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A Brief Review on CT of Anatomic Variation of The Paranasal Sinuses and Nasal Cavity

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ABSTRACT:
This study aimed to analyze the anatomical variations of the paranasal sinuses using computed tomography (CT) imaging, focusing on their prevalence, patterns, and clinical implications. A cross-sectional observational study was conducted on 80 participants aged 18–65 years at the Departments of Anatomy and Radiodiagnosis, Government Medical College Anantnag, J&K. CT scans were performed with a multi-slice scanner, and axial, coronal, and sagittal sections were obtained with a slice thickness of 0.5–1 mm. Anatomical variations such as concha bullosa, deviated nasal septum, Haller cells, Onodi cells, Agger Nasi cells, and sinus pneumatization variations were analyzed. Data were statistically evaluated to assess the prevalence and association of these variations with demographic factors like age and sex. The study revealed a high prevalence of anatomical variations, with Deviated Nasal Septum (52.50%) and Concha Bullosa (45.00%) being the most common. Ethmoidal sinus variations were the most frequent among individual sinuses (40.00%), followed by frontal (25.00%), sphenoidal (22.50%), and maxillary (12.50%) sinus variations. Significant associations were found between demographic factors and variations, with males showing higher prevalence rates for Concha Bullosa (59.57%) and Deviated Nasal Septum (63.83%). Participants aged 31–50 years exhibited the highest prevalence of Deviated Nasal Septum (55.56%), while younger participants had a higher prevalence of Concha Bullosa (45.45%). This study highlights the high prevalence and clinical significance of anatomical variations in the paranasal sinuses. These findings underscore the importance of CT imaging in diagnosing sinonasal conditions and preoperative planning for functional endoscopic sinus surgery to reduce complications and improve outcomes.

KEYWORDS: paranasal sinus, anatomical variants, sinus surgery, ethnic ,Deviated Nasal Septum, Concha Bullosa, CT imaging

INTRODUCTION:

The nasal cavity is related to the paranasal sinuses, which are air-filled chambers found inside the skull and face bones. These structures are essential for insulating delicate organs like the eyes and dental roots, lowering the weight of the skull, filtering and humidifying the air we breathe, and resonating sound. The physiology and pathophysiology of the sinuses can be significantly impacted by these structural variations, which are frequently modest. 1Computed Tomography (CT) imaging, which offers precise and in-depth visualisation of the paranasal sinuses' intricate architecture, has completely changed our knowledge of and ability to evaluate them. CT scans, in contrast to traditional radiography, provide three-dimensional imaging that enables accurate detection of sinus structures, their variations, and related anomalies.

A variety of structural abnormalities, such as concha bullosa, deviated nasal septum (DNS), Haller cells, Onodi cells, Agger Nasi cells, and changes in sinus pneumatization, are examples of anatomical anomalies in the paranasal sinuses. These differences could be unintentional observations in people who don't have any symptoms or they could put them at risk for sinonasal disorders. For instance, concha bullosa and DNS are two of the most common types and are commonly linked to chronic sinusitis, nasal blockage, and poor sinus drainage. Similarly, despite being less frequent, Haller and Onodi cells are clinically significant because they may obstruct sinus drainage channels or provide surgical difficulties because of their close proximity to vital tissues like the optic nerve.

Understanding these differences is essential for safe and efficient intervention in surgical settings, especially functional endoscopic sinus surgery (FESS). Preoperative imaging is crucial for surgical planning in FESS, which is frequently used to treat sinonasal disorders such as chronic rhinosinusitis. Unidentified anatomical

differences can raise the risk of intraoperative complications such ocular injury, cerebrospinal fluid leak, or optic nerve damage. These results emphasise how crucial it is to use region-specific data to guide surgical and therapeutic procedures that are customised for local people.
5The study of anatomical variations in the paranasal sinuses has implications for medical education and research in addition to its diagnostic and surgical applications. Healthcare workers, especially radiologists, otolaryngologists, and surgeons, need to understand the spectrum of typical anatomical variation in order to distinguish between normal variations and pathological findings. Additionally, research on sinus anatomy and its variations helps develop better surgical methods, diagnostic instruments, and treatment plans, all of which improve patient outcomes.6 Despite the increasing amount of literature on this subject, many aspects of sinus anatomy and its variations are still poorly understood. For example, more research is necessary to determine how developmental factors, environmental effects, and chronic inflammation affect the genesis and manifestation of these variances.
Furthermore, developments in imaging technology, including cone beam CT and three-dimensional reconstruction, may enhance our comprehension of sinus architecture and increase the precision of diagnosis. 7, 8 The purpose of this study is to employ CT imaging to examine the structural variations of the paranasal sinuses, with an emphasis on their prevalence, patterns, and clinical significance. This study aims to offer important insights into the function of these variants in sinonasal disorders and their importance in surgical planning by analysing a cohort of people referred for CT scans because of sinonasal complaints. It is anticipated that the results would add to the body of knowledge already in existence, helping medical professionals make better judgements and treat patients.

MATERIAL AND METHODS:

The Departments of Anatomy and Radiodiagnosis at Government Medical College Anantnag, J&K, were the sites of this cross-sectional observational study.
The 80 participants in the study were those who were sent to the Radiodiagnosis Department for paranasal sinus CT scans because of clinical grounds, such as sinusitis or other related disorders. The Institutional Ethics Committee of Government Medical College Anantnag, J&K, gave its clearance for the study, which was carried out in accordance with ethical standards. Before being included, each participant provided written informed consent. Strict precautions were taken during the investigation to guarantee the participants' anonymity and privacy.

CT Scanning Protocol:

Every participant had a paranasal sinus CT scan using a multi-slice CT scanner. With a slice thickness of 0.5–1 mm, axial, coronal, and sagittal sections were acquired. To find differences in the frontal, ethmoidal, sphenoidal, and maxillary sinuses, the scans were carefully examined. Anatomical variations such as concha bullosa, deviated nasal septum, Haller cells, Onodi cells, agger nasi cells, and changes in sinus pneumatization were among the specific observations.

Participant Evaluation

Clinical information was methodically documented for each participant, including patient age, sex, and presenting symptoms. To guarantee a thorough assessment for every person, the CT results were carefully examined and recorded.

Data Analysis:

SPSS version 25.0 was used to tabulate and analyse the gathered data. The distribution of anatomical variations was summarised using descriptive statistics, such as percentages and frequencies. To assess relationships between demographic factors and the existence of these variances, statistical tests were employed.

Inclusion Criteria

- Individuals aged 18–65 years.
- Patients referred for CT scans of paranasal sinuses.

- Participants willing to provide informed consent for inclusion in the study.

Exclusion Criteria

- Patients with prior surgical interventions or trauma to the paranasal sinuses.
- Individuals with significant congenital anomalies or facial deformities.
- Participants unwilling to give consent.

RESULTS

1. Demographic Characteristics of Participants

Eighty people, divided into three age groups, participated in the study. The age groups of 18–30 years (27.50%) and 51–65 years (27.50%) had identical numbers of participants, with the majority (45.00%) being between the ages of 31 and 50. A thorough examination is made possible by this distribution, which shows a balanced representation across age groups. In terms of sex, males made up 58.75% (n=47) of the study group, and females made up 41.25% (n=33). Males are more likely to seek medical attention for sinus-related conditions or anatomical predispositions, which may account for their preponderance.

Characteristic	Frequency (n=80)	Percentage (%)
Age Group (years)		
18–30	22	27.50
31–50	36	45.00
51–65	22	27.50
Sex		
Male	47	58.75
Female	33	41.25

Table 1: Demographic Characteristics of Participants

2. Distribution of Anatomical Variations in Paranasal Sinuses

Participants frequently exhibited anatomical variances, with significant differences noted (p value < 0.05).Concha Bullosa was discovered in 45.00% of participants (n=36, p=0.002), highlighting its correlation with sinonasal obstruction and diseases and making it one of the most common variations. The most common anomaly, Deviated Nasal Septum, was seen in 52.50% (n=42, p=0.001), highlighting its substantial influence on nasal airflow and susceptibility to sinusitis. Haller cells were seen in 22.50% (n=18, p=0.015), which narrows the maxillary sinus outflow tract and causes sinus infections. Onodi cells were less frequent, found in 12.50% of participants (n=10, p=0.045), but they were clinically relevant because of their proximity to the optic nerve, which increased the risk of surgical complications.

Anatomical Variation	Frequency (n=80)	Percentage (%)	p-value
Concha Bullosa	36	45.00	0.002*
Deviated Nasal Septum	42	52.50	0.001*
Haller Cells	18	22.50	0.015*
Onodi Cells	10	12.50	0.045*
Agger Nasi Cells	28	35.00	0.010*
Sinus Pneumatization Variations	24	30.00	0.008*

Table 2: Distribution of Anatomical Variations in Paranasal Sinuses

3. Frequency of Variations in Individual Sinuses

Significant patterns were found when looking at sinus-specific differences (p value < 0.05). The ethmoid sinuses' complex and diverse structure is reflected in the most common variation, which was seen in 40.00% of individuals (n=32, p=0.003).function in sinus endoscopic procedures. Sphenoidal sinus variations were found in 22.50% of subjects (n=18, p=0.011), emphasising its significance because their closeness to important neurovascular systems. Despite being the least common at 12.50% (n=10, p=0.048), maxillary sinus variations are nonetheless important because of their effects on sinus pathology and surgical planning.

Sinus	Frequency (n=80)	Percentage (%)	p-value
Frontal Sinus Variations	20	25.00	0.020*
Ethmoidal Sinus Variations	32	40.00	0.003*
Sphenoidal Sinus Variations	18	22.50	0.011*
Maxillary Sinus Variations	10	12.50	0.048*

Table 3: Frequency of Variations in Individual Sinuses

4. Association Between Demographic Factors and Anatomical Variations

Significant correlations between anatomical changes and demographic characteristics (age and sex) were found by statistical analysis (p value < 0.05). Men showed a higher frequency of other variations (48.48%, p=0.021), suggesting possible sex-specific patterns in sinonasal anatomy, while females showed a higher frequency of Concha Bullosa (59.57%, p=0.015) and Deviated Nasal Septum (63.83%, p=0.015), possibly due to anatomical differences or a greater predisposition to sinus-related conditions. Participants between the ages of 31 and 50 showed the highest prevalence of Deviated Nasal Septum (55.56%, p=0.002) and other variants (50.00%, p=0.002), most likely as a result of cumulative anatomical and environmental variables over time. over time. Concha Bullosa was more common in younger participants (18–30 years old) (45.45%, p=0.045), which may indicate influenced by developmental variables, while older participants (51–65 years old) had higher rates of Deviated Nasal S eptum (63.64%, p=0.032), which may be related to aging-related structural alterations.

Factor	Concha Bullosa (%)	Deviated Nasal Septum (%)	Other Variations (%)	p-value
Male (n=47)	28 (59.57)	30 (63.83)	18 (38.30)	0.015*
Female (n=33)	8 (24.24)	12 (36.36)	16 (48.48)	0.021*
Age 18–30 (n=22)	10 (45.45)	8 (36.36)	12 (54.55)	0.045*
Age 31–50 (n=36)	16 (44.44)	20 (55.56)	18 (50.00)	0.002*
Age 51–65 (n=22)	10 (45.45)	14 (63.64)	4 (18.18)	0.032*

Table 4: Association Between Demographic Factors and Anatomical Variations

5. Frequency of Multiple Variations in Participants

Significant trends were found in the prevalence of various anatomical changes in the subjects (p value < 0.05). There were no differences found in 20.00% of participants (n=16, p=0.050), indicating that anatomical variances are comparatively widespread in the general population. The frequency of isolated anomalies was shown by the presence of one variation in 30.00% of participants (n=24, p=0.018). A significant probability of coexisting anatomical changes is shown by the two most prevalent variations, which affected 37.50% of subjects (n=30, p=0.006). The intricacy of sinonasal anatomy in some individuals and its possible influence on clinical presentations and surgical outcomes were highlighted by the observation of three or more variations in 12.50% of participants (n=10, p=0.045).

Number of Variations	Frequency (n=80)	Percentage (%)	p-value
No Variation	16	20.00	0.050
One Variation	24	30.00	0.018*
Two Variations	30	37.50	0.006*
Three or More Variations	10	12.50	0.045*

Table 5: Frequency of Multiple Variations in Participants

DISCUSSION

Advances in CT and functional endoscopic surgery stimulated interest in the anatomy of the paranasal areas. The idea that inflammatory sinus disease results from compromised or disrupted mucociliary drainage channels of the sinuses into the ostiomeatal is a fundamental one in endoscopic sinus surgery. intricate. Restoring this functional drainage is the goal of FESS. For both radiologists involved in the preoperative work-up and surgeons performing endoscopic sinus surgery, a thorough understanding of anatomic differences in the paranasal sinus region is essential. In recent years, endoscopic examination and CT have proven to be the best combination, and they are already recognised as the "standard of care" for sinus disorders.

- ***Turbinate Variations***

One of the most prevalent modifications of the sinonasal anatomy is concha bullosa, which is the pneumatization of the concha. Pneumatization of the middle turbinate occurs most frequently, whereas pneumatization of the superior turbinate occurs infrequently. Only a few studies describe the inferior turbinate. inferior concha bullosa, the majority of which have been documented in case reports.

Numerous publications have discovered a substantial correlation between the nasal septal convexity's deviation from the concha and the existence of a concha, whether it be dominant or unilateral. This suggests that the septum's deviation from the concha is not the consequence of the concha forcing the septum away. Instead, there seems to be some unidentified developmental connection between the nasal septum and concha. There was no evidence to suggest whether the nasal septum "senses" the concha's mass effect and develops away from this side, or whether the concha enlarges to partially fill the expanded air channel after the septal deviation develops first.

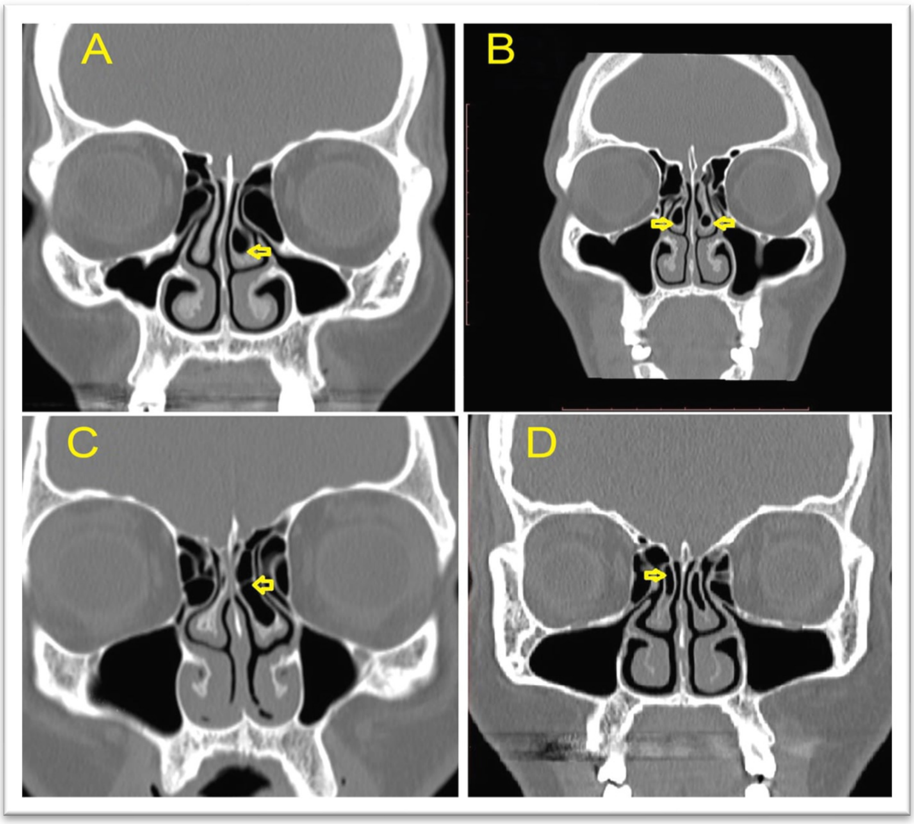

Fig 1 : Turbinate Variations

- ***Uncinate Process Variations***

One important bone component of the lateral nasal wall is the uncinate process. It defines the hiatus semilunaris, which forms an exit for the infundibulum, an anteriorly and inferiorly orientated recess, along with the nearby ethmoid bulla. The posterior side of the infundibulum is accessed by the maxillary sinuses through the ostium; uncinectomy is the initial technique to show the maxillary sinus during FESS

. Impaired sinus ventilation can result from the infundibulum being compressed by an expanded or distorted free border of the uncinated process. Other, less significant differences include hypoplasia and pneumatization (2%–14%).

It has been suggested that the expansion of agger nasi cells into the most anterosuperior part of the uncinate process is the cause of uncinate pneumatization, even if the precise mechanism is unknown. This polymorphism has been linked to infundibulum narrowing, which results in reduced sinus ventilation. Notably, maxillary sinus hypoplasia has been linked to lateral displacement and uncinate process hypoplasia. The ethmoid infundibulum closes superiorly to create a blind pouch known as the terminal recess when the uncinate process inserts into the lamina papyracea.

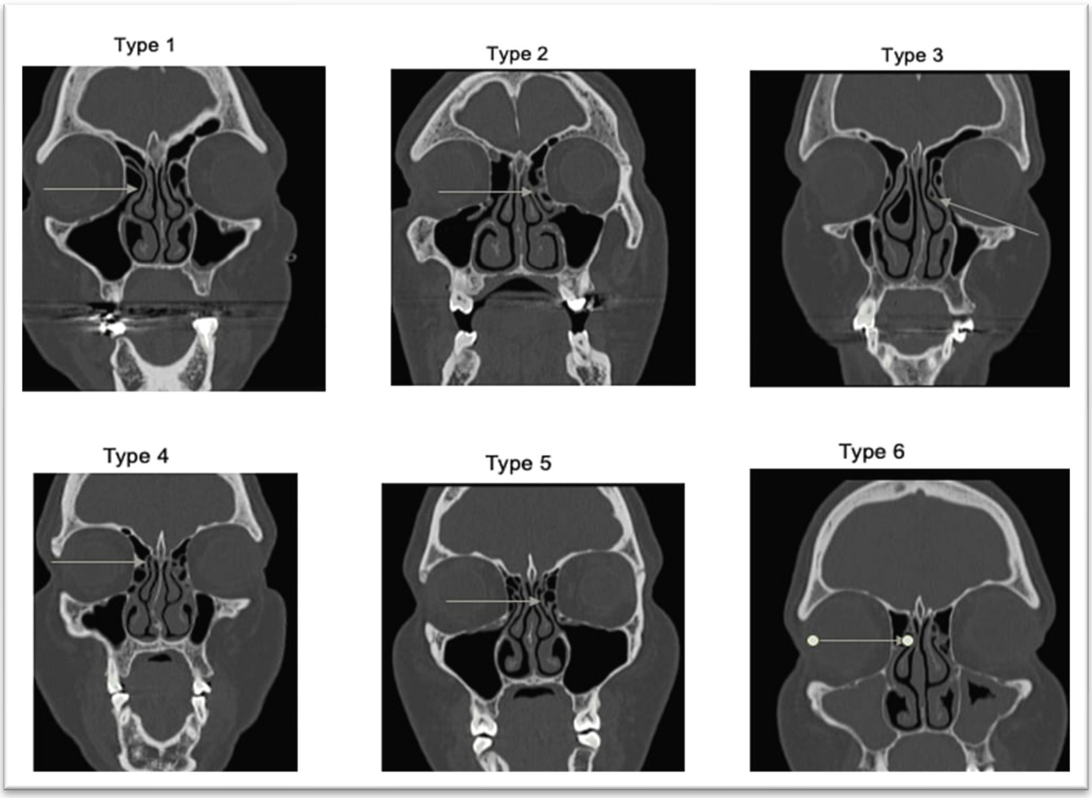

Fig 2: Uncinate Process Variations

- ***Ethmoid Cells Variations***

The Latin word for nasal mound is where the name "agger nasi" originates. Located in the anterior superior region of the middle turbinate, agger nasi cells are thought to be the most anterior of all ethmoid cells. They can pneumatize posteriorly to constrict the frontal recess, and they are typically found bilaterally. sinusitis in the front. The best CT pictures for locating the agger nasi cells are coronal and sagittal reformatted images. According to reports, their incidence varies from 10% to 98%. The reduced incidence in paediatric children may be explained by the fact that frontal sinus expansion causes agger nasi cells to continue developing even after the ethmoid sinus has finished developing. Crucially, during endoscopy, these cells can offer access to the frontal sinus.

The ethmoid cells that grow into the floor of orbit, or the roof of the maxillary sinus, next to and above the maxillary sinus ostium are known as Haller cells or infraorbital cells. They were first identified by Albert von Haller in 1765. They might considerably narrow the posterior aspect of the ethmoidal if they enlarge. The maxillary sinus's ostium and infundibulum above Due to the inconsistent definition, their prevalence is surprisingly variable, ranging from 8% to 57%. Because of its detrimental effect on maxillary sinus ventilation by constricting the infundibulum and ostium, it has been suggested as a potential etiologic factor in recurrent maxillary sinusitis, making it a clinically important variant.

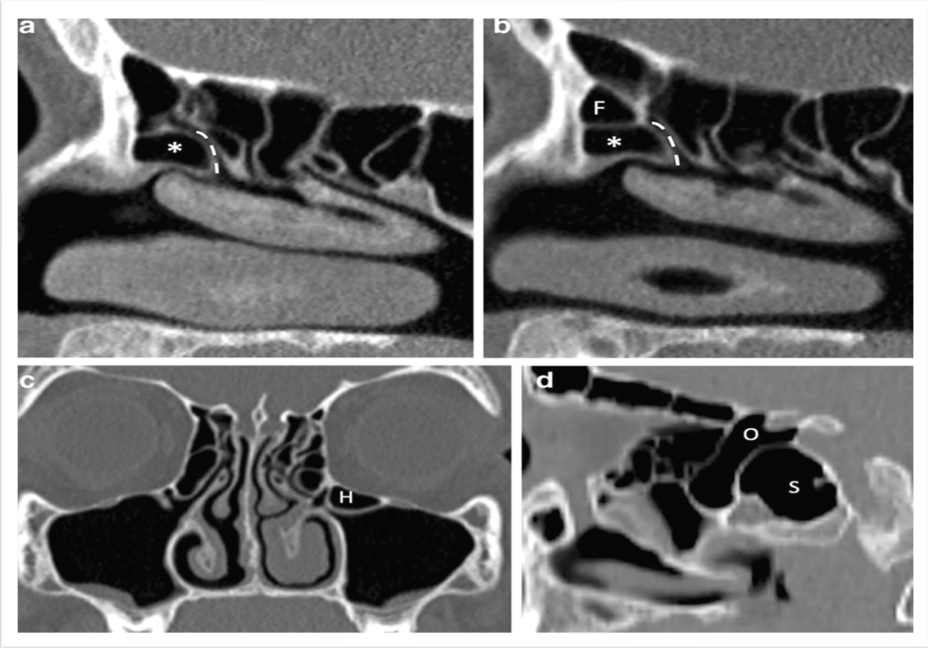

Fig 3: Ethmoid Cells Variations

- ***Nasal Septum Variations***

The most prevalent physical condition affecting the nasal septum is nasal septal deviation. Developmental (typically smooth, "C-shaped" or "S-shaped" nasal septum with incidence more frequently in the anterior septum) or traumatic (generally uneven, angulated, and displaced sometimes). It could be osseous, cartilaginous, or osseocartilaginous. In addition to making surgical access challenging and obstructing normal mucous flow, septal deviation can cause secondary inflammation and infection by displacing the middle turbinate and restricting the middle meatus. Because of different physical characteristics and the degree of deviation, the reported prevalence of septal variants in the literature ranges from 26% to 97%.

Depending on their size, nasal septal spurs can constrict the nasal cavities, making surgical access more difficult and impairing nasal breathing. The posterior part of the nasal septum is often home to air cells. interact with the sphenoid sinus, facilitating the propagation of infections to these cells. They are often insignificant and caused by the extension of air from the sphenoid sinus or crista galli, but occasionally they may obstruct the middle meatus's drainage

- ***Frontal Recess Cells***

Front-ethmoidal (Kuhn) cells are superior to agger nasi cells. In 1994, Bent and Kuhn identified four different kinds of frontal sinus cells (FSC). A single cell in the frontal outflow tract above the agger nasi is described by type 1 FSC, which is the most common type. Above the agger nasi, there is a tier of type 2 cells. The frontal sinus itself is where type 3 cells stretch cephalad past the frontal recess. With a few exceptions, type 2 cells are shown to be the second most prevalent in most research.

- ***Maxillary Sinus Variations***

With a mean incidence of 29%, the maxillary sinus septum, which separates the maxillary antrum into bony compartments, is the most commonly reported maxillary sinus variation in the literature. The major septa are thought to have developed during the face's midline's embryonic development. Secondary Conversely, septa are thought to develop as a result of bone resorption in the sinus base as a result of alveolar ridge atrophy after tooth loss during the maxillary sinus pneumatization process. Selcuk et al. discovered a strong association between the anteriorly localised maxillary sinus septa and infraorbital fissure widening. They also showed that the position of antral septa was often vertical at anterior and horizontal at posterior.

A rare disorder called maxillary sinus hypoplasia can be mistakenly identified as chronic sinusitis. According to reports, its prevalence ranges from 1% to 11%. at its development at the embryologic stage, the maxillary sinus may become hypoplastic, accompanying syndromes including Apert, Crouzon, and Treacher. Collins, or subsequently as a result of structural, iatrogenic, or traumatic factors. Opponents of the widely held belief that infundibular blockage may result in negative pressure and maxillary underdevelopment point to the occurrence of maxillary sinus hypoplasia patients with a completely normal osteomeatal complex.

The term "ethmomaxillary sinus" refers to the expansion of the posterior ethmoid cells into the maxillary sinus. empties into the superior meatus. According to reports, its occurrence ranges from 0.7% to 2%, and it is typically accompanied by a maxillary sinus that is hypoplastic. If a CT scan is not performed before endoscopic sinus surgery, it could result in Anatomical confusion throughout the surgery

- ***Sphenoid Sinus Variations***

Different levels of pneumatization may be seen in the sphenoid sinus and surrounding bony structures. Sphenoid sinuses are closely associated with several variants, such as the cavernous sinus, internal carotid artery, optic, and vidian canals. More broadly, the optic nerve is located in the optic canal. the least nourished along its length, making it more vulnerable to damage from direct inflammatory invasion of sinus disorders. Additionally, if the surgeon damages the nerve inside the sinus, there is a danger of blindness. Optic nerve protrusion into the sphenoid sinus has been observed to occur between 7% and 35% of the time.

Additionally, the internal carotid artery may come into direct touch with the sinus mucosa due to a dehiscence in the bone protecting it, which could result in an infection in the cavernous sinuses. However, carotid artery damage may occur if the surgeon was unaware of this variation prior to surgery. caused deadly bleeding or blindness. Internal carotid artery protrusion and dehiscence vary greatly in frequency, ranging from 5.2% to 67% and 2% to 23%, respectively.

CONCLUSIONS:

In PNS, many anatomical variations may be often observed. Every variance has anatomical and surgical relevance, so each case should be considered separately. thoroughly examined before to surgery in order to maximise patient benefit and prevent major problems.

The most prevalent structural changes in the paranasal sinuses are Deviated Nasal Septum (52.50%) and Concha Bullosa (45.00%), as this study demonstrates. Among individual sinuses, ethmoidal sinus variants were the most common (40.00%), highlighting their intricate architecture. These variances were shown to be significantly correlated with demographic characteristics including age and sex. In order to reduce difficulties and enhance patient outcomes, the results highlight the therapeutic significance of identifying these anatomical variations in the diagnosis and treatment of sinonasal disorders as well as in the preoperative planning of functional endoscopic sinus surgery.

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