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Original Research Article

Quantitative assessment of maxillary sinus dimensions and volume in chronic rhinosinusitis with antrochoanal polyps: A case-control study

Amit Kumar[1], Richi Sinha[1], Mahesh Kumar[1], Deepak Kumar[1], Sarita Kumari Mishra[1]*

[1]Dept. of ENT. Indira Gandhi Institute of Medical Sciences, Patna, Bihar, India.

Abstract

Background: Chronic rhinosinusitis with nasal polyps (CRSwNP) is a common inflammatory condition (10% prevalence) characterized by a type 2 eosinophil-dominated inflammation. Anatomical factors that impair sinus drainage may contribute to disease, but the role of sinus volume in CRSwNP is unclear.
Objective: To determine whether reduced maxillary sinus volume is associated with chronic maxillary rhinosinusitis with antrochoanal polyps (ACPs).
Materials and Methods: In a prospective case-control study, 36 patients with unilateral ACP underwent nasal endoscopy and CT imaging. Maxillary sinus dimensions (anteroposterior, craniocaudal, mediolateral, and mid-axial width) were measured on CT, and sinus volume was calculated using PACS software. Each patient's unaffected contralateral sinus served as the control. Paired t-tests compared case vs control measurements.
Results: Maxillary sinuses with ACPs had a smaller mean volume (21.1 vs 24.5 cm^3) than control sides, a difference trending toward significance ($p = 0.053$). The mean anteroposterior length was significantly reduced in ACP sinuses (3.82 vs 4.09 cm, $p = 0.010$). Differences in craniocaudal height and maximum width were not significant ($p > 0.05$). The mid-sinus width was slightly smaller in cases (2.68 vs 2.88 cm, $p = 0.055$).
Conclusion: Maxillary sinuses affected by ACPs tended to be smaller, especially in the anteroposterior dimension, compared to healthy sinuses. This suggests a potential anatomical predisposition for ACP development, warranting confirmation in larger studies.

Keywords: Chronic rhinosinusitis, Nasal polyps, Antrochoanal polyp, Maxillary sinus volume, Computed tomography

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1. Introduction

Chronic rhinosinusitis (CRS) is a persistent inflammatory condition of the nasal and paranasal mucosa lasting at least 12 weeks.[1] It affects approximately 10–15% of the population and is classically subdivided into CRS with nasal polyps (CRSwNP) and without nasal polyps (CRSsNP).[2,3] CRSwNP is often driven by a type 2 (Th2) immune response with prominent eosinophilic inflammation, leading to edematous polypoid tissue in the sinonasal cavity. This phenotype can significantly impair patients' quality of life.[4]

Multiple etiological factors contribute to CRSwNP. These include local factors (anatomic variations, mucociliary dysfunction), general host factors (genetic predisposition, immune deficiencies), and environmental factors (allergens, smoking).[5,6] Structural abnormalities that narrow the ostiomeatal complex such as a deviated septum or concha bullosa can compromise sinus ventilation and drainage, creating conditions favorable for chronic inflammation.[7,8] Indeed, even minor mucosal swelling in a confined ostiomeatal passage may precipitate maxillary sinus outflow obstruction and recurrent sinusitis.[9,10] However, the relationship between sinonasal anatomy and CRS severity is not straightforward; many patients with anatomical variants do not develop disease, underscoring the multifactorial nature of CRS pathogenesis.[11,12]

One anatomical factor of particular interest is the size of the paranasal sinuses. The maxillary sinus the largest of the sinuses has an average adult volume of roughly 15–20 mL.[13] Marked deviations in sinus volume (e.g., hypoplasia or extensive pneumatization) could influence the propensity for chronic sinus disease by altering local airflow, drainage

*Corresponding author: Sarita Kumari Mishra
Email: dr.sarita.m@gmail.com

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patterns, and mucosal contact surfaces. Chronic maxillary rhinosinusitis with antrochoanal polyps provides a unique model to examine this: an ACP is a solitary polypoid mass that originates within the maxillary antrum and extends through the ostium into the choana.[14] It is essentially a large, unilateral nasal polyp occupying a maxillary sinus. If reduced sinus dimension and volume predisposes to stasis and inflammation, patients with ACP might be expected to have smaller maxillary sinuses compared to individuals without disease.

To date, the correlation between maxillary sinus dimension and volume and CRSwNP remains unclear, with scant literature directly addressing sinus size as a risk factor. We hypothesized that patients with chronic maxillary rhinosinusitis would have smaller maxillary sinus volumes compared to disease-free sinuses. The present study was conducted to quantitatively assess maxillary sinus dimensions and volume in patients with unilateral ACP and to analyze their association with the presence of chronic inflammatory polyps. By improving understanding of these anatomic contributions to CRSwNP, this research may help refine preoperative evaluation and prognostication for endoscopic sinus surgery.

2. Materials and Methods

Study Design and Population: We conducted a prospective, observational case-control study in a tertiary care otolaryngology center between 2023 and 2025. Ethical approval was granted (letter no. 966/IEC/IGIMS/2023), and written informed consent was obtained from parents. Patients diagnosed with chronic maxillary rhinosinusitis due to an antrochoanal polyp were recruited. Inclusion criteria were unilateral ACP confirmed by nasal endoscopy and computed tomography (CT) of the paranasal sinuses. Patients with any prior sinus surgery, bilateral polyposis, or sinonasal tumors were excluded. A total of 36 patients (21 males, 15 females) met the criteria and were enrolled after obtaining informed consent.

Imaging and Measurements: All patients underwent preoperative CT scanning of the paranasal sinuses (axial and coronal planes). Key linear dimensions of each maxillary sinus were measured using Picture Archiving and Communication System (PACS) software. These included the maximum anteroposterior (AP) length (horizontal depth of the sinus) in case and control (**Figure 1**, **Figure 2**), the maximum craniocaudal (CC) height (vertical dimension), and the maximum mediolateral width (horizontal width on coronal section). In addition, the mediolateral width at the midpoint of the sinus (measured on an axial slice halfway between the sinus roof and floor) was recorded in case and control (**Figure 1**, **Figure 2**). Each patient's diseased sinus (with the ACP) and contralateral healthy maxillary sinus were measured in the same manner in the case and control. Using the measured linear dimensions, the software then calculated the sinus volume in cubic centimeters (cm^3). Two independent observers performed all measurements to ensure reliability, and any discrepancies were resolved by consensus.

Data Analysis: The anatomical measurements and volumes of the ACP-involved sinuses (cases) were compared to the values of the normal contralateral sinuses (controls) within the same individuals. Because each patient served as their own control, paired Student's t-tests were applied for statistical comparison of continuous variables (AP length, CC height, width, mid-width, and volume). A p-value < 0.05 was considered statistically significant. Statistical analysis was carried out using SPSS software (version 20.0; IBM Corp., Armonk, NY).

3. Results

Patient Characteristics: The study included 36 patients with unilateral antrochoanal polyps, comprising 21 males (58.3%) and 15 females (41.7%). Ages ranged from 11 to 68 years, with a plurality of patients (33%) in the 10–20-year age group (**Table 1**). Overall, younger individuals and adolescents formed a substantial portion of the study population. A slight male predominance was observed. The polyp was located in the left maxillary sinus in 21 patients (58.3%) and in the right maxillary sinus in 15 patients (41.7%), indicating a modest left-side preponderance of ACP in our sample.

Maxillary Sinus Measurements: The anatomical dimensions of ACP-involved sinuses versus contralateral normal sinuses are summarized in the following results. The anteroposterior (AP) length of the maxillary sinus was significantly smaller on the polyp side. The mean AP dimension in case sinuses was 3.82 ± 0.49 cm, compared to 4.09 ± 0.38 cm in controls (a mean reduction of approximately 0.27 cm, $p = 0.010$) (**Graph 1**). The craniocaudal (vertical) height showed no meaningful difference, with case sinuses averaging 3.86 ± 0.50 cm versus 3.90 ± 0.41 cm in controls ($p = 0.707$). Similarly, the maximum mediolateral width did not differ significantly between polyp and normal sides (2.92 ± 0.42 cm vs 3.09 ± 0.52 cm, $p = 0.12$). However, the width at the mid-sinus level on axial view tended to be smaller in ACP sinuses (mean 2.68 ± 0.37 cm) than in controls (2.88 ± 0.49 cm), although this difference just failed to reach statistical significance ($p = 0.055$) (**Graph 2**).

Sinus Volume: The volumetric analysis indicated that maxillary sinuses harboring an ACP had a lower volume on average than their healthy counterparts. The mean sinus volume in the case group was 21.1 ± 6.7 cm^3, compared to 24.5 ± 7.8 cm^3 in the control group (**Graph 3**). This corresponded to an average volume reduction of about 3.4 cm^3 (roughly 14% smaller) associated with the presence of an ACP. While this trend suggested a smaller sinus cavity on the diseased side, the volume difference did not achieve conventional statistical significance ($p = 0.053$). These data show overlapping volume ranges between case and control

sides, with a tendency toward smaller cavities in ACP-affected sinuses. No significant correlation was observed between patient age and sinus dimensions or volume in this cohort.

Table 1: Distribution of age

Age (in years)	No. of Cases	Percentage
10 - 20	12	33.3%
20 - 30	6	16.7%
30 - 40	7	19.4%
40 - 50	4	11.1%
50 - 60	4	11.1%
>= 60	3	8.3%

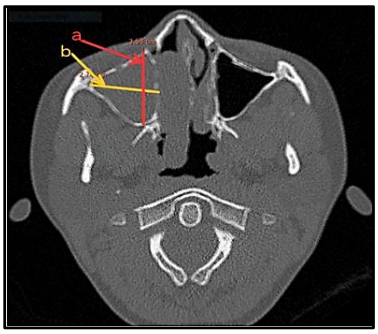


Figure 1: Showing maximum anteroposterior **(a)** and medial to lateral **(b)** length at the middle of the maxillary sinus in the case group in axial view.

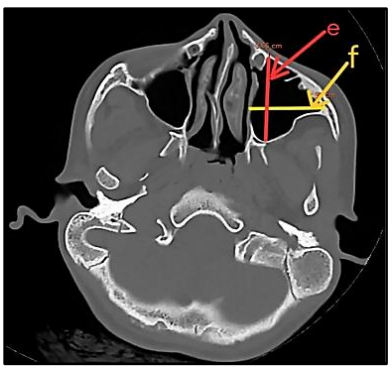
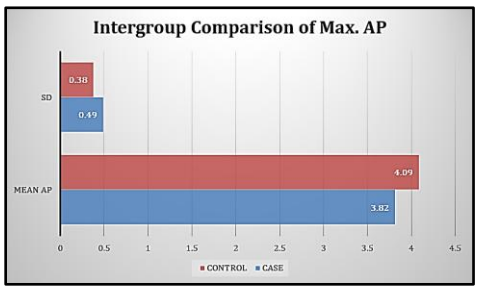
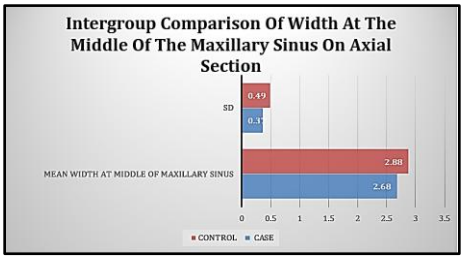


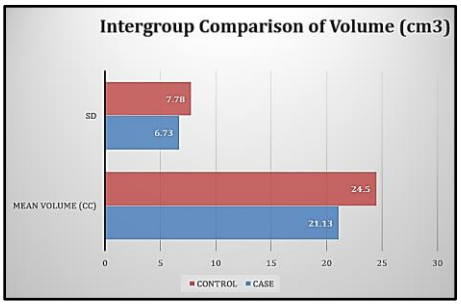
Figure 2: Showing maximum anteroposterior **(e)** and medial to lateral **(f)** length at the middle of the maxillary sinus **(f)** in the control group in axial view.



Graph 1: The maximum anteroposterior dimension in the case group had a mean of 3.82 cm with a standard deviation of 0.49 cm, while in the control group, the mean was slightly higher at 4.09 cm with a standard deviation of 0.38.



Graph 2: Bar chart showing intergroup comparison of maximum width between the case and control groups.



Graph 3: Bar chart showing intergroup comparison of volume (Cm3) between the case and control groups

4. Discussion

Chronic rhinosinusitis with nasal polyps (CRSwNP) represents a multifactorial disease process in which both inflammatory milieu and anatomy play roles. In this study, we specifically investigated whether an anatomical parameter maxillary sinus volume is associated with the occurrence of antrochoanal polyps, a form of CRSwNP arising from the maxillary sinus. Our results demonstrated that the maxillary sinuses harboring ACPs tended to be anatomically smaller than their healthy counterparts, particularly in the anteroposterior dimension. The mean AP length of the sinus was significantly reduced on the polyp side by about 0.27 cm ($p = 0.01$), and the sinus volume was on average 14% smaller with an ACP, although the volume difference only approached statistical significance ($p = 0.053$). These findings support the notion that a diminutive maxillary sinus (especially one that is foreshortened in depth) may predispose to impaired sinus drainage and ventilation, thereby promoting stasis of secretions, chronic mucosal inflammation, and ultimately polyp formation.[15]

Our observations align with and extend the current understanding of ACP pathophysiology. Anatomically, a narrower maxillary sinus could exacerbate the "vicious cycle" of ostiomeatal blockage and inflammation described in CRS.[9,10] A smaller sinus cavity has less volumetric buffer for mucosal swelling and may more readily develop negative pressure or hypoventilation in the setting of ostial obstruction. This concept is consistent with the clinical behavior of ACPs, which often recur if the sinus ostium remains inadequately open after surgery. It is also notable that the only dimension to differ significantly in our cohort was the anteroposterior length; this suggests that the forward

depth of the antrum (which correlates with overall sinus volume) is a critical factor. The lack of significant differences in height and width indicates that it is the reduction in sinus cavity depth/size rather than a particular planar diameter that may contribute most to ACP development.

We compared our findings with previously published data. Demographics: The slight male predominance in our ACP patients (58% male) is in line with prior reports that adult ACP has a higher incidence in males.[16] (In pediatric cases of ACP, no clear sex difference has been observed[16] and our sample included relatively few pre-adult patients.) We also noted a left-sided bias (58% left, 42% right) in polyp laterality, which is comparable to the approximately 52–60% left-side prevalence reported in other series.[17] The reason for left predominance is not well understood and might be coincidental in small samples, but it has been reported across different populations.

Maxillary Sinus Size and Gender: Although not the primary focus of this study, we observed that male patients generally had larger maxillary sinus dimensions and volumes than female patients. This trend is consistent with numerous radiologic studies in diverse populations, which have found significantly greater sinus size in males. For instance, Khanal et al. and Prabhat et al. both reported that mean maxillary sinus volumes are higher in males than females in adult cohorts.[14,15] Similarly, forensic investigations by Kanthem and colleagues, as well as Bangi et al., have utilized the larger sinus measurements in males as a parameter for sex determination.[16,17] Our data support these observations, as the male subset of our patients tended to exhibit larger absolute sinus measurements on both the affected and unaffected sides (data not shown). Importantly, however, the paired case-control design of our analysis (comparing each patient's two sinuses) minimizes any confounding effect of sex on the case-vs-control differences.

It is interesting to compare our volumetric findings to a literature report suggesting that ACP patients might have larger maxillary sinuses on average.[12] In that study, nasal septal deviation and a high sinus volume were noted among ACP cases, though no causal relationship was established.[12] Our results did not corroborate an association between larger sinus volume and ACP; on the contrary, we found a tendency toward smaller sinus volumes in ACP-affected sides. This discrepancy could stem from differences in methodologies (e.g. the previous report may have measured raw sinus dimensions across individuals, whereas our within-patient comparison more directly isolates the effect of the polyp). It is also possible that what appears as a "large" sinus in cross-section could actually be a result of bony remodeling by long-standing pressure from an ACP, rather than a predisposing factor. More research is needed to clarify this aspect.

Strengths and Limitations: To our knowledge, this study is among the first to quantitatively evaluate maxillary sinus volume in the context of CRSwNP with ACP. By using each patient's contralateral normal sinus as a control, we controlled for inter-individual variability in sinus size and other host factors like allergy status and mucociliary function. However, our sample size was relatively small (n = 36), which limits the statistical power, especially for detecting volume differences that fell just short of significance. A larger cohort might clarify whether the observed 3–4 cm^3 volume reduction in ACP sinuses is consistently significant. Another limitation is that we relied on linear measurements and an ellipsoid volume approximation via PACS; direct volumetric segmentation of the sinus on high-resolution imaging could yield more precise volume assessments. We also did not specifically account for other anatomical variations (such as concha bullosa or degree of septal deviation) in our analysis, which could influence sinus aeration.

Implications and Future Directions: Despite these limitations, our findings suggest an anatomical predisposition wherein a smaller maxillary sinus cavity may favor the development of an antrochoanal polyp. This insight could be relevant to preoperative evaluation: patients with notably small sinuses on imaging might warrant closer observation for polyp recurrence or more aggressive management of the ostiomeatal complex during surgery. For future research, a larger multi-center study could confirm the correlation between sinus volume and CRSwNP outcomes. It would also be valuable to incorporate detailed analysis of other variables such as age, gender, and co-existing anatomical variants (e.g. septal deviation, turbinate pneumatization), as well as inflammatory biomarkers, to build a more comprehensive risk profile for ACP. In summary, recognizing the potential contribution of sinus anatomy to chronic rhinosinusitis may help refine patient stratification and personalize surgical planning in the management of nasal polyposis.

5. Conclusion

Our case-control analysis indicates that a smaller maxillary sinus in particular, one with a reduced anteroposterior depth may be associated with the presence of chronic rhinosinusitis with antrochoanal polyps. Patients with ACP had a significantly shorter maxillary sinus cavity and a trend toward lower sinus volume compared to their disease-free side. These findings suggest that anatomical sinus size could play a contributory role in the pathogenesis of sinonasal polyps, possibly by facilitating sinus outlet obstruction and chronic inflammation. Further research in larger cohorts, controlling for additional variables, is warranted to confirm this correlation and to better understand how sinus anatomy interacts with other risk factors in CRSwNP. Recognizing such anatomical predispositions can ultimately help refine surgical planning and improve patient outcomes in chronic rhinosinusitis.

6. Conflict of Interest

None.

7. Source of Funding

None.

8. Ethical Approval

Institutional Ethical Committee Letter No: 966/IEC/IGIMS/2023 Dated 10.04.2023.

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