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Prevalence of Various Anatomical Variants of the Nasal Cavity and Paranasal Sinuses using Multidetector Computed Tomography among Patients Presenting with Chronic Sinusitis

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ABSTRACT:

Background: Chronic rhinosinusitis (CRS) is a common inflammatory disorder of the nasal cavity and paranasal sinuses. Anatomical variations may influence sinonasal drainage and contribute to disease pathogenesis. Multidetector computed tomography (MDCT) plays a crucial role in identifying these variations and guiding management. This study aimed to determine the prevalence of sinonasal anatomical variants using MDCT and evaluate their association with disease severity and demographic factors in patients with CRS.

Methods: This hospital-based cross-sectional study included 150 patients with clinically and radiologically confirmed CRS. MDCT scans were performed to identify anatomical variants. Statistical analysis was conducted using Chi-square and Kruskal–Wallis tests, with a p-value <0.05 considered significant.

Results: Deviated nasal septum (DNS) was observed in 81 patients (54.0%), paradoxical middle turbinate in 79 (52.7%), agger nasi cells in 79 (52.7%), Haller cells in 77 (51.3%), and concha bullosa in 76 (50.7%). Maxillary and ethmoid sinus involvement was most common (90; 60.0%). No statistically significant association was found between anatomical variants and disease severity: DNS ($\chi^2=2.00$, $p=0.368$), agger nasi cells ($\chi^2=0.43$, $p=0.806$), concha bullosa ($\chi^2=1.02$, $p=0.601$), Haller cells ($\chi^2=2.57$, $p=0.277$), frontal cells ($\chi^2=3.50$, $p=0.174$), maxillary septation ($\chi^2=3.74$, $p=0.155$), accessory ostium ($\chi^2=0.48$, $p=0.786$), uncinate pneumatization ($\chi^2=0.01$, $p=0.994$), and paradoxical middle turbinate ($\chi^2=1.38$, $p=0.503$). No significant gender-based differences were observed, e.g., DNS ($\chi^2=0.000$, $p=1.000$). Age ($H=3.845$, $p=0.146$) and symptom duration ($H=0.715$, $p=0.700$) were also not associated with severity.

Conclusion: Anatomical variants are highly prevalent in CRS but are not independently associated with disease severity. MDCT remains essential for preoperative evaluation and surgical planning.

1. INTRODUCTION

The nasal cavity and paranasal sinuses form a complex, integrated anatomical unit within the craniofacial skeleton, playing a crucial role in respiration, vocal resonance, and conditioning of inspired air. These air-filled cavities undergo progressive

pneumatization from childhood through early adulthood, extending into the frontal, maxillary, ethmoid, and sphenoid bones.[1] Their physiological functions include reducing skull weight, enhancing voice resonance, humidifying and warming inhaled air, and contributing to local immune defense mechanisms. Due to their intimate anatomical relationship with critical structures such as the orbit, optic nerve, anterior skull base, and major रक्त vessels, precise knowledge of sinonasal anatomy is essential for accurate diagnosis and safe surgical intervention.[2]

A defining feature of the sinonasal region is its considerable anatomical variability among individuals. Variations may involve differences in sinus size, shape, degree of pneumatization, and drainage pathways. These differences are particularly significant in the osteomeatal complex, which serves as the primary drainage pathway for the frontal, maxillary, and anterior ethmoid sinuses. Even minor anatomical deviations in this region can disrupt normal airflow and mucociliary clearance, predisposing individuals to pathological conditions.[3]

Obstruction of the osteomeatal complex initiates a cascade of pathological changes, including mucus retention, impaired mucociliary clearance, bacterial proliferation, and chronic inflammation, ultimately leading to chronic rhinosinusitis (CRS).[4] Chronic rhinosinusitis is defined as a persistent inflammatory condition of the nasal cavity and paranasal sinuses lasting more than 12 weeks despite appropriate medical therapy. It is clinically characterized by symptoms such as nasal obstruction, nasal discharge, facial pain or pressure, and reduced or lost sense of smell, supported by objective findings on nasal endoscopy or imaging studies.[5]

CRS represents a significant global health burden, affecting quality of life, work productivity, and healthcare utilization. Its impact is particularly pronounced in low- and middle-income countries, where environmental pollution, recurrent infections, and limited access to specialized care exacerbate disease prevalence and severity.[6] The etiopathogenesis of CRS is multifactorial, involving a combination of environmental factors, immune dysfunction, allergic responses, and microbial influences. Among these, anatomical variations play a critical role by narrowing or obstructing sinus drainage pathways, particularly at the osteomeatal complex.[7]

Several anatomical variants of the nasal cavity and paranasal sinuses have been identified as clinically significant contributors to CRS. The middle turbinate, an important anatomical landmark in endoscopic sinus surgery, may undergo pneumatization, forming a concha bullosa. When enlarged, this variation can compromise the middle meatus, leading to impaired sinus ventilation and drainage.[8] Similarly, variations such as agger nasi cells, Haller cells, and Onodi cells have important clinical implications. Agger nasi cells can obstruct the frontal recess, Haller cells may narrow the maxillary infundibulum, and Onodi cells are closely related to the optic nerve and internal carotid artery, posing potential surgical risks.[9]

To standardize the evaluation of sinonasal anatomy and pathology, several classification systems are utilized. These include the Keros classification for olfactory fossa depth, the Mladina classification for nasal septal deviation, and the Lund-Mackay scoring system for assessing the severity of sinus disease. These systems enhance the consistency of radiological reporting and assist in surgical planning.[10]

Functional Endoscopic Sinus Surgery (FESS) is the preferred treatment for patients with CRS who do not respond to medical therapy. Successful surgical outcomes depend heavily on a thorough preoperative assessment of sinonasal anatomy, particularly the identification of anatomical variations that may increase surgical difficulty or risk. Failure to recognize these variations can result in serious complications such as orbital injury, cerebrospinal fluid leakage, or damage to the optic nerve.[11]

Computed tomography (CT) of the paranasal sinuses is considered the gold standard imaging modality for evaluating sinonasal anatomy and disease extent. Multidetector computed tomography (MDCT), in particular, provides high-resolution images with excellent visualization of bony structures, sinus aeration, and drainage pathways. Multiplanar reconstructions, especially in coronal and sagittal planes, closely resemble the surgical perspective, making MDCT indispensable in preoperative planning for FESS.[12] The radiologist plays a pivotal role in identifying anatomical variants, mapping critical structures, and guiding surgeons through detailed preoperative assessment.[13]

Despite its clinical importance, there is limited Indian literature comprehensively evaluating the prevalence of sinonasal anatomical variants in patients with chronic sinusitis using MDCT. A systematic assessment of these variations is essential to improve diagnostic accuracy, optimize surgical planning, and minimize intraoperative complications.[14] This study aimed to

determine the prevalence of various anatomical variants of the nasal cavity and paranasal sinuses using multidetector computed tomography among patients presenting with chronic sinusitis.

2. MATERIALS AND METHODS

2.1 Study Design

This study was designed as a hospital-based, observational cross-sectional analytical study aimed at assessing the prevalence of anatomical variants of the nasal cavity and paranasal sinuses among patients with chronic sinusitis. A cross-sectional framework was appropriate because the objective was to evaluate the distribution of anatomical variations and their association with disease at a single point in time rather than establishing causality or longitudinal outcomes. The analytical component allowed for exploration of associations between anatomical variants and clinical or radiological features of chronic sinusitis.

2.2 Study Setting

The study was conducted in the Department of Radiodiagnosis at Sree Balaji Medical College and Hospital, a tertiary care teaching institution located in Chennai. The institution caters to a large and diverse patient population, ensuring an adequate case mix of patients presenting with sinonasal complaints. All imaging procedures and data collection were carried out within this department using standardized protocols.

2.3 Study Duration

The study was carried out over a period of 18 months, from June 2024 to January 2026. This duration was chosen to ensure sufficient patient recruitment, representation across different seasons (which may influence sinonasal disease patterns), and adequate time for data collection, analysis, and validation.

2.4 Study Population

The study population consisted of adult patients presenting with sinonasal symptoms who were referred from the ENT outpatient department to the radiology department for computed tomography (CT) evaluation of the paranasal sinuses. Only those patients who fulfilled the predefined eligibility criteria and provided informed consent were included. This ensured that the study population was clinically relevant and representative of patients undergoing routine diagnostic evaluation for chronic sinusitis.

2.5 Inclusion Criteria

Patients were included based on clinical, radiological, and demographic criteria. Clinically, individuals presenting with symptoms suggestive of chronic sinusitis—such as nasal obstruction, facial pain or pressure, and rhinorrhea persisting for at least 12 weeks were considered eligible. Radiologically, inclusion required evidence of chronic sinusitis on CT imaging, including features such as mucosal thickening, sinus opacification, intrasinus calcifications, sinus polyps, or sclerosis of the sinus bony walls. Demographically, the study included both male and female patients aged above 18 years, ensuring a non-gender-specific adult population.

2.6 Exclusion Criteria

Patients were excluded if they had conditions that could confound the assessment of normal anatomical variants. These included a history of facial trauma that might alter sinonasal anatomy, prior sinonasal surgeries such as functional endoscopic sinus surgery (FESS) or rhinoplasty, and known or suspected neoplasms of the paranasal sinuses. Additionally, individuals below 18 years of age were excluded to avoid variability due to incomplete sinus development. Pregnant women were also excluded due to concerns regarding radiation exposure from CT imaging.

2.7 Sample Size Calculation

The sample size was calculated using the standard formula:

$$n = (Z^2\alpha/2 \times p \times (1 - p)) / d^2$$

Where n represents the required sample size, $Z\alpha/2$ is the standard normal deviate at a 95% confidence level (1.96), p is the expected prevalence of anatomical variations (assumed to be 30% or 0.30), and d is the allowable error (7–8%). Based on these

parameters, the calculated sample size ranged between 126 and 165 participants. Considering feasibility, resource constraints, and the study duration, a final sample size of 150 patients was selected and enrolled.

2.8 Sampling Method

A consecutive non-probability sampling technique was employed. All eligible patients presenting during the study period were sequentially recruited until the desired sample size was achieved. While this approach is practical in clinical settings, it does introduce potential selection bias, which should be acknowledged when interpreting the results.

2.9 Study Tools and Equipment

The primary imaging modality used in this study was multidetector computed tomography (MDCT) of the paranasal sinuses, performed using a Siemens Pioneer 32-slice CT scanner equipped with advanced image reconstruction software. Supporting infrastructure included a Picture Archiving and Communication System (PACS) for image storage, retrieval, and analysis. Data collection was facilitated using a structured proforma, and informed consent forms were provided in both English and Tamil to ensure patient comprehension.

2.10 Imaging Protocol

All patients underwent CT scanning following a standardized protocol. Written informed consent was obtained prior to imaging, and a detailed clinical history was recorded. Scans were performed using a non-contrast technique with the patient in a supine position and the head in neutral alignment. Both axial and coronal images were acquired. The scanning parameters included a tube voltage of 120 kVp, tube current ranging from 100 to 150 mA, slice thickness between 0.6 and 1.25 mm, and reconstruction intervals of 0.5 to 1.0 mm.

Image interpretation was carried out systematically using PACS. Both bone and soft tissue window settings were utilized to ensure comprehensive evaluation of sinonasal structures. Multiplanar reconstructions, including coronal and sagittal views, were generated when necessary to better delineate anatomical details and variants.

2.11 Data Collection

Patient recruitment involved identification from ENT outpatient referrals, followed by systematic screening using inclusion and exclusion criteria. Eligible patients were enrolled after obtaining written informed consent and assigned unique study identification numbers.

Clinical data collected included demographic details such as age, gender, and occupation, along with symptom duration, severity, prior treatments, and associated comorbidities. Imaging data collection involved a detailed and systematic evaluation of anatomical variants using a standardized reporting format. Findings were correlated with clinical presentation wherever applicable. To ensure data reliability and minimize observer bias, all imaging interpretations were reviewed and validated by a senior radiologist.

2.12 Data Analysis

Statistical analysis was performed using IBM SPSS Statistics version 28.0. Categorical variables were expressed as frequencies and percentages, while continuous variables were summarized using mean and standard deviation. The prevalence of each anatomical variant was calculated individually.

Inferential statistical tests were applied to assess associations and differences. The Chi-square test was used for evaluating relationships between categorical variables. The independent t-test was used to compare means between two groups, while analysis of variance (ANOVA) was employed for comparisons involving more than two groups. Fisher's exact test was applied when expected cell counts were small. A p-value of less than 0.05 was considered statistically significant.

2.13 Ethical Considerations

The study was conducted following approval from the Institutional Human Ethics Committee of Sree Balaji Medical College and Hospital (002/SBMCH/IHEC/2024/2198). All participants provided written informed consent prior to inclusion. Confidentiality of patient information was strictly maintained, and all procedures adhered to ethical principles governing biomedical research involving human participants.

3. RESULTS AND DISCUSSION

3.1 Basic Characteristics of Study Participants

Table 1: Demographic and Clinical Characteristics among the study participants (n = 150)

Variable	Category	n (%)
Age Group (years)	18–30	32 (21.3%)
	31–45	58 (38.7%)
	46–60	40 (26.7%)
	>60	20 (13.3%)
Gender	Male	82 (54.7%)
	Female	68 (45.3%)
Duration of Symptoms	≤24 weeks	48 (32.0%)
	>24 weeks	102 (68.0%)
Severity of CRS	Mild	59 (39.3%)
	Moderate	47 (31.3%)
	Severe	44 (29.3%)

Among 150 patients, the majority were in the 31–45 years age group (58; 38.7%), followed by 46–60 years (40; 26.7%). Males constituted 82 (54.7%) and females 68 (45.3%). Most patients had prolonged symptoms beyond 24 weeks (102; 68.0%), indicating chronic disease burden. Mild CRS was most common (59; 39.3%), with moderate (47; 31.3%) and severe (44; 29.3%) cases also substantially represented.

Table 2: Clinical Symptom Profile among the study participants (n = 150)

Symptom	Present n (%)	Absent n (%)
Nasal Obstruction	150 (100.0%)	0 (0.0%)
Rhinorrhea	150 (100.0%)	0 (0.0%)
Facial Pain	78 (52.0%)	72 (48.0%)
Post-nasal Drip	53 (35.3%)	97 (64.7%)

Nasal obstruction and rhinorrhea were present in all patients (150; 100%), making them universal symptoms. Facial pain was reported in 78 patients (52.0%), while post-nasal drip was seen in 53 patients (35.3%). This shows that while nasal symptoms are consistent, other symptoms vary considerably across patients.

3.2 Radiological Characteristics

Table 3: Radiological Features of Chronic Sinusitis among the study participants (n = 150)

CT Finding	Present n (%)	Absent n (%)
Mucosal Thickening	150 (100.0%)	0 (0.0%)
Sinus Opacification	150 (100.0%)	0 (0.0%)

Sclerosis of Bony Wall	38 (25.3%)	112 (74.7%)
Sinus Polyps	7 (4.7%)	143 (95.3%)
Intrasinus Calcification	0 (0.0%)	150 (100.0%)

Mucosal thickening and sinus opacification were present in all patients (150; 100%), confirming them as hallmark CT features of CRS. Bony wall sclerosis was observed in 38 patients (25.3%), suggesting chronic inflammatory changes. Sinus polyps were relatively rare (7; 4.7%), and no cases of intrasinus calcification were identified.

Table 4: Distribution of Sinus Involvement among the study participants (n = 150)

Sinus Involvement	**n (%)**
Maxillary + Ethmoid	90 (60.0%)
Maxillary only	20 (13.3%)
Maxillary + Ethmoid + Frontal	15 (10.0%)
Pansinusitis	10 (6.7%)
Ethmoid only	10 (6.7%)
Sphenoid involvement	5 (3.3%)

The most common involvement was maxillary and ethmoid sinuses (90; 60.0%), indicating dominance of osteomeatal complex pathology. Isolated maxillary sinus involvement occurred in 20 patients (13.3%), while pansinusitis and ethmoid-only disease were each seen in 10 patients (6.7%). Sphenoid sinus involvement was least common (5; 3.3%).

Table 5: Prevalence of Key Anatomical Variants among the study participants (n = 150)

Anatomical Variant	**Present n (%)**	**Absent n (%)**
Deviated Nasal Septum (DNS)	81 (54.0%)	69 (46.0%)
Paradoxical Middle Turbinate	79 (52.7%)	71 (47.3%)
Agger Nasi Cells	79 (52.7%)	71 (47.3%)
Haller Cells	77 (51.3%)	73 (48.7%)
Concha Bullosa	76 (50.7%)	74 (49.3%)
Accessory Maxillary Ostium	55 (36.7%)	95 (63.3%)
Maxillary Hypoplasia	47 (31.3%)	103 (68.7%)
Uncinate Process Pneumatization	45 (30.0%)	105 (70.0%)
Maxillary Sinus Septation	44 (29.3%)	106 (70.7%)

Anatomical variants were highly prevalent in the study population. Deviated nasal septum was the most common variant (81; 54.0%), followed closely by paradoxical middle turbinate and agger nasi cells (each 79; 52.7%). Haller cells (77; 51.3%) and concha bullosa (76; 50.7%) were also frequently observed. Less common variants included accessory maxillary ostium (55; 36.7%), maxillary hypoplasia (47; 31.3%), uncinate process pneumatization (45; 30.0%), and maxillary sinus septation (44; 29.3%).

Table 6: Association Between Sinonasal Anatomical Variants and Chronic Rhinosinusitis Severity (Chi-square Analysis, n = 150)

Anatomical Variant	Mild (n=59) n (%)	Moderate (n=47) n (%)	Severe (n=44) n (%)	χ^2 (df=2)	p-value
DNS	33 (55.9%)	24 (51.1%)	24 (54.5%)	2.00	0.368
Agger Nasi Cell	31 (52.5%)	24 (51.1%)	24 (54.5%)	0.43	0.806
Concha Bullosa	30 (50.8%)	23 (48.9%)	23 (52.3%)	1.02	0.601
Haller Cell	27 (45.8%)	26 (55.3%)	24 (54.5%)	2.57	0.277
Frontal Cells/Bullae	25 (42.4%)	27 (57.4%)	24 (54.5%)	3.50	0.174
Maxillary Septation	14 (23.7%)	16 (34.0%)	14 (31.8%)	3.74	0.155
Maxillary Hypoplasia	16 (27.1%)	17 (36.2%)	14 (31.8%)	2.49	0.287
Accessory Ostium	22 (37.3%)	18 (38.3%)	15 (34.1%)	0.48	0.786
Uncinate Pneumatization	18 (30.5%)	14 (29.8%)	13 (29.5%)	0.01	0.994
Paradoxical MT	30 (50.8%)	24 (51.1%)	25 (56.8%)	1.38	0.503

The distribution of anatomical variants across mild, moderate, and severe chronic sinusitis showed no statistically significant differences. For example, deviated nasal septum (DNS) was present in 33 (55.9%) mild, 24 (51.1%) moderate, and 24 (54.5%) severe cases ($\chi^2 = 2.00$, $p = 0.368$). Similarly, concha bullosa ($p = 0.601$), agger nasi cells ($p = 0.806$), and Haller cells ($p = 0.277$) showed comparable distributions across severity groups. Even variants that appeared slightly higher in moderate or severe disease, such as frontal cells (57.4% in moderate group), failed to reach statistical significance ($p = 0.174$). Overall, all p-values were >0.05, indicating no significant association between anatomical variants and disease severity.

Table 7: Comparison of Age and Symptom Duration Across Chronic Rhinosinusitis Severity Groups (Kruskal–Wallis Test, n = 150)

Variable	Mild (n=59) Median (IQR)	Moderate (n=47) Median (IQR)	Severe (n=44) Median (IQR)	H-statistic	p-value
Age (years)	43.0 (30–52)	40.0 (31–51)	47.5 (34–56)	3.845	0.146
Duration (weeks)	33 (22–43)	33 (23–43)	31 (22–43)	0.715	0.700

There was no statistically significant difference in age distribution across severity groups ($H = 3.845$, $p = 0.146$). Although the severe group had a slightly higher median age of 47.5 years compared to mild (43.0 years) and moderate (40.0 years), this difference was not significant. Similarly, duration of symptoms showed minimal variation, with median values of 33 weeks in mild and moderate groups and 31 weeks in severe cases ($H = 0.715$, $p = 0.700$). These findings indicate that neither age nor symptom duration significantly influenced disease severity.

3.3 Association parameters

Table 8: Association Between Sinonasal Anatomical Variants and Gender Distribution (Chi-square Analysis, n = 150)

Anatomical Variant	Male (n=82) n (%)	Female (n=68) n (%)	χ^2	p-value
DNS	41 (50.0%)	40 (58.8%)	0.000	1.000
Agger Nasi Cell	44 (53.7%)	35 (51.5%)	0.186	0.666
Concha Bullosa	39 (47.6%)	37 (54.4%)	0.999	0.318
Haller Cell	42 (51.2%)	35 (51.5%)	0.000	1.000
Frontal Cells/Bullae	38 (46.3%)	38 (55.9%)	0.939	0.333
Accessory Ostium	28 (34.1%)	27 (39.7%)	0.686	0.408
Maxillary Hypoplasia	22 (26.8%)	25 (36.8%)	1.275	0.259
Uncinate Pneumatization	25 (30.5%)	20 (29.4%)	0.001	0.971
Maxillary Septation	24 (29.3%)	20 (29.4%)	0.040	0.842
Paradoxical MT	43 (52.4%)	36 (52.9%)	0.011	0.918

No statistically significant association was found between gender and any anatomical variant. Deviated nasal septum (DNS) was present in 41 males (50.0%) and 40 females (58.8%) ($\chi^2 = 0.000$, $p = 1.000$), indicating identical distribution. Similarly, agger nasi cells (53.7% vs. 51.5%, $p = 0.666$), concha bullosa (47.6% vs. 54.4%, $p = 0.318$), and Haller cells (51.2% vs. 51.5%, $p = 1.000$) showed no gender-based differences. All other variants also demonstrated p-values >0.05, confirming that anatomical variations were independent of gender in this study population.

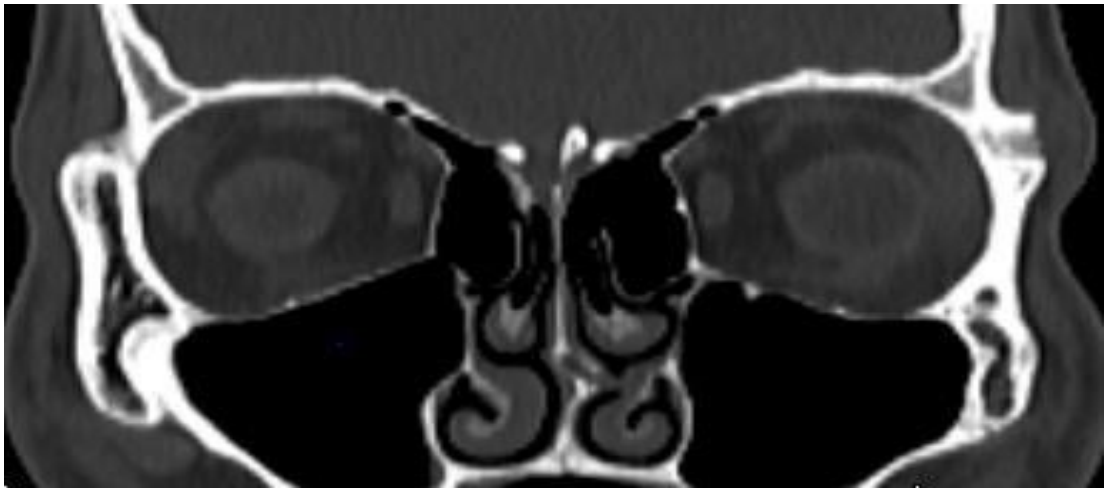

Figure 1: Deviated nasal septum towards the left with ipsilateral bony spur at the base (Mladina type - V).

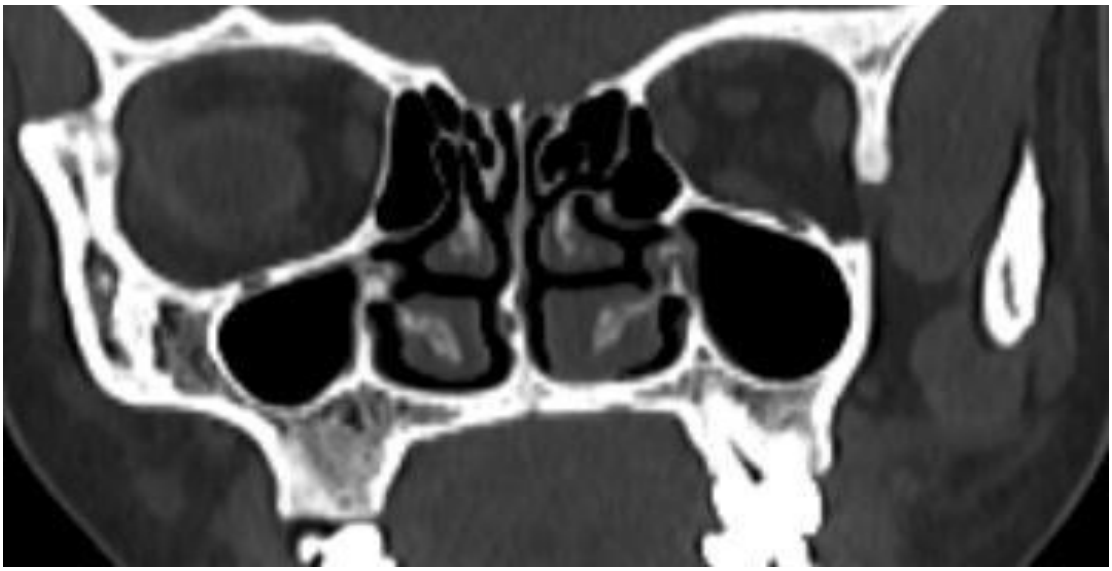

Figure 2: Mild deviated nasal septum towards the right in the form of septal ridge not affecting nasal valve function (Mladina type - I).

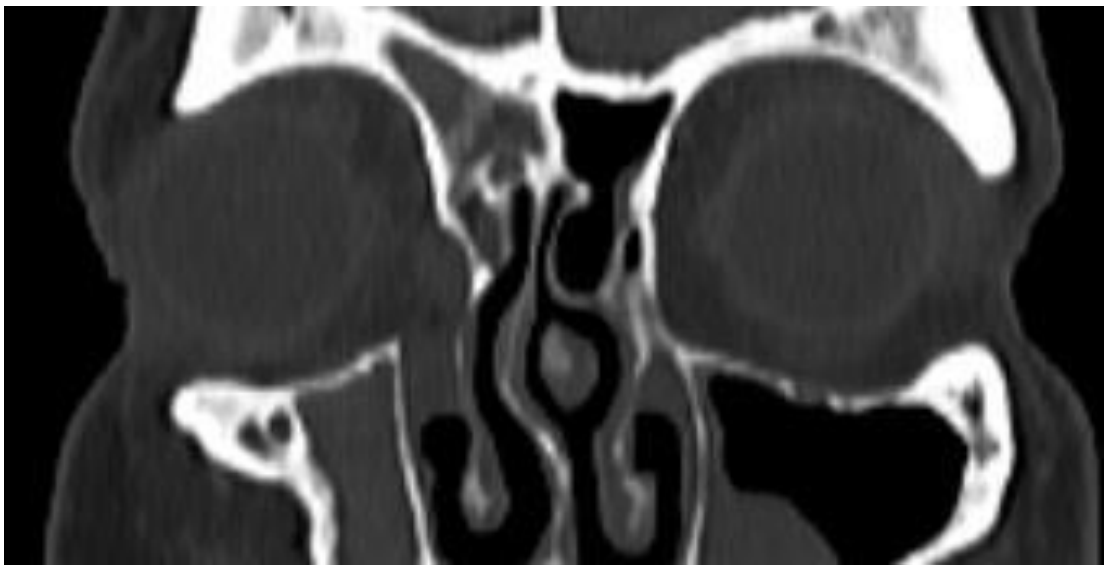

Figure 3: "S"- shaped deviated nasal septum (Mladina type – IV).

The figures illustrate representative patterns of deviated nasal septum (DNS) based on the Mladina classification. Figure 1 demonstrates a left-sided septal deviation associated with an ipsilateral bony spur at the base, consistent with Mladina type V, which is often considered more structurally significant due to its potential to compromise airflow. Figure 2 shows a mild right-sided septal deviation presenting as a septal ridge without significant impact on the nasal valve area, corresponding to Mladina type I, typically regarded as a minor variant. Figure 3 depicts an "S"-shaped septal deviation involving both sides of the nasal septum, classified as Mladina type IV, representing a complex deformity that may variably affect nasal airflow depending on its extent and orientation.

3.4 DISCUSSION

CRS remains a highly prevalent condition in otorhinolaryngological practice, with MDCT serving as the cornerstone for its evaluation and preoperative planning. The present study was conducted to determine the prevalence of sinonasal anatomical variants in patients with CRS and to evaluate their association with disease severity and demographic factors.

The demographic profile of the study population demonstrated a mean age of 42.9 ± 13.4 years, with a slight male predominance (54.7%). These findings are consistent with previous studies, including those by Bhattacharyya and Maru and Gupta, which reported that CRS predominantly affects the working-age population with a modest male preponderance.[6,13] The mean duration of symptoms was 32.8 ± 11.7 weeks, indicating chronic disease persistence. However, the Kruskal–Wallis analysis revealed no statistically significant association between age or duration of symptoms and disease severity ($p > 0.05$), suggesting that CRS severity is influenced by a complex interplay of factors beyond simple temporal progression.

Radiologically, mucosal thickening and sinus opacification were present in all patients (100%), reinforcing their status as hallmark features of CRS. Similar findings have been reported in multiple CT-based studies, where these features form the basis of radiological diagnosis.[12,13] Sclerosis of the sinus walls (25.3%) reflected chronic inflammatory changes, while sinus polyps were relatively uncommon (4.7%), indicating that the majority of patients belonged to the non-polypoid CRS subtype.

The pattern of sinus involvement revealed a predominance of maxillary and ethmoid sinus disease (60%), highlighting the central role of the osteomeatal complex in CRS pathophysiology. These findings align with Zinreich et al. and Kantarci et al., who demonstrated that obstruction at the osteomeatal complex is strongly associated with anterior ethmoid and maxillary sinus disease.[10,14]

Among anatomical variants, deviated nasal septum (DNS) emerged as the most common finding (54.0%), followed closely by paradoxical middle turbinate, agger nasi cells, Haller cells, and concha bullosa, each with a prevalence of approximately 50%. This high prevalence is consistent with both Indian and international literature. Bolger et al. identified DNS as the most frequent variant, while Indian studies by Maru and Gupta and Verma et al. reported similar findings.[13,15] However, despite their high prevalence, none of these variants demonstrated a statistically significant association with disease severity.

The absence of significant associations between anatomical variants and CRS severity is a key finding of this study. For instance, DNS showed comparable distribution across mild (55.9%), moderate (51.1%), and severe (54.5%) cases ($p = 0.368$). Similar non-significant patterns were observed for concha bullosa ($p = 0.601$), agger nasi cells ($p = 0.806$), and Haller cells ($p = 0.277$). These findings are in agreement with Calhoun et al. and Danese et al., who emphasized that anatomical variants alone are insufficient to cause CRS and act primarily as contributory factors in the presence of mucosal inflammation.[16]

Paradoxical middle turbinate and agger nasi cells were present in 52.7% of patients, but again showed no significant association with disease severity or gender. This supports the concept that these variants are clinically relevant only when they significantly alter airflow or drainage pathways, particularly in conjunction with inflammatory changes.[10,17] Similarly, Haller cells, despite their anatomical proximity to the maxillary ostium, did not demonstrate a significant correlation with disease severity ($p = 0.277$), reinforcing that their impact depends on size and associated mucosal pathology.[7]

Concha bullosa was observed in 50.7% of patients, with equal distribution of lamellar and bulbous types. Although previous studies have suggested a stronger association between bulbous concha bullosa and osteomeatal obstruction, the present study did not demonstrate a statistically significant relationship with disease severity ($p = 0.601$), in line with findings from Calhoun et al. and Stallman et al.[16,18]

Other variants, including accessory maxillary ostium (36.7%), maxillary hypoplasia (31.3%), uncinate process pneumatization (30.0%), and maxillary sinus septation (29.3%), also showed no significant association with severity or gender. These findings further support the multifactorial nature of CRS, where structural variants alone are insufficient to determine disease burden.[3,19]

Gender-based analysis also revealed no statistically significant differences in the prevalence of any anatomical variant (all $p > 0.05$). This is consistent with previous studies indicating that sinonasal anatomical variations are independent of sex.[7] The Keros classification revealed Type II as the most common configuration (70%), followed by Type I (20%) and Type III (10%). This distribution is consistent with Indian and international studies, including Singh et al., and underscores the importance of preoperative evaluation of skull base anatomy to minimize surgical complications.[20]

The overall findings of this study reinforce the concept that CRS is a multifactorial disease, where anatomical variants act as predisposing rather than causative factors. The lack of significant associations between variants and disease severity highlights the dominant role of mucosal inflammation, environmental exposures, and host immune responses in disease progression.

This study has few limitations. Being a single-center, cross-sectional study, the findings may not be generalizable to the broader population. The absence of a control group limits the ability to establish causal relationships between anatomical variants and CRS. Additionally, lack of intraoperative endoscopic correlation restricts validation of radiological findings. Variability in CT interpretation and absence of interobserver agreement assessment may also introduce bias.

Despite these limitations, the study has important clinical implications. The high prevalence of anatomical variants underscores the necessity of detailed MDCT evaluation prior to functional endoscopic sinus surgery (FESS). Although these variants are not independently associated with disease severity, their identification is critical for surgical planning and avoidance of complications. A structured radiological reporting approach, as suggested by O'Brien et al., can enhance surgical safety.[19] Future multicentric prospective studies with larger sample sizes and inclusion of control groups are required to better delineate the role of anatomical variants in CRS pathogenesis.

4. CONCLUSION

The present study demonstrated a high prevalence of sinonasal anatomical variants among patients with chronic rhinosinusitis, with deviated nasal septum, concha bullosa, agger nasi cells, and Haller cells being the most common findings. Despite their frequent occurrence, none of the anatomical variants showed a statistically significant association with disease severity, gender, or clinical parameters such as age and duration of symptoms. These findings indicate that while anatomical variations may contribute to altered sinonasal drainage and predispose to disease, they do not independently determine the severity of chronic rhinosinusitis. Multidetector computed tomography remains an essential tool for comprehensive evaluation and preoperative mapping, enabling identification of clinically relevant variants and potential surgical risk factors. The results reinforce the multifactorial nature of chronic rhinosinusitis, where anatomical, inflammatory, and environmental factors interact, emphasizing the need for a holistic approach to diagnosis and management.

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AUTHOR CONTRIBUTIONS

Harsh Kushwaha: Conceptualization, Investigation, Data Curation, Formal Analysis, Writing—Original Draft. **G. Murugan:** Conceptualization, Methodology, Supervision, Validation, Writing—Review & Editing.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

ETHICS STATEMENT

The study was conducted following approval from the Institutional Human Ethics Committee of Sree Balaji Medical College and Hospital (002/SBMCH/IHEC/2024/2198)

DATA AVAILABILITY STATEMENT

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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