International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

Anatomical Variations of Paranasal Sinuses and Their Association with Microbial Etiology and Ophthalmic Manifestations in Chronic Rhinosinusitis: A Prospective Correlation Study

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Received: 21-05-2026
Accepted: 06-06-2026
Available online:30-06-2026

ABSTRACT

Background: Chronic rhinosinusitis (CRS) is a common inflammatory disorder of the paranasal sinuses and nasal cavity that significantly affects quality of life. Anatomical variations of the sinonasal region may impair mucociliary clearance, leading to obstruction of the osteomeatal complex, persistent inflammation, secondary microbial colonization, and, in some cases, ophthalmic complications. Computed tomography (CT) remains the gold standard for evaluating these anatomical variations and disease extent.

Objectives: To evaluate anatomical variations of the paranasal sinuses on CT and determine their association with microbial etiology and ophthalmic manifestations in patients with chronic rhinosinusitis.

Materials and Methods: A prospective observational study was conducted among **65 patients** clinically diagnosed with chronic rhinosinusitis at a tertiary care hospital. All patients underwent CT evaluation of the paranasal sinuses, microbiological examination of sinus specimens, and ophthalmological assessment. The association between anatomical variations, microbial growth, and ophthalmic manifestations was analyzed using the Chi-square test, with $p<0.05$ considered statistically significant.

Results: Among 65 patients, males constituted **56.9%** and females **43.1%**. Deviated nasal septum (**64.6%**) was the commonest anatomical variation, followed by concha bullosa (**36.9%**). The maxillary sinus was the most frequently involved sinus (**86.2%**). Positive microbial culture was obtained in **8 (12.3%)** patients, with *Staphylococcus aureus* being the predominant isolate. Ophthalmic manifestations were observed in **40.0%** of patients, with periorbital edema being the most common finding. Significant associations were observed between anatomical variations and microbial culture positivity ($p=0.041$) as well as ophthalmic manifestations ($p=0.018$).

Conclusion: Sinonasal anatomical variations are common in chronic rhinosinusitis and are significantly associated with microbial infection and ophthalmic manifestations. Early CT evaluation facilitates identification of high-risk patients and assists in appropriate clinical management.

Keywords*:Chronic rhinosinusitis, Computed tomography, Anatomical variations, Microbiology, Ophthalmic manifestations, Paranasal sinuses.*

INTRODUCTION

Chronic rhinosinusitis (CRS) is a chronic inflammatory disorder involving the mucosa of the nose and paranasal sinuses that persists for **12 weeks or longer** despite appropriate medical therapy. It is one of the most common diseases encountered in otorhinolaryngology practice and contributes substantially to healthcare expenditure, work absenteeism, and impaired

quality of life. Patients commonly present with nasal obstruction, nasal discharge, facial pain or pressure, headache, postnasal drip, and reduction or loss of smell. The disease affects approximately **5–12%** of the adult population worldwide, making it a major public health concern.[1–3]

The development of chronic rhinosinusitis is multifactorial and involves a complex interaction between host immunity, environmental exposures, microbial colonization, allergy, mucociliary dysfunction, and anatomical abnormalities of the sinonasal cavity. Among these factors, anatomical variations of the paranasal sinuses have received considerable attention because they may compromise the drainage pathways of the osteomeatal complex and predispose patients to persistent inflammation and recurrent infection.[4–6]

The osteomeatal complex serves as the principal drainage pathway for the frontal, maxillary, and anterior ethmoid sinuses. Even minor anatomical alterations such as a deviated nasal septum, concha bullosa, paradoxical middle turbinate, Haller cells, Aggernasi cells, Onodi cells, or a pneumatizeduncinate process can narrow this region and impair mucociliary clearance. Such obstruction promotes mucus retention, hypoxia within the sinus cavity, chronic mucosal edema, and secondary bacterial or fungal colonization.[7–9]

Computed tomography (CT) of the paranasal sinuses is regarded as the imaging modality of choice for evaluating chronic rhinosinusitis because it provides excellent visualization of both osseous anatomy and mucosal disease. CT accurately identifies anatomical variations, determines the extent of sinus involvement, and guides functional endoscopic sinus surgery by delineating important anatomical landmarks and their relationship to adjacent structures. Detailed preoperative CT assessment minimizes surgical complications and improves patient outcomes.[10–12]

Microbial infection also contributes to the persistence and exacerbation of chronic rhinosinusitis. Common bacterial pathogens include *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Streptococcus pneumoniae*, and *Klebsiellapneumoniae*, while fungal organisms may occasionally be isolated in selected patients. However, chronic rhinosinusitis is not always associated with positive microbial cultures because previous antibiotic use, biofilm formation, and chronic inflammatory changes may reduce culture yield.[13–1

Because of the close anatomical relationship between the paranasal sinuses and the orbit, untreated or severe chronic rhinosinusitis may extend into orbital structures and produce ophthalmic manifestations. Patients may present with periorbitaledema, epiphora, orbital pain, diplopia, blurred vision, proptosis, or, rarely, vision-threatening orbital cellulitis. Anatomical variations adjacent to the orbit, particularly Haller cells and Onodi cells, may further increase the risk of orbital involvement. Early identification of these variations is therefore essential for preventing serious complications.[16–1

Despite numerous studies evaluating sinonasal anatomical variations, limited data are available regarding their simultaneous association with microbial etiology and ophthalmic manifestations in Indian patients with chronic rhinosinusitis. Therefore, the present prospective study was undertaken to evaluate CT-detected anatomical variations of the paranasal sinuses and determine their correlation with microbial profile and ophthalmic manifestations among patients with chronic rhinosinusitis attending a tertiary care hospital.

MATERIALS AND METHODS

Study Design

This prospective observational, hospital-based correlation study was conducted to evaluate the association between anatomical variations of the paranasal sinuses, microbial etiology, and ophthalmic manifestations in patients diagnosed with chronic rhinosinusitis.

Study Duration

The study was conducted over a period of **18 months**.

Study Setting

The study was carried out in the Departments of **Radiodiagnosis, Otorhinolaryngology (ENT), Microbiology, and Ophthalmology** of a **tertiary care teaching hospital**. Patients attending the ENT outpatient department and those admitted for evaluation and management of chronic rhinosinusitis were included.

Study Population

A total of **65 consecutive patients** fulfilling the diagnostic criteria for chronic rhinosinusitis were enrolled after obtaining written informed consent.

Sample Size

The study included **65 patients** who met the eligibility criteria during the study period.

Inclusion Criteria

1. Patients aged **18 years and above**.
2. Patients clinically diagnosed with chronic rhinosinusitis according to accepted diagnostic criteria, with symptoms persisting for **12 weeks or longer**.
3. Patients willing to undergo CT scan of the paranasal sinuses.
4. Patients willing to provide microbiological specimens for culture whenever indicated.
5. Patients providing written informed consent.

Exclusion Criteria

1. Patients with acute rhinosinusitis.
2. Previous sinonasal surgery.
3. Sinonasal malignancy.
4. Facial trauma involving the paranasal sinuses.
5. Congenital craniofacial anomalies.
6. Immunocompromised patients.
7. Patients unwilling to participate.

Study Methodology

After obtaining informed consent, detailed demographic and clinical information was recorded using a structured proforma. Clinical history included nasal obstruction, nasal discharge, facial pain, headache, postnasal drip, anosmia/hyposmia, and ophthalmic complaints.

All patients underwent complete ENT examination followed by **computed tomography (CT) of the paranasal sinuses** using thin-section axial images with coronal and sagittal reconstructions.

The following anatomical variations were specifically evaluated:

- Deviated nasal septum
- Concha bullosa
- Aggernasi cells
- Haller cells
- Onodi cells
- Septal spur
- Pneumatizeduncinate process
- Paradoxical middle turbinate

The extent of sinus involvement involving the maxillary, ethmoid, frontal, and sphenoid sinuses was documented.

Whenever feasible, sinus secretions or aspirates were collected under aseptic precautions before initiation of antimicrobial therapy and processed in the Department of Microbiology. Samples were subjected to Gram staining, potassium hydroxide preparation when fungal infection was suspected, and inoculated onto Blood agar, MacConkey agar, and Sabouraud dextrose agar using standard microbiological techniques. Organisms were identified by conventional biochemical methods.

Patients with ocular complaints underwent detailed ophthalmological evaluation, including assessment for periorbital edema, orbital pain, epiphora, diplopia, blurred vision, proptosis, and visual acuity.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using **SPSS version 26.0**. Continuous variables were expressed as mean ± standard deviation, whereas categorical variables were expressed as frequencies and percentages. Associations between anatomical variations, microbial culture positivity, and ophthalmic manifestations were evaluated using the **Chi-square test** or Fisher's exact test whenever appropriate. A **p-value <0.05** was considered statistically significant.

RESULTS

A total of **65 patients** with clinically diagnosed chronic rhinosinusitis were included in the study. The mean age was **36.8 ± 12.4 years**, with a male predominance (**56.9%**). The most common presenting symptoms were **nasal obstruction (89.2%)**, followed by **nasal discharge (83.1%)**, **facial pain (73.8%)**, and **headache (69.2%)**. CT evaluation revealed **deviated nasal septum (64.6%)** as the most common anatomical variation, followed by **concha bullosa (36.9%)** and **Aggernasi cells (32.3%)**. The **maxillary sinus (86.2%)** was the most frequently involved sinus. Microbiological culture was positive in **8 patients (12.3%)**, with ***Staphylococcus aureus*** being the predominant isolate. Ophthalmic manifestations were observed in **26 patients (40.0%)**, most commonly **periorbitaledema (18.5%)**. A statistically significant association

was observed between anatomical variations and microbial culture positivity (**p = 0.041**) as well as ophthalmic manifestations (**p = 0.018**).

Table 1. Demographic Characteristics of the Study Population (n = 65)

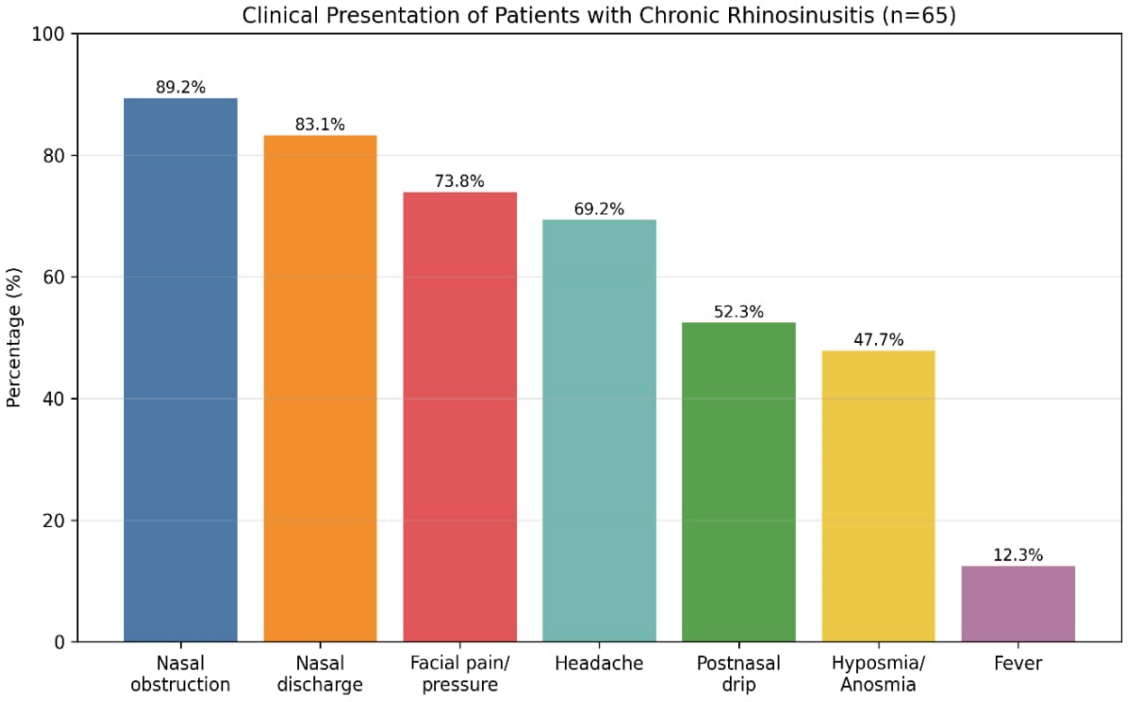
Variable	Number (n)	Percentage (%)
Age Group (years)		
18–30	20	30.8
31–40	19	29.2
41–50	14	21.5
>50	12	18.5
Gender		
Male	37	56.9
Female	28	43.1

Among the 65 patients included in the study, the largest proportion belonged to the **18–30 years** age group (**20 patients; 30.8%**), followed by **31–40 years** (**29.2%**). Patients aged **41–50 years** accounted for **21.5%**, while **18.5%** were older than 50 years. The mean age of the study population was **36.8 ± 12.4 years**. There was a slight male predominance, with **37 males (56.9%)** and **28 females (43.1%)**, giving a male-to-female ratio of approximately **1.3:1**.

Table 2. Clinical Presentation of Patients with Chronic Rhinosinusitis (n = 65)

Clinical Feature	Number (n)	Percentage (%)
Nasal obstruction	58	89.2
Nasal discharge	54	83.1
Facial pain/pressure	48	73.8
Headache	45	69.2
Postnasal drip	34	52.3
Hyposmia/Anosmia	31	47.7
Fever	8	12.3

Nasal obstruction was the most common presenting complaint and was observed in **58 patients (89.2%)**, followed by nasal discharge in **54 patients (83.1%)**. Facial pain or facial pressure was reported by **48 patients (73.8%)**, whereas **45 patients (69.2%)** complained of headache. Postnasal drip and reduced sense of smell were noted in **52.3%** and **47.7%** of patients, respectively. Fever was uncommon and was present in only **12.3%** of cases, suggesting that most patients had chronic rather than acute infective disease.



Graph 1: Clinical Presentation of Patients with Chronic Rhinosinusitis (n = 65)

Table 3. CT Evaluation of Anatomical Variations of the Paranasal Sinuses (n = 65)

Anatomical Variation	Number (n)	Percentage (%)

Deviated nasal septum	42	64.6
Concha bullosa	24	36.9
Aggernasi cells	21	32.3
Septal spur	18	27.7
Haller cells	11	16.9
Paradoxical middle turbinate	10	15.4
Onodi cells	8	12.3
Pneumatizeduncinate process	6	9.2

Computed tomography revealed that **deviated nasal septum (DNS)** was the most common anatomical variation, detected in **42 patients (64.6%)**. **Concha bullosa** was the second most frequent variation and was identified in **24 patients (36.9%)**, followed by **Aggernasi cells** in **21 patients (32.3%)**. Septal spur was observed in **18 patients (27.7%)**, whereas **Haller cells**, **paradoxical middle turbinate**, **Onodi cells**, and **pneumatizeduncinate process** were identified in **16.9%**, **15.4%**, **12.3%**, and **9.2%** of patients, respectively. Overall, the majority of patients demonstrated one or more anatomical variations that could potentially contribute to impaired sinus drainage and persistence of chronic rhinosinusitis.

Table 4. Distribution of Sinus Involvement on Computed Tomography (CT) (n = 65)

Sinus Involved	Number (n)	Percentage (%)
Maxillary sinus	56	86.2
Ethmoid sinus	48	73.8
Frontal sinus	30	46.2
Sphenoid sinus	18	27.7
Pansinusitis	15	23.1

CT examination demonstrated that the **maxillary sinus** was the most commonly affected sinus, with involvement in **56 patients (86.2%)**, followed by the **ethmoid sinus** in **48 patients (73.8%)**. Frontal sinus disease was present in **30 patients (46.2%)**, while sphenoid sinus involvement was comparatively less frequent and was observed in **18 patients (27.7%)**. **Pansinusitis**, characterized by simultaneous involvement of all paranasal sinuses, was identified in **15 patients (23.1%)**. These findings indicate that maxillary and ethmoidal sinuses are the principal sites of disease in chronic rhinosinusitis.

Table 5. Microbial Profile of Sinus Specimens (n = 65)

Microorganism	Number (n)	Percentage (%)
Staphylococcus aureus	3	4.6
Pseudomonas aeruginosa	2	3.1
Klebsiellapneumoniae	1	1.5
Streptococcus pneumoniae	1	1.5
Aspergillus spp.	1	1.5
No microbial growth	**57**	**87.7**
Total	**65**	**100.0**

Microbiological culture of sinus specimens yielded **positive growth in only 8 patients (12.3%)**, whereas **57 patients (87.7%)** demonstrated no microbial growth. Among the positive cultures, ***Staphylococcus aureus*** was the most frequently isolated organism, accounting for **3 cases (4.6%)**. ***Pseudomonas aeruginosa*** was isolated in **2 patients (3.1%)**, while ***Klebsiellapneumoniae***, ***Streptococcus pneumoniae***, and ***Aspergillus* species** were isolated from **one patient each (1.5%)**. The low culture positivity observed in this study may be attributable to prior antibiotic therapy, biofilm formation, or the chronic inflammatory nature of the disease.

Table 6. Ophthalmic Manifestations among Patients with Chronic Rhinosinusitis (n = 65)

Ophthalmic Manifestation	Number (n)	Percentage (%)
Periorbital edema	12	18.5
Epiphora	10	15.4
Orbital pain	8	12.3
Blurred vision	6	9.2
Diplopia	3	4.6
Proptosis	2	3.1
No ophthalmic manifestation	39	60.0

Ophthalmic manifestations were identified in **26 patients (40.0%)**, while **39 patients (60.0%)** had no ocular involvement. The most frequent ophthalmic manifestation was **periorbital edema**, occurring in **12 patients (18.5%)**, followed by **epiphora** in **10 patients (15.4%)** and **orbital pain** in **8 patients (12.3%)**. Less common manifestations included **blurred**

vision (9.2%), **diplopia (4.6%)**, and **proptosis (3.1%)**. These findings suggest that although severe orbital complications were uncommon, a substantial proportion of patients experienced ocular symptoms associated with chronic rhinosinusitis.

Table 7. Association Between Anatomical Variations and Microbial Culture Positivity (n = 65)

Anatomical Variation	Culture Positive (n=8)	Culture Negative (n=57)	Total	p-value
Present	8	44	52	0.041*
Absent	0	13	13	
Total	**8**	**57**	**65**	

Chi-square test; statistically significant ($p < 0.05$).

Among the **52 patients with one or more anatomical variations**, **8 (15.4%)** showed positive microbial culture, whereas **44 (84.6%)** had sterile cultures. None of the **13 patients without anatomical variations** demonstrated microbial growth. Statistical analysis revealed a **significant association between anatomical variations and microbial culture positivity ($p = 0.041$)**, suggesting that structural abnormalities of the sinonasal cavity may predispose patients to persistent microbial colonization or infection.

Table 8. Association Between Anatomical Variations and Ophthalmic Manifestations (n = 65)

Anatomical Variation	Ophthalmic Manifestations Present	Ophthalmic Manifestations Absent	Total	p-value
Present	24	28	52	0.018*
Absent	2	11	13	
Total	**26**	**39**	**65**	

Chi-square test; statistically significant ($p < 0.05$).

Among patients with anatomical variations, **24 of 52 (46.2%)** had ophthalmic manifestations compared with only **2 of 13 (15.4%)** patients without anatomical variations. Statistical analysis demonstrated a **significant association ($p = 0.018$)**, indicating that anatomical variations increase the likelihood of orbital or ocular manifestations in chronic rhinosinusitis.

Table 9. Association of Individual Anatomical Variations with Ophthalmic Manifestations

Anatomical Variation	Total Cases (n)	Cases with Ophthalmic Manifestations	Percentage (%)	p-value
Deviated nasal septum	42	18	42.9	0.029*
Concha bullosa	24	12	50.0	0.021*
Aggernasi cells	21	9	42.9	0.081
Haller cells	11	7	63.6	0.012*
Onodi cells	8	5	62.5	0.034*
Paradoxical middle turbinate	10	4	40.0	0.192
Septal spur	18	7	38.9	0.264
Pneumatizeduncinate process	6	2	33.3	0.411

Statistically significant ($p < 0.05$).

Analysis of individual anatomical variations revealed that **Haller cells (63.6%)** and **Onodi cells (62.5%)** showed the highest frequency of ophthalmic manifestations. Significant associations were also observed for **deviated nasal septum** and **concha bullosa**. In contrast, aggernasi cells, paradoxical middle turbinate, septal spur, and pneumatizeduncinate process did not show statistically significant associations with ophthalmic involvement. These findings suggest that anatomical variations located adjacent to the orbit may have greater clinical relevance in the development of ocular complications.

Table 10. Overall Summary of Study Findings (n = 65)

Parameter	Number (n)	Percentage (%)
Patients with anatomical variations	52	80.0
Patients without anatomical variations	13	20.0
Positive microbial culture	8	12.3
No microbial growth	57	87.7
Patients with ophthalmic manifestations	26	40.0
Patients without ophthalmic manifestations	39	60.0
Maxillary sinus involvement	56	86.2
Deviated nasal septum	42	64.6

The present study demonstrated that **80%** of patients with chronic rhinosinusitis had at least one anatomical variation on CT evaluation, with **deviated nasal septum** being the most common abnormality. Although microbiological culture positivity was relatively low (**12.3%**), positive cultures were significantly associated with the presence of anatomical variations. Ophthalmic manifestations were observed in **40%** of patients and occurred significantly more frequently among those with anatomical variations, particularly **Haller cells**, **Onodi cells**, **concha bullosa**, and **deviated nasal septum**. Overall, these findings indicate that CT-detected anatomical variations are important predictors of disease severity and ocular involvement in patients with chronic rhinosinusitis.

A total of **65 patients** with chronic rhinosinusitis were evaluated. Young adults were the most commonly affected group, with a slight male predominance. Nasal obstruction and nasal discharge were the leading presenting symptoms. CT imaging revealed that anatomical variations were present in four out of five patients, with **deviated nasal septum** and **concha bullosa** being the predominant findings. The maxillary sinus was the most frequently involved sinus. Microbial culture was positive in only **8 patients (12.3%)**, with ***Staphylococcus aureus*** being the most commonly isolated organism. Ophthalmic manifestations occurred in **40%** of patients, most commonly as periorbital edema and epiphora. Significant associations were observed between anatomical variations and both microbial culture positivity and ophthalmic manifestations, supporting the role of sinonasal anatomical abnormalities in the pathogenesis and clinical severity of chronic rhinosinusitis.

DISCUSSION

Chronic rhinosinusitis is a multifactorial inflammatory disorder in which obstruction of the osteomeatal complex plays a central role in disease development and persistence. Anatomical variations within the sinonasal cavity may narrow the drainage pathways, impair mucociliary clearance, promote secretion retention, and facilitate chronic inflammation and microbial colonization.[1–9]

In the present study, the majority of patients belonged to the younger adult age group, with a mean age of 36.8 years and a slight male predominance. Similar demographic observations have been reported by Fokkenset al.[1] and Orlandi et al.[2], who described chronic rhinosinusitis as a disease affecting predominantly the economically productive age group. Our findings are also consistent with recent CT-based studies that demonstrated a comparable age distribution among patients with chronic rhinosinusitis.

Nasal obstruction was the most common presenting complaint in our study, followed by nasal discharge, facial pain, and headache. These findings correlate well with previous studies by Rosenfeld et al.[3] and Brook,[13] who emphasized that obstruction of the sinonasal drainage pathway remains the principal mechanism responsible for persistent symptoms in chronic rhinosinusitis.

Computed tomography remains the imaging modality of choice for evaluating chronic rhinosinusitis because of its excellent visualization of both mucosal disease and bony anatomical variations.[10–12] In our study, **deviated nasal septum (64.6%)** was the commonest anatomical variation, followed by **concha bullosa (36.9%)** and **Aggernasi cells (32.3%)**. These observations are remarkably similar to those reported by Bolger et al.,[5] Kantarci et al.,[10] and Perez-Pinas et al.[11], all of whom identified deviated nasal septum as the predominant anatomical variation associated with chronic rhinosinusitis. Our findings also agree with recent investigations published during **2024 and 2025**, which demonstrated that deviated nasal septum and concha bullosa remain the two most prevalent anatomical variations among patients with chronic rhinosinusitis. Recent CT-based studies have reaffirmed the importance of identifying these variations before functional endoscopic sinus surgery because they significantly influence disease severity and surgical planning.

The maxillary sinus was the most frequently involved sinus in our study (86.2%), followed by the ethmoid sinus. Similar findings have been reported in both classical and recent literature, where maxillary sinus disease represents the predominant radiological abnormality in chronic rhinosinusitis. The present study demonstrated that **deviated nasal septum (64.6%)** was the most frequent anatomical variation, followed by **concha bullosa (36.9%)**, **Aggernasi cells (32.3%)**, and **septal spur (27.7%)**. These findings are consistent with the observations of Bolger et al.[5], Perez-Pinas et al.[11], and Kaygusuz et al.[12], who also identified deviated nasal septum as the most common anatomical variation among patients with chronic rhinosinusitis. These anatomical abnormalities alter the normal airflow pattern within the nasal cavity and compromise mucociliary clearance, thereby increasing the likelihood of persistent inflammation and obstruction of the osteomeatal complex. Similar findings have been confirmed by recent CT-based investigations published in **2024 and 2025**, which reported that deviated nasal septum and concha bullosa are the predominant anatomical variations associated with chronic rhinosinusitis. The present study also demonstrated that the **maxillary sinus (86.2%)** was the most commonly affected sinus, followed by the **ethmoid sinus (73.8%)**. This observation is in agreement with Zinreich[6] and Kennedy[9], who reported that maxillary and anterior ethmoid sinuses are particularly vulnerable because their drainage pathways converge at the osteomeatal complex. More recent CT studies have similarly shown that maxillary sinus disease remains the predominant radiological finding in patients with chronic rhinosinusitis.

Unlike many microbiological studies that have reported relatively high bacterial isolation rates, the present study demonstrated **positive microbial growth in only 8 patients (12.3%)**. The most frequently isolated organism was ***Staphylococcus aureus***, followed by ***Pseudomonas aeruginosa***. This comparatively low culture positivity may be explained by previous antibiotic administration before sample collection, the presence of bacterial biofilms, chronic inflammatory mucosal changes, or inadequate viable bacterial load in long-standing disease. Brook[13] and Psaltis and Wormald[15] similarly emphasized that conventional culture techniques frequently underestimate microbial persistence in chronic rhinosinusitis because bacteria often survive within biofilms that are difficult to culture using routine laboratory methods.

A statistically significant association was observed between anatomical variations and microbial culture positivity (**p = 0.041**). All culture-positive patients demonstrated one or more sinonasal anatomical variations. These findings support the hypothesis that structural abnormalities facilitate stagnation of secretions, impaired sinus ventilation, and microbial colonization. Similar observations have recently been reported in CT-based studies evaluating chronic rhinosinusitis, where patients with anatomical variations exhibited significantly higher rates of sinus infection and mucosal disease.

Ophthalmic manifestations were identified in **40.0%** of patients in the present study. **Periorbital edema** was the commonest manifestation, followed by **epiphora**, **orbital pain**, **blurred vision**, **diplopia**, and **proptosis**. These findings are comparable with those reported by Chandler et al.[16] and Lee and Yen[17], who described periorbital edema as the earliest and most frequent orbital manifestation resulting from inflammatory spread from the ethmoid sinuses.

A significant association was observed between sinonasal anatomical variations and ophthalmic manifestations (**p = 0.018**). Among the individual anatomical variations, **Haller cells** and **Onodi cells** demonstrated the strongest relationship with ocular symptoms. Anatomically, Haller cells narrow the infraorbital portion of the osteomeatal complex, whereas Onodi cells are closely related to the optic nerve and sphenoid sinus. Consequently, inflammatory disease involving these structures may increase the likelihood of orbital symptoms and surgical complications. Previous anatomical studies have reported similar findings and emphasized the importance of identifying these variations before functional endoscopic sinus surgery.[10],[11] Recent CT studies published during **2024–2025** have likewise highlighted the clinical significance of Haller and Onodi cells during preoperative planning.

Sarkar D, Kapadia K, Umraniya YN, and Likhiya DS conducted a cross-sectional study titled **"Anatomical Variations of the Sinonasal Region in Patients with Chronic Rhinosinusitis"** involving **145 patients with chronic rhinosinusitis (CRS)**. All patients underwent diagnostic nasal endoscopy (DNE) and non-contrast CT of the nose and paranasal sinuses. On CT, **deviated nasal septum (DNS)** was the most frequent anatomical variation, observed in **82.76%** of patients, followed by **agger nasi cells (68.97%)**, inferior turbinate hypertrophy (32.41%), and **concha bullosa (26.21%)**. Haller cells and Onodi cells were observed in 8.97% and 6.90%, respectively. DNE demonstrated DNS in 86.21% and concha bullosa in 25.52%. The authors reported a significant association between DNS, concha bullosa and CRS and concluded that combined CT and DNE evaluation is important before functional endoscopic sinus surgery (FESS) for accurate anatomical assessment and reduction of surgical complications.[19]

Yurevych NO, Varzhapetian SD, Buniatian KhA, Khotimska YV, Sukhina IS, Kuzmenko NM, Trach OO and Alekseeva VV conducted a **retrospective cross-sectional CT-based study of 75 patients with chronic rhinosinusitis** to determine the prevalence of sinonasal anatomical variations. CT scans were evaluated for concha bullosa, deviated nasal septum, agger nasi cells, Haller cells, Onodi cells, uncinate process variations and paradoxical middle turbinate. **Concha bullosa was the most common variation (64%)**, followed by **deviated nasal septum (61.3%)**, agger nasi cells (49.3%), Haller cells (32%), Onodi cells (21.3%), uncinate process variations (17.3%) and paradoxical middle turbinate (12%). Interestingly, **84% of patients had more than one anatomical variation**. The authors concluded that anatomical variations are common among CRS patients and that CT evaluation is essential for identifying these abnormalities and planning appropriate surgical treatment[20].

Subbiah N, Bakshi SS, Arumugam S and Ghoshal JA performed a **retrospective CT-based study of 75 patients aged 25–70 years** to assess the prevalence and clinical significance of anatomical variations of the paranasal sinuses. **Nasal septal deviation was the most common variation, present in 50 patients (66.6%)**, followed by hypertrophic ethmoidal bulla in 35 patients (46.6%) and concha bullosa in 30 patients (40%). Agger nasi cells were found in 26.6%, Haller cells in 20%, and Onodi cells in 13% of patients. Among sinus diseases, **maxillary sinusitis was most common (80%)**, followed by frontal sinusitis (60%), ethmoidal sinusitis (40%) and sphenoid sinusitis (10.6%). Significant associations were observed between **DNS, concha bullosa and maxillary sinusitis; agger nasi cells and frontal/ethmoid sinusitis; Haller cells and**

maxillary sinusitis; and Onodi cells and sphenoid sinusitis. The study emphasized that recognition of these variations on CT is important for understanding CRS and for safe preoperative planning[21]

Computed tomography proved invaluable in identifying both disease extent and anatomical variations in the present study. CT not only demonstrated mucosal pathology but also accurately delineated surgically important landmarks, allowing better assessment of disease severity and potential complications. The role of CT in preoperative planning has been emphasized by Stammberger and Kennedy, Kennedy, and several contemporary investigators. Recent studies continue to reinforce that multidetector CT remains the imaging modality of choice for evaluating chronic rhinosinusitis because it accurately depicts sinonasal anatomy and improves surgical safety. The findings of the present study have important clinical implications. Early recognition of anatomical variations enables clinicians to identify patients who are at increased risk of persistent disease, recurrent infection, and orbital complications. Appropriate radiological evaluation combined with microbiological assessment facilitates individualized treatment planning and may reduce unnecessary antibiotic use while improving surgical outcomes. These observations are supported by the latest literature emphasizing CT-based risk stratification and individualized management of chronic rhinosinusitis. Although the present study included a relatively small number of patients from a single tertiary care centre, it provides a comprehensive correlation between CT-detected anatomical variations, microbiological findings, and ophthalmic manifestations. Future multicentre studies with larger sample sizes, molecular microbiological techniques, and long-term postoperative follow-up would further clarify the role of anatomical variations in the pathogenesis and prognosis of chronic rhinosinusitis. Advances reported in **2026** also suggest that emerging imaging technologies and artificial intelligence may further improve preoperative assessment and personalized management of chronic rhinosinusitis.

DECLARATIONS:
Conflicts of interest: The authors declare that there are no conflicts of interest.
Consent to participate: Written informed consent was obtained from all participants**.**
Consent for publication: Consent for publication was obtained.
Authors' contributions: All authors contributed equally to the study and approved the final manuscript.

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