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Study of Anatomical Variations on High Resolution Computed Tomography [HRCT] Para Nasal Sinuses in Chronic Rhinosinusitis

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Abstract

Introduction

Chronic rhinosinusitis (CRS) is a common and debilitating condition affecting millions of individuals globally, having a significant burden on healthcare systems and public health resources. The prevalence of CRS has been estimated up to 10% to 12% of the population, establishing it one of the most common chronic diseases worldwide. CRS is defined as inflammation of the nasal and paranasal sinuses for 12 weeks or longer, even after appropriate medical therapy. Its impact extends beyond the upper respiratory tract, as it is associated with many systemic effects such as fatigue, sleep disturbances, impaired productivity along with reduced quality of life. Patients with CRS often report prolonged physical discomfort due to symptoms such as nasal congestion, purulent nasal discharge, facial pain or facial pressure, and reduced or complete loss of smell.[1] Chronic rhinosinusitis is often classified into two primary subtypes: CRS with nasal polyps (CRSwNP) and CRS without nasal polyps (CRSsNP). These subtypes differ in their clinical presentation, underlying pathophysiology, and response to treatment.[1]

The etiology of CRS is multifactorial with host, environmental, and microbial factors are major contributors. With host component, anatomical variations in the paranasal sinuses is major contributor in the pathogenesis of CRS. This can disrupt the sinus ventilation and drainage pathways resulting in an environment favouring to mucus stasis and bacterial colonization leading to persistent inflammation. Therefore, understanding the role of anatomical variations is essential, both for diagnosing CRS and tailoring the effective treatment strategies, including surgical intervention.[2]

High-resolution computed tomography (HRCT) is the gold standard for evaluating sinonasal anatomy and pathology. It enables precise identification of anatomical

variations, supports CRS diagnosis, and is critical for preoperative planning in functional endoscopic sinus surgery (FESS).

This study aims to assess the role of anatomical variations in the pathogenesis of CRS and highlight the diagnostic value of HRCT in evaluating these changes.

Keywords: Chronic Rhinosinusitis, Ethmoid Skull Base, Predominance

Aims and Objectives

My objectives are to study various anatomical variations in Paranasal sinuses in patients diagnosed with Chronic Rhinosinusitis as assessed by HRCT and to assess the extent and severity of disease [CRS] in relation to these anatomical variations.

Materials and Methods

1. This prospective observational study was conducted in the Department of Otorhinolaryngology [ENT], KD Medical College, Hospital and Research centre, Mathura, Uttar Pradesh, for a period of 18 months from August 2023 to January 2025, among patients diagnosed with Chronic Rhinosinusitis [on the basis of Lanza and Kennedy 3 Criteria] after obtaining an informed written consent from the patients/ guardian.

Inclusion Criteria

- Patients diagnosed with chronic Rhinosinusitis.

Exclusion criteria

- Patients with nasal mass.
- Patients with previous sinus surgery.
- Patients with any other concomitant nasal or paranasal pathology.

2. Detailed history and clinical examination was done and recorded in performa. Diagnostic Nasal Endoscopy was performed in all the patients followed by HRCT of Paranasal sinuses [PNS] was performed in Radiodiagnosis department in KDMCH & RC Mathura.
3. Data was collected and analysed for presence of anatomical variations [diagnosed on HRCT] in patients of CRS.

Sample Size: - 75

Sample size (n) = Z2 .p.q / d2

Where,

Z = standard normal variant corresponding to the level of significance

p = expected prevalence

q = 1-p

E = absolute error or precision

Sample size (n) = Z2.p.q / d2

= (1.96)2 .5. 95/ (5)2

= 1824/ 25 = 72.9

Results and Discussion

In the present study, an attempt has been has made to study the incidence and influence of anatomical variations of Paranasal sinuses in patients diagnosed with Chronic rhinosinusitis.

Most of the patients were within the age group of 20-39 years contributing to 45.33% of the study population. This finding is consistent with a study done by Tiwari and Goyal[4] which reported a similar demographic trend among CRS patients. Further, the age group of 40-59 years accounts for 29.33%cases, and the age group of 60-79 years category comprises 14.67% study subjects, suggesting that middle-aged individuals also form a major proportion of those affected by CRS with sinonasal anatomical variations. Adolescents aged 10-19 years make up 9.33% of the study population, and only one (1.33%) of the participants was of 80 years, reflecting a lower prevalence of anatomical variations in the elderly population. This pattern of presentation of CRS is consistent with observations5,6 which suggest that while anatomical variations are often congenital, their clinical manifestation and disease burden in the form of CRS

tend to peak in early to middle adulthood, possibly due to cumulative environmental exposures, including personal habits like smoking and inflammatory triggers such as inhalation of allergens and pollution.

In terms of sex distribution, 64% participants were male, while 36% were females, indicating a significant male predominance in CRS in the present study. Similar results were quoted by Tiwari and Goyal[4] and Talugula et al.[7], with observation of more prevalence of anatomical variations in males as compared to females. However, in the study done by Behnke et al[8], from USA reported that women experienced higher burden of CRS than men with similar outcomes after treatment.

Frontal cells are important group of air cells that influence frontal sinus drainage. There are four types of frontal cells described by Kuhn (Kuhn's classification). In our study, type 1 frontal cells were the most commonly observed variation, found in 64.7% on right side and 59% on left side while type 2 were found in 35.2% on the right side and 41% on the left side. Type 3 and type 4 frontal cells were not found in any of the patients. These findings align with Kuhn (1987), who first introduced this classification and reported that type 1 cells are the most frequently encountered, followed by type 2, whereas type 3 and 4 cells are rare. Lee et al.[9] also reported that the most common type of frontal cells was type 1 with a prevalence of 37% and 19% for Type 2. Similar results also reported by DelGaudio et al.[10] But Johari et al.[11] reported higher prevalence of type 2 cells (31.1 %) as compared to type 1 (28.8%) in patients with sinusitis. Similar observation was reported by Eweiss and Khalil[12] also with type 2 in 26.4% as compared to type 1 in 21.4%.

Our study found that the sellar type of sphenoid sinus pneumatization was the most common, observed in 81% participants, followed by the pre sellar type in 18.9% cases. No case of conchal type pneumatization was identified. These findings were consistent with Tan and Ong13 who observed a 55%prevalence of the sellar type (most common type) and 20% for the presellar type. Similarly, Hamid etal.14 reported that the sellar type in 70-80% of cases, while the presellar type accounted for 20-30%, and the conchal type was rare.

The study of Nasal septum and its deviation was included in the present study of evaluation of anatomical variations in paranasal sinuses in CRS patients due to its significant influence in pathogenesis of CRS. DNS was the most commonly observed anatomical variation, found in 72% patients. Similar results were reported by Pérez-Piñas et al.[15] with prevalence of 80% and Devaraja etal.[16] with 83.4 %. However, lower prevalence of DNS was reported by Asruddin et al.[17] in 38%, and Karkiet al.[18] in 56.8%., which may be due to different study populations or radiological assessment techniques. In our study, DNS was found in 61.1%males and 38.9% females. This is similar to observation of Mamatha et al.[19] who also reported a higher prevalence of DNS in males. DNS can lead to nasal obstruction, altered airflow, and predisposition to chronic rhinosinusitis, particularly when combined with other variations such as concha bullosa and Haller cells.

The study by Patla et al.[20] focuses on anatomical variations of the uncinate process, specifically its superior attachment and pneumatization, using CT scans in 100 patients. In their study, the most common superior attachment of the uncinate process was Type 6 (insertion into the middle turbinate) in 41%, followed by Type 1 (lamina papyracea) in 34.5%, Type 2 (posterior wall of agger nasi cell) at 16.5% and Type 5 (ethmoid skull base) seen in 7%. Then types 3 and 4 were rare and reported in only0.5% each. Pneumatization of the uncinate process was rare, occurring in 4% of cases, predominantly on the

left side. We observed that 93.3% of uncinate processes attached to the lamina papyracea, with 6.7% attaching to the middle turbinate. Pneumatization of the uncinate process was not seen in our study. So these observations suggest that attachment of uncinate process to the lamina papyracea is associated with higher prevalence of CRS but attachment of uncinate process to middle turbinate i.e type 6 with higher incidence of CRS as reported by Patla et al.20 in comparison to our study observations with only 6.7%, needs further study.

Agger nasi cells, located anterior to the middle turbinate, were present in 80% cases in our study, making them another frequently observed anatomical variation. This is similar to the prevalence reported by Karki et al.[18] (87.6%) and Lee et al.[9] (89%). In our study, Agger nasi cells were identified in 41 (68.3%) males and 19 (31.7%) females. Their presence is clinically relevant as they are the most anteriorly located ethmoid air cells and are directly involved in frontal sinus drainage.

Concha bullosa, a pneumatized middle turbinate that can contribute to nasal obstruction, was present in 42.7% cases in our study. This is similar to the findings of Fathima et al.[21] who found concha bullosa in 44% of study subjects. But in studies done by Tiwari and Goyal4 and Pérez-Piñas et al.[16], contrasting findings were observed with prevalence of concha bullosa in 76.6% and 73% of study subjects respectively.

Haller cells, accessory air cells that can narrow the infundibulum and predispose patients to maxillary sinusitis, were identified in 6.7% of participants in our study. Right-sided Haller cells in 60% cases were more common than left-sided ones found in 40% cases. These results were similar with the findings of Chakraborty and Jain[22], who reported a 9.7% prevalence of Haller cells and suggested their role in maxillary sinusitis due to obstruction of the infundibulum. However a higher prevalence of 20% and 39% have been reported by Pérez-Piñas et al.[15] and Devaraja et al.[16] respectively.

Another important anatomical variation, the Paradoxical Middle Turbinate (PMT), which was found in 9.3% cases in our study with a slight male predominance [57.1% males and 42.9% females]. Most of the cases were found on the right side in 57.1% cases, followed by the left sided in 28.6% and bilateral involvement in 14.3%. Similar results were reported by Chaitanya et al.[23] (11%) with sided dominance and Reeti et al.[29] (18%). However, studies done by Karki et al.[18] and Asruddin et al.[17] showed prevalence of Paradoxical middle turbinate in 39.4% and 48% respectively.

Onodi cell, an important assessment due to their proximity to the optic nerve, was observed in one (1.3%) case in our study. The prevalence of Onodi cell observed by previous studies was higher. Karkiet al.[18] reported a prevalence of 23.8%, Devaraja et al.[16] 23% and Tan and Ong[13] 15%. Though, the Onodicell is rare, it poses a substantial surgical risk due to its close proximity to the optic nerve.[32] The prevalence of sphenoiditis reported to be higher in patients with Onodi cell, therefore may be a contributing factor in etiology of sinusitis.[24]

Kero's Classification showed that Type 2 (4-7 mm) was the most commonly observed variant, found in60% of the study cases, of which 38.7% were males and 21.3% were females, while Type 1 (≤3 mm) was less frequent and was found in 40% patients of which 25.3% were males and 14.7% were females. No patient with type 3 (≥8 mm) was detected in our study population. These findings are consistent with studies done by Devaraja et al.[16], Almushayti et al.[25] and Yousef et al.26 who also documented Type 2 was the most prevalent variant found in 88.7% cases, 63.5% and 79.5% respectively.

Pneumatization of anterior clinoid process was observed in only 4% cases in our study. But as per the observation

of Devaraja et al.[16], 27.1% cases had pneumatization of anterior clinoid process. Out of 3 patients, 2 (66.7%) were males and 1 (33.3%) was female, while in the study reported by Burulday et al.[27] also observed more number of males (37.5%) as compared to females (33.3%). Pneumatization rates of anterior clinoid process are high as mentioned in previous studies[18,28], but we found less cases and it can be attributed to variations in demographic profile of enrolled cases.[28]

The study's findings reinforce existing research on the high prevalence of sinonasal anatomical variations, and their potential implications for sinus disease and endoscopic surgery. The presence of concha bullosa, agger nasi cells, and uncinate process variations, frontal cell types (Kuhn's classification), sphenoid sinus pneumatization types, paradoxical middle turbinate highlights the importance of detailed radiological assessment. Given the surgical risks associated with Haller cells, Onodi cells, and extreme pneumatization patterns, High-Resolution Computed Tomography (HRCT) remains an indispensable tool for preoperative planning, helping clinicians tailor surgical interventions and minimize complications.

S. No.	ANATOMICAL VARIATION (%)		TOTAL n (%)	MALE n (%)	FEMALE n (%)
1	Deviated nasal septum (72%)		54	33 (61.1%)	21 (38.9%)
	i.	Right	16 (29.6%)	13 (24.1%)	3 (5.6%)
	ii.	Left	28 (51.9%)	14 (25.9%)	14 (25.9%)
	iii.	Bilateral	10 (18.5%)	6 (11.1%)	4 (7.4%)
2	Paradoxical middle turbinate (9.3%)		7	4 (57.1%)	3 (42.9%)
	i.	Right	4 (57.1%)	2 (28.6%)	2 (28.6%)
	ii.	Left	2 (28.6%)	2 (28.6%)	0
	iii.	Bilateral	1 (14.3%)	0	1 (14.3%)
3	Uncinate process attachments (80%)		60	37 (61.7%)	23 (38.3%)
	i.	Lamina papyracea	56 (93.3%)	33 (55%)	23 (38.3%)
	ii.	Middle turbinate	4 (6.7%)	4 (6.7%)	0
	iii.	Base of skull	0	0	0
	Free Uncinate process (20%)		15	11 (73.3%)	4 (26.7%)
4	Frontal recess narrowing (6.7%)		5	3 (60%)	2 (40%)
	i.	Right	2 (40%)	2 (40%)	0
	ii.	Left	3 (60%)	1 (20%)	2 (40%)
	iii.	Bilateral	0	0	0
5	Agger nasi cells (80%)		60	41 (68.3%)	19 (31.7%)
	i.	Right	15 (25%)	8 (13.3%)	7 (11.7%)
	ii.	Left	15 (25%)	13 (21.6%)	2 (3.3%)
	iii.	Bilateral	30 (50%)	20 (33.3%)	10 (16.7%)
6	Haller cells (6.7%)		5	4 (80%)	1 (20%)
	i.	Right	3 (60%)	3 (60%)	0
	ii.	Left	2 (40%)	1 (20%)	1 (20%)
	iii.	Bilateral	0	0	0
7	Onodi cells (1.3%)		1	1 (100%)	0
	i.	Right	1 (100%)	1 (100%)	0
	ii.	Left	0	0	0
8	Pneumatized anterior clinoid process (4%)		3	2 (66.7%)	1 (33.3%)
	i.	Right	1 (33.3%)	1 (33.3%)	0
	ii.	Left	2 (66.7%)	1 (33.3%)	1 (33.3%)
	iii.	Bilateral	0	0	0
9	Pneumatized posterior clinoid process (0)		0	0	0
	i.	Right	0	0	0
	ii.	Left	0	0	0
	iii.	Bilateral	0	0	0
10	Herzallah cells (0)		0	0	0
	i.	Right	0	0	0
	ii.	Left	0	0	0
	iii.	Bilateral	0	0	0
11	Concha bullosa (42.7%)		32	25 (78.1%)	7 (21.8%)
	i.	Right	20 (62.4%)	17 (53.1%)	3 (9.3%)
	ii.	Left	10(31.2%)	6 (18.7%)	4 (12.5%)
	iii.	Bilateral	2 (6.3%)	2 (6.3%)	0
12	Maxillary sinus narrowing (0)		0	0	0
	i.	Right	0	0	0
	ii.	Left	0	0	0
13	Sphenoid sinus types (49.3%)		37	23 (62.1%)	14 (37.8%)
	i.	Presellar	7 (18.9%)	6 (16.2%)	1 (2.7%)
	ii.	Sellar	30 (81%)	17 (45.9%)	13 (35.1%)
	iii.	Conchal	0	0	0
14	Depth of Olfactory fossa (100%)		75	48 (64%)	27 (36%)
	i.	Kero's type 1	30 (40%)	19 (25.3%)	11 (14.7%)
	ii.	Kero's type 2	45 (60%)	29 (38.7%)	16 (21.3%)
	iii.	Kero's type 3	0	0	0
15	Kuhn's classification of frontal cell types on right side (45.3%)		34	18 (52.9%)	16 (47.1%)
	i.	Type 1	22 (64.7%)	12 (35.3%)	10 (29.4%)
	ii.	Type 2	12 (35.2%)	6 (17.6%)	6 (17.6%)
	iii.	Type 3	0	0	0
	iv.	Type 4	0	0	0
16	Kuhn's classification of frontal cell types on left side (58.7%)		44	25 (56.8%)	19 (43.2%)
	i.	Type 1	26 (59%)	15 (34.1%)	11 (25%)
	ii.	Type 2	18 (41%)	10 (22.7%)	8 (18.1%)
	iii.	Type 3	0	0	0
	iv.	Type 4	0	0	0

Conclusion

The findings of this study provide a comprehensive understanding of the prevalence and distribution of anatomical variations in the nasal and paranasal sinuses. The results indicate a predominance of younger and middle-aged individuals, with a significant male majority, aligning with previous studies on sinonasal anatomy.

Deviated Nasal Septum was identified as the most common nasal anatomical variation, along with paranasal sinus ones. This is in consistent with existing literature that has reported similar observations signifying the possible influence of septal deviation on nasal airflow and sinonasal pathologies such as chronic nasal obstruction and sinusitis.

Paranasal sinuses anatomical variations, such as Uncinate Process Attachments, Agger Nasi Cells, and Concha Bullosa, were more prevalent, consistent with previously reported findings. The high occurrence of these variations emphasizes their role in sinonasal drainage and airflow regulation. Uncinate Process variations, particularly those involving attachment to the Lamina Papyracea, can influence sinus ventilation and predispose individuals to chronic rhinosinusitis. Similarly, Agger NasiCells, known for their impact on frontal sinus drainage, were commonly observed, further supporting their clinical significance in the development of sinonasal pathologies. The presence of Concha Bullosa, which can contribute to nasal obstruction and mucosal contact headaches, signifies the importance of considering these anatomical variations in patient management.

Less frequently observed variations, such as Haller Cells and Onodi Cells, also remain significant due to their potential impact on sinus disease and surgical risks. Haller Cells, which can contribute to maxillary sinusitis and infraorbital nerve irritation, require careful assessment to prevent complications during sinus surgery. Onodi Cells, due to their proximity to the optic nerve and sphenoid sinus, poses a heightened surgical risk, necessitating the detailed radiological evaluation before surgical interventions.

The study also assessed Kero's Classification, where Type 2 (4-7 mm) was the most commonly observed variant. This finding is consistent with previous studies indicating that Type 2 was the most prevalent, suggesting the depth of the olfactory fossa and thereby increasing the risk of injury during endoscopic sinus surgery.

The predominance of the sellar type in sphenoid sinus pneumatization also aligns with established anatomical studies, reinforcing its typical presentation in sinonasal anatomy. The absence of the conchal type further supports the notion that this variation is relatively rare.

The clinical significance of these findings lies in their direct impact on etiopathogenesis, diagnosis and planning the surgical treatment. Anatomical variations can increase the risk of complications, highlighting the need of detailed preoperative imaging for a safer and more effective surgical approach. The study highlights the importance of understanding sinonasal anatomical variations in both routine clinical assessments and specialized surgical procedures.

In conclusion, the study confirms the high prevalence of certain anatomical variations in the sinonasal region and their potential clinical implications. The findings emphasize the importance of detailed radiological evaluation for accurate diagnosis and mapping the surgical treatment. However, future research with larger sample sizes and diverse populations could provide deeper insights into the variations observed and their correlations with clinical outcomes. A better understanding of these anatomical variations can enhance surgical precision, improve patient outcomes, and minimize complications associated with sinonasal procedures.

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