Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol. 7 No. 2 (2026): June 2026 Issue
https://doi.org/10.51168/10d9qg02
Original Article

Clinical and Radiological Correlation of Anatomical Variations of the Nose and Paranasal Sinuses in Patients with Chronic Rhinosinusitis: A Retrospective Observational Study.

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ABSTRACT

Background

Chronic rhinosinusitis (CRS) is a common inflammatory disorder of the nose and paranasal sinuses. Sinonasal anatomical variations may impair sinus drainage and mucociliary clearance. Computed tomography (CT) is essential for identifying these variations and assessing disease severity.

Materials and Methods

This retrospective observational study included 100 patients with CRS who underwent diagnostic nasal endoscopy and CT at Kalinga Institute of Medical Sciences, Bhubaneswar. Clinical records and CT findings were reviewed for anatomical variations. Radiological severity was assessed using the Lund–Mackay scoring system. Chi-square, independent Student's t-test, and Pearson correlation analysis were performed, with $p<0.05$ considered statistically significant.

Results

Among the cohort, the mean age was 37.8±12.4 years, with a male predominance (58%). Deviated nasal septum (62%) was the most common anatomical variation, followed by concha bullosa (39%), agger nasi cells (36%), paradoxical middle turbinate (21%), Haller cells (17%), Onodi cells (11%), enlarged ethmoid bulla (18%), and uncinate process variations (14%). Patients with multiple anatomical variations demonstrated significantly higher Lund–Mackay scores (mean 13.2±4.1) compared to patients without significant anatomical variations (8.4±3.6; $p<0.001$). Significant associations were observed between deviated nasal septum and maxillary sinus disease, concha bullosa and osteomeatal complex obstruction, and Haller cells with ipsilateral maxillary sinusitis. A moderate positive correlation was observed between the number of anatomical variations and radiological severity ($r=0.53$, $p<0.001$).

Conclusion

Sinonasal anatomical variations are common in CRS and significantly associated with radiological disease severity. CT evaluation aids appropriate management and surgical planning.

Recommendation

Routine CT assessment of sinonasal anatomical variations should be considered to support individualized treatment and surgical planning.

Keywords: *Chronic rhinosinusitis; Computed tomography; Anatomical variations; Lund–Mackay score; Osteomeatal complex*
Submitted: *April 20, 2026* ***Accepted:*** *May 30, 2026* ***Published:*** *June 30, 2026*

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INTRODUCTION

Chronic rhinosinusitis (CRS) represents one of the most common chronic inflammatory disorders affecting the upper respiratory tract and constitutes a substantial public health concern worldwide. It is characterized by persistent inflammation involving the nasal cavity and paranasal sinus mucosa lasting for at least twelve consecutive weeks despite appropriate medical management. The disease significantly impairs patients' quality of life by causing persistent nasal obstruction, facial pressure, mucopurulent nasal discharge, reduction or loss of smell, sleep disturbances, fatigue, and decreased work productivity. Beyond its direct clinical consequences, CRS contributes considerably to healthcare utilization through repeated physician visits, prolonged medical therapy, radiological investigations, and surgical interventions. Owing to its chronicity and tendency for recurrence, CRS continues to present diagnostic and therapeutic challenges for otorhinolaryngologists despite considerable advances in medical and surgical management strategies.[1]

The prevalence of chronic rhinosinusitis varies across geographical regions depending on environmental, climatic, genetic, and diagnostic factors. Population-based studies estimate that approximately 5–12% of adults worldwide suffer from CRS, making it one of the leading chronic diseases encountered in otorhinolaryngology practice. In developing countries, the burden may be even higher due to delayed healthcare access, untreated allergic disorders, environmental pollution, recurrent upper respiratory infections, and occupational exposures. The socioeconomic impact of CRS is substantial because affected individuals frequently experience absenteeism, reduced work efficiency, impaired cognitive performance, and diminished overall quality of life comparable to chronic systemic illnesses such as diabetes mellitus and congestive heart failure.[2]

The pathophysiology of chronic rhinosinusitis is multifactorial and involves a complex interplay between host immunity, environmental exposures, microbial colonization, allergic inflammation, mucociliary dysfunction, epithelial barrier abnormalities, biofilm formation, and anatomical factors. Earlier concepts considered bacterial infection to be the principal etiological factor; however, current evidence recognizes CRS as a chronic inflammatory disorder in which persistent mucosal inflammation often persists despite eradication of microorganisms. Contemporary research has highlighted the importance of immune dysregulation involving T-helper cell responses, eosinophilic inflammation, cytokine imbalance, epithelial dysfunction, and alterations in the sinonasal microbiome. These mechanisms collectively contribute to persistent mucosal edema, obstruction of sinus drainage pathways, impaired ventilation, and accumulation of inflammatory secretions.[3]

The osteomeatal complex represents the principal drainage pathway for the anterior group of paranasal sinuses and serves as a critical anatomical region in the development of chronic rhinosinusitis. Obstruction of this complex disrupts physiological mucociliary clearance, resulting in retention of secretions, negative sinus pressure, bacterial proliferation, and chronic inflammation. Numerous anatomical variations surrounding the osteomeatal complex have therefore attracted considerable attention because of their potential role in narrowing drainage pathways and predisposing susceptible individuals to recurrent or chronic sinus disease. Nevertheless, whether these variations independently cause CRS or simply coexist with inflammatory disease remains an area of ongoing investigation.[4]

Advances in endoscopic sinus surgery have significantly enhanced understanding of sinonasal anatomy and its clinical relevance. Detailed anatomical knowledge is indispensable because the paranasal sinuses exhibit considerable interindividual variability. These variations may influence disease pathogenesis, complicate surgical access, and increase the risk of intraoperative complications involving the orbit, skull base, optic nerve, or internal carotid artery. Consequently, careful preoperative identification of anatomical variations has become an integral component of comprehensive CRS evaluation.[5]

Among the various anatomical variations, deviated nasal septum is the most frequently encountered abnormality. Septal deviation may reduce nasal airflow, alter mucociliary clearance, narrow the middle meatus, and contribute to osteomeatal obstruction. The degree rather than the mere presence of septal deviation appears to determine its clinical significance. Several investigators have reported higher frequencies of ipsilateral maxillary sinus disease among patients with marked septal deviation, whereas others have observed no independent association after controlling for confounding variables. Such inconsistencies continue to stimulate research into its actual contribution to chronic rhinosinusitis.[6]

Concha bullosa, defined as pneumatization of the middle turbinate, represents another common anatomical variation with reported prevalence ranging from approximately 15% to over 50% in different populations. Depending on its size and extent of pneumatization, concha bullosa may compress the uncinate process or narrow the middle meatus, thereby interfering with normal sinus drainage. Large bilateral conchae bullosae have particularly been implicated in patients with recurrent CRS and may require surgical reduction during functional endoscopic sinus surgery (FESS).[7]

Agger nasi cells are the most anterior ethmoidal air cells and form an important landmark during endoscopic sinus surgery. Although commonly present in healthy individuals, enlarged agger nasi cells may narrow the frontal recess and contribute to impaired frontal sinus drainage. Frontal sinusitis remains one of the more technically challenging forms of CRS because of the complex anatomy of the frontal recess and the considerable anatomical variability encountered in this

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region. Recognition of agger nasi cells on preoperative CT imaging therefore has substantial surgical importance.[8]

Haller cells, also known as infraorbital ethmoid cells, are located along the medial orbital floor adjacent to the maxillary sinus ostium. Prominent Haller cells may compromise the infundibulum or narrow the osteomeatal complex, thereby increasing susceptibility to ipsilateral maxillary sinus disease. Although their prevalence varies considerably among radiological studies, several investigators have demonstrated significant associations between large Haller cells and chronic maxillary sinusitis.[9]

Onodi cells are posterior ethmoid air cells extending superolateral to the sphenoid sinus and exhibit close anatomical relationships with the optic nerve and internal carotid artery. Although these cells may not directly contribute to chronic rhinosinusitis, their identification is essential because failure to recognize them during surgery may result in catastrophic orbital or vascular complications. Their importance therefore extends beyond disease pathogenesis to surgical safety and risk reduction.[10]

Additional anatomical variations, including paradoxical middle turbinate, enlarged ethmoid bulla, accessory maxillary ostium, uncinate process variations, septal spurs, frontal cells, supraorbital ethmoid cells, and sphenoid sinus septations, have also been investigated as possible contributors to CRS. Individually, these variations may exert only modest effects, but combinations of multiple variations may significantly alter sinonasal airflow dynamics and impair mucociliary clearance, thereby increasing the likelihood of chronic inflammation.[11]

Clinical evaluation of CRS relies upon a combination of symptom assessment, nasal endoscopy, and radiological imaging. International guidelines recommend diagnosis based on the presence of characteristic symptoms accompanied by objective evidence of sinonasal inflammation demonstrated by nasal endoscopy or CT imaging. Nasal endoscopy permits direct visualization of mucosal edema, nasal polyps, purulent secretions, crusting, and middle meatal pathology. However, endoscopy alone cannot reliably delineate deep sinonasal anatomy or accurately identify all anatomical variations, emphasizing the complementary role of imaging.[12]

High-resolution computed tomography has become the imaging modality of choice for evaluating chronic rhinosinusitis because of its excellent spatial resolution and ability to depict both inflammatory changes and intricate sinonasal anatomy. CT scanning accurately demonstrates mucosal thickening, sinus opacification, obstruction of drainage pathways, osteomeatal complex involvement, bony remodeling, and numerous anatomical variations that influence surgical planning. Coronal images are particularly valuable because they closely resemble the operative perspective during functional endoscopic sinus surgery.[13]

The Lund–Mackay scoring system remains the most widely accepted radiological scoring method for chronic rhinosinusitis. This standardized system evaluates each sinus and the osteomeatal complex to quantify radiological disease severity objectively. Its simplicity, reproducibility, and widespread validation have facilitated comparisons among clinical studies and enabled assessment of treatment outcomes. Several investigators have attempted to correlate Lund–Mackay scores with symptom severity, endoscopic findings, and anatomical variations, although reported associations have varied considerably.[14]

Multiple studies have explored the relationship between anatomical variations and chronic rhinosinusitis; however, published findings remain inconsistent. Some investigators report strong associations between specific anatomical variations and localized sinus disease, whereas others conclude that many variations merely represent incidental developmental findings without independent pathological significance. These discrepancies may be attributable to differences in study design, sample size, ethnic variability, imaging techniques, disease definitions, and methods used to classify anatomical variants. Consequently, further studies examining both clinical and radiological correlations remain warranted.[15]

Understanding the prevalence and significance of anatomical variations is particularly important in tertiary referral centers where functional endoscopic sinus surgery is frequently performed. Accurate identification of anatomical landmarks minimizes operative complications, facilitates complete disease clearance, and reduces recurrence rates. Furthermore, recognizing clinically significant anatomical variations enables individualized surgical planning tailored to each patient's unique sinonasal anatomy.[16]

The present retrospective observational study was therefore undertaken to evaluate the prevalence of anatomical variations of the nose and paranasal sinuses among patients with chronic rhinosinusitis and to determine their clinical and radiological correlation using computed tomography and standardized radiological scoring. By examining the relationship between anatomical variants, clinical presentation, and CT severity, the study aims to contribute additional evidence regarding the role of sinonasal anatomy in chronic rhinosinusitis while emphasizing the importance of meticulous radiological assessment before surgical intervention.

MATERIALS AND METHODS

Study Design

This was a retrospective observational study conducted to evaluate the clinical and radiological correlation of anatomical variations of the nose and paranasal sinuses among patients diagnosed with chronic rhinosinusitis (CRS). The study involved a retrospective review of hospital medical records, diagnostic nasal endoscopy

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findings, and computed tomography (CT) scans of the paranasal sinuses performed during the study period.

Study Setting

The study was conducted in the Department of Otorhinolaryngology, Kalinga Institute of Medical Sciences, Bhubaneswar**.** Clinical records of patients attending the ENT outpatient department or admitted for evaluation or management of chronic rhinosinusitis were retrospectively reviewed.

Study Population

The study population consisted of adult patients clinically diagnosed with chronic rhinosinusitis who underwent diagnostic nasal endoscopy and CT of the paranasal sinuses during the study period.

Sample Size Determination

A total of **100 patients** fulfilling the predefined eligibility criteria were included in the study.

Sampling Technique

A consecutive sampling method was employed. All eligible patients who satisfied the inclusion and exclusion criteria during the study period were included consecutively until the required sample size of 100 was reached.

Eligibility Criteria

Inclusion Criteria

Patients meeting all of the following criteria were included:

- Age ≥18 years.
- Clinical diagnosis of chronic rhinosinusitis according to accepted diagnostic criteria.
- Presence of symptoms for at least 12 consecutive weeks.
- Availability of complete clinical records.
- Availability of diagnostic nasal endoscopy findings.
- Availability of high-resolution CT scans of the paranasal sinuses.
- Adequate CT image quality for assessment of sinonasal anatomy.

Exclusion Criteria

Patients with any of the following were excluded:

- Acute rhinosinusitis.
- Previous sinonasal surgery.
- Sinonasal malignancy.
- Facial trauma involving the nose or paranasal sinuses.
- Congenital craniofacial anomalies.
- Extensive sinonasal fungal disease.
- Incomplete medical records.
- Poor-quality CT scans.
- Pregnancy, where applicable during imaging.

Diagnostic Criteria

Patients were diagnosed with chronic rhinosinusitis based on the diagnostic criteria proposed in the European Position Paper on Rhinosinusitis and Nasal Polyps (EPOS 2020)**.**

The diagnosis required the presence of two or more symptoms for at least 12 weeks, with at least one of the following:

- Nasal obstruction, blockage, or congestion; or
- Nasal discharge, anterior or posterior,

with or without:

- Facial pain or pressure; and
- Reduction or loss of smell.

Objective evidence of sinonasal inflammation was demonstrated by either diagnostic nasal endoscopy showing mucopurulent discharge, mucosal oedema, or nasal polyps, or CT showing mucosal changes involving the osteomeatal complex and/or paranasal sinuses.

Clinical Evaluation

The following demographic and clinical variables were extracted from the medical records.

Demographic characteristics:

- Age
- Sex

Clinical presentation:

- Nasal obstruction
- Nasal discharge
- Facial pain
- Facial pressure
- Headache
- Hyposmia/anosmia
- Sneezing
- Postnasal drip
- Cough
- Halitosis

Clinical history:

- Duration of symptoms
- Smoking history
- Allergic rhinitis
- Bronchial asthma
- Diabetes mellitus
- Hypertension

Diagnostic Nasal Endoscopy

Diagnostic nasal endoscopy had been performed using rigid 0° and 30° nasal endoscopes. The following findings were recorded from the medical records:

- Septal deviation
- Nasal polyps
- Middle meatal discharge
- Mucosal oedema
- Inferior turbinate hypertrophy

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- Middle turbinate abnormalities
- Purulent secretions
- Osteomeatal complex obstruction

CT Scan Protocol

High-resolution computed tomography (HRCT) of the paranasal sinuses was performed using a multidetector CT scanner. The CT protocol included axial acquisition with coronal reconstruction, using a slice thickness of **1–3 mm** with bone and soft-tissue algorithms. Both axial and coronal images were reviewed. Coronal images were primarily used to assess the osteomeatal complex because they closely approximate the surgical perspective used during functional endoscopic sinus surgery.

Radiological Evaluation

Each CT scan was evaluated for:

Sinus involvement

- Maxillary sinus
- Frontal sinus
- Anterior ethmoid sinus
- Posterior ethmoid sinus
- Sphenoid sinus

Osteomeatal complex

- Presence or absence of obstruction

Anatomical variations

- Deviated nasal septum (DNS)
- Septal spur
- Concha bullosa
- Paradoxical middle turbinate
- Agger nasi cells
- Haller cells
- Onodi cells
- Enlarged ethmoid bulla
- Pneumatized uncinate process
- Medially bent uncinate process
- Laterally bent uncinate process
- Accessory maxillary ostium
- Supraorbital ethmoid cells
- Frontal cells

Definitions of Anatomical Variations

Deviated Nasal Septum: Any deviation of the nasal septum sufficient to narrow the nasal cavity or middle meatus.

Concha Bullosa: Pneumatization of the middle turbinate identified on CT imaging.

Agger Nasi Cell: The most anterior ethmoidal air cell located anterior to the attachment of the middle turbinate.

Haller Cell: An infraorbital ethmoid air cell located along the medial orbital floor adjacent to the maxillary ostium.

Onodi Cell: A posterior ethmoid air cell extending superolaterally to the sphenoid sinus.

Paradoxical Middle Turbinate: A middle turbinate demonstrating lateral convexity rather than the normal medial convexity.

Enlarged Ethmoid Bulla: An ethmoid bulla sufficiently enlarged to narrow the middle meatus.

Uncinate Process Variations: Abnormal medial or lateral deviation, pneumatization, or abnormal attachment of the uncinate process.

Radiological Severity Assessment

Disease severity was assessed using the **Lund–Mackay CT scoring system**. Each sinus was scored as follows:

- **0:** No abnormality
- **1:** Partial opacification
- **2:** Complete opacification

The osteomeatal complex was scored as:

- **0:** Patent
- **2:** Obstructed

The maximum possible score was 24. Disease severity was categorized as:

Outcome Measures

Primary Outcome

The primary outcome was the association between sinonasal anatomical variations and chronic rhinosinusitis.

Secondary Outcomes

The secondary outcomes included:

- Frequency of individual anatomical variations.
- Correlation between anatomical variations and Lund–Mackay score.
- Association between anatomical variations and specific sinus involvement.
- Relationship between anatomical variations and clinical symptom severity.
- Identification of surgically significant anatomical variations.

Data Collection

Clinical records of eligible patients were retrieved from the hospital medical records department. Demographic characteristics, presenting complaints, diagnostic nasal endoscopy findings, available laboratory investigations, and CT findings were extracted using a standardized data-collection proforma.

CT images were reviewed for anatomical variations, sinus involvement, osteomeatal complex obstruction, and Lund–Mackay score. The collected data were entered into a password-protected spreadsheet for statistical analysis.

Minimizing Bias

To minimize potential selection and information bias, **consecutive sampling** was used to include all eligible patients during the study period. Predefined inclusion and exclusion criteria were applied uniformly. Clinical and radiological information was extracted using a standardized data-collection proforma, and CT findings were assessed using predefined anatomical and Lund–Mackay scoring criteria. Patients with incomplete records

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or inadequate CT image quality were excluded to minimize errors arising from incomplete or unreliable information.

Statistical Analysis

Statistical analysis was performed using **IBM SPSS Statistics version 26.0** (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. The Chi-square test was used to assess associations between categorical variables, including anatomical variations and CRS severity. Continuous variables were compared using the independent Student's *t*-test. Pearson's correlation coefficient was used to assess the relationship between the number of anatomical variations and the Lund–Mackay score. A two-tailed *p*-value <0.05 was considered statistically significant.

Ethical Considerations

Ethical approval was obtained from the Kalinga Institute of Medical Sciences, Bhubaneswar. Patient confidentiality and anonymity were maintained throughout the study. All data were de-identified before analysis, and the study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

RESULTS

A total of **100 patients** with chronic rhinosinusitis who fulfilled the study eligibility criteria were included in the analysis. Demographic characteristics, clinical presentation, radiological findings, anatomical variations, and their associations with disease severity were evaluated. Statistical significance was considered at **p <0.05**.

Demographic Characteristics

The study population comprised **58 (58.0%) males** and **42 (42.0%) females**, with a male-to-female ratio of **1.38:1**. The age of the patients ranged from **18 to 69 years**, with a mean age of **37.8 ± 12.4 years**. The majority of patients belonged to the **31–40 years** age group (29%), followed by the **41–50 years** age group (23%). The detailed age and gender distribution of the study participants is presented in **Table 1**.

Table 1. Age and Gender Distribution of Study Participants (n = 100)

Age Group (Years)	Male	Female	Total	Percentage (%)
18–20	3	2	5	5.0
21–30	12	8	20	20.0
31–40	17	12	29	29.0
41–50	14	9	23	23.0
51–60	8	7	15	15.0
>60	4	4	8	8.0
Total	**58**	**42**	**100**	**100**

The age distribution is graphically illustrated in **Figure 1**, demonstrating that chronic rhinosinusitis was most frequently encountered in individuals aged 31–50 years.

Clinical Presentation

The frequencies of presenting symptoms are summarized in **Table 2**. Nasal obstruction was the most common presenting symptom (91%), followed by nasal discharge (82%), facial pain or pressure (66%), headache (58%), hyposmia/anosmia (47%), postnasal drip (43%), sneezing (39%), cough (24%), and halitosis (18%).

Table 2. Clinical Presentation of Patients

Clinical Feature	Frequency	Percentage (%)
Nasal obstruction	91	91.0
Nasal discharge	82	82.0
Facial pain/pressure	66	66.0
Headache	58	58.0

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Clinical Feature	Frequency	Percentage (%)
Hyposmia/Anosmia	47	47.0
Postnasal drip	43	43.0
Sneezing	39	39.0
Cough	24	24.0
Halitosis	18	18.0

The distribution of clinical symptoms is shown in **Figure 2**, highlighting nasal obstruction and nasal discharge as the predominant complaints.

Associated Comorbidities

The associated clinical conditions observed among the study participants are summarized in **Table 3**. Allergic rhinitis was the most common comorbidity (34%), followed by smoking history (29%), diabetes mellitus (19%), bronchial asthma (16%), and hypertension (15%).

Table 3. Associated Clinical Conditions

Comorbidity	Frequency	Percentage (%)
Allergic rhinitis	34	34.0
Smoking history	29	29.0
Diabetes mellitus	19	19.0
Bronchial asthma	16	16.0
Hypertension	15	15.0

Diagnostic Nasal Endoscopy Findings

The diagnostic nasal endoscopy findings are summarized in **Table 4**. Mucosal oedema (73%) and middle meatal discharge (69%) were the most frequent endoscopic abnormalities. Deviated nasal septum and osteomeatal complex obstruction were identified in 62% and 61% of patients, respectively.

Table 4. Diagnostic Nasal Endoscopy Findings

Endoscopic Finding	Frequency	Percentage (%)
Mucosal oedema	73	73.0
Middle meatal discharge	69	69.0
Deviated nasal septum	62	62.0
Osteomeatal complex obstruction	61	61.0
Inferior turbinate hypertrophy	38	38.0
Nasal polyps	26	26.0
Purulent discharge	22	22.0

Distribution of Anatomical Variations on CT Scan

The anatomical variations identified on computed tomography are presented in **Table 5**. Deviated nasal septum (62%) was the most common anatomical variation, followed by concha bullosa (39%), agger nasi cells (36%), paradoxical middle turbinate (21%), enlarged ethmoid bulla (18%), Haller cells (17%), uncinate process variations (14%), Onodi cells (11%), accessory maxillary ostium (9%), and supraorbital ethmoid cells (6%).

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Table 5. Anatomical Variations Identified on CT Scan

Anatomical Variation	Frequency	Percentage (%)
Deviated nasal septum	62	62.0
Concha bullosa	39	39.0
Agger nasi cells	36	36.0
Paradoxical middle turbinate	21	21.0
Enlarged ethmoid bulla	18	18.0
Haller cells	17	17.0
Uncinate process variation	14	14.0
Onodi cells	11	11.0
Accessory maxillary ostium	9	9.0
Supraorbital ethmoid cells	6	6.0

Distribution of Sinus Involvement

The radiological distribution of sinus involvement is shown in **Table 6**. Maxillary sinus disease was the commonest finding (78%), followed by ethmoid sinus involvement (63%), frontal sinus disease (34%), sphenoid sinus disease (27%), and osteomeatal complex obstruction (61%).

Table 6. Distribution of Sinus Involvement on CT Scan

Sinus	Frequency	Percentage (%)
Maxillary sinus	78	78.0
Ethmoid sinus	63	63.0
Frontal sinus	34	34.0
Sphenoid sinus	27	27.0
Osteomeatal complex obstruction	61	61.0

Lund–Mackay CT Severity Score

The mean Lund–Mackay score for the study population was **11.4 ± 4.6** (range 3–22). Based on radiological severity, 14% of patients had mild disease, 37% had moderate disease, and 49% had severe disease, as shown in **Table 7**.

Table 7. Lund–Mackay Severity Categories

Severity	Score	Frequency	Percentage (%)
Mild	0–4	14	14.0
Moderate	5–10	37	37.0
Severe	>10	49	49.0

Association Between Anatomical Variations and Radiological Severity

The relationship between the number of anatomical variations and radiological severity is summarized in Table 8**.** Patients with two or more anatomical variations had significantly higher Lund–Mackay scores than those with one or no anatomical variation (13.2 ± 4.1 vs. 8.4 ± 3.6; p <0.001**).**

Table 8. Association Between Number of Anatomical Variations and Lund–Mackay Score

Number of Anatomical Variations	Mean Lund–Mackay Score	p-value
0–1 Variation	8.4 ± 3.6	
≥2 Variations	13.2 ± 4.1	<0.001*

**Independent Student's t-test.*

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Association of Specific Anatomical Variations with Radiological Findings

The associations between selected anatomical variations and radiological findings are presented in **Table 9**. Deviated nasal septum showed a significant association with maxillary sinus disease ($\chi^2 = 8.94$, **p = 0.003**), concha bullosa was significantly associated with osteomeatal complex obstruction ($\chi^2 = 10.76$, **p = 0.001**), and Haller cells were significantly associated with ipsilateral maxillary sinusitis ($\chi^2 = 5.62$, **p = 0.018**). No statistically significant association was observed between Onodi cells and severe chronic rhinosinusitis ($\chi^2 = 1.14$, **p = 0.287**).

Table 9. Chi-square Analysis of Anatomical Variations

Anatomical Variation	Associated Finding	Chi-square	p-value
Deviated nasal septum	Maxillary sinus disease	8.94	0.003*
Concha bullosa	Osteomeatal complex obstruction	10.76	0.001*
Haller cells	Ipsilateral maxillary sinusitis	5.62	0.018*
Onodi cells	Severe CRS	1.14	0.287

**Statistically significant.*

Correlation Between Anatomical Variations and Disease Severity

The correlation between the number of anatomical variations and the Lund–Mackay score is presented in **Table 10**. Pearson correlation analysis demonstrated a **moderate positive correlation** between these variables (**r = 0.53, p <0.001**), indicating that increasing numbers of anatomical variations were associated with greater radiological disease severity (Figure 5).

Table 10. Pearson Correlation Analysis

Variables	Correlation Coefficient (r)	p-value
Number of anatomical variations vs. Lund–Mackay score	0.53	<0.001*

**Statistically significant.*

Summary of Findings

Overall, the present study demonstrated that **deviated nasal septum, concha bullosa, and agger nasi cells** were the most frequently encountered anatomical variations. Maxillary sinus involvement represented the predominant radiological finding, while nearly half of the patients exhibited severe disease according to the Lund–Mackay scoring system. Patients with multiple anatomical variations had significantly higher radiological severity scores, and a moderate positive correlation was observed between the number of anatomical variations and disease severity. Significant associations were identified between deviated nasal septum and maxillary sinus disease, concha bullosa and osteomeatal complex obstruction, and Haller cells with ipsilateral maxillary sinusitis, highlighting the clinical importance of comprehensive preoperative CT evaluation.

DISCUSSION

The present retrospective observational study evaluated the association between sinonasal anatomical variations and chronic rhinosinusitis (CRS). Deviated nasal septum, concha bullosa, and agger nasi cells were the most common anatomical variations identified on CT. Patients with multiple anatomical variations had significantly higher Lund–Mackay scores, and the number of variations showed a moderate positive correlation with radiological disease severity. These findings support the role of detailed CT evaluation in the assessment of CRS.

The mean age of the study population was 37.8 years with a slight male predominance, similar to previous studies reporting that CRS is more common among young and middle-aged adults. Nasal obstruction and nasal discharge were the predominant symptoms, while mucosal oedema and middle meatal discharge were the most frequent endoscopic findings, consistent with established diagnostic criteria for CRS.[17–20]

CT demonstrated that a deviated nasal septum was the most frequent anatomical variation, followed by concha bullosa and agger nasi cells. Significant associations were observed between deviated nasal septum and maxillary sinus disease, concha bullosa and osteomeatal complex obstruction, and Haller cells with ipsilateral maxillary sinusitis. These findings agree with previous reports suggesting that anatomical variations involving the osteomeatal complex may impair sinus drainage and contribute to persistent inflammation.[21–23]

The study also showed that patients with two or more anatomical variations had significantly greater radiological disease severity than those with fewer variations. Although anatomical variations alone may not directly cause CRS, their combined presence appears to

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increase the likelihood of obstruction and impaired mucociliary clearance, thereby contributing to disease severity.

The major strengths of this study include standardized diagnostic criteria, systematic CT assessment, and use of the validated Lund–Mackay scoring system. Limitations include the retrospective single-centre design and relatively small sample size, which may limit generalizability. Larger prospective multicentre studies are needed to further clarify the independent role of sinonasal anatomical variations in CRS.

Overall, the findings emphasize that high-resolution CT remains essential for identifying clinically significant anatomical variations, guiding surgical planning, and improving the management of patients with chronic rhinosinusitis.

Generalizability

The findings of this study may apply to adult patients with chronic rhinosinusitis evaluated using diagnostic nasal endoscopy and CT of the paranasal sinuses, particularly in tertiary-care otorhinolaryngology settings. The observed associations between sinonasal anatomical variations and radiological disease severity may therefore be relevant to similar patient populations. However, generalization to the wider population should be undertaken cautiously because the study was conducted at a single institution and included a relatively limited sample of patients. Differences in patient characteristics, disease profiles, referral patterns, imaging protocols, and clinical practices across institutions may influence the prevalence and clinical significance of anatomical variations. Multicenter studies involving larger and more diverse populations are needed to confirm the present findings and improve their external validity.

CONCLUSION

The present retrospective observational study demonstrated that anatomical variations of the nose and paranasal sinuses are common among patients with chronic rhinosinusitis. Deviated nasal septum, concha bullosa, and agger nasi cells were the most frequently identified anatomical variations on computed tomography. Patients with multiple anatomical variations demonstrated significantly higher Lund–Mackay scores, and a moderate positive correlation was observed between the number of anatomical variations and radiological disease severity.

Computed tomography proved to be an indispensable imaging modality for evaluating both the extent of sinonasal disease and clinically important anatomical variations that may influence sinus drainage and surgical planning. The combined use of clinical assessment, diagnostic nasal endoscopy, and high-resolution CT provides a comprehensive evaluation of patients with chronic rhinosinusitis and facilitates accurate diagnosis and individualized management.

Although anatomical variations alone are unlikely to be the sole cause of chronic rhinosinusitis, they may contribute to osteomeatal complex obstruction, impaired mucociliary clearance, and increased disease severity when associated with chronic mucosal inflammation. Therefore, meticulous preoperative identification of these variations is essential for optimizing functional endoscopic sinus surgery, minimizing intraoperative complications, and improving surgical outcomes.

Further prospective multicentre studies involving larger study populations and long-term follow-up are recommended to better define the independent role of sinonasal anatomical variations in the pathogenesis, radiological severity, and surgical outcomes of chronic rhinosinusitis.

Limitations

This study has several limitations. First, its retrospective design relied on existing clinical records and imaging data, which may have resulted in incomplete documentation and limited the availability of certain clinical variables. Second, the study was conducted at a single tertiary-care institution and included a relatively limited number of patients, which may restrict the generalizability of the findings to other populations and healthcare settings. Third, the observational nature of the study allows identification of associations between anatomical variations and radiological disease severity but does not establish a causal relationship. These limitations may have influenced the completeness of the available data and the extent to which the observed associations can be generalized to the broader population with chronic rhinosinusitis.

Recommendation

Based on the findings of this study, careful evaluation of sinonasal anatomical variations using CT should be incorporated into the assessment of patients with chronic rhinosinusitis, particularly when surgical intervention is being considered. Identification of clinically significant anatomical variations and their relationship with sinus disease may assist in individualized treatment planning. Future multicenter prospective studies with larger sample sizes are recommended to further evaluate the clinical significance of these variations and establish their predictive value for treatment and postoperative outcomes.

List of Abbreviations

CRS Chronic Rhinosinusitis
CT Computed Tomography
HRCT High-Resolution Computed Tomography
DNS Deviated Nasal Septum
ENT Ear, Nose and Throat
EPOS European Position Paper on Rhinosinusitis and Nasal Polyps
OMC Osteomeatal Complex
SD Standard Deviation
SPSS Statistical Package for the Social Sciences

FESS Functional Endoscopic Sinus Surgery

Source of Funding
This study received no specific financial support or funding from any government, commercial, or non-profit organization.

Conflict of Interest
The authors declare that they have no conflict of interest related to this study.

Availability of Data
The data supporting the findings of this study are not publicly available because they contain information derived from patient medical records. However, relevant anonymized data may be made available from the corresponding author upon reasonable request, subject to institutional and ethical restrictions.

Author Contributions
The actual individual contributions are not provided in the reviewer notes or the methodology you supplied, so these should be confirmed by the authors rather than invented.

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PUBLISHER DETAILS:

Student's Journal of Health Research (SJHR)
(ISSN 2709-9997) Online
(ISSN 3006-1059) Print
Category: Non-Governmental & Non-profit Organization
Email: studentsjournal2020@gmail.com
WhatsApp: +256 775 434 261
Location: Scholar's Summit Nakigalala, P. O. Box 701432, Entebbe Uganda, East Africa