

Computed Tomographic Study of Remarkable Anatomic Variations in Paranasal Sinus Region and their Clinical Importance - A Retrospective Study

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Abstract

Introduction: With the advent of functional endoscopic sinus surgery and coronal computed tomography (CT) imaging, more attention has been paid toward paranasal region anatomy. Detailed knowledge of anatomic variations in paranasal sinus region is critical for surgeons performing endoscopic sinus surgery as well as for the radiologist involved in the pre- and post-operative assessment. The anatomical variants with some accompanying pathologies would directly influence the success of diagnostic and therapeutic management of paranasal sinus diseases. Our study intends to explore the anatomy of paranasal air sinus through CT and to describe its variants, which may predispose to chronic sinusitis and complications in endoscopic sinonasal surgery. **Materials and Methods:** This was a retrospective study carried out in a tertiary institution. Two hundred and fifty patients without paranasal sinus symptoms who presented for head CT studies and gave consent for a coronal section scan of the paranasal sinuses to be taken in addition to the axial section of the head were included in the study. The CT examination was performed with GE Hispeed-NX/I Base-2002 Dual Slice Helical CT machine. **Results:** Among 250 study population, 100 were females and 150 males. Among these 423 cases of anatomical variants were observed. The most common anatomical variants were pneumatization of the middle nasal turbinates 30.73%. This is followed by agger nasi cells 21.64%, Haller's cells 22.91%, septal deviation 21.91%, and sphenoid sinus septation (20.18%). **Discussion:** CT is the gold standard in the radiologic investigation of the paranasal sinuses, sinonasal lesions, and inflammatory disease or pre- and post-surgical assessment. It has the capability of disclosing in greatest detail any anatomical variations, which could be causing or precipitating the sinusitis.

Keywords: Anatomical variations, maxillary sinus, nasal septal deviation, paranasal sinuses, turbinate's

INTRODUCTION

The paranasal sinuses are group of air-filled spaces surrounding the nasal cavity.^[1] Radiological evaluation of the sinuses is essential to define the location and extent of sinonasal diseases and in planning for surgical intervention. Diseases of the ethmoidal sinus cannot be read as easily as maxillary or frontal sinus diseases using standard plain films due to its overlap of surrounding structures.^[2] The role of magnetic resonance imaging is limited but may provide information on fungal infections or differentially thickened mucosa from fluid retention in paranasal sinuses. Computed tomography (CT) is considered the method of choice in delineating normal anatomy and evaluating variations in the paranasal sinuses, and it is extremely useful in the

pre- and post-operative planning and follow-up in cases of endonasal interventions. Anatomical variations of ethmoid labyrinth during the development of the paranasal sinuses are common.^[3] Recognition of these variants is important to both the rhinologist and radiologist.

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The aim of this study is to show the anatomy of the paranasal sinuses outlined by the CT among Indian adults and to describe the frequency of variations in sinonasal region which not only predispose to chronic sinusitis but may lead to complications in endoscopic sinonasal surgery. Poor drainage from the paranasal sinuses may reduce mucociliary clearance, thus predisposing to inflammatory processes and causing endonasal endoscopic surgery complications.

MATERIALS AND METHODS

The present retrospective study included data from 250 patients (100 females and 150 males) with an age range between 18 and 82 years from all cases of CT scan images of the paranasal sinuses obtained in the radiology

department of our health institution over a 2 year' period (March 2017–February 2019). The patients were referred for CT scan due to clinical symptoms referable to sinonasal region. Patients with facial trauma, positive paranasal sinus pathology, head and neck tumors, and previous surgery were excluded. The CT examination was performed with GE Hispeed-NX/I Base-2002 Dual Slice Helical CT machine. The coronal section slice thickness was 5 mm with a table index of 4 mm. The section was taken from anterior frontal sinus to posterior sphenoid sinus with 120 kVP and 150–250 mA tube current, and scan time was 5 seconds. Proper positioning of the patient's head is important to obtain CT images. For axial views, the patient's hard palate is placed perpendicular to the CT scanner table. The axial slice thickness was 3 mm taken at every 3 mm interval and captured such that the external auditory canal is in line with the inferior orbital rim. The coronal images were

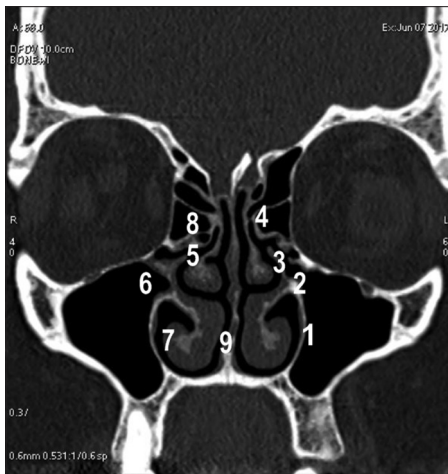


Figure 1: A coronal computed tomography image showing the osteomeatal complex and the nasal cavity. (1) Maxillary sinus, (2) maxillary ostium, (3) infundibulum, (4) ethmoidal bulla, (5) middle nasal turbinate, (6) uncinated process, (7) inferior nasal turbinate, (8) hiatus semilunaris, (9) nasal septum

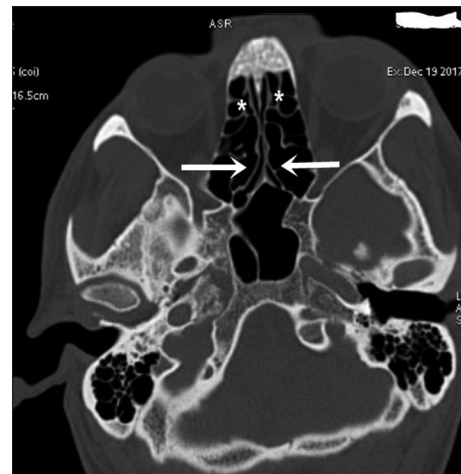


Figure 2: Axial computed tomography image shows the sphenoid sinuses and the sphenoethmoidal recess (arrows), Ethmoidal labyrinths (star)



Figure 3: Sagittal computed tomography image of the (1) paranasal sinus shows frontal sinus, ethmoidal sinus (arrow) and sphenoidal sinus (asterisk)

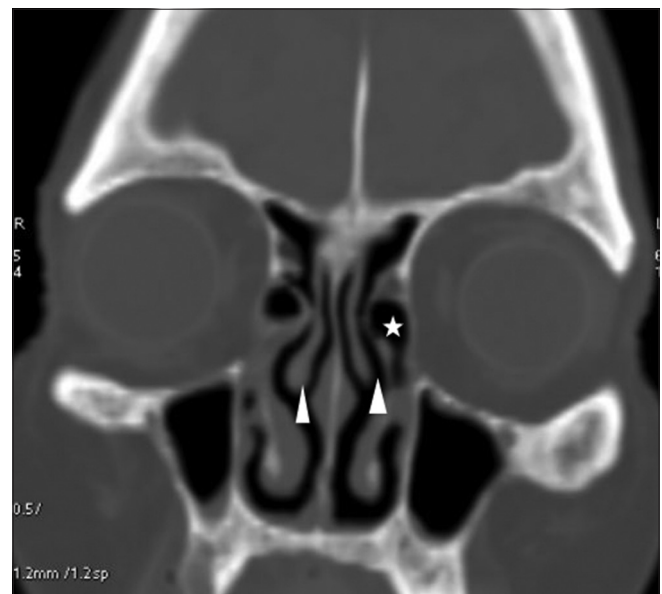


Figure 4: Coronal computed tomography image shows bilateral paradoxical middle turbinate (arrow head) and ethmoid bulla (star)

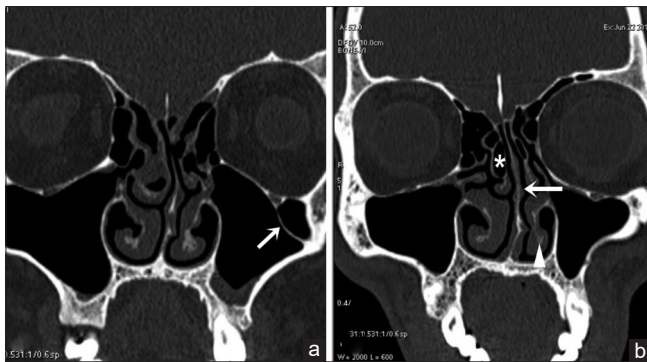


Figure 5: Coronal computed tomography images showing (a) Multiple septations in the left maxillary sinus (arrow), (b) Pneumatized right middle conchae (white star), hypoplastic left inferior conchae (arrow head), deviated nasal septum (long arrow)

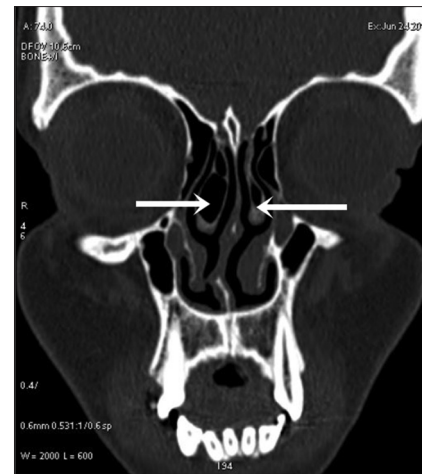


Figure 6: Coronal computed tomography image shows bilateral middle turbinate pneumatization (arrow)

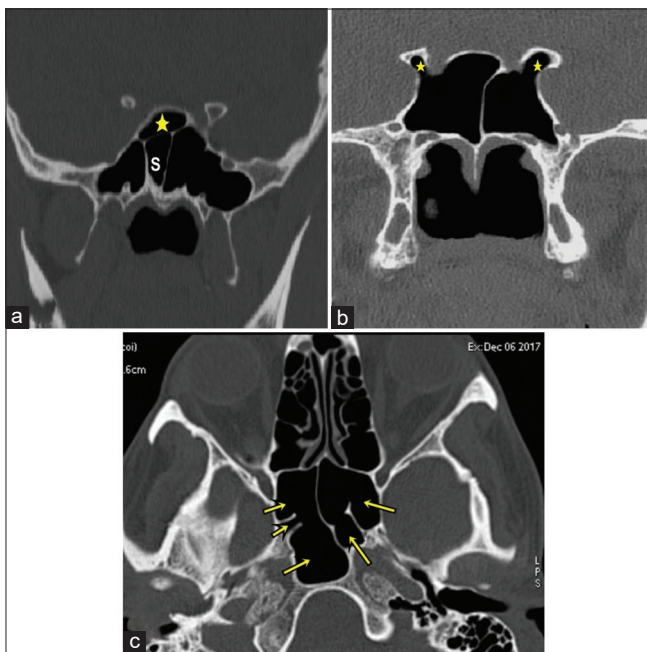


Figure 7: Coronal computed tomography images show (a) Onodi cells (yellow star), (b) Extension into the anterior clinoid process bilaterally (yellow star), and (c) Multiple sphenoid sinus septations (yellow arrows)

taken so that the gantry was perpendicular to the patient's hard palate. The exposure factors were the same as in the coronal scan.

Image analysis and interpretation-retrospective review by consensus were performed by three staff radiologists at different points of time to look for sites and abnormalities in the architecture of paranasal sinuses. The sinuses showing opacification and involvement of any extra sinus structures including orbit, face, pterygopalatine fossa, masticator space, and cavernous sinus were noted. The presence of abnormalities evaluated on the CT.

Anatomy of the paranasal sinuses, osteomeatal complex, and nasal walls

Maxillary sinuses [Figure 1]

It is pyramidal in shape with the apex in the zygomatic process

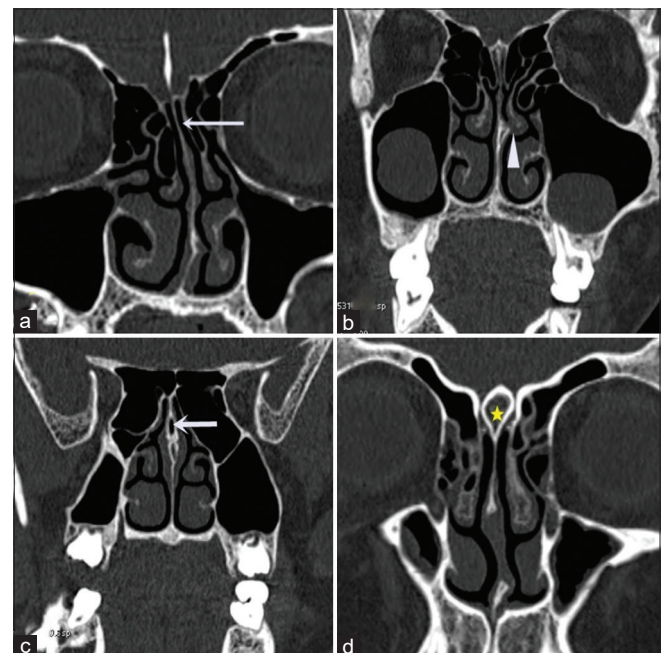


Figure 8: Coronal computed tomography images showing (a) Nasal septum deviation (arrow), (b) Nasal septum spur fused with left inferior turbinate (arrow head), (c) Pneumatization of nasal septum (chevron) and (d) Pneumatization of crista galli (yellow star)

of the maxilla bone and the base at the lateral wall of the nose. The maxillary sinus drains through its ostium which opens at the posterior part of the infundibulum and empties into the middle meatus in the lateral wall of the nose [Figure 1]. Sometimes, accessory ostium if present opens anterior or posterior to the lower part of the uncinate process of the inferior turbinate.

Ethmoid sinuses

The ethmoidal bone has four delicate structures; a horizontal lamina called the cribriform plate, a perpendicular plate, and two lateral masses called the labyrinths [Figure 2]. The lateral wall of the labyrinth is a paper-thin bone which forms the

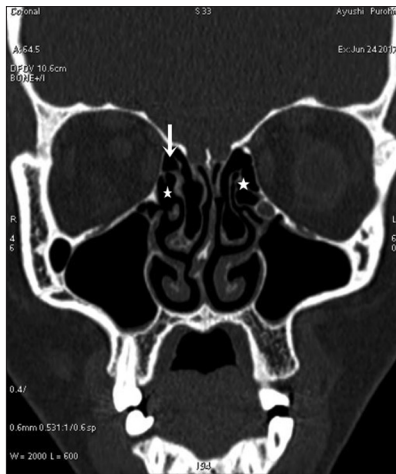


Figure 9: Coronal computed tomography images: frontal cell (arrow head), agger nasi cell (star)

medial wall of the orbit. Each ethmoidal labyrinth consists of multiple thin-walled, highly variable air cells arranged in three groups; anterior, middle and posterior clusters. The anterior and middle ethmoid cells open only at their aperture which drains through the infundibulum into the middle meatus at the lateral wall of the nasal cavity. The ostia of the posterior air cells open into the superior meatus. The superior and middle nasal conchae project from the medial wall of the ethmoid sinus.

Sphenoid sinuses

Sphenoid bone contains paired sphenoid sinuses which are separated by thin bony septum. The sphenoid sinus is the most variable cavity of the human body, which makes it difficult to approach and assess the sinuses, and it is surrounded by important structures such as the internal carotid artery, optic nerve (ON), and vidian canal.^[4] Each ostium opens into the sphenoidal recess behind the superior [Figure 2].

Frontal sinus

It lies between the outer and inner tables of the frontal bone in the diploic tissue. The two sinuses are commonly unequal in size and are separated by a bony septum in the midline. The sinus drain through frontal recess [Figure 3] which is an hourglass-shaped structure and usually drains into the middle meatus in 62% or into the ethmoid infundibulum in 38%.^[5] maxillary sinus linking the with the nasal cavity through maxillary sinus ostium and the infundibulum. The infundibulum is bounded superiorly by the hiatus semilunaris and ethmoid bulla, inferiorly by the maxillary sinus, laterally by the inferomedial wall of the orbit and medially by the uncinat process and [Figure 1].

Turbinates

These are the superior, middle, and the inferior turbinates. Sometimes, there may be supreme turbinate/concha present lateral to the superior turbinate. The middle turbinate lies inferomedial to the anterior ethmoid air cells, and superiorly, it is attached to the cribriform plate and laterally to the lamina papyracea. The middle turbinate continues posteriorly, forming the roof for the posterior part of the middle meatus. Beneath

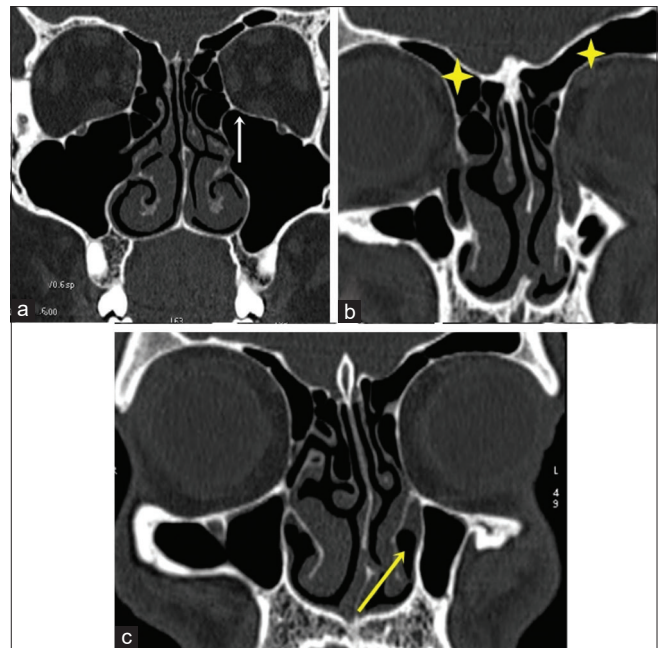


Figure 10: Coronal computed tomography images; (a) Haller's cell (white arrow), (b) supra-orbital cell (star) and (c) pneumatization of the left inferior turbinate (yellow arrow)

each turbinate is a meatus. The anterior ethmoidal cells drain into the middle meatus, the posterior ethmoidal cells drain into the superior meatus while inferior meatus receives opening of nasolacrimal duct.

Ethmoidal bulla [Figure 4]

The ethmoidal bulla is the largest and most constant of the anterior ethmoid cells; however, its degree of pneumatization varies considerably, ranging from failure of pneumatization (torus ethmoidalis) to a giant ethmoid bulla.

Crista galli

The crista galli is in the midline above the cribriform plate. Curved posterior border gives attachment to falx cerebri, whereas its shorter thicker anterior border is joined to the frontal bone by two small alae, completing the margins of the foramen caecum. Embryologically, the crista galli is derived from the ethmoid bone.^[1]

Uncinate process

It is attached inferiorly to the inferior turbinate. Anteriorly, the uncinat process is attached to the nasolacrimal apparatus; posteriorly, it has a free margin; and superiorly, its attachment is not constant. It may attach to the skull base, the middle turbinate. Nasal septum [Figure 1]: The nasal septum forms the medial wall of the nasal cavity. It is formed by the septal cartilage anteriorly and the vomer and perpendicular plate of the ethmoid bone posteriorly. It extends from the cribriform plate superiorly to the hard palate inferiorly.

Lacrimal duct

The lacrimal bone articulates with the nasal bone and with the inferior concha, enclosing the nasolacrimal duct between

them which opens into the upper part of the inferior meatus about 1 cm behind the anterior end of the concha [Figure 3b].

RESULTS

Of the 250 participants included in the study, study population, 449 cases of anatomical variants were recorded [Table 1]. The most common anatomical variants were pneumatization of the middle nasal turbinates (35.80%). This is followed by agger nasi cells 21.64%, Haller's cells 22.91%, septal deviation 21.91%, and sphenoid sinus septation (20.18%).

DISCUSSION

Maxillary sinus variants

The variation in size and shape of maxillary sinus is not uncommon. Pneumatization of maxillary sinus can extend toward palatine, and alveolar recess and also septations of the maxillary sinuses can occur [Figure 5a]. Accessory maxillary ostium may be congenital or secondary to sinonasal diseases.^[6] The presence of septa at or near the floor of the sinus is of interest to the dental clinician when performing sinus floor elevation procedures because of an increased likelihood of surgical complications, such as tearing of the

Schneiderian membrane.^[7] Maxillary sinus pneumatization is characterized by the maxillary sinus extension to alveolar ridge, anterior region, maxillary tuberosity, palate, zygomatic bone, and/or orbital region. Pneumatization, particularly the alveolar extension, can exacerbate the problem of remnant bone caused by atrophy of the maxilla, leaving only few millimeters of bone to implant insertion.^[7]

Nasal turbinates variants

Pneumatization of the middle turbinate is one of the most frequent common variations whereas the superior turbinate and the inferior turbinates are less frequent. The pneumatization of the middle turbinate [Figures 5b and 6] may involve the vertical lamella, bulbous segment or both. Asruddin *et al.*^[8] Reddy A *et al.*^[9] Freitas AP *et al.*^[2] and Gibelli D *et al.*^[10] reported prevalence between 30% and 15% respectively. The prevalence of middle turbinate pneumatization in this study was 30.73% which is within the range. However, higher prevalence was reported by Aramani *et al.*^[11] Kayalioglu *et al.*^[12] and Gerlach *et al.*^[13] who got more than 60%. There may also be abnormal curvature of the middle turbinate toward the midline and this is called the paradoxical middle turbinates [Figure 4]. We had not found accessory or secondary middle turbinate in this study. The anatomical variations of the inferior turbinates are rare. Pneumatizations of the inferior turbinate, bifid inferior turbinates and hypertrophy or hypoplasia [Figure 5b] of the osseous and soft tissue of the inferior turbinates are some of the reported alterations of this structure in the literature. However, some anatomic variations may lead to chronic sinusitis or complications during sinus surgery, including procedures such as sinus lift surgery, which is performed prior to dental implant placement. Thus, a meticulous understanding of the anatomy of the sino-nasal complex is of great importance for minimizing and/or eliminating surgical complications.

Sphenoid sinus variants

There may be an extension of pneumatization of the sphenoid sinus towards the lateral recess of the sphenoid bone (bilateral), the clinoid process [Figure 7b], the vomer, palatine bone, the lesser wings, greater wings, the pterygoid process, and clivus. Pneumatization of the anterior clinoid process may be unilateral or bilateral; anterior clinoid pneumatization was noted in 14 (8.36%) patients in this study. This is similar to 13% recorded by GH Hewaidi and Omami^[14] in patients who underwent CT scan of the paranasal sinuses. There may be dehiscence in the bony wall between the carotid arteries and the sphenoid. Deviation of the septum or multiple septa [Figure 7c] may be present. With extensive pneumatization, the bone covering the carotid arteries, ONs, maxillary nerves, and vidian nerve can be thin or even absent, making these structures susceptible to iatrogenic injuries.^[15]

Frontal sinus variants

The frontal sinus varies in its extent of pneumatization which may include the lamina of the frontal bone and crista galli.

Table 1: The bony anatomical variations and the frequency

Variants	Number of patients (%)
Frontal sinus	
Extended	2 (0.91)
Hypoplastic	6 (4.64)
Maxillary sinuses	
Septation	13 (7.36)
Hypoplasia	2 (0.91)
Extended	8 (3.73)
Sphenoid sinuses	
Septation	30 (20.18)
Extensions	24 (11.79)
Anterior clinoid pneumatization	14 (8.36)
Onodi cells	17 (6.27)
Ethmoid sinus	
Supraorbital cells	15 (5.36)
Frontal cells	25 (13.73)
Agger nasi	45 (21.64)
Haller's cells	47 (22.91)
Turbinates	
Superior turbinate pneumatization	14 (6.36)
Agenesis of both nasal turbinates	3 (0.91)
Middle turbinate pneumatization	72 (30.73)
Inferior turbinate pneumatization	2 (0.91)
Hypoplastic inferior turbinate	16 (11.55)
Paradoxical middle turbinate	4 (1.82)
Fusion of septum and inferior turbinate	2 (0.91)
Nasal septum	
Deviation of nasal septum	45 (21.91)
Crista galli/septal pneumatization	17 (7.18)

Hajjiannou *et al.*^[16] using CT scans in a series of 99 patients noted pneumatization of the crista galli in 14% and also Som *et al.*^[17] found 26 patients (13%) with crista galli pneumatization, all from either the left or right frontal sinuses. In our series, pneumatized crista galli [Figure 8d] was found in 17 (7.18%) cases. A study conducted in Iran found that hypoplastic frontal sinus was detected in 10.6% of patients^[18] and in 8.4% of patients in the study by Stallman in Germany.^[19] Hypoplasia of the frontal sinus was found in 6 (4.64%) of the participants and extensive pneumatization in 2 (0.91%) in our study.

Ethmoidal sinus variation

Agger nasi cells [Figure 9]

Located anterior to the middle turbinate and anterior to the frontal recess is the agger (ridge) nasi. The cells open into the ethmoidal infundibulum. Even after functional endoscopic sinus surgery, most of the air cells cannot be completely removed hence allowing persistent mucosal disease and recurrent infection. Several authors reported varied prevalence of this variant Bolger *et al.*^[7] had very high prevalence of 98.5%, while Aramani *et al.*^[11] very low prevalence of 1.9%. In this study, we got a prevalence of 45 (21.64%) which is comparable to that of Dua *et al.*^[20] who got prevalence of 40%.

Haller's cells [Figure 10a]

A progressive ethmoid pneumatization into an infraorbital location leads to the formation of Haller's cells. It can be clinically significant because of their strategic location close to natural ostia of the maxillary sinus, and several studies reported medium and large size Haller's cells attribute to increase the risk of maxillary sinus mucosal disease and predispose to infections.^[20] Maxillary chronic sinusitis was attributed to association with Haller's cell.^[21] The prevalence of Haller's cells as observed by Asruddin *et al.* 28%^[8] and Mathew *et al.* 30%.^[22] Similar findings were observed in our study 47 (22.91%). However, Shahab *et al.*^[23] Aramani *et al.*^[11] recorded lower prevalence of 8.9% and 1.9%, respectively.

Onodi cells [Figure 7a]

These cells are intimately related to the ON due to its migration to the anterior region of the sphenoid sinus from the most posterior ethmoid cells. Disease conditions within these cells may cause optic neuropathy. ON may be predisposed to injury during ESS. The prevalence of onodi cells in this study was 17 (6.27%) which is similar to the prevalence recorded by Pinas *et al.*^[24] on cadaveric studies. Higher prevalence had been recorded ranging from 39% to 90%.^[25,26] Supraorbital cells [Figure 10b]: These are the ethmoid cells that extend superolaterally between the middle orbital wall and the ethmoid roof. According to Park *et al.*,^[27] it has a prevalence of 7 (3.6%) in our study, we found similar findings.

Frontal cells or Kuhn's cells

These are ethmoid cells intimately related to agger nasi cells. We observed frontal cells in 26 (13.73%) of the 250 patients studied [Figure 9]. Eweiss and Khalil^[28] found frontal cells in 78.571% of the 110 patients in their study.

Nasal septum variation

Variation in the nasal septum results in chondrovomer junction deformity, pneumatization of nasal septum [Figure 8c], nasal bone spur, and deviated nasal septum [Figures 5a and 8a]. Nasal septal spur [Figure 8b] is a generally asymptomatic bone deformity that may cause restriction of the nasal airflow. There could also be a fusion of the turbinate with nasal septum [Figure 8b]. In our study pneumatizations of the inferior nasal turbinate was found in 2 (0.91) participants [Figure 10c]. Septal deviation is a shift in the midline position of the septum to either left or right, and may be cartilaginous, osseous or combined deviation involving the osseous or cartilaginous part of the septum clinical significance of nasal septum variation such as severe deviation – nasal obstruction, noisy breathing during sleep, and/or epistaxis, hypoplasia. In our study, we observed septal deviation in 21.91% of our participants. Some studies have recorded different prevalence of NSD which ranged from 30-80%.^[8,10]

CONCLUSION

We suggest that remarkable anatomic variations of paranasal region and their possible pathologic consequences of the paranasal sinuses in three dimensions of axial, coronal and sagittal imaging acquired and adequately reviewed prior to avoid potential complications of during surgical interventions involving this region by surgeons.

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Conflicts of interest

There are no conflicts of interest.

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