Original Research Article

A review of common anatomical variants of paranasal sinuses and nasal cavity and its frequency of occurrence as evidenced on multi-detector computed tomography

Vettrivizhi Sampath Arutperumselvi[1], Anbalagan Malaisamy[2], Karthik Krishna Ramakrishnan[3*], Sneha Yarlagadda[4], Praveen K. Sharma[5], Arunthathy Thangarajah[6], Seena Cheppala Rajan[7]

[1,2]Junior Resident, [3]Assistant Professor, [4]Senior Resident, [5]Associate Professor, [6]Professor, [7]Professor and Head
Department of Radio-Diagnosis, Saveetha Medical College and Hospital, Saveetha University, Thandalam, Chennai, Tamil Nadu, India
[*]Corresponding author email: **kkdrkr@gmail.com**

International Archives of Integrated Medicine, Vol. 9, Issue 1, January, 2022.
Available online at http://iaimjournal.com/
ISSN: 2394-0026 (P) **ISSN: 2394-0034 (O)**
Received on: 12-12-2021 **Accepted on:** 23-12-2021
Source of support: Nil **Conflict of interest:** None declared.

How to cite this article: Vettrivizhi Sampath Arutperumselvi, Anbalagan Malaisamy, Karthik Krishna Ramakrishnan, Sneha Yarlagadda, Praveen K. Sharma, Arunthathy Thangarajah, Seena Cheppala Rajan. A review of common anatomical variants of paranasal sinuses and nasal cavity and its frequency of occurrence as evidenced on multi-detector computed tomography. IAIM, 2022; 9(1): 8-21.

Abstract

This study was carried out to know the frequency of occurrence of common anatomic variants in computed tomography of paranasal sinuses and nasal cavity. Non contrast Computed tomography (CT) of paranasal sinuses of 100 patients referred to Department Of Radiology, Saveetha Medical College were retrospectively studied. The Multi-detector computed tomography (MDCT) scans were evaluated for various anatomical variants of paranasal sinuses and nasal cavity. The frequency of occurrence was calculated in percentage.We found out that deviated nasal septum (DNS) was the most common variant in this study, seen in 86% of cases, followed by Agger nasi cells which was seen in 56% and the third most common was supra-orbital ethmoidal cells seen in 42% of the study population. All the cases included in the study, had minimum of one variant. Most of the study population showed multiple anatomical variations of paranasal sinus and nasal cavity. In conclusion, multidetector Computed tomography plays an important role is the assessment of various anatomical variants of the paranasal sinuses and nasal cavity. Pre-operative MDCT of Paranasal sinuses, gives the surgeons most if not all of the anatomical information they need to tailor surgeries. Considering the relatively high frequency of occurrence of these variants, it is essential for the radiologists to have a precise knowledge of imaging features of normal anatomy and anatomical variants of Paranasal sinuses.

Key words

CT-PNS, MDCT, Agger nasi, Onodi Cells, DNS, Sphenoid Sinus, Kero's, Delanos, Concha Bullosa.

Introduction

Paranasal sinuses are paired air-filled spaces in the skull whose function is, to lighten the skull, humidification of air and it also acts as a resonant chamber to voice. They include maxillary sinus, ethmoid sinus, frontal sinus and sphenoid sinuses [1].

A number of anatomic variants of paranasal sinus are known to occur [2]. With wide availability of MDCT and development of minimally invasive functional endoscopic sinus surgery (FESS), pre-operative imaging of paranasal nasal sinuses has increased [3].

MDCT provides accurate information regarding the normal anatomy, anatomic variants, drainage pathways and the extent of associated sinonasal diseases [2]. It has the potential to provide accurate information for preoperative mapping of paranasal sinuses and nasal cavity and helps the surgeon to tailor the surgery appropriately for the patient.

Computed Tomography scan is the best investigation of choice for paranasal sinuses. Modern multi-slice CT scanner acquires thin axial plane slices, reconstruction of sagittal and coronal planes can be done from it. The coronal plane is best to evaluate the osteomeatal complex. The axial plane helps in identifying the basal lamella of the middle turbinate which divides anterior and posterior ethmoid sinuses [4].

Conventional radiography gives useful information regarding maxillary sinus and frontal sinus pathology. But its role in the evaluation of osteomeatal complexes, nasal cavity, sphenoid sinus and ethmoid sinus is limited [3].

MDCT not only provides detailed information of the anatomy, its variants, extent of the diseases involving paranasal sinuses but also provides useful information regarding the adjacent bones and soft tissues as well, thereby making MDCT the imaging modality of choice for evaluating paranasal sinus and its variants [1, 3].

Normal anatomy

Maxillary sinus is within the body of maxilla. Bounded superiorly by floor of orbit, medially by lateral wall of nasal cavity, inferiorly by alveolar process of maxilla and posterior to it is the pterygopalatine fossa. Maxillary ostium (3 mm to 10 mm) is located along its medial wall [5].

Frontal sinus is separated from the anterior cranial fossa by its superior and posterior wall and are located superior to orbit and ethmoid sinus [6] and between the inner and outer table of frontal bone [7].

Ethmoid sinus consists of group of cells divided into anterior and posterior by the basal lamella. It is located inferior to frontal sinus, medial to orbit and anterior to sphenoid sinus [8]. Roof is formed by fovea ethmoidalis which separates it from anterior cranial fossa [9].

Anterior ethmoidal air cells are anteriorly bounded by the ethmoid infundibulum, posteriorly by the basal lamella, base of the skull bounds it superiorly and lamina papyracea laterally [8].

Anterior boundary of posterior ethmoidal air cells is the basal lamella, posterior boundary is anterior sphenoidal wall, medial is superior turbinate, lateral is the lamina papyracea and superiorly the base of the skull [10].

Sphenoid sinus is within the sphenoid bone, located posterior to ethmoidal air cells. Posterior wall of the ethmoid sinus forms the anterior wall of the sphenoid sinuses. The most reliable landmark is the ostium that lies 1 cm superior to the superior turbinate. As sphenoid sinus is in close proximity with the vital structures like internal carotid artery and optic nerve, assessment of its pneumatization is very essential [11].

The final drainage pathway of maxillary, frontal and anterior ethmoidal sinuses is the osteomeatal complex which consists of maxillary ostium, infundibulum and hiatus semilunaris and its bony margins are formed by uncinate process, lateral margin of the middle turbinate and infero-medial wall of the orbit [12].

An additional sinus drainage pathway draining frontal sinuses are the frontal recess which drains into the middle meatus or infundibulum depending on the anterior attachment site of the uncinate process and it is best evaluated on sagittal reconstructed CT images and located along the posterior margin of the agger nasi cell [12].

The posterior ethmoidal air cells and sphenoid sinus drain through spheno-ethmoidal recess.

Anatomical variants of paranasal sinus

Several studies have shown that there is no significant difference in the prevalence of any paranasal sinus and nasal cavity variants among patients with minimal and those with clinically significant radiologic evidence of sinonasal disease [2].

Few studies state that the anatomical variants can affect the OMC and frontal recess and predispose to recurrent and refractory rhino-sinusitis by narrowing or obstructing the drainage pathway and altering the sinus ventilation and mucocilliary clearance [2]. It can also alter the surgical landmarks in the region of the sinus drainage tracts [13].

The anatomic variants affecting the osteomeatal complex are concha bullosa, Haller cells, paradoxical rotation of the middle turbinate and nasal septal deviation. Prominent or variant frontal recess cells can affect the frontal recess [13].

Perez P, et al. and Stammberger, et al. proved that coronal CT is more informative than axial CT in identifying anatomical variations and also for better visualization of the sinuses along with adjacent structures by the surgeons [14, 15].

Concha bullosa

Pneumatization of the middle turbinate is called Concha bullosa. It is the extension of normal pneumatization of ethmoidal air cells (**Figure - 4**) [14]. Concha bullosa can cause narrowing of the middle meatus, lateral deviation of uncinate process which can obstruct infundibulum [13] and thereby can be implicated in the pathogenesis of rhino-sinusitis. However, some studies have shown that the prevalence of concha bullosa is the same in patients with and without sinus disease [16].

KERO'S classification

Olfactory fossa is classified based on its depth and the length of lateral lamella of the cribriform plate.

Type I: Distance between cribriform plate and fovea ethmoidalis is 1-3 mm.

Type II: Distance between cribriform plate and fovea ethmoidalis is 4-7 mm.

Type III: Distance between cribriform plate and fovea ethmoidalis is 8-16 mm [17].

In most of the cases, the cribriform plate is symmetrical, when asymmetric, it is an anatomical variant [14]. In case of asymmetrically positioned cribriform plate, the more inferiorly placed lateral lamella is at a greater risk of injury during FESS [7]. Assessing the asymmetry is very important to avoid inadvertent injury during surgery.

Deviated nasal septum

Deviated nasal septum with bony spur can affect the sinus outflow pathways by laterally displacing middle turbinate and narrowing the middle meatus. (**Figure - 12**). Shpilberg, et al. defined it on coronal MDCT scans as any bending of the septal contour [2]. Pressure is put on the nasal turbinates by asymmetrical nasal septal positions [18].

Haller cells

Kennedy, et al. defined Haller cells as pneumatized ethmoidal cells seen projecting below the ethmoidal bullae within the orbital floor adjacent to the opening of the maxillary sinus [20] (**Figure - 2**). A Haller cell is an ethmoidal air cell which can cause narrowing of the maxillary antrum and proximal infundibulum, as it is situated lateral to the maxillo-ethmoidal suture in the medial orbital floor [13]. It was Identified first by Albrecht von Haller in the year 1765 [21]. Larger Haller cell can narrow the infundibulum and can cause sinusitis [20]. Haller cells are air cells that are located between the ethmoid bullae, orbital lamina of the ethmoid bone and orbital floor as defined by Bolger, et al. [22].

During procedures like functional endoscopic sinus surgery (FESS), increased risk of injury to orbit is associated with presence of infra-orbital air cell [23].

Agger nasi cells

Agger nasi cell is the anterior most ethmoid air cell, located below the frontal sinus forming significant part of the anterior wall of the frontal recess (**Figure - 1**). Agger nasi cells may impinge upon the frontal sinus drainage tract, extending infero-laterally to lacrimal fossa and located antero-superior to the hiatus semilunaris. Recognition of this relationship is important in management of chronic frontal sinusitis [24, 25].

Paradoxical rotation of the middle turbinates

In paradoxical rotation, middle turbinate is rotated inwards, which may in turn cause middle meatus narrowing, lateral deviation of uncinate process with infundibular narrowing (**Figure - 5**) and obstruction of the drainage pathway [13].

Frontal recess cells

The agger nasi cell which represents the anterior most ethmoid air cell is a named frontal recess cell. It is seen pneumatized in majority of cases and forms a part of anterior boundary of the frontal recess [13].

Kuhn classification - frontal cells - associated with frontal recess

Frontal cells are additional subsets of frontal recess cells, which form portion of anterior margin of frontal recess.

Type 1 - Single cell seen above the agger nasi cell.

Type 2 - Two or more small cells seen above the agger nasi cell.

Type 3 – A large cell seen above the agger nasi cell with extension into the frontal sinus.

Type 4 - Rare, fronto-ethmoidal cells, entirely contained within the frontal sinus [13].

Onodi cells

Posterior most ethmoidal cells are Onodi cells, seen extending posterior, lateral and superior to the sphenoid sinus, medial to the optic nerve (**Figure - 3**). First described by Adolf Onodi in 1903. Extensive pneumatization can expose the circumference of optic nerve, surrounded by air spaces [26]. Onodi cells are also known as spheno-ethmoidal cells and its identification on imaging is significant to surgeon during functional endoscopic sinus surgery. When Onodi cells are present, both optic nerve and carotid artery may be exposed within the posterior ethmoidal cells [19]. The best orientation is seen on axial cuts as the course of optic nerve can be followed as a relation [27].

Maxillary sinus hypoplasia

An uncommon condition, often diagnosed incorrectly as chronic sinusitis [14]. When severe, it impedes mucocilliary clearance and more prone to retention of mucus. Finding maxillary sinus ostium may be difficult in case of hypoplasia [28]. Failure in recognizing maxillary sinus hypoplasia, can cause injury to medial orbital wall intra-operatively [29].

Maxillary sinus hypoplasia classification

Type 1: Mild - Normally developed uncinate process and well-developed infundibular passage with affected sinus showing varying degree of mucosal thickening.

Type 2: Significant – Uncinate process is hypoplastic or absent with ill-defined or absent infundibular passage and affected sinus show total opacification.

Type 3: Profound - Absent uncinate process with the sinus represented by shallow cleft in lateral nasal wall of the nose [2].

Sphenoid sinus pneumatization

Pattern of sphenoid sinus pneumatization is divided into 3 types - (i) Conchal (ii) Pre-Sellar (iii) Sellar.

Conchal: Area below the Sella is solid block of bone without pneumatization.

Pre-Sellar: Sphenoid sinus pneumatized to the level of frontal plane of the Sella and not extending beyond.

Sellar: Most common type, in which pneumatization extends into the body of the sphenoid, can also extend beyond the floor of Sella and can reach clivus [11].

Pterygoid process pneumatization

It is recognized, if it extends beyond horizontal plane crossing vidian canal, providing route for endoscopic repair of cerebrospinal fluid leakage and endoscopic biopsy of skull base lesions [30] (**Figure - 13**).

Anterior clinoid process pneumatization

Optico-carotid recess is a small space in lateral wall of sphenoid sinus, between carotid prominence inferiorly and optic canal superiorly (**Figure - 10**). The optico-carotid recess concurs with the ipsilateral optic nerve or the internal carotid artery protrusion into sphenoid sinus [31]. If the clinoid process is pneumatized, a deep recess might be there in the upper part of lateral wall of sphenoid sinus [23].

Materials and methods

Study population of 100 patients who underwent MDCT study of Paranasal sinus and nasal cavity from January 2021 to April 2021 were retrospectively studied for anatomical variants. Study was conducted in Saveetha medical college and hospital, Chennai, India.

All patients referred for MDCT Paranasal sinuses and nasal cavity above 18 years were included in the study. Patients with previous sino-nasal disease, head and neck malignancy, facial trauma and those younger than 18 years were excluded from the study.

The images were acquired on PHILIPS INGUNITY 128 slice CT machine with tube potential of 120 KV, helical scan with Rot value of 0.6 sec/HE and 39.4 mm/rot scan and CT paranasal sinuses examined using multiple reconstruction techniques. The axial plane was inferior orbital meatal plane (anthropologic plane), coronal and sagittal reconstructions were post processed.

The data was manually analyzed for the presence of anatomical variants in paranasal sinuses and frequency of occurrence was documented and calculated in percentage.

Results

Out of 100 patients, 55 were male and 45 were female. Maximum variants (39%) were noted in age group 21-30 years seen. Deviated nasal septum was the most common in our study (86%) followed by agger nasi cells (56%), supra-orbital cells (42%), concha bullosa(26%), frontal sinus hypoplasia(22%), pterygoid plate pneumatization (21%), Haller cells (19%), Onodi cells (19%), anterior clinoid pneumatization (18%), crista galli pneumatization (18%), paradoxical middle turbinate (9%), maxillary sinus septations (8%), maxillary sinus hypoplasia (5%), frontal sinus hyper-pneumatization (4%), maxillary sinus hyper-pneumatization (2%). A minimum of one anatomical variant was seen in all the case included in the study. We also observed that most of the cases in our study population showed more than one anatomical variant (**Table – 1 to 8**).

Table – 1: Gender distribution.

Gender	Number	%
Male	55	55%
Female	45	45%
Total	100	100%

Table – 2: Age distribution.

Age in years	Number	%
≤ 20	10	10%
21-30	39	39%
31-40	26	26%
41-50	10	10%
51-60	12	12%
>60	03	3%
Total	100	100

Table – 3: Pattern of sphenoid sinus pneumatisation.

Pattern	Number	%
Concha	4	4%
Pre sellar	14	14%
Sellar	82	82%
Total	100	100%

Table – 4: Delanos classification of optic nerve.

Type	Number	%
Type 1	74	76%
Type 2	16	16%
Type 3	0	0%
Type 4	10	10%
Total	100	100%

Table – 5: Kero's classification of olfactory fossa.

Type	Number	%
Type 1	7	7%
Type 2	68	68%
Type 3	17	17%
Asymmetric	7	7%
Total	100	100%

Table – 6: Sphenoid sinus septation.

Sphenoid sinus septa	No. of cases	%
Single	54	54%
Multiple	46	46%
Total	100	100%

Table – 7: Sphenoid sinus septa attached to ICA canal.

Sphenoid sinus septa attached to ICA canal	No. of cases	%
Not attached	80	80%
Right	6	6%
Left	8	8%
Bilateral	6	6%
Total	20	100%

Discussion

Deviated Nasal Septum

According to various studies, nasal septum deviation varies from 18% to 80%. Study by Tiwari, et al. reported 88.2% of study population with deviated nasal septum [33] and 85% as reported by Farhan, et al. [33].

In our study of 100 patients, most common variant was deviated nasal septum, reported in 86% of study population, which is very close to other studies (**Figure - 12**).

Frontal Sinus Variants

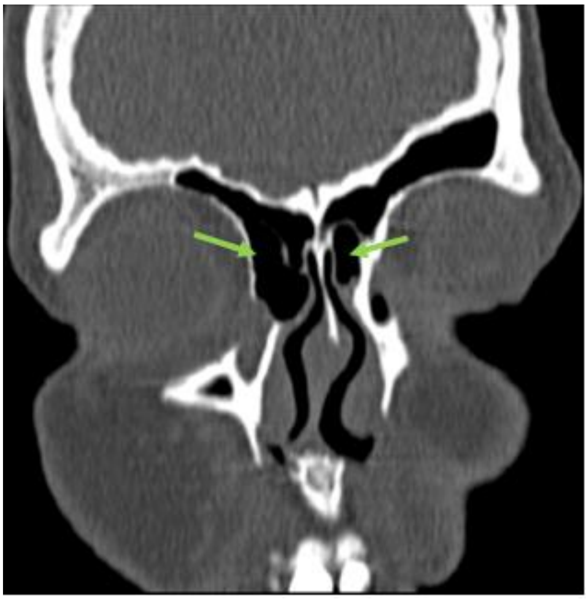
In our study, 22% of patient showed Frontal sinus hypoplasia (**Figure - 6**), which was slightly higher to 15% seen in study by Devareddy, et al. [34].

Frontal sinus hyper-pneumatization (**Figure - 7**) is seen in 4% of study population in our study.

Table – 8: overall frequency of paranasal sinus anatomical variants.

Anatomical variants in CT	Bilateral involvement	Right side involvement	Left side involvement	Total No. of cases	%
Nasal septum deviation	‘s’ shaped - 15	31	40	86	86%
Agger nasi cells	49	2	5	56	56%
Supraorbital cells	34	4	4	42	42%
Concha bullosa	14	3	9	26	26%
Frontal sinus hypoplasia	11	8	3	22	22%
Pterygoid plate pneumatisation	7	7	7	21	21%
Haller cells	9	5	5	19	19%
Onodi cells	7	7	5	19	19%
Anterior clinoid process pneumatisation	8	8	2	18	18%
Crista galli pneumatisation	NA	NA	NA	18	18%
Paradoxical middle turbinate	5	2	2	9	9%
Maxillary sinus septation	2	5	1	8	8%
Maxillary sinus hypoplasia	2	2	1	5	5%
Frontal sinus hyperplasia	4	0	0	4	4%
Maxillary sinus hyperplasia	2	0	0	2	2%

Figure - 1: CT Coronal image showing bilateral agger nasi cells.



Concha Bullosa

In a study by Mazza, et al., concha bullosa was reported in 29% (35) and 33% was observed by Farhan, et al. [33] which is slightly higher than our study, n which we report, 26% of the study population show concha bullosa of which 14% reported bilateral variant.

Figure - 2: CT Coronal image showing bilateral Haller cells.

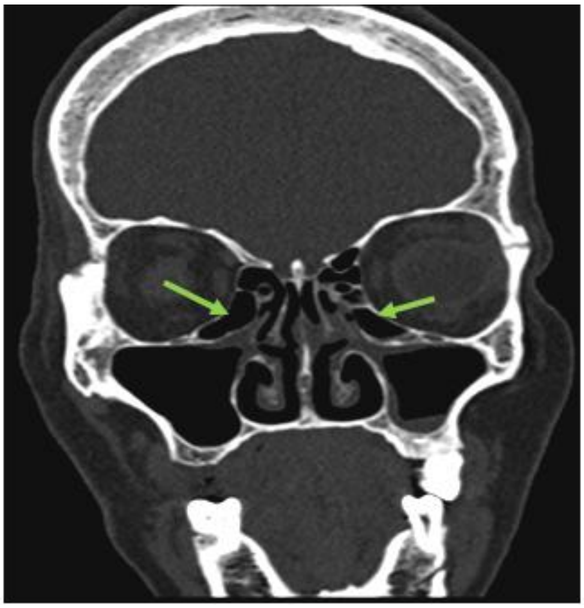


Figure - 3: CT Coronal image showing left Onodi cell.

Figure - 4: CT Axial image showing right concha bullosa.

Paradoxical Roatation of Middle Turbinate

Our study reported 9% of the study population with this variant, 5% seen bilaterally and 2% right and left, which is very close to 8% reported by Dua, et al. But little lower than few other studies which reported 14% - 25% cases showing paradoxical rotation of middle turbinate [18, 37, 38, 39].

Agger Nasi Cells

Review of literature, shows prevalence of Agger nasi cells vary from 10 to 98.5%. Study by Talaiepour AR, et al., showed Agger nasi cell in 56.7% of cases [40] and another study by Devareddy et al. reported Agger nasi cells in 26% of study population [34].

Figure - 5: CT Coronal image showing bilateral paradoxical middle turbinates.

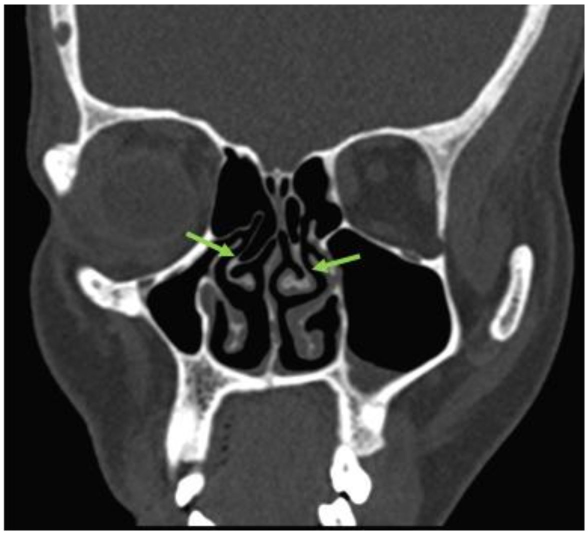


Figure - 6: CT Coronal image showing bilateral frontal sinus hypoplasia.

In our study we report 56% of study population showing agger nasi cells, which is similar to study by Devareddy, et al., of which 49 % was seen bilaterally.

Onodi Cells

Study by John Earwaker, et al. showed 24 % of Onodi cells [41] and study by Dua, et al. showed occurrence of Onodi cells in 6% of cases [36]. While in our study we report 19% of cases with Onodi cells, of which 7 % seen bilaterally.

Figure - 7: CT Axial image showing bilateral frontal sinus hyper-pneumatization.

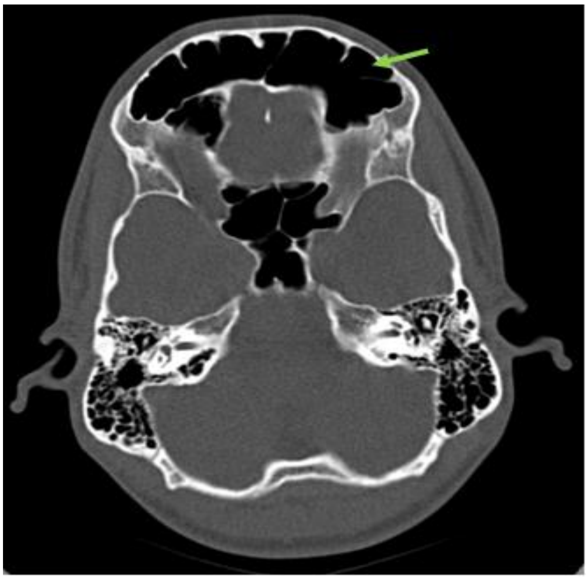
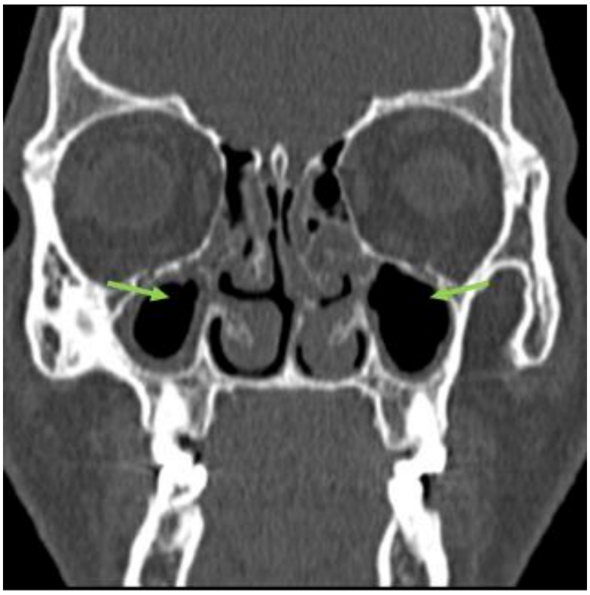


Figure - 8: CT Coronal image showing bilateral maxillary sinus hypoplasia.



Haller Cells

Studies by Mamtha, et al. and HH Wanamaker, et al. reported 17.5% and 20% of Haller cells respectively [42, 43] which is similar to 19% seen in our study, of which 9% was seen bilaterally.

Figure - 9: CT Axial image showing bilateral maxillary sinus septations.

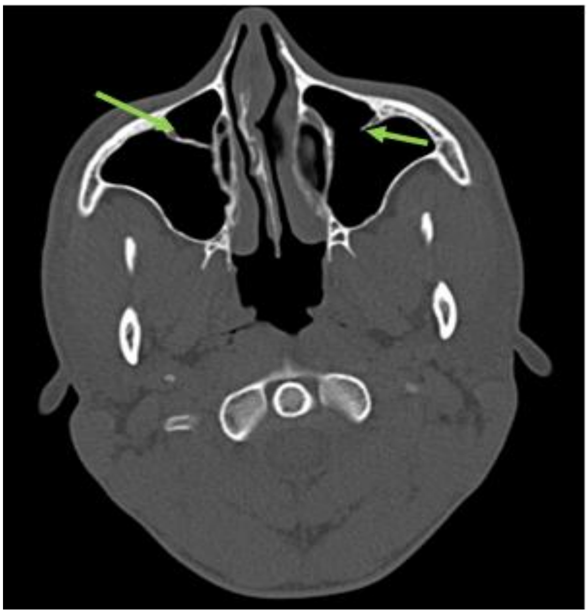
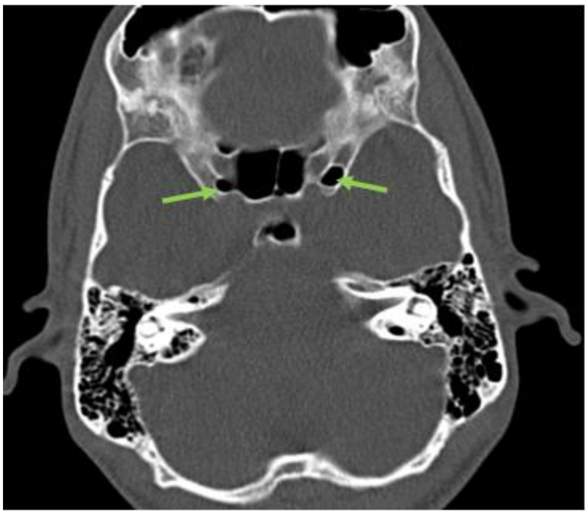


Figure - 10: CT Axial image showing bilateral anterior clinoid process pneumatisation.



Anterior Clinoid Process Pneumatisation

Nouraei, et al. and Shpilberg, et al. reported 18% and 16.7% anterior clinoid process pneumatization in their study respectively. Which is similar to 18% reported in our study, with 8% seen bilaterally (**Figure - 10**).

Kero's Classification of Olfactory Fossa

In a study in Indian population, Murthy et al. reported Kero's Type I in 19.5%, type II in 71.5% and type III in 9% [45].

Figure - 11: CT Coronal image showing pneumatized crista galli.

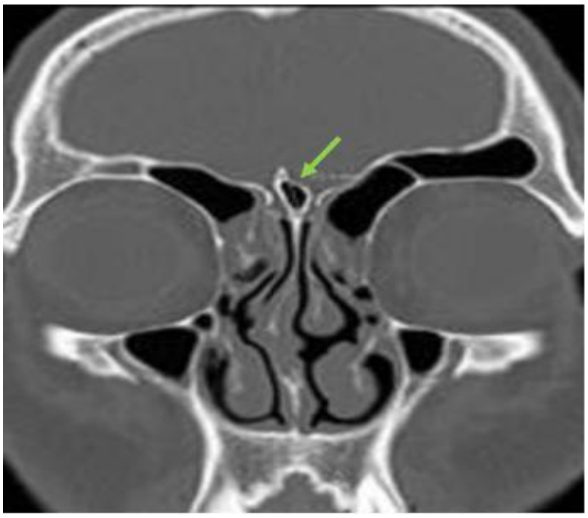
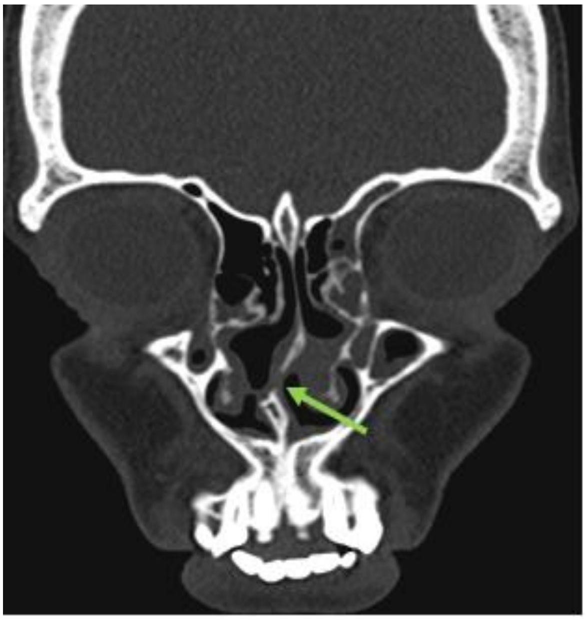


Figure - 12: CT Coronal image showing 'S' shaped deviated nasal septum.



Another study by Farhan, et al. reported 25.7% of type II, 62.3%, and 11.9% of type III [33].

In this study, we report, Kero's type I in 7%, type II in 68% and type III in 17%. Kero's Type II is the most common type of olfactory fossa reported in this study, as seen in other studies.

Figure - 13: CT Coronal image showing bilateral pterygoid process pneumatisation.

Delanos Classification of Optic Nerve

Study by Delano et al. reported 76%, 15%, 6%, 3% of types I, II, III, IV respectively [46]. Type I was the most common.

In our study, most common type is also type I seen in 74% and 16 % of type II, 0% of type III and 10% of type IV was seen.

Maxillary Sinus Septation

Study by Aliu Abdul Hameed, et al. reported 24.6% of maxillary sinus septum [47].

In our study, 8% of the study population showed maxillary sinus septa of which 2% seen bilaterally, 5% in right and 1% in left maxillary sinus and all seen on the anterior wall of sinus (**Figure - 9**). This is lower than the study by Aliu Abdul Hameed, at al.

Maxillary Sinus Hypoplasia

In our study, 5% of study population show maxillary sinus hypoplasia, of which 2% seen bilaterally (**Figure - 8**).

Study by Devareddy, et al. showed maxillary sinus hypoplasia 3% bilaterally which is similar to our study [34].

Maxillary sinus hyper-pneumatization is seen bilaterally in 2% of our study population.

Supraorbital Ethmoidal Cells

Souza, et al. reported 35% of study population with supraorbital ethmoidal cells which is lower than 42% as reported in our study. In our study 34% was seen bilaterally.

Carlos, et al. reported much higher occurrence of supraorbital ethmoidal cells of 69.1% in his study [49].

Crista Galli Pneumatisation

In our study we report 18% of cases with Crista galli pneumatization (**Figure - 11**) which is higher to 9.9% reported by Shpilberg et al. and 8.3% in another study by Amita Kumari, et al. [2, 50].

Variations In Sphenoid Sinus Septa

Study by Battal, et al. in Turkish population reported single intersphenoidal septum in 64.3% and multiple intersphenoidal septa in 32.1% [51].

Another study by Farhan, et al. show single intersphenoidal septum in 72.3% and multiple or accessory intersphenoidal septa in 24.5% of cases [33].

We found single intersphenoidal septa in 54% and multiple intersphenoidal septa seen in 46% of cases.

In our study, sphenoid sinus septa attached to ICA was seen in 20%, of which 6% found on the right and 8% found on the left and 6% bilaterally. Our data is higher than results by Farhan, et al. who reported sphenoid sinus septa attached to the ICA in 13.1% subjects, of which 3.8% on the right, 4.6 % on the left, and 4.6% present bilaterally [33].

Sphenoid Sinus Pneumatization Pattern

Most common in our study is Sellar variant as reported in study by O'Brien WT Sr, et al. seen in 82%, presellar variant in 14% and concha variant in 4% [52].

Pterygoid Process Pneumatization

In our study, we report 21% of study population show pterygoid process pneumatization. This is in accordance with 27.1% as reported by Shpilberg, et al. [2].

In our study, 7% show right sided pneumatization, 7% show left sided pneumatization and 7% showed bilateral pneumatization (**Figure - 13**).

Conclusion

MDCT plays a crucial role in the assessing the anatomical variants of the paranasal sinuses and nasal cavity. Considering the relatively high frequency of occurrence of these variants, a precise knowledge of imaging features of normal anatomy and anatomical variation of Paranasal sinuses and its location is of utmost importance for surgeons, especially in patients with recurrent and refractory sinusitis who may require surgical treatment.

Pre-operative MDCT PNS, plays a very important part in helping the surgeons get all the required anatomical information they need to appropriately plan the surgery for any particular patient and to avoid fatal and life threatening intra-operative complications. Hence, it is essential for the radiologists to have clear understanding of these common anatomic variants, its incidence and its imaging features.

References

1. Narasipur Lingaiah. Anatomical Variations of Paranasal Sinuses on Coronal CT-Scan in Subjects with Complaints Pertaining to PNS. Int J AnatRadiol Surg., 5(4): 27–33.
2. Shpilberg KA, Daniel SC, Doshi AH, Lawson W, Som PM. CT of Anatomic Variants of the Paranasal Sinuses and Nasal Cavity: Poor Correlation With

Radiologically Significant Rhinosinusitis but Importance in Surgical Planning. Am J Roentgenol., 2015 May 22; 204(6): 1255–60.

3. Mallikarjun M. Devareddy, Shilpa Devakar. Evaluation of anatomical variations in nose and paranasal sinuses by using multidetector computed tomography. International Journal of Contemporary Medicine Surgery and Radiology, 2019; 4(3): C146-C151.
4. Y Ramakrishnan, I Zammit-Maempel, N S Jones. Paransal sinus computed tomography anatomy: a surgeon’s perspective. The Journal of Laryngology & Otology, 2011; 125: 1141 – 1147.
5. Vaid S, Vaid N. Normal Anatomy and Anatomic Variants of the Paranasal Sinuses on Computed Tomography. Neuroimaging Clin N Am., 2015 Nov; 25(4): 527-48.
6. Ksungur EH, Biçakçi K, Inal M, Akgül E, Binokay F, Aydogan B. CT demonstration of accessory nasal turbinates: secondary middle turbinate and bifid inferior turbinate. European Journal of Radiology, 1999; 31: 174–6.
7. Yoshino M, Miyasaka S, Sato H, Seta S. Classification system of frontal sinus patterns by radiography. Its application to identification of unknown skeletal remains. Forensic Science International, 1987; 34: 289–299.
8. Basic N, Basic V, Jukic T, Basic M, Jelic M, Hat J. Computed tomographic imaging to determine the frequency of anatomical variations in pneumatization of the ethmoid bone. European Archives of Otorhinolaryngology, 1999; 256: 69–71.
9. Nitinavakarn B, Thanaviratananich S, Sangsilp N. Anatomical variations of the lateral nasal wall and paranasal sinuses: a CT study for endoscopic sinus surgery (ESS) in Thai patients. Journal of Medical Association of Thailand, 2005; 88(6): 763-8.
10. Aykut M, Gümüsburun E, Müderris S, Adigüzel E. The secondary nasal middle concha. Surgical and Radiologic Anatomy, 1994; 16: 307–9.
11. Binal C, Muhammed AS, Ahmet BY. A retrospective analysis of sphenoid sinus hypoplasia and agenesis using dental volumetric CT scan in Turkish individuals: Diagnostic and Interventional Radiology, 2011; 17: 205 – 8.
12. Yonetsu K, Watanabe M, Nakamura T. Age-related expansion and reduction in aeration of the sphenoid sinus: volume assessment by helical CT scanning. American Journal of Neuroradiology, 2000; 21: 179–82.
13. A. Chmielik. The prevalence and CT detection of Onodi cell types. EurSocRadiol., 1–15.
14. Stammberger H. Endoscopic sinus surgery-concepts in treatment of recurring rhinosinusitis. Part II. Surgical technique. Otolaryngology Head and Neck Surgery, 1986; 94: 147–56.
15. Perez P, Sabate J, Carmona A. Anatomical variations in the human paranasal sinus region studied by CT. Journal of Anatomy, 2000; 197: 221–27.
16. Reddy UD, Dev B. Pictorial essay: Anatomical variations of paranasal sinuses on multidetector computed tomography-How does it help FESS surgeons?. Indian J Radiol Imaging., 2012; 22(4): 317-324. doi:10.4103/0971-3026.111486.
17. Hatipoğlu HG, Cetin MA, Yüksel E. Concha Bullosa Types: Their Relationship with Sinusitis, Ostiomeatal and Frontal Recess Disease. Diagnostic and Interventional Radiology, 2005; 11(3): 145- 9.
18. Badia L, Lund VJ, Wei W, Ho WK. Ethnic variation in sinonasal anatomy on CT-scanning. Rhinology, 2005; 43: 210-14.

19. Hanna EH, Levine HL, Timen S, Kotton B. Hypoplasia of the maxillary antrum: anatomic abnormalities, diagnostic difficulties and surgical implications. American Journal of Rhinology, 1993; 7: 105-10.
20. Kennedy DW, Zinreich SJ, Shaalan H, Kuhn F, Navlerio R, Loch E. Endoscopic middle meatal antrostomy theory, technique and patency. Laryngoscope (Suppl)., 1987; 97: 1–9.
21. Mathew R, Omami G, Hand A, Fellows D, Lurie A. Cone beam CT analysis of Haller cells: prevalence and clinical significance. Dentomaxillofac Radiol., 2013; 42(9).
22. Bolger WE, Woodruff Jr WW, Morehead J, Parsons DS. Maxillary sinus hypoplasia classification and description of associated uncinate process hypoplasia. Otolaryngology Head and Neck Surgery, 1990; 103: 759–65.
23. Vasilica Baldea. CT study of the sphenoid sinus pneumatization types. Romanian J Rhinol., 2012; 2(2): 17–30.
24. Calhoun KH, Waggenspack GA. CT evaluation of the paranasal sinuses in symptomatic and asymptomatic populations. Otolaryngology Head and Neck Surgery, 1991; 104: 480 –3.
25. Driben JS, Bolger WE, Robles HA, Cable B, Zinreich SJ. The reliability of computerized tomographic detection of the Onodi (sphenoethmoid) cell. American Journal of Rhinology, 1998; 12: 105–11.
26. Morimoto N, Ogihara N, Katayama K, Shiota K. Threedimensional ontogenetic shape changes in the human cranium during the fetal period. Journal of Anatomy, 2008; 212: 627-35.
27. Kayalioglu G, Oyar O, Govsa F. Nasal cavity and paranasal sinus bony variations: a computed tomographic study. Rhinology, 2000; 38(3): 108–13.
28. Tetiker H, Kosar M, Çullu N, Sahan M, Gençer C, Derin S. Pneumatization of crista galli in Pre-adult and Adult Stages. International Journal of Morphology, 2016; 34(2): 541-44.
29. Hewaidi G, Omami G. Anatomic Variation of Sphenoid Sinus and Related Structures in Libyan Population: CT Scan Study. Libyan Journal of Medicine, 2008; 3(3): 128-33.
30. Som P. M., Park E. E., Naidich T. P., Lawson W. Crista galli pneumatization is an extension of the adjacent frontal sinuses. AJNR Am. J. Neuroradiol., 30(1): 2009; 31-3.
31. Duque CS, Casiano RR, Surgical Anatomy and Embryology of the Frontal Sinus. In: Kountakis S, Senior BA, Draf W. The Frontal Sinus, Springer, 2005.
32. Tiwari R, Goyal R. Study of Anatomical Variations on CT in Chronic Sinusitis. Indian J Otolaryngol Head Neck Surg., 2015; 67(1): 18-20. doi:10.1007/s12070-014-0734-2
33. Farhan N, Naqvi SU, Rasheed B, et al. Identification of Significant Anatomical Variations in the Nose and Anterior Skull Base Using Computed Tomography: A Cross-Sectional Study. Cureus, 2020; 12(6): e8449. Published 2020 Jun 5. doi:10.7759/cureus.8449
34. Devareddy, Mallikarjun, Devakar, Shilpa. Evaluation of Anatomical Variations in Nose and Paranasal Sinuses by using Multidetector Computed Tomography. International Journal of Contemporary Medicine, Surgery and Radiology, 2019; 4. 10.21276/ijcmsr.2019.4.3.32.
35. Mazza D, Bontempi E, Guerrisi A, Del Monte S, Cipolla G, Perrone A, Lo Mele L, Marini M. Paranasal sinuses anatomic variants: 64-slice CT evaluation. Minerva Stomatol., 2007 Jun; 56(6): 311-8. English, Italian. PMID: 17625488.
36. Dua K, Chopra H, Khurana AS, Munjal M. CT scan variations in chronic

sinusitis. Indian J Radiol Imaging., 2005; 15: 315.
37. Aramani A., Karadi R., Kumar S. A Study of Anatomical Variations of Osteomeatal Complex in Chronic Rhinosinusitis Patients-Ct Findings, 2014; 8(10): KC01-KC04.
38. Tonai A, Baba S. Anatomic variations of the bone in sinonasal CT. Acta Otolaryngol Suppl., 1996; 525: 9-13. PMID: 8908262.
39. Adeel M, Rajput MS, Akhter S, Ikram M, Arain A, Khattak YJ. Anatomical variations of nose and para-nasal sinuses; CT scan review. J Pak Med Assoc., 2013 Mar; 63(3): 317-9. PMID: 23914628.
40. Talaiepour AR, Sazgar AA, Bagheri A. Anatomic variations of the paranasal sinuses on CT scan images. Journal of Dentistry of Tehran University of Medical Sciences, 2005, 142-6.
41. Earwaker J. Anatomic variants in sinonasal CT. Radiographics, 1993 Mar; 13(2): 381-415.
42. Mamatha H, Shamasundar NM, Bharathi MB, Prasanna LC. Variations of ostiomeatal complex and its applied anatomy: a CT scan study. Indian J Sci Technol., 2010; 3: 904–907.
43. HH Wanamaker. Role of Haller's cell in headache and sinus disease: a case report. Otolaryngol Head Neck Surg., 1996; 114: 324–27. [PubMed] [Google Scholar]
44. Nouraei SA, Elisay AR, Dimarco A, Abdi R, Majidi H, Madani SA, Andrews PJ. Variations in paranasal sinus anatomy: implications for the pathophysiology of chronic rhinosinusitis and safety of endoscopic sinus surgery. J Otolaryngol Head Neck Surg., 2009 Feb; 38(1): 32-7. PMID: 19344611.
45. V AM, Santosh B. A Study of Clinical Significance of the Depth of Olfactory Fossa in Patients Undergoing Endoscopic Sinus Surgery. Indian J Otolaryngol Head Neck Surg., 2017 Dec; 69(4): 514-522. doi: 10.1007/s12070-017-1229-8. Epub 2017 Nov 7. PMID: 29238684; PMCID: PMC5714917.
46. DeLano MC, Fun FY, Zinreich SJ. Relationship of the optic nerve to the posterior paranasal sinuses: a CT anatomic study. Am J Neuroradiol., 1996; 17: 669–675. [PubMed] [Google Scholar]
47. Abdul-Hameed A, Daudu ZA, Mohammad MS, Abubakar B, Shiitu BS, Danjuma UJ, Abdo Aziz MM. Normal anatomical variations of maxillary sinus septa using computerized tomography from Sokoto Northwestern Nigeria. West Afr J Radiol., 2016; 23: 12-5.
48. Souza SA, Souza MM, Gregório LC, Ajzen S. Anterior ethmoidal artery evaluation on coronal CT scans. Braz J Otorhinolaryngol., 2009 Jan-Feb; 75(1): 101-6. doi: 10.1016/s1808-8694(15)30839-9. PMID: 19488568.
49. Carlos, Avian & E. Gelera, January. Prevalence of Supraorbital Ethmoid Air Cells among Filipinos. Philippine Journal of Otolaryngology-Head and Neck Surgery, 2018; 33: 21-23. 10.32412/pjohns.v33i2.261.
50. Amita Kumari, Manoj Mathur, Amarjit Kaur, Navkiran Kaur, Jasvir Singh, Samrin Haq. Computed tomographic evaluation of anatomical variants of paranasal sinuses in sinusitis. Int. J. of Adv. Res., 2017; 5 (Feb): 1515-1521] (ISSN 2320-5407). www.journalijar.com
51. Battal B, Akay S, Karaman B, et al. The relationship between the variations of sphenoid sinus and nasal septum. Gulhane Med J., 2014; 56: 232–237. [Google Scholar]
52. O'Brien WT Sr, Hamelin S, Weitzel EK. The Preoperative Sinus CT: Avoiding a "CLOSE" Call with Surgical Complications. Radiology, 2016 Oct; 281(1): 10-21.