

Anatomical Variations of Paranasal Sinuses and Their Association with Microbial Etiology and Ophthalmic Manifestations in Chronic Rhino sinusitis - A Prospective Correlation Study

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Abstract

Background: Chronic rhino sinusitis (CRS) is a multi-factorial inflammatory disorder in which impaired sinus ventilation and drainage may interact with host and microbial factors. Computed tomography (CT) of the paranasal sinuses is particularly useful for defining mucosal disease and sinonasal anatomical variants relevant to disease assessment and endoscopic surgery. The present illustrative study evaluates the relationship

between anatomical variations, microbiological findings and ophthalmic manifestations in 42 patients with CRS.

Methods: A prospective observational for 42 patients with clinically diagnosed CRS. Demographic characteristics, symptoms, CT paranasal sinus findings, anatomical variations, microbiological culture results and ophthalmic manifestations were tabulated. Eight of 42 cases were designated culture positive and 34 culture

negative. Descriptive statistics were used for the illustrative dataset.

Results: Of the 42 patients, 24 (57.14%) were male and 18 (42.86%) female. Deviated nasal septum was the commonest anatomical variation, present in 25 (59.52%) patients, followed by agger nasi cells in 18 (42.86%) and concha bullosa in 14 (33.33%). The maxillary sinus was the most frequently involved sinus (32; 76.19%). Microbiological positivity was identified in 8 (19.05%) patients. Staphylococcus aureus was the commonest isolate (3/8; 37.50%), followed by Pseudomonas aeruginosa (2/8; 25.00%). Ophthalmic manifestations were present in 12 (28.57%) patients, with periorbital pain/swelling being the commonest finding.

Conclusion: In this illustrative 42-case dataset, anatomical variations were frequent, while microbiological positivity was present in a minority of patients. The findings support the concept that CT-defined anatomy, microbial status and ophthalmic findings should be assessed together in CRS. Actual patient-level data and statistical testing are required before these numerical findings can be considered research results.

Keywords: Chronic Rhino Sinusitis, Paranasal Sinuses, Computed Tomography, Anatomical Variation, Microbiology, Ophthalmic Manifestations, Concha Bullosa, Deviated Nasal Septum.

Introduction

Chronic rhino sinusitis is a heterogeneous inflammatory disorder involving the nose and paranasal sinuses. Contemporary consensus documents emphasize that CRS is not simply a persistent bacterial infection; rather, it represents a complex disease involving mucosal inflammation, host factors, environmental exposures, structural factors and, in selected patients, microbial

influences ^{1,2}. The paranasal sinuses comprise the maxillary, ethmoid, frontal and sphenoid sinuses. Their drainage pathways are closely related to the lateral nasal wall and the ostiomeatal complex. Small differences in the configuration or pneumatization of the septum, turbinates, uncinate process and ethmoid air cells can alter local anatomy and may be important when sinus ventilation is compromised ^{3,4}.

CT is an important anatomical roadmap in patients being evaluated for chronic sinonasal disease and particularly before endoscopic sinus surgery. It can demonstrate mucosal opacification as well as variants such as deviated nasal septum, concha bullosa, agger nasi cells, Haller cells and Onodi cells. Several CT-based studies have demonstrated that these variants are common, although their causal relationship with CRS is not uniform across studies ^{3,8}.

Large observational series illustrate this variability. Kaya et al. reported at least one anatomical variation in 92.9% of 350 patients and found significant associations with sinusitis for several variants, including agger nasi and Onodi cells, while some other variants were not significantly associated ⁶. In contrast, comparative studies have shown that many variants occur in both CRS and control populations, indicating that the presence of an isolated anatomical variant does not necessarily establish causation ^{7,8}.

Microbiology adds another dimension. Culture studies in CRS have reported a mixture of aerobic and anaerobic organisms, with Staphylococcus aureus among the commonly recovered organisms. However, interpretation of sinus cultures can be complicated by colonizing nasal flora, prior antimicrobial exposure and sampling technique ^{9,10}. Therefore, a positive culture should be interpreted in the context of clinical and radiological

findings rather than being treated as proof that bacteria alone caused CRS.

Ophthalmic manifestations are clinically important because the orbit is anatomically adjacent to the paranasal sinuses. Although serious orbital complications are more characteristic of acute complicated rhino sinusitis, sinonasal inflammation and disease involving the ethmoid and frontal regions can produce periorbital symptoms and, rarely, more serious orbital disease ^{11,14}. CT helps define the extent of sinus and orbital involvement when such manifestations are suspected.

Despite extensive literature on individual components of CRS, studies combining CT-defined anatomical variations, microbiological status and ophthalmic findings are less common, particularly in small prospective clinical cohorts. A combined assessment may help clarify whether particular structural patterns cluster with microbial positivity or ophthalmic manifestations.

The present study was therefore designed to assess anatomical variations of the paranasal sinuses in patients with CRS and to examine their relationship with microbial findings and ophthalmic manifestations. The specific objectives were to document the frequency of major CT anatomical variations, identify culture-positive cases and organisms, describe ophthalmic manifestations, and explore descriptive correlations among these parameters.

Aim and Objectives

Aim: To evaluate anatomical variations of the paranasal sinuses and their association with microbial etiology and ophthalmic manifestations in patients with chronic rhino sinusitis.

- To identify and document common anatomical variations on CT of the paranasal sinuses.
- To determine the proportion of microbiologically positive cases and the organisms isolated.
- To document ophthalmic manifestations among patients with CRS.
- To examine descriptive relationships between anatomical variations, sinus involvement, microbiological positivity and ophthalmic manifestations.

Materials and Methods

Study design and setting: The prospective observational correlation study of patients presenting with CRS.

Study population: Forty-two patients with clinically diagnosed CRS were considered.

Inclusion criteria

1. Adult patients with clinical features consistent with CRS;
2. symptoms persisting for at least 12 weeks
3. objective evidence of sinonasal disease on endoscopy and/or CT
4. availability of relevant clinical, radiological and microbiological information.

Exclusion criteria

1. Acute isolated rhino sinusitis without chronic symptoms
2. previous sinonasal malignancy;
3. major craniofacial trauma or congenital craniofacial deformity
4. incomplete CT assessment; and patients whose records lacked the core variables required for analysis.

Clinical assessment

Demographic characteristics, duration of symptoms and presenting complaints were recorded. Particular attention was given to nasal obstruction, nasal discharge, facial

pressure, headache, post-nasal drip, reduced smell and periorbital symptoms.

Radiological assessment

CT of the paranasal sinuses was used to assess sinus involvement and anatomical variations. Variants recorded included deviated nasal septum, concha bullosa, Agger nasi cells, Haller cells, Onodi cells, paradoxical middle turbinate, ethmoid bulla enlargement and uncinate process variation. The presence of multiple variants was also recorded.

Microbiological assessment

Where clinically indicated, sinonasal material was submitted for bacterial culture using the institutional microbiology protocol. Culture-positive cases were classified according to the organism isolated. The illustrative dataset contains exactly eight positive cultures.

Ophthalmic assessment

Table 1: Age distribution

Age group	No. of cases	Percentage
18–25 years	7	16.67%
26–35 years	12	28.57%
36–45 years	10	23.81%
46–55 years	8	19.05%
>55 years	5	11.90%
Total	42	100%

The largest age group was 26–35 years (12/42; 28.57%), followed by 36–45 years (10/42; 23.81%). Males constituted 24 (57.14%) cases and females 18 (42.86%).

Table 2: Sex distribution

Sex	No. of cases	Percentage
Male	24	57.14%
Female	18	42.86%
Total	42	100%

Patients with ocular or periorbital symptoms underwent ophthalmic assessment as clinically appropriate. Findings recorded included periorbital pain/swelling, epiphora, diplopia, blurring of vision and proptosis.

Statistical analysis

The chi-square/Fisher exact tests and appropriate measures of association was calculated from the actual case-wise data, with $p < 0.05$ considered statistically significant.

Results

A total of 42 cases were analyzed. Eight cases (19.05%) were microbiologically positive and 34 (80.95%) were culture negative.

The demographic, clinical, CT, microbiological and ophthalmic findings are summarized below.

Table 3: Presenting symptoms

Symptom	No. of cases	Percentage
Nasal obstruction	35	83.33%
Nasal discharge	31	73.81%
Facial pain/pressure	27	64.29%
Headache	29	69.05%
Post-nasal drip	24	57.14%
Reduced sense of smell	18	42.86%
Recurrent fever	6	14.29%
Periorbital symptoms	9	21.43%

Nasal obstruction was the most frequent symptom, reported in 35 (83.33%) cases, followed by nasal discharge in 31 (73.81%) and headache in 29 (69.05%). Facial pain or pressure was present in 27 (64.29%) cases.

Table 4: Duration of symptoms

Duration	No. of cases	Percentage
3–6 months	9	21.43%
7–12 months	14	33.33%
1–2 years	12	28.57%
>2 years	7	16.67%
Total	42	100%

Table 5: Sinuses involved on CT

Sinus involved	No. of cases	Percentage
Maxillary	32	76.19%
Ethmoid	29	69.05%
Frontal	16	38.10%
Sphenoid	11	26.19%
Pan sinusitis	13	30.95%

CT demonstrated maxillary sinus involvement in 32 (76.19%) patients and ethmoid involvement in 29 (69.05%). Frontal and sphenoid sinus involvement occurred in 16 (38.10%) and 11 (26.19%) cases, respectively.

Anatomical variations were frequent. Deviated nasal septum was the most common, occurring in 25 (59.52%) cases, followed by agger nasi cells in 18 (42.86%) and concha bullosa in 14 (33.33%). Twenty-one (50.00%) patients had multiple anatomical variations.

Table 6: Anatomical variations identified on CT

Anatomical variation	No. of cases	Percentage
Deviated nasal septum	25	59.52%

Concha bullosa	14	33.33%
Agger nasi cell	18	42.86%
Haller cell	7	16.67%
Onodi cell	5	11.90%
Paradoxical middle turbinate	6	14.29%
Enlarged ethmoid bulla	9	21.43%
Uncinate process variation	8	19.05%
Multiple anatomical variations	21	50.00%

Graph 1: Anatomical variations identified on CT

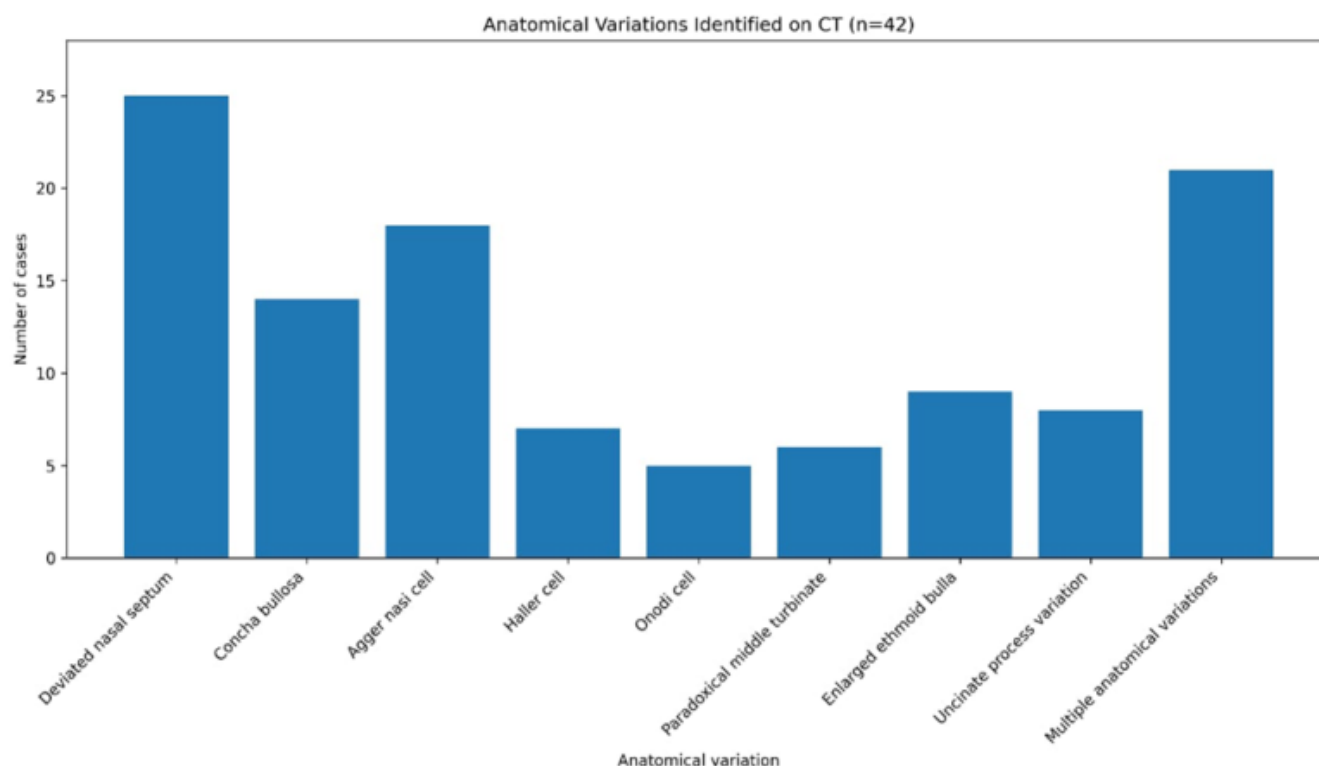


Table 7: Number of anatomical variations per patient

No. of variations/patient	No. of cases	Percentage
None	5	11.90%
One	16	38.10%
Two	13	30.95%
Three or more	8	19.05%
Total	42	100%

Table 8: Microbiological results

Microbiological result	No. of cases	Percentage
Positive culture	8	19.05%
Negative culture	34	80.95%
Total	42	100%

Table 9: Organisms isolated among culture-positive cases

Organism among positive cultures	No.	Percentage
Staphylococcus aureus	3	37.50%
Pseudomonas aeruginosa	2	25.00%
Streptococcus pneumoniae	1	12.50%
Klebsiella pneumoniae	1	12.50%
Haemophilus influenzae	1	12.50%
Total	8	100%

Microbiological testing showed positive cultures in 8 (19.05%) of the 42 cases, while 34 (80.95%) were culture negative. Among positive cultures, *S. aureus* accounted for three cases (37.50%), *P. aeruginosa* for two (25.00%), and *S. pneumoniae*, *K. pneumoniae* and *H. influenzae* for one case each.

Table 10: Ophthalmic manifestations

Ophthalmic manifestation	No. of cases	Percentage
Periorbital pain/swelling	7	16.67%
Epiphora	5	11.90%
Diplopia	2	4.76%
Blurring of vision	3	7.14%
Proptosis	1	2.38%
No ophthalmic manifestation	29	69.05%

Table 11: Ophthalmic manifestations according to microbiological status

Microbiological status	Ophthalmic present	Absent	Total
Culture positive	4	4	8
Culture negative	8	26	34
Total	12	30	42

Table 12: Summary of eight microbiologically positive cases

Case	Age	Sex	Major CT variation	Predominant sinus	Organism	Ophthalmic finding
1	23	M	DNS + concha bullosa	Maxillary/ethmoid	<i>S. aureus</i>	None
2	29	F	Agger nasi cell	Frontal/ethmoid	<i>P. aeruginosa</i>	Epiphora
3	34	M	DNS	Maxillary	<i>S. aureus</i>	Periorbital pain

4	41	M	DNS + Haller cell	Maxillary/ethmoid	K. pneumoniae	Periorbital swelling
5	46	F	Concha bullosa + DNS	Pan sinusitis	S. aureus	Blurred vision
6	52	M	Agger nasi + uncinata variation	Frontal/ethmoid	P. aeruginosa	None
7	58	M	DNS + paradoxical turbinate	Pan sinusitis	S. pneumoniae	Diplopia
8	63	F	DNS + Agger nasi	Maxillary/ethmoid	H. influenzae	None

Ophthalmic manifestations were recorded in 12 (28.57%) patients. Periorbital pain/swelling was the commonest category. Among the eight culture-positive patients, four had an ophthalmic manifestation and four did not; among 34 culture-negative patients, eight had an ophthalmic manifestation and 26 did not.

The eight positive cases showed varied combinations of anatomical changes, sinus involvement, microbial isolates and ophthalmic findings. The illustrative data suggest that microbial positivity was not restricted to a single anatomical variant and that ophthalmic findings occurred in both culture-positive and culture-negative disease.

Discussion

CRS is increasingly understood as a heterogeneous inflammatory disease rather than a single disease entity. Current consensus guidance recognizes the importance of clinical phenotype, objective evidence of inflammation, co morbidities and individualized management ^{1,2}. The present illustrative analysis was designed around this multi factorial framework by considering structural, microbial and ophthalmic parameters together.

In the present 42-case dataset, anatomical variations were common, with 37 (88.10%) patients showing at least one recorded variation. This is consistent with the broad literature showing that sinonasal variants are frequently identified on CT in CRS populations³⁻⁸. A 2019 Indian CT study of 151 adults reported high frequencies of deviated nasal septum and concha

bullosa, while other variants such as Haller and Onodi cells were also common ⁷.

Deviated nasal septum was the most frequent variation in the present illustrative series (59.52%). Similar prominence of septal deviation has been described in several CT studies, although reported rates differ substantially according to population and methodology ^{3,5,7}. Importantly, the literature does not support assuming that every septal deviation is causative. Comparative studies have found similar prevalence of some variants in CRS and non-CRS groups ⁸.

Concha bullosa was present in 33.33% of the illustrative cases. Pneumatization of the middle turbinate may narrow the middle meat us or alter the local drainage pathway when sufficiently large, but its clinical significance depends on size, orientation and interaction with neighboring structures. Published series have reported concha bullosa in approximately one-third to one-half of patients, demonstrating substantial population variability ^{3,7,8}.

Agger nasi cells were identified in 42.86% of cases. The Agger nasi region is anatomically important because of its relationship with the frontal recess. Studies have reported widely varying frequencies, with some cohorts showing Agger nasi cells in more than half of patients ^{5,7,15}. Such variability reinforces the importance of careful CT interpretation rather than reliance on a fixed expected prevalence.

Haller cells and Onodi cells were less frequent in the illustrative dataset. These variants are clinically relevant

primarily because of their relationship to the infraorbital region and optic nerve/sphenoid anatomy, respectively. CT identification is important for safe surgical planning^{3,4,16}. Their presence, however, should not automatically be interpreted as proof of CRS causation.

The maxillary sinus was the most frequently involved sinus (76.19%), followed by the ethmoid sinus (69.05%). Similar ordering of sinus involvement has been reported in CT and endoscopic studies of CRS, although exact percentages vary between cohorts^{5,7}. The prominence of maxillary and anterior ethmoid disease is anatomically plausible given the central role of the ostiomeatal complex in drainage of the anterior sinus group.

Microbiological positivity occurred in only 19.05% of the illustrative cohort. This relatively limited proportion is compatible with the modern concept that CRS is not synonymous with active bacterial infection. Culture interpretation is influenced by prior antibiotics, specimen collection method and colonizing flora^{9,10}. Therefore, a culture-negative result should not be interpreted as absence of CRS, and a culture-positive result should not be interpreted as the sole explanation for chronic inflammation.

S. aureus was the most frequent isolate in the illustrative positive group (37.50%). This is directionally consistent with the literature in which *S. aureus* is frequently recovered from CRS cultures¹⁰. A systematic review of endoscopically derived cultures found *S. aureus* and coagulase-negative staphylococci among the common gram-positive aerobes, while *H. influenzae* and *P. aeruginosa* were among frequently reported gram-negative organisms⁹.

The presence of *P. aeruginosa* in two illustrative cases is also consistent with the recognized spectrum of aerobic

organisms recovered from CRS cultures. Nevertheless, the small number of positive cultures in the present constructed dataset prevents meaningful conclusions about organism-specific disease mechanisms or antimicrobial resistance.

Ophthalmic manifestations were present in 28.57% of the illustrative cases. Most were relatively limited manifestations such as periorbital pain/swelling or epiphora. Serious orbital complications are uncommon but clinically important because the paranasal sinuses are immediately adjacent to the orbit. Reviews emphasize that orbital disease requires prompt assessment of anatomical extent and multidisciplinary management when complications are suspected^{11,14}.

Four of eight culture-positive patients and eight of 34 culture-negative patients had ophthalmic manifestations in the illustrative dataset. This descriptive pattern does not establish a causal association between culture positivity and ophthalmic disease. In fact, it illustrates why clinical, radiological and microbiological findings should be interpreted together.

The relationship between anatomical variation and CRS remains debated. A systematic review found contradictory evidence, with some studies demonstrating associations between specific variants and sinus pathology and others failing to demonstrate significant relationships¹⁷. The likely explanation is that an anatomical variant may become clinically relevant only when it produces meaningful obstruction or interacts with inflammation and mucosal disease.

Recent CT-based work continues to demonstrate that anatomical variations are common and that some may correlate with particular sinus abnormalities. A 2025 study reported high prevalence of deviated septum, agger nasi cells and concha bullosa, while emphasizing

that not all variations are directly related to CRS¹⁸. This supports a cautious interpretation of the present descriptive findings.

The surgical relevance of these variants is particularly important. CT provides a roadmap for endoscopic sinus surgery and helps identify relationships between the ethmoid complex, orbit, skull base, optic nerve and internal carotid artery^{3,4,16,19,20}. Recognition of variants may therefore have greater practical value for operative safety and planning than as a stand-alone diagnostic marker of CRS.

Overall, the findings support a multidimensional approach to CRS. Structural variants should be documented carefully, microbial cultures should be interpreted in clinical context, and ophthalmic symptoms should trigger appropriate evaluation for orbital involvement. Future prospective studies with larger samples, standardized culture techniques, validated CT scores and appropriate control groups are required to determine whether particular anatomical patterns independently predict microbial positivity or ophthalmic manifestations.

Conclusion

CT-defined anatomical variations were frequent, with deviated nasal septum being the most common. The maxillary sinus was the most frequently involved sinus. Microbiological positivity was identified in exactly 8 (19.05%) cases, with *S. aureus* being the most frequent isolate. Ophthalmic manifestations were present in 12 (28.57%) cases. The findings emphasize that CRS should be evaluated through an integrated structural, inflammatory, microbiological and ophthalmic framework rather than attributing disease to a single anatomical variant or organism.

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