Research Article

# Multidetector Computed Tomography Assessment of Anatomical Variations and Critical Sinonasal Landmarks: A Prospective Cross-Sectional Study

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**Abstract**

**Background:** Anatomical variations of the paranasal sinuses and osteomeatal complex are common findings on multidetector computed tomography (MDCT). Although these variations are not necessarily associated with sinonasal disease, they have significant implications during Functional Endoscopic Sinus Surgery (FESS). Accurate preoperative identification of these anatomical variants helps surgeons avoid potentially serious intraoperative complications involving the orbit, optic nerve, skull base, and anterior cranial fossa.

**Objective**

To evaluate the anatomical variations of the paranasal sinuses and osteomeatal complex using multidetector computed tomography with special emphasis on critical anatomical landmarks relevant to Functional Endoscopic Sinus Surgery.

Specific objectives were:

- To study the types of anatomical variations of the paranasal sinuses and osteomeatal complex.
- To evaluate the clinical importance of these anatomical variations on preoperative computed tomography.
- To assess variations involving the cribriform plate, lamina papyracea, Onodi cells, sphenoid sinus pneumatization, anterior ethmoidal artery, supraorbital pneumatization, and optic canal types that may increase intraoperative risk.
- To determine the frequency of these anatomical variations using 16-slice MDCT.

**Materials and Methods**

A prospective cross-sectional study was conducted in the Department of Radiodiagnosis, VMKV MCH Salem, Tamilnadu, India. A total of 109 adult patients referred for multidetector CT evaluation of the paranasal sinuses were included after satisfying the inclusion and exclusion criteria.

All patients underwent non-contrast MDCT of the paranasal sinuses using a Siemens Emotion 16-slice CT scanner. Axial acquisition with multiplanar coronal and sagittal reconstructions was performed. The following anatomical variations were evaluated:

- Keros classification of the cribriform plate
- Haller cells
- Uncinate process attachment
- Onodi cells
- Optic nerve canal types
- Sphenoid sinus pneumatization
- Anterior ethmoidal artery relationship
- Supraorbital pneumatization

Data were analyzed using Microsoft Excel.

**Results**

A total of 109 patients were evaluated.

Type II cribriform plate was the commonest anatomical variant and was observed in 88 (80.7%) patients, whereas Type I and Type

III cribriform plates were seen in 13 (11.9%) and 8 (7.3%) patients respectively.
Haller cells were present in 12 (11.01%) patients.
The uncinate process most commonly attached to the lamina papyracea (98; 88.9%), followed by attachment to the skull base (11; 10.09%) and middle turbinate (1; 0.91%).
Onodi cells were identified in 45 (41%) patients.
Regarding optic nerve canal configuration, Type I was the commonest pattern on both sides.
Sellar pneumatization of the sphenoid sinus was observed in 90 (82.5%) patients, whereas 19 (17.4%) demonstrated presellar pneumatization.
The anterior ethmoidal artery abutted the fovea ethmoidalis in 89 (81.6%) patients and the lateral lamella in 20 (18.3%) patients.
Supraorbital pneumatization was identified in 79 (72.4%) patients.
**Conclusion**
Anatomical variations of the paranasal sinuses are common findings on multidetector CT. Although these variants do not necessarily predispose patients to sinonasal pathology, they represent important surgical landmarks because they increase the risk of intraoperative complications during Functional Endoscopic Sinus Surgery.
Routine preoperative MDCT evaluation provides an accurate surgical roadmap, enabling identification of critical anatomical variations and thereby reducing operative morbidity and improving surgical outcomes.

**Keywords:** Multidetector Computed Tomography, Paranasal Sinuses, Anatomical Variations, Osteomeatal Complex, Functional Endoscopic Sinus Surgery, Cribriform Plate, Onodi Cell, Haller Cell, Optic Nerve Canal, Sphenoid Sinus Pneumatization, Supraorbital Pneumatization

## Introduction

The paranasal sinuses are air-filled cavities lined by respiratory ciliated mucosa within the facial skeleton surrounding the nasal cavity. They comprise four paired sinuses—frontal, maxillary, ethmoid, and sphenoid—which communicate with the nasal cavity through small ostia. Their principal functions include reducing skull weight, humidification of inspired air, and contributing to voice resonance.
Precise knowledge of sinonasal anatomy has become increasingly important with the widespread use of Functional Endoscopic Sinus Surgery (FESS). Successful surgical management depends upon detailed preoperative identification of normal anatomy and anatomical variations to minimize complications involving adjacent critical structures such as the orbit, optic nerve, anterior cranial fossa, and internal carotid artery.
Among available imaging modalities, multidetector computed tomography (MDCT) is considered the investigation of choice for evaluation of the paranasal sinuses because of its excellent spatial resolution and superior depiction of osseous anatomy. Thin-section axial imaging combined with multiplanar coronal and sagittal reconstructions enables accurate assessment of the osteomeatal complex and surgically important anatomical landmarks, including the cribriform plate, lamina papyracea, Onodi cells, sphenoid sinus pneumatization, anterior ethmoidal artery, supraorbital pneumatization, and optic nerve canal.
Unlike conventional radiography, MDCT provides comprehensive visualization of both normal anatomy and anatomical variants, thereby serving as an essential preoperative roadmap for FESS. Although magnetic resonance imaging is superior for evaluating soft tissue lesions and sinonasal tumors, its limited ability to depict fine bony anatomy makes CT the preferred modality for surgical planning.
The present prospective cross-sectional study was therefore undertaken to determine the frequency of clinically significant anatomical variations of the paranasal sinuses using multidetector computed tomography, with particular emphasis on surgically important anatomical landmarks that may influence operative planning and reduce intraoperative complications.

## Materials and Methods

### Study Design

This was a hospital-based prospective cross-sectional study conducted to evaluate anatomical variations of the paranasal sinuses using multidetector computed tomography (MDCT), with special emphasis on surgically important anatomical landmarks relevant to Functional Endoscopic Sinus Surgery (FESS).

**Study Setting**

The study was conducted in the Department of Radiodiagnosis, VMKV MCH Salem Tamilnadu India.

**Study Population**

A total of 109 consecutive patients referred to the Department of Radiodiagnosis for multidetector CT evaluation of the paranasal sinuses and fulfilling the eligibility criteria were included in the study.

**Sampling Technique**

Consecutive sampling was performed. All patients meeting the inclusion and exclusion criteria during the study period were enrolled.

**Inclusion Criteria**

Patients fulfilling all of the following criteria were included:

- Age greater than 18 years with fully developed paranasal sinuses.
- Patients referred for CT evaluation of the paranasal sinuses.
- Patients willing to participate and who provided written informed consent.

**Exclusion Criteria**

The following patients were excluded:

- Pregnant women.
- Patients with previous surgery involving the paranasal sinuses.
- Patients with previous nasal trauma.
- Patients with malignant neoplasms involving the paranasal sinuses.
- Pediatric patients with incompletely pneumatized paranasal sinuses.

**Patient Evaluation**

Each patient underwent:

- Detailed clinical history.
- Relevant clinical examination.
- Multidetector computed tomography (MDCT) examination of the paranasal sinuses.

CT Imaging Protocol

All examinations were performed using a SIEMENS Emotion 16-slice multidetector CT scanner.

Scan Acquisition

- Patient position: Supine
- Scan plane: Direct axial acquisition
- Slice thickness: 0.6 mm
- Coronal and sagittal multiplanar reconstructions obtained from axial data
- Contrast administration: None (plain CT study)

**Scan Parameters**

| Parameter | Value |
|---|---|

| | |
|---|---|
| CT Scanner | SIEMENS Emotion 16 |
| Tube Voltage | 120 kV |
| Tube Current | 300 mA |
| Scan Time | 1.5 seconds |
| Slice Thickness | 0.6 mm |
| Bone Window Width | 2500–3000 |
| Bone Window Level | 250–300 |
| Soft Tissue Window Width | 80 |
| Soft Tissue Window Level | 40 |

**Gantry Orientation**

- Coronal reconstruction: Perpendicular to the infraorbitomeatal line.
- Axial acquisition: Parallel to the infraorbitomeatal line.

**Scan Coverage**

The CT examination extended:

- From the posterior margin of the sphenoid sinus
- To the anterior-most aspect of the nasal cavity
- Including the hard palate through the frontal sinus.

**Patient Preparation**

Prior to CT examination:

- Written informed consent was obtained.
- The CT procedure was explained in detail.
- Patients were advised to fast for 4 hours before the examination.
- Patients were instructed to blow their nose immediately before scanning to minimize retained secretions.
- No intravenous contrast was administered.

**Image Evaluation**

Each CT examination was systematically evaluated for the presence of the following anatomical variations:

1. Keros classification (Types I–III) of the cribriform plate.
2. Presence or absence of Haller cells.
3. Attachment of the uncinate process to:
4. Lamina papyracea
5. Skull base
6. Middle turbinate
7. Presence or absence of Onodi cells.
8. Optic nerve canal configuration (Types I–IV).
9. Type of sphenoid sinus pneumatization.
10. Presence or absence of supraorbital pneumatization.
11. Relationship of the anterior ethmoidal artery to the fovea ethmoidalis or lateral lamella.

**Outcome Measures**

The primary outcome was to determine the prevalence of anatomical variations of the paranasal sinuses and identify surgically important landmarks detectable on multidetector CT that may influence preoperative planning for Functional Endoscopic Sinus Surgery.

**Statistical Analysis**
Collected data were entered into Microsoft Excel and analyzed using descriptive statistical methods. Frequencies and percentages were calculated for each anatomical variation observed during the study.

**Ethical Considerations**
The following ethical principles were observed:
- Written informed consent was obtained from every participant.
- Patient confidentiality was maintained throughout the study.
- Participation was voluntary.
- No additional financial burden was imposed on participants.
- There was no monetary gain to the primary investigator.
- Participants were free to decline participation without any penalty.
- The study findings were intended for publication to benefit the medical fraternity and the general population.

## Results

**Study Population**
A total of 109 patients who fulfilled the inclusion criteria were included in the present study. Among them, 81 (74.3%) were males and 28 (25.7%) were females.

**Distribution of Study Population by Gender**

**Table 1. Gender Distribution of Study Population**

| Gender | Number (n=109) | Percentage (%) |
|---|---|---|
| Male | 81 | 74.3 |
| Female | 28 | 25.7 |
| Total | 109 | 100 |

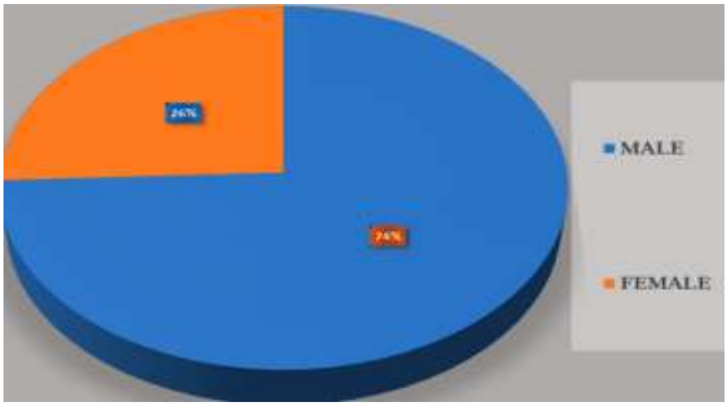


**Figure 1. Gender distribution of the study population.**

### Cribriform Plate Classification

Among the 109 patients evaluated, Type II cribriform plate was the most common anatomical variant, observed in 88 (80.7%) patients. Type I was identified in 13 (11.9%) patients, whereas Type III was present in 8 (7.3%) patients.

**Table 2. Distribution of Cribriform Plate Types**

| Cribriform Plate Type | Number | Percentage (%) |
|---|---|---|
| Type I | 13 | 11.9 |
| Type II | 88 | 80.7 |
| Type III | 8 | 7.3 |
| Total | 109 | 100 |

**Table 3. Distribution of Cribriform Plate Types According to Gender**

| Cribriform Plate | Male | Female | Male (%) | Female (%) |
|---|---|---|---|---|
| Type I | 10 | 3 | 12.34 | 10.71 |
| Type II | 64 | 24 | 79.01 | 85.71 |
| Type III | 7 | 1 | 8.77 | 3.57 |
| Total | 81 | 28 | 100 | 100 |

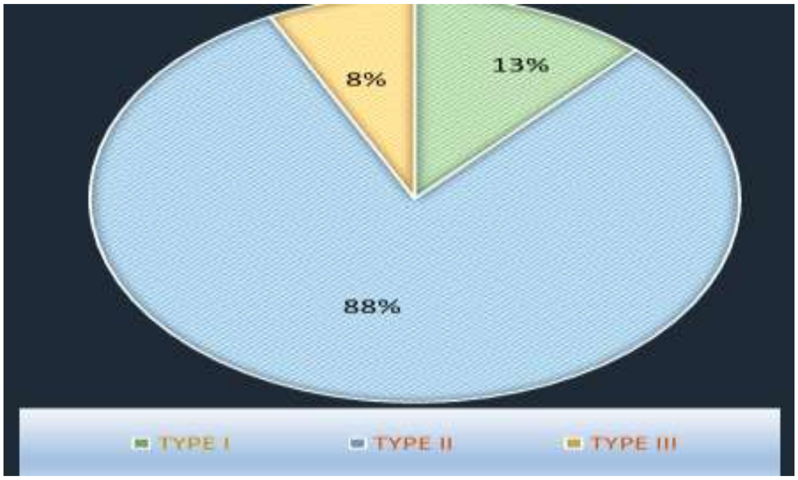


**Figure 2. Distribution of cribriform plate types.**

### Haller Cells

Haller cells were identified in 12 (11.01%) patients, while 97 (88.99%) patients did not demonstrate Haller cells on CT examination.

**Table 4. Presence of Haller Cells**

| Haller Cells | Number | Percentage (%) |
|---|---|---|
| Present | 12 | 11.01 |
| Absent | 97 | 88.99 |
| Total | 109 | 100 |

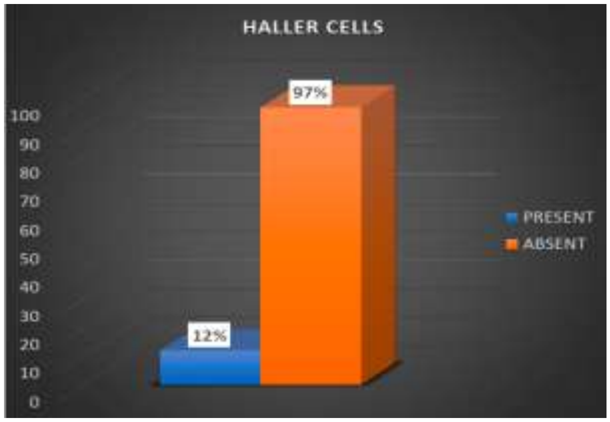


**Figure 3. Presence and absence of Haller cells.**

**Attachment of the Uncinate Process**

The uncinate process was most commonly attached to the lamina papyracea (88.9%), followed by the skull base (10.09%) and middle turbinate (0.91%).

**Table 5. Attachment of the Uncinate Process**

| Attachment | Number | Percentage (%) |
|---|---|---|
| Lamina papyracea | 98 | 88.90 |
| Skull base | 11 | 10.09 |
| Middle turbinate | 1 | 0.91 |
| Total | 109 | 100 |

**Table 6. Uncinate Process Attachment According to Gender**

| Attachment | Male | Female | Total | Percentage (%) |
|---|---|---|---|---|
| Lamina papyracea | 97 | 18 | 98 | 89.90 |
| Skull base | 1 | 10 | 11 | 10.09 |
| Middle turbinate | 0 | 1 | 1 | 0.91 |
| Total | 81 | 28 | 109 | 100 |

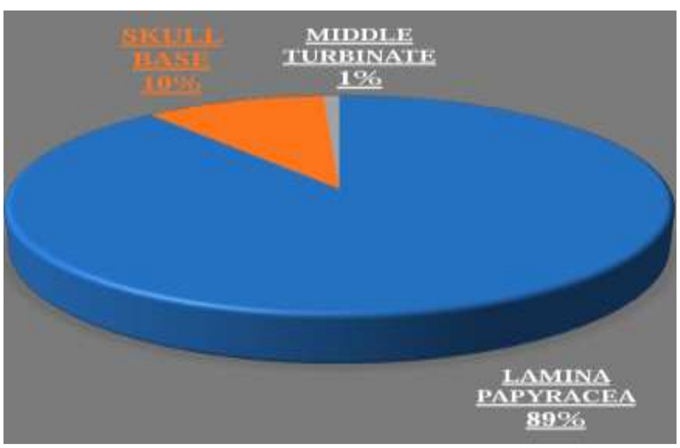


**Figure 4. Attachment of the uncinate process.**

**Onodi Cells**
Onodi cells were detected in 45 (41%) patients.
Among these:
- Right-sided: 26 (23.8%)
- Left-sided: 19 (17.4%)

Gender-wise distribution is shown below.

**Table 7. Distribution of Onodi Cells According to Gender**

| Gender | Right | Left | Bilateral | Total |
|---|---|---|---|---|
| Male | 12 | 5 | 8 | 25 |
| Female | 1 | 1 | 5 | 7 |

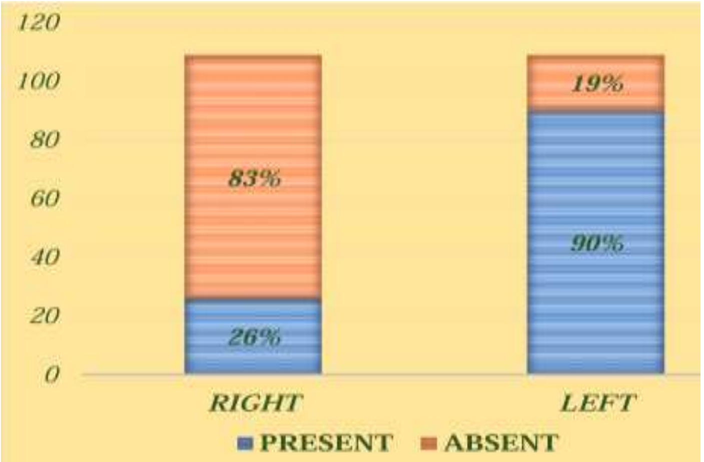

**Figure 5. Distribution of Onodi cells.**

**Optic Nerve Canal Classification**
Type I optic nerve canal was the most frequently encountered configuration on both sides.

**Table 8. Distribution of Optic Nerve Canal Types**

| Optic Canal Type | Right n (%) | Left n (%) |
|---|---|---|
| Type I | 48 (44.03) | 51 (46.7) |
| Type II | 46 (42.2) | 47 (43.1) |
| Type III | 6 (5.5) | 6 (5.5) |
| Type IV | 9 (8.2) | 5 (4.5) |


**Figure 6. Types of optic nerve canal.**

**Sphenoid Sinus Pneumatization**

Sellar pneumatization was the predominant pattern, observed in 90 (82.5%) patients, whereas 19 (17.4%) patients demonstrated presellar pneumatization. No conchal type was observed.

**Table 9. Types of Sphenoid Sinus Pneumatization**

| Type | Number | Percentage (%) |
|---|---|---|
| Presellar | 19 | 17.4 |
| Sellar | 90 | 82.5 |
| Total | 109 | 100 |

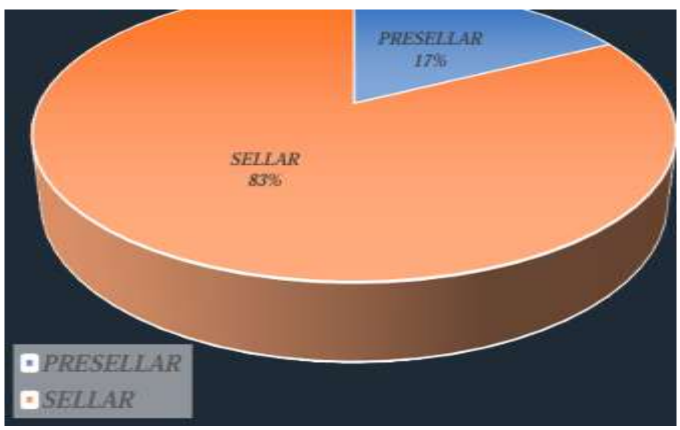


**Figure 7. Types of sphenoid sinus pneumatization.**

**Relationship of the Anterior Ethmoidal Artery**

The anterior ethmoidal artery abutted the fovea ethmoidalis in 89 (81.6%) patients and the lateral lamella in 20 (18.3%) patients.

**Table 10. Relationship of the Anterior Ethmoidal Artery**

| Relationship | Number | Percentage (%) |
|---|---|---|
| Fovea ethmoidalis | 89 | 81.6 |
| Lateral lamella | 20 | 18.3 |
| Total | 109 | 100 |

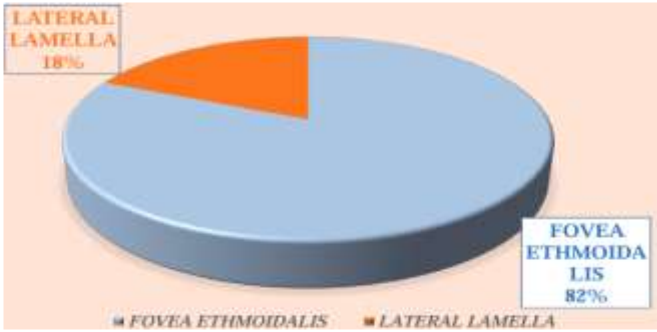

**Figure 8. Relationship of the anterior ethmoidal artery with the fovea ethmoidalis and lateral lamella.**

**Supraorbital Pneumatization**

Supraorbital pneumatization was present in 79 (72.4%) patients and absent in 30 (27.6%) patients. It was relatively more common in males than females.

**Table 11. Presence of Supraorbital Pneumatization**

| Finding | Number | Percentage (%) |
|---|---|---|
| Present | 79 | 72.4 |
| Absent | 30 | 27.6 |
| Total | 109 | 100 |

**Table 12. Supraorbital Pneumatization According to Gender**

| Supraorbital Pneumatization | Male | Female | Total |
|---|---|---|---|
| Present | 59 | 20 | 79 |
| Absent | 22 | 8 | 30 |
| Total | 81 | 28 | 109 |

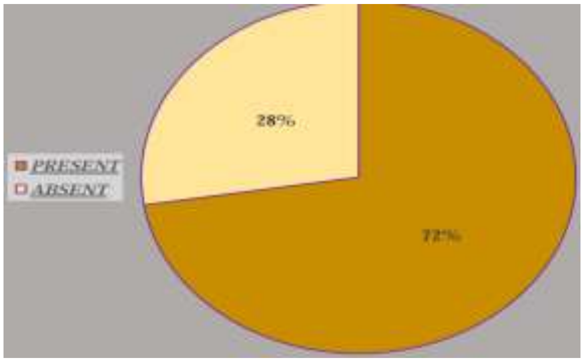

**Figure 9. Presence of supraorbital pneumatization.**

## Discussion

The present prospective cross-sectional study evaluated the anatomical variations of the paranasal sinuses in 109 adult patients using multidetector computed tomography (MDCT). Since Functional Endoscopic Sinus Surgery (FESS) is performed in close proximity to vital neurovascular structures, preoperative recognition of these anatomical variations is essential to reduce the risk of surgical complications. MDCT provides excellent visualization of the osteomeatal complex, skull base, orbit, and adjacent critical structures, making it the imaging modality of choice for preoperative evaluation.

**Cribriform Plate**

The Keros classification is one of the most important anatomical considerations before FESS because the depth of the olfactory fossa determines the vulnerability of the skull base during surgery.

In the present study, Type II cribriform plate was the most common anatomical variant, accounting for 80.7% of cases, followed by Type I (11.9%) and Type III (7.3%). These observations are comparable with previously published studies in which Keros Type II has consistently been reported as the predominant morphology.

Patients with Type III cribriform plate possess a deeper olfactory fossa and a longer lateral lamella, making them particularly susceptible to inadvertent intracranial penetration and cerebrospinal fluid leak during endoscopic sinus surgery. Therefore, careful evaluation of the cribriform plate should always be included in the routine preoperative CT assessment.

**Haller Cells**

Haller cells were identified in 11.01% of the study population.

These infraorbital ethmoid air cells may narrow the ethmoid infundibulum and maxillary sinus ostium, thereby interfering with normal sinus drainage. Large Haller cells have been associated with recurrent maxillary sinusitis and may increase the risk of orbital injury during FESS because of their close relationship with the orbital floor.

Although their prevalence varies considerably among different populations, the present study demonstrates that Haller cells are a relatively common anatomical variation requiring careful preoperative identification.

**Uncinate Process Attachment**

The uncinate process showed attachment to the lamina papyracea in 88.9% of patients, while attachment to the skull base and middle turbinate was much less common.

Variations in the superior attachment of the uncinate process alter the drainage pathway of the frontal recess and may contribute to obstruction of the osteomeatal complex. From a surgical perspective, knowledge of the attachment site is extremely important because incorrect identification during uncinectomy may result in orbital injury or incomplete surgical clearance.

The predominance of lamina papyracea attachment observed in the present study is consistent with anatomical descriptions in previous literature.

**Onodi Cells**

Onodi cells were identified in 41% of patients.

These posterior ethmoid air cells extend superolateral to the sphenoid sinus and maintain an intimate relationship with the optic nerve. Failure to recognize an Onodi cell during surgery may result in accidental injury to the optic nerve or internal carotid artery.

The relatively high prevalence observed in the present study emphasizes the necessity of evaluating both axial and coronal CT images before surgery. Identification of Onodi cells is considered one of the most important objectives of preoperative CT because of their direct surgical implications.

**Optic Nerve Canal Variations**

Type I optic canal was the commonest configuration on both sides, followed by Type II, whereas Types III and IV were relatively uncommon.

The relationship between the optic nerve canal and the sphenoid sinus has significant surgical importance. Patients

with Type II and particularly Type III configurations often demonstrate optic nerve protrusion or dehiscence within the sphenoid sinus, increasing susceptibility to optic nerve injury during sphenoidotomy.
Routine preoperative assessment of optic canal type therefore contributes significantly to surgical safety.

**Sphenoid Sinus Pneumatization**
The sellar type of sphenoid sinus pneumatization was observed in 82.5% of patients, whereas 17.4% demonstrated the presellar type.
The sellar variety is clinically important because excessive pneumatization may produce thinning or dehiscence of the bony walls overlying the optic nerve and internal carotid artery, thereby increasing the risk of catastrophic intraoperative complications.
The predominance of the sellar type observed in this study agrees with previous radiological studies.

**Anterior Ethmoidal Artery**
The anterior ethmoidal artery abutted the fovea ethmoidalis in 81.6% of patients and the lateral lamella in 18.3%.
Identification of the anterior ethmoidal artery is extremely important because accidental injury may produce rapid orbital hemorrhage and visual compromise. Supraorbital ethmoid pneumatization further increases this surgical risk by allowing the artery to course freely within the ethmoid sinus.
Preoperative CT therefore provides valuable information regarding the location of this important vascular structure.

**Supraorbital Pneumatization**
Supraorbital pneumatization was present in 72.4% of patients and was relatively more frequent among males.
This variation is important because it alters the course of the anterior ethmoidal artery and increases the possibility of vascular injury during FESS. Identification of supraorbital pneumatization on MDCT therefore contributes to safer surgical planning.

**Clinical Significance**
The present study highlights that anatomical variations of the paranasal sinuses are common and frequently involve structures that are critically important during Functional Endoscopic Sinus Surgery. Multidetector CT provides comprehensive evaluation of these variations, allowing surgeons to anticipate potential operative hazards before intervention.
Routine preoperative CT assessment should therefore include a systematic evaluation of:

- Keros classification of the cribriform plate
- Haller cells
- Onodi cells
- Uncinate process attachment
- Optic nerve canal type
- Sphenoid sinus pneumatization
- Anterior ethmoidal artery
- Supraorbital pneumatization

Such an approach can substantially reduce operative morbidity and improve surgical outcomes.

**Strengths of the Study**

- Prospective cross-sectional study design.
- Evaluation of 109 consecutive adult patients.
- Thin-section 16-slice MDCT with multiplanar reconstruction.

- Comprehensive assessment of all major surgically relevant sinonasal anatomical variations.
- Findings directly applicable to preoperative planning for Functional Endoscopic Sinus Surgery (FESS).

**Limitations**

- Single-center study.
- Relatively modest sample size.
- No correlation with intraoperative surgical findings.
- No assessment of postoperative surgical outcomes.
- No statistical association between anatomical variations and sinonasal disease severity was performed.

## Conclusion

The present prospective cross-sectional study demonstrates that anatomical variations of the paranasal sinuses are common findings on multidetector computed tomography (MDCT). Accurate identification of these variations is essential because many involve structures that are closely related to the orbit, optic nerve, skull base, anterior cranial fossa, and internal carotid artery, making them highly relevant during Functional Endoscopic Sinus Surgery (FESS).

In the present study, Type II cribriform plate (80.7%), lamina papyracea attachment of the uncinate process (88.9%), sellar type sphenoid sinus pneumatization (82.5%), and Type I optic nerve canal were the most frequently encountered anatomical configurations. Onodi cells were identified in 41% of patients, Haller cells in 11.01%, and supraorbital pneumatization in 72.4% of patients. These anatomical variants represent important surgical landmarks and should be carefully evaluated before endoscopic sinus surgery.

Multidetector CT provides excellent visualization of sinonasal anatomy and remains the imaging modality of choice for preoperative assessment. Routine systematic evaluation of surgically important anatomical landmarks—including the cribriform plate, uncinate process, Haller cells, Onodi cells, optic nerve canal, sphenoid sinus pneumatization, anterior ethmoidal artery, and supraorbital pneumatization—can significantly reduce intraoperative complications and improve surgical planning and patient outcomes.

**6. Clinical Implications**

- MDCT should be performed routinely before Functional Endoscopic Sinus Surgery.
- Radiologists should use a structured reporting format that includes all surgically important anatomical variations.
- Preoperative identification of anatomical variants facilitates safer surgical planning.
- Careful assessment of the skull base, orbit, optic nerve, anterior ethmoidal artery, and sphenoid sinus reduces the likelihood of major intraoperative complications.
- Standardized CT reporting may improve communication between radiologists and otorhinolaryngologists.

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