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Association of maxillary sinus volume and deviated nasal septum (DNS) assessed by computed tomography (CT) in patients with chronic maxillary sinusitis in tertiary care hospital of Nepal

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Abstract

Introduction: Deviated nasal septum (DNS) is a common anatomical variation frequently associated with chronic maxillary rhinosinusitis (CRS). Changes in nasal airflow dynamics due to DNS can alter sinus ventilation and muco-ciliary drainage, potentially affecting maxillary sinus volume. Radiological assessment, particularly computed tomography (CT), plays a vital role in evaluating sinonasal anatomy and pathology.

Method: This cross-sectional, prospective study was done in Department of Radiology, Patan Hospital, among patients diagnosed with CRS who underwent paranasal sinus (PNS) CT scans. MSV were measured using CT imaging software, and the presence and severity of DNS were documented. Statistical analysis was performed using SPSS v 20.

Result: Among the patients, 237 (78.2%) had DNS, predominantly on the right side (54.0%). The mean MSV was significantly smaller on the deviated side (13.21±2.98 cm³) compared to the contralateral side (14.56±3.15 cm³, p<0.001). Increasing DNS severity was associated with progressive reduction in MSV (mild: 0.58 ± 0.61 cm³; moderate: 1.63±0.85 cm³; severe: 3.07±1.22 cm³; p<0.001). A strong negative correlation was found between deviation angle and ipsilateral MSV (r=–0.62, p<0.001). Mucosal thickening occurred in 84.2% of patients, mainly on the deviated side (62.4%, p=0.002), and was more frequent in moderate-to-severe deviations. Pyramidal sinus morphology predominated, with no significant right–left differences in patients without DNS

Conclusion: DNS significantly reduces ipsilateral sinus volume and increases mucosal changes. CT-based volumetric evaluation and septal assessment are vital for CRS diagnosis and surgical planning.

Keywords: Chronic maxillary sinusitis, Computed tomography, Deviated nasal septum, Maxillary sinus volume, Paranasal sinuses

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Introduction

The maxillary sinuses, located in the maxillary bones, begin developing in the third week of gestation from the first branchial arch. They grow rapidly between ages 3–7 and again after age 12, with gradual decline into early adulthood. The average volume is about 15 ml, with dimensions of 33 mm in height, 23–25 mm in width, and 34 mm in anteroposterior length.[1] While the exact mechanisms of paranasal sinus growth are not fully understood, factors such as nasal airflow, brain growth, muscle tension, and facial development are believed to contribute.[2] Deviated Nasal Septum (DNS) can obstruct sinus drainage, leading to congestion and a higher risk of Chronic Rhino-sinusitis (CRS), while also disrupting airflow, reducing ciliary movement which affects maxillary sinu volume (MSV) development.[3] Computed Tomography (CT)-based studies in Nepal have shown that deviated nasal septum is common (≈49.5%), with larger mean maxillary sinus volumes in males than females; however, no significant association was found between DNS type or laterality and maxillary sinus volume. The global prevalence of CRS measured in epidemiologic studies varies between 5% to 12% while the prevalence of CRS in Nepal was found to be 9.52%.[4,5]

Some studies suggest that severe DNS can significantly reduce MSV on the affected side, although results are not always consistent. Understanding the link between DNS and MSV is crucial for diagnosing and managing sinusitis and related conditions.[6] Meta-analysis done in India have showed a significant association between DNS and MSV, indicating that DNS may decrease MSV, particularly on the deviated side.[7] While variations in sinus volume may contribute to sinusitis, research on the effects of DNS and MSV is limited in our country. This study aims to address this limitation and clarify this association using CT imaging may improve understanding of anatomical risk factors and aid in better diagnosis and management of chronic maxillary sinusitis.

Method

This observational, prospective study was conducted in the Department of Radiology at Patan Hospital, a tertiary care center in Nepal, over a period of five months from Jun to Oct 2025. Ethical clearance was obtained from the Institutional Review Committee (IRC) of Patan Academy of Health Sciences (PAHS) (Ref. drs2508152073). A total of 303 patients diagnosed clinically with CRS, based on ≥12-week duration of ≥2 of the following symptoms; nasal obstruction, mucopurulent drainage, facial pain/pressure/fullness, or anosmia, were included. Radiological confirmation was based on CT evidence of mucosal inflammation.

Inclusion criteria comprised patients over the age of 18 years with symptoms consistent with CRS who underwent CT imaging of the paranasal sinuses for one or more of the following indications: failure of medical treatment, preoperative evaluation for functional endoscopic sinus surgery (FESS), assessment of anatomical variations such as a deviated nasal septum, or suspicion of complications. Exclusion criteria included patients with a history of previous nasal or sinus surgery (e.g., FESS, septoplasty), those with anatomical obliteration of the maxillary sinuses due to pathology (e.g., malignancy), and CT scans of inadequate quality due to motion or metallic artifacts.

All subjects underwent CT of the paranasal sinuses using a 128-slice CT scanner (Ingenuity, Philips Medical System). The scanning protocol included axial acquisition from the base of the skull to the vertex with 1.25 mm collimation, 0.8 mm reconstruction interval, 140 kVp, average tube current of 300 mA, and a pitch of 1.375. Images were evaluated using Philips Medical Systems workstation (Best, The Netherlands), employing multiplanar reformation and volume rendering techniques. The aerated maxillary sinus volume was calculated using the volume–tissue–air mode.

Measurements were taken in all three planes (axial, sagittal, and coronal) to determine maxillary sinus dimensions. Height (maximum craniocaudal diameter), width (maximum transverse diameter), and length (maximum anteroposterior diameter) were manually measured. Based on the overall morphology, each sinus was classified as either spherical or pyramidal in shape. The sinus volume was then calculated using the following geometric formulas.[9]

- For spherical sinuses: V=43πr3V=34πr3
- For pyramidal sinuses: V=13A×hV=31A×h, where *A* is the base area and *h* is the Deviated Nasal Septum (DNS) was assessed on coronal CT images. The direction of deviation was defined by the convexity of the septal curvature. The angle of deviation was measured using a line drawn from the anterior nasal spine to the crista galli as a midline reference, and another line extending from the anterior nasal spine to the most deviated point of the septum. DNS was classified into three categories according to the following grading system: mild (<9°), moderate (9°–15°), and severe (>15°).[10]

Each patient's CT scan was evaluated for mucosal disease (defined as ≥3 mm mucosal thickening).[8] In patients with DNS, the MSV on the deviated side was compared with the contralateral (non-deviated) side. All measurements were taken in millimeters and volumes in cubic centimeters.

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS v22).. Descriptive statistics were reported as mean±standard deviation (SD). The paired t-test was used to compare MSV between the deviated and non-deviated sides. Analysis of variance (ANOVA) was applied to compare differences among the three DNS angle groups (mild, moderate, severe). A p-value of <0.05 was considered statistically significant.

Result

A total of 303 patients meeting the inclusion criteria were enrolled in this study. The mean age was 36.8±11.9 years (18–68 years). There were172(56.76%) males and 131(43.24%) females, with a male-to-female ratio of 1.3:1. CT findings consistent with chronic mucosal inflammation (≥3 mm mucosal thickening) were present in 272(89.76%) patients.

Out of 303 patients, 237(78.21%) had DNS, while 66(21.79%) had a relatively straight septum. Among those with DNS, deviation was towards the right side was seen in 128(54.01%), Table 1.

Table 1. Proportion of different grades and side of deviated nasal septum (N=237)

Grades	n (%)
Mild (<9°)	84(35.44)
Moderate (9–15°)	97(40.93)
Severe (>15°)	56(23.63)
Deviation towards right side	128(54.01)
Deviation towards left side	109(45.99)
Mean deviation angle	11.80 ± 4.90°

Out of the total patients, majority presented with moderate degree of deviation (9–15°), accounting for 97(40.93%) patients, Table 1. The mean maxillary sinus volume (MSV) was calculated separately for the deviated and contralateral non-deviated sides. Across all patients with DNS, the mean MSV was significantly smaller on the deviated side (13.21±2.98 cm³) compared to the non-deviated side (14.56±3.15 cm³) (p<0.001), Table 2.

Maxillary sinus volume (MSV) decreased progressively with increasing grades of nasal septal deviation. In mild deviation (<9°), the mean MSV on the deviated side was 13.98±2.67 cm³ compared with 14.56±2.83 cm³ on the contralateral side, with mean difference of 0.58±0.61 cm³ (p=0.041). Moderate deviation (9–15°) showed a greater reduction, 13.03±2.54 cm³ vs 14.66±2.76 cm³, with mean difference of 1.63±0.85 cm³ (p<0.001), and severe deviation (>15°) demonstrated the largest difference (11.82±2.15 cm³ vs 14.89±3.11 cm³, mean difference of 3.07±1.22 cm³ (p<0.001). ANOVA trend analysis confirmed a significant progressive decrease in MSV with increasing deviation severity (p<0.001), Table 3.

A strong negative correlation was observed between the deviation angle and ipsilateral maxillary sinus volume (MSV) (Pearson r=–0.62, p<0.001), indicating that greater septal deviation is associated with smaller sinus volume, Figure 1.

Mucosal thickening of ≥3 mm was present in 255(84.21%) patients, predominantly affecting

Table 2. Comparison of maxillary sinus volumes between the deviated and contralateral sides

Parameter	Deviated side (mean±SD)	Contralateral side (mean±SD)	Mean difference (cm³)	p-value
Maxillary sinus volume (cm³)	13.21±2.98	14.56±3.15	1.35±1.02	<0.001*

*paired t-test

Table 3. Relationship between nasal septal deviation severity and maxillary sinus volume (N=237)

Grade of DNS	Frequency	Deviated side (cm³)	Contralateral side (cm³)	Mean difference (cm³)	p-value
Mild (<9°)	84	13.98 ± 2.67	14.56 ± 2.83	0.58 ± 0.61	0.041*
Moderate (9–15°)	97	13.03 ± 2.54	14.66 ± 2.76	1.63 ± 0.85	<0.001*
Severe (>15°)	56	11.82 ± 2.15	14.89 ± 3.11	3.07 ± 1.22	<0.001*

*ANOVA trend tests significant (p<0.001)

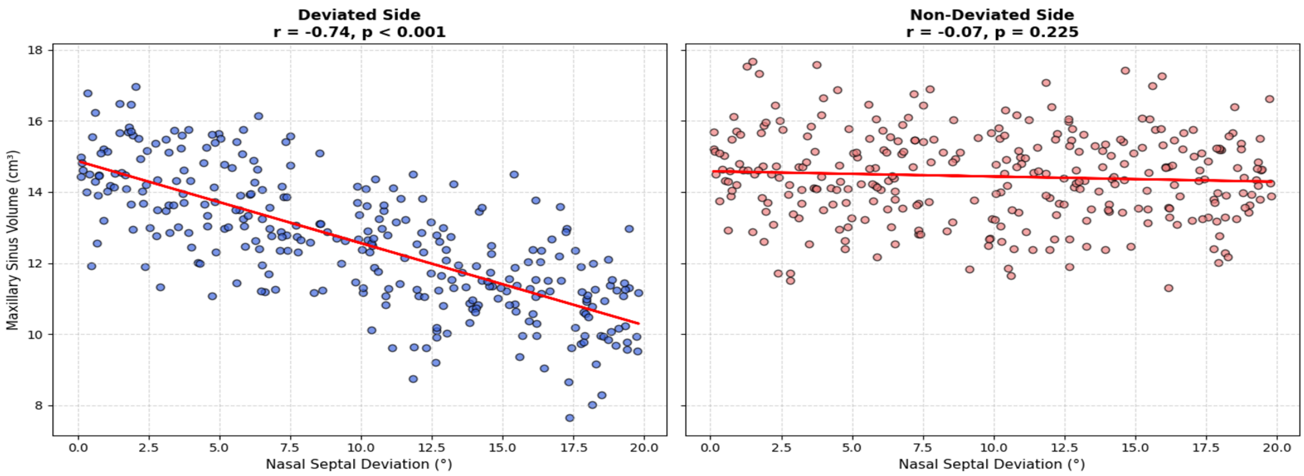

Figure 1. Scatterplot showing correlation of maxillary sinus volumes (MSV) with nasal deviation

Table 4. Relationship between severity of DNS and frequency of ipsilateral maxillary sinusitis (N=237)

Grade of DNS	Number of patients (n)	Ipsilateral sinusitis present (n, %)	Chi-square (χ^2)	p-value
Mild (<9°)	84	41(48.80)	χ^2 = 19.72	<0.001*
Moderate (9–15°)	97	69(71.13)		
Severe (>15°)	56	47(83.92)		

*Statistically significant (p < 0.05).

the deviated side in 189(62.4%) of the individuals. The mean mucosal thickness on the deviated side (4.56±1.22 mm) was significantly greater than on the contralateral side (3.73±1.08 mm) (p=0.002). Patients with moderate to severe deviation had higher rates of ipsilateral maxillary sinusitis, Table 4. These findings confirm that DNS is significantly associated with reduced sinus aeration and a higher frequency of mucosal pathology on the deviated side.

Regarding sinus shape, pyramidal morphology was more prevalent 203(66.99%) than spherical morphology 100(33.01%). Although sinus shape did not significantly differ between deviation groups (p=0.18), spherical sinuses tended to have slightly smaller mean volumes (12.94±2.61 cm³) than pyramidal ones (14.08±2.95 cm³).

No statistically significant difference was observed between right and left sinuses in patients without DNS (p=0.47), confirming that the observed volumetric asymmetry in the study cohort was mainly due to septal deviation rather than natural side-to-side variation.

Discussion

Our study demonstrated a significant reduction in the maxillary sinus volume on the side of septal deviation compared to the contralateral, non-deviated side. This asymmetry was more pronounced in patients with moderate and severe deviation (≥9°).[11] These findings are in close agreement with the results of multiple studies conducted internationally.

A CT-based study conducted in India among 130 patients observed that maxillary sinus volume was smaller on the side of septal deviation, with a progressive reduction corresponding to increasing severity of the deviation.[12] They also reported that osteomeatal complex (OMC) obstruction and ipsilateral sinusitis occurred significantly more frequently in patients with severe septal deviation, highlighting the impact of anatomical variations on sinus ventilation.[12] Similarly, a systematic review and meta-analysis conducted in Iran, which included both CT and Cone beam CT studies, found a significant association between DNS and reduced ipsilateral maxillary sinus volume, with mean volumetric differences ranging from 2.0 to 2.9 cm.[13] Comparable findings have been observed in studies from India and Turkey, where reduced maxillary sinus volumes were reported on the side of deviation, particularly in cases with moderate-to-severe DNS, further supporting the relationship between septal deviation, impaired sinus aeration, and increased susceptibility to chronic sinusitis.

In a cone bone CT study of 150 adults conducted in Iraq, the mean MSV on the side of septal deviation was significantly smaller than on the non-deviated side. These findings support the hypothesis that nasal septal deviation can alter sinus pneumatization, potentially impairing sinus ventilation and predisposing to chronic sinus pathology.[14] Similar findings were seen in a study done among the Korean population, emphasizing that mechanical obstruction from DNS can disturb normal airflow and mucociliary clearance within the sinonasal tract.[15]

Not all studies have found a relationship between septal deviation and maxillary sinus characteristics. Research from the USA and Turkey reported no significant correlation between septal deviation and either sinus volume or mucosal disease.[16,17] These differences may be due to variations in craniofacial anatomy across populations, the degree or site of septal deviation, differences in study populations, or the imaging and measurement methods used. In contrast, our study, involving a large Nepalese cohort and using standardized imaging with precise quantitative measurements, demonstrates a clear anatomical–functional association, highlighting the importance of population-specific data in understanding sinonasal anatomy.

Although few studies in Nepal have explored sinus volumetry, a study done at a tertiary hospital in Pokhara provided baseline CT-based measurements of maxillary sinus diameters in patients.[18] While their results showed mean maxillary sinus volumes similar to ours, they did not investigate the influence of septal deviation on sinus morphology. The present study addresses this gap by systematically quantifying the volumetric asymmetry associated with deviated nasal septum in a CRS cohort, offering novel insights into sinonasal anatomy in the Nepalese population. These findings may have important implications for surgical planning and personalized management of patients with septal deviation and sinus disease

The observed reduction in maxillary sinus volume (MSV) on the deviated side can be explained by both developmental and pathophysiological mechanisms. During facial growth, the maxillary sinuses expand through pneumatization from the lateral nasal wall. Mechanical deviation of the septum can alter airflow patterns, pressure gradients, and the local growth environment, leading to asymmetric sinus development.[19] A study conducted in the USA emphasized that septal deviation in early life may physically restrict pneumatization of the ipsilateral sinus, resulting in smaller bony cavities that persist into adulthood.[20,21] Such anatomical asymmetry may predispose the affected sinus to impaired ventilation and drainage, creating an ideal condition for chronic inflammation and contributing to the pathogenesis of chronic rhinosinusitis in patients with DNS.

In adults, chronic airflow turbulence caused by septal deviation can disrupt normal sinus ventilation and mucociliary transport. Reduced ventilation on the deviated side may lead to hypoxia of the sinus mucosa, impaired mucociliary clearance, and a tendency toward mucosal swelling. This ongoing inflammatory cycle can further decrease the effective aerated sinus volume by thickening the mucosa and narrowing the sinus ostium. Authors from Austria and the USA described how these changes in sinonasal airflow create a “vicious cycle” of obstruction and inflammation, particularly in the osteomeatal complex (OMC) region.[20,21]

Our study found that patients with higher septal deviation angles (>15°) had smaller sinus volumes and more frequent mucosal thickening on the deviated side, suggesting a possible dose-response relationship. These findings indicate that both developmental hypo pneumatization and secondary mucosal changes contribute to the volume asymmetry observed on CT. Clinically, this asymmetry may impair sinus ventilation and drainage, increase the risk of chronic inflammation and exacerbate symptoms in patients with CRS, highlighting the importance of assessing septal deviation when planning management or surgical interventions.

CRS is a multifactorial disease influenced by anatomy, microbes, allergies, and environmental factors. Variations like a deviated nasal septum, concha bullosa, and Haller cells can block the osteomeatal complex, causing mucus buildup and infection. Our findings show that such anatomical variations, particularly septal deviation, are associated with reduced maxillary sinus volume and mucosal thickening, highlighting their role in predisposing patients to CRS.

In our study, CT evidence of mucosal inflammation was more frequent on the deviated side in patients with moderate to severe DNS. This aligns with reports from other populations showing greater disease severity on the side of septal deviation. However, the strength of this association has varied between studies, with some reporting weaker correlations, possibly due to differences in study population, imaging methods, or ethnic and anatomical variations.[10,22] Our findings in a Nepalese cohort suggest that septal deviation can significantly contribute to sinus pathology by impairing drainage, emphasizing the importance of considering population-specific anatomical factors in CRS management.

In resource-limited healthcare settings such as Nepal, identifying anatomical risk factors like DNS on CT can guide clinical decision-making. Patients with CRS refractory to medical therapy and concurrent significant DNS may benefit from combined functional endoscopic sinus surgery (FESS) and septoplasty to restore ventilation and drainage pathways. Our study thus supports a more individualized surgical approach based on radiological anatomy.

The current study highlights the importance of detailed CT evaluation in CRS patients. Routine measurement of DNS angle and direction, as well as comparative analysis of maxillary sinus volumes, can aid in surgical planning. ENT surgeons should consider the possibility that the deviated side may harbor more extensive disease and require careful exploration during functional endoscopic sinus surgery (FESS).

In addition, understanding normal sinus volumes and their expected asymmetry is critical for radiologists and maxillofacial surgeons. Variations in sinus size influence procedures such as maxillary sinus floor augmentation for dental implants, Caldwell-Luc operations, and orbital floor repairs. Establishing normative sinus volumetric data in the Nepalese population, as provided by this study, contributes to improved local reference standards for such interventions.

This study has certain limitations. MSV were calculated using geometric assumptions, which could slightly underestimate the true measurements. Being conducted at a single center and lacking a healthy control group restricts the generalizability of the findings and makes it challenging to differentiate between developmental variations and changes caused by chronic inflammation. Moreover, factors such as dental problems, allergic rhinitis, and environmental exposures were not separately examined, and radiological assessment of mucosal disease was not correlated with clinical symptoms or outcomes.

Future investigations should incorporate automated 3D volumetric techniques, multicenter recruitment, and longitudinal designs, including comparisons before and after septoplasty. Linking imaging results with endoscopic and histopathological data would provide a better understanding of the clinical relevance of sinus volume changes and clarify the impact of septal deviation on sinus ventilation and mucosal pathology.

Conclusion

DNS is significantly associated with reduced maxillary sinus volume on the ipsilateral side in patients with CRS. The degree of deviation correlates with the extent of sinus volume reduction and a higher frequency of mucosal disease, particularly in moderate and severe cases. No inherent right–left asymmetry was observed in patients without septal deviation, highlighting the specific impact of DNS on sinus anatomy and pathology.

These findings suggest that DNS may disrupt normal sinonasal airflow, impairing ventilation and drainage and predisposing the sinus mucosa to chronic inflammation. Incorporating CT-based volumetric assessment and precise septal angle measurement into routine preoperative evaluation can improve surgical planning and outcome prediction. Given the high prevalence of DNS and CRS in the Nepalese population, such imaging-based anatomical assessment is recommended in tertiary care settings

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Conflict of Interest

None

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Author Contribution

Concept, design, planning: PJ, SKC, SS, YD ; Literature review: PJ; Data collection: PJ; Data analysis: PJ, SKC Draft manuscript: PJ, SKC; Revision of draft: PJ, SKC, SS, YD; Final manuscript: PJ; Accountability of the work: PJ, SKC, SS, YD.

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