum (Figure 8). When viewed in coronal CT scans, they may be mistaken for Kuhn type 3 or 4 cells.

Suprabullar cells are located above the ethmoid bulla. Unlike the frontal bulla, they do not transcend the boundary of the anterior superior nasal spine (Figure 9). These cells may compromise the frontal sinus ostium, and they may transmit the anterior ethmoidal artery (AEA) in conjunction with supraorbital cells. Intraoperative injury of the AEA may lead to intraorbital and intracranial hemorrhage [22,23]. Preoperative CT analysis permits the early recognition of these potential hazards, helping to avoid complications during surgery.

RESULTS

A total of 162 coronal CT data sets were analyzed and compared with MPRs. Of these, 74 (45.68%) of the patients were female, and 88 (54.32%) were male.

Table 2 shows the percentage difference between the coronal analysis and subsequent MPR analysis regarding the identification of specific anatomical variants.

Table 2. Differences (in percent) between coronal and multiplanar analysis.

Anatomical variant	Reader 1	Reader 2	Mean value
Agger nasi cells	25	23	24
Frontoethmoid Kuhn cells	34	26	30
Pneumatized interfrontal septum	10	7	8.5
Frontal bullae	17	4	10.5
Suprabullar cells	30	40	35

In the case of agger nasi cells, reader 1 changed his original reading in 25% of cases after analyzing the MPRs. Reader 2 changed his reading in 23% of cases.

The readings on the frontoethmoid cells changed in 34% of cases (reader 1) and 26% of cases (reader 2) after analysis of the MPRs.

The readings on the pneumatized interfrontal septum were changed in 10% of cases (reader 1) and 7% of cases (reader 2). The differences for the frontal bullae were 17% (reader 1) and 4% (reader 2).

The rate of reading changes based on multiplanar analysis was particularly high for the suprabullar cells. The discordance in this category was 30% for reader 1 and 40% for reader 2.

The McNemar test (chi-square test for dependent random samples) was used to check the discordance rates for statistical significance. This test is suitable for repeated measurements of

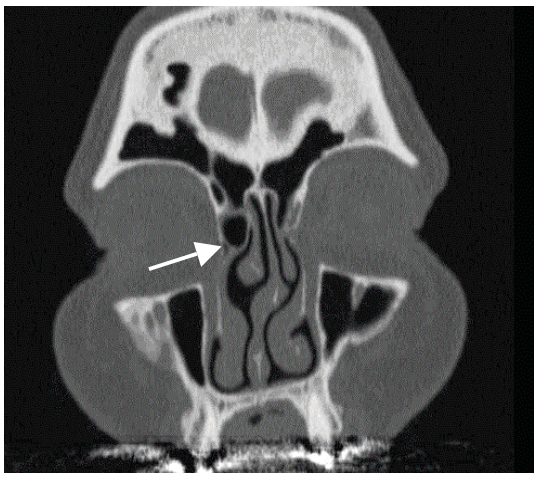

Figure 1a. Agger nasi cell in the coronal plane (white arrow).

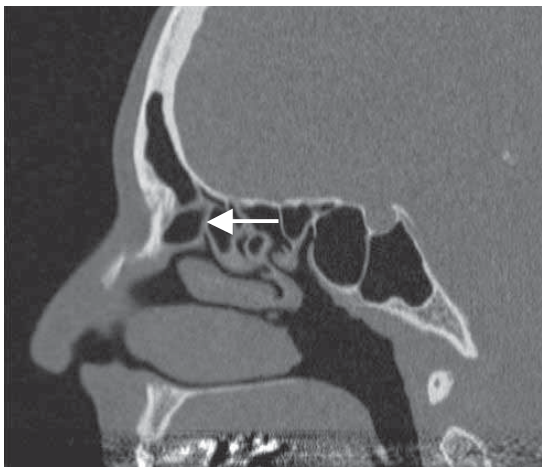

Figure 1b. Agger nasi cell in the sagittal plane.

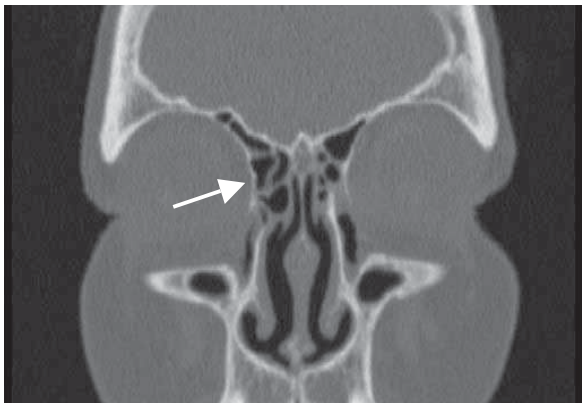

Figure 2a. K2 cells above an agger nasi cell in the coronal plane (white arrow).

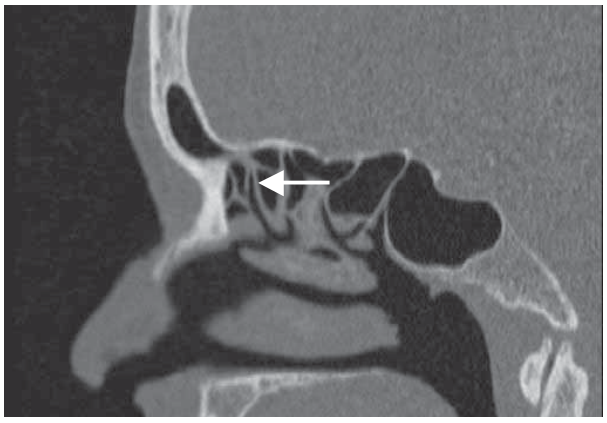

Figure 2b. K2 cells with an agger nasi cell in the sagittal plane.

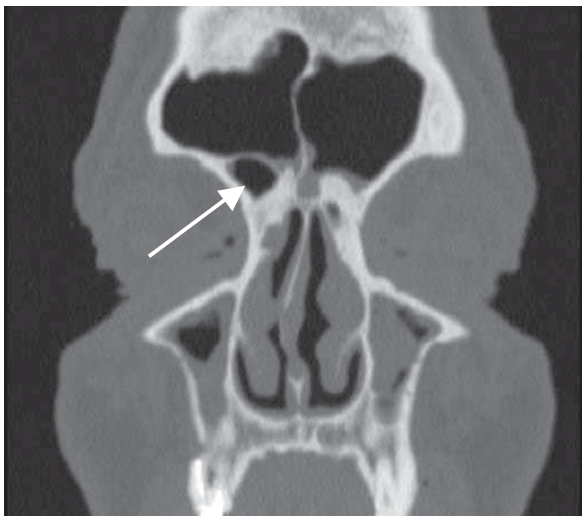

Figure 3a. K3 cell in the coronal plane (white arrow).

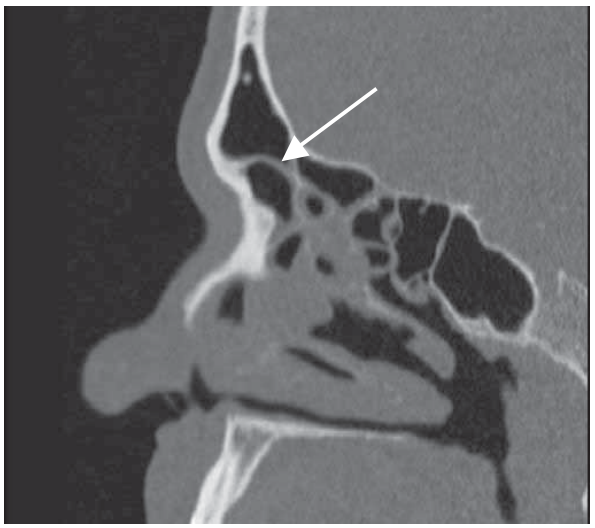

Figure 3b. K3 cell above the agger nasi cell in the sagittal plane.

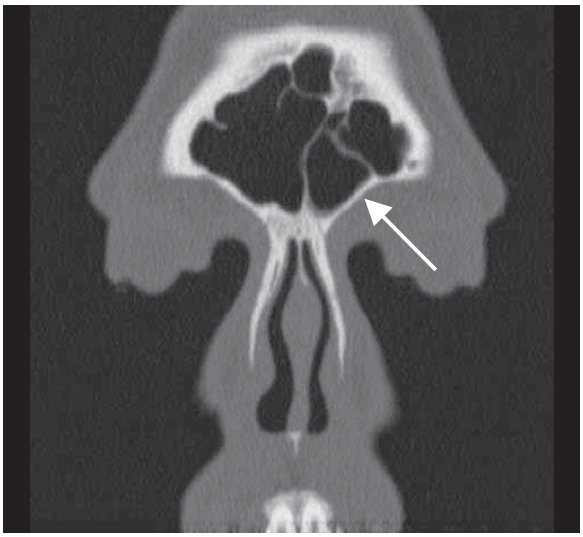

Figure 4a. K4 cell in the coronal plane (white arrow).

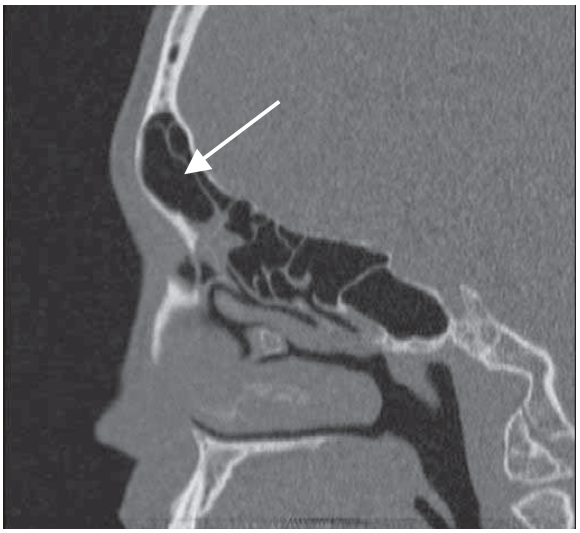

Figure 4b. K4 cell above an agger nasi cell on the left side, viewed in the sagittal plane.

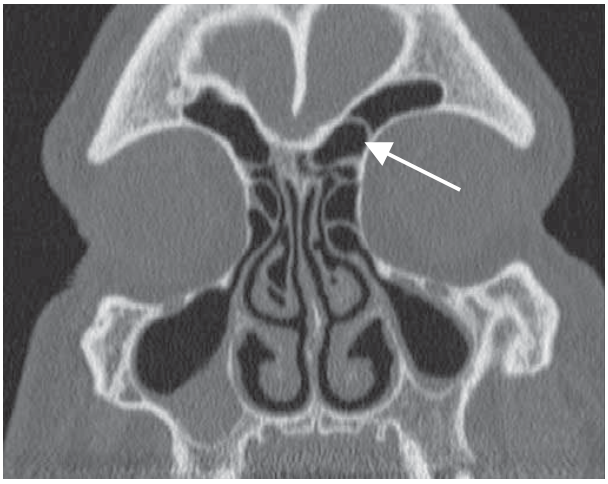

Figure 5a. Frontal bulla configuration in the coronal plane (patient left side).

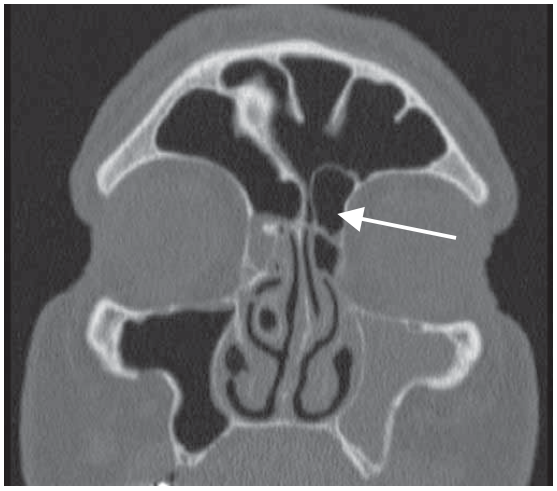

Figure 5b. K3 cell configuration in the coronal plane (patient left side).

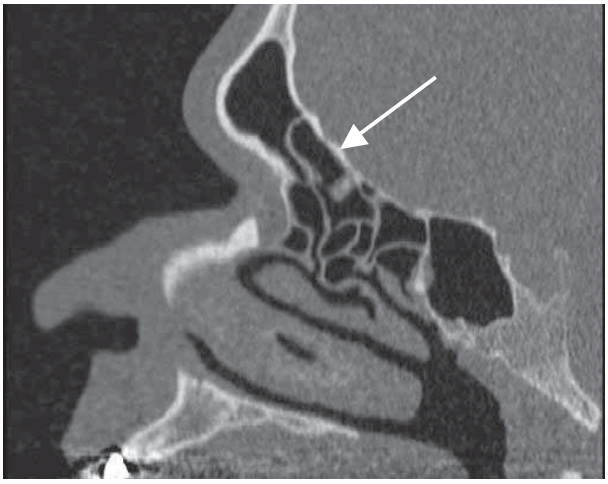

Figure 6a. Frontal bulla configuration in the sagittal plane: pneumatized into the frontal sinus at the skull base.

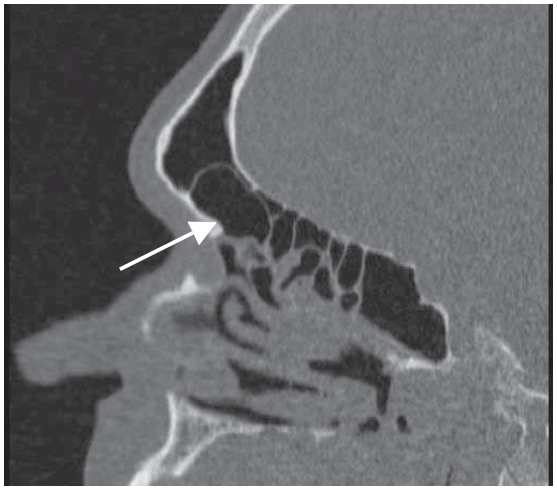

Figure 6b. K3 cell configuration in the sagittal plane: pneumatized into the frontal sinus from the agger nasi.

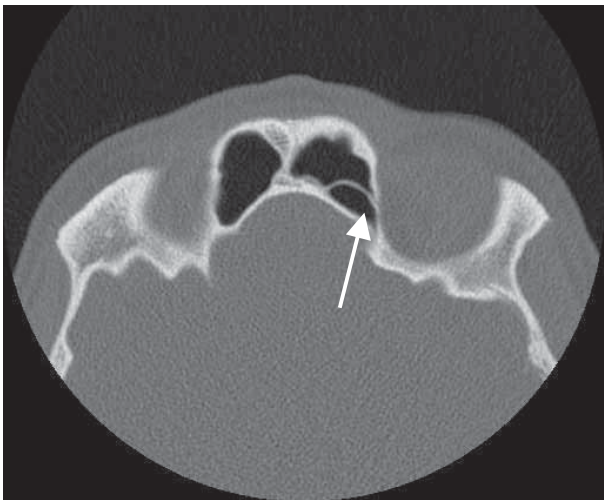

Figure 7a. Frontal bulla configuration in the arial plane: insertion on the skull base (patient left side).

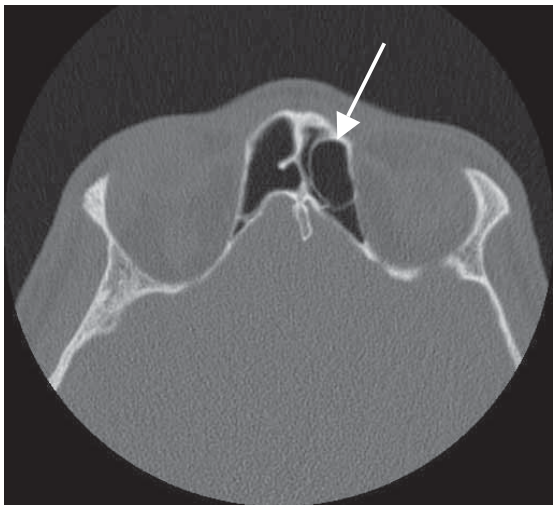

Figure 7b. K3 cell configuration in the arial plane: lateral/frontal insertion (patient left side).

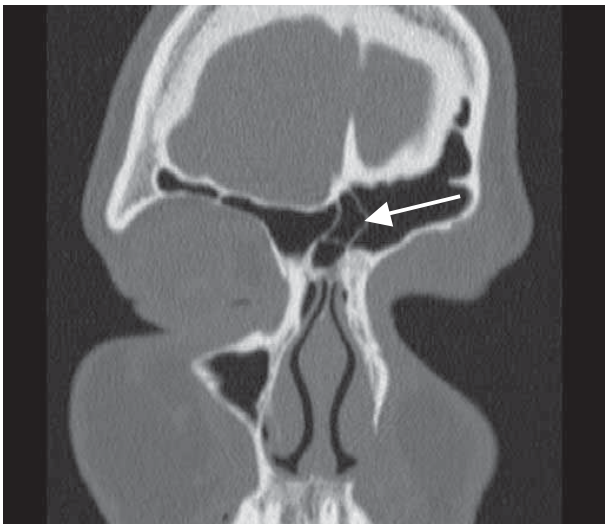

Figure 8a. Pneumatized interfrontal septum in the coronal plane.

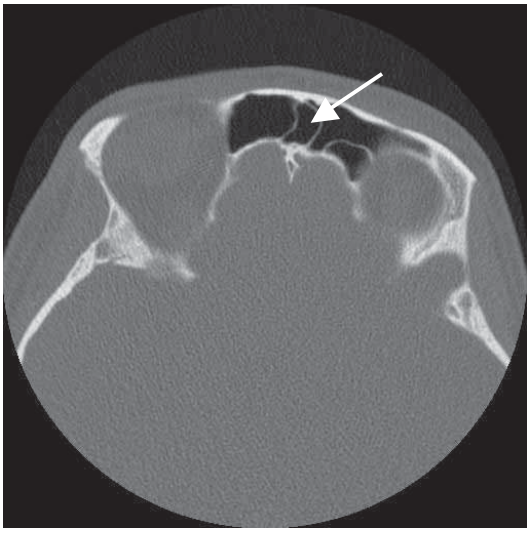

Figure 8b. Pneumatized interfrontal septum in the axial plane (white arrow).

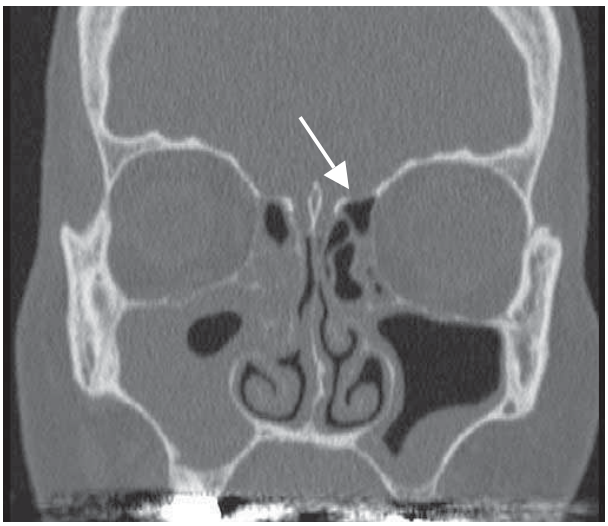

Figure 9a. Suprabullar cell in the coronal plane (white arrow).

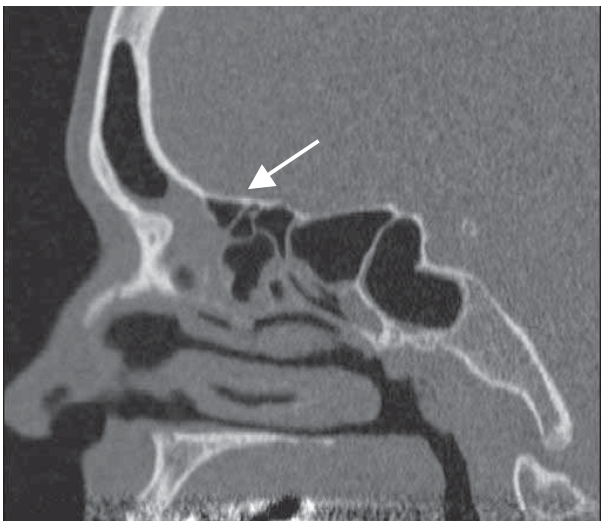

Figure 9b. Suprabullar cell in the sagittal plane (white arrow).

dichotomous features and tracks the significance of changes in repeated analyses.

DISCUSSION

The preoperative detection of anatomical variants on high-resolution CT scans is helpful in curtailing intraoperative risks. Table 2 shows the interobserver variability between the initial coronal analysis and subsequent multiplanar analysis. Discordances up to 40% occurred with both readers. The percentage differences between the initial coronal readings and MPR readings were highest in the categories of the agger nasi cells, frontoethmoid Kuhn cells, and suprabullar cells. In all categories but the Kuhn cells, reader 1 identified more cells in the multiplanar analysis than in the coronal-only analysis. That reader identified fewer Kuhn cells in the MPR analysis. This is due mainly to the fact that frontal bullae closely resemble K3 cells when viewed in coronal scans. Reader 2 identified more cells by multiplanar analysis than by coronal-only analysis in all categories except the pneumatized interfrontal septum.

Despite individual differences in analyzing the MPRs compared with coronal-only analysis, we found that both readers could correctly identify a larger number of frontoethmoid cells when MPRs were available for analysis.

Interobserver variability is inevitable when it comes to interpreting anatomical variants in the sinus region. Despite all efforts to employ a uniform nomenclature and definition for specific groups of cells, there is still variability in the assessment of the cells by different readers, because many variants differ only in small structures. These subtle differences are not clearly visible in all cases. This principle is illustrated by the frontal bullae. Cells in this category that extend far laterally into the frontal sinus could theoretically be classified as frontal bullae even if they do not significantly compromise the frontal recess. In cases like this, it is very difficult to avoid interobserver differences in determining the category of the variant under study.

Cells that have a similar appearance but show a different configuration pose an intraoperative risk. Examples are K3 cells and frontal bullae (Figures 5, 6, 7). A pneumatized interfrontal septum (Figure 8) may also have a similar configuration to a K3 cell or frontal bulla when viewed in the coronal plane. Both readers revised their initially positive readings on K3 cells in the coronal plane after analyzing the MPRs.

The discordance for the suprabullar cells was notably high for both readers. These cells have a small lumen and may be missed in 3-mm-thick coronal sections or may be misdiagnosed as a suprabullar recess.

The McNemar test was used to determine whether the change in a reader's assessment of an anatomical variant trended significantly in one direction. This proved to be the case for all cells except the pneumatized interfrontal septum, confirming that both readers changed their readings significantly after analyzing the MPRs.

The statistically insignificant difference in their readings of the pneumatized interfrontal septum may relate to the obvious location of the cell in the interfrontal septum, which is easily identified on routine scans. In most cases, this anatomical variant can be correctly identified in the coronal plane. Sagittal and axial planes are helpful only in evaluating extension into the frontal sinus. On the other hand, coronal scans with a 3-mm slice thickness are generally inadequate for distinguishing an agger nasi cell from a terminal recess. Similarly, a coronal-only analysis is insufficient for distinguishing between frontoethmoid cells and frontal bullae.

Table 3 shows that the differences between coronal-only analysis and multiplanar analysis are statistically significant. Thus, MPRs are recommended over pure coronal scans for evaluating the frontal recess and its anatomical variants owing to the improvement in structure recognition.

Table 3. p-Values in the McNemar test of comparative evaluations.

	Reader 1	Reader 2
Agger nasi cell	< 0.05	< 0.05
Frontoethmoid Kuhn cell	< 0.05	< 0.05
Pneumatized interfrontal septum	< 0.05	0.835
Frontal bulla	< 0.05	< 0.05
Suprabullar cell	< 0.05	< 0.05

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