

An Observational Study of Anatomical Variations of Ostiomeatal Complex affecting Mucociliary Clearance

<https://doi.org/10.47210/bjohns.2026.v34i1.276>

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ABSTRACT

Introduction

The ostiomeatal complex (OMC) is vital for sinus drainage and mucociliary clearance. Anatomical variations like deviated nasal septum (DNS) and concha bullosa may predispose to chronic rhinosinusitis (CRS). This study assessed the impact of DNS severity and variations on sinus involvement using Lund-Mackay (LM) scores.

Materials and Methods

A retrospective study of 73 patients (>18 years) undergoing Computed Tomography (CT) of paranasal sinuses was conducted. DNS was graded as: I (<5°), II (5–10°), III (10–15°), IV (>15°). Anatomical variations were recorded, and LM scoring applied to all sinuses and OMC. Statistical analysis included Spearman correlation and Chi-square test ($p < 0.05$ significant).

Results

Mean age was 38.8 ± 13.6 years; 58.9% had right-sided DNS. Concha bullosa was most common ($n = 57$). Right DNS strongly correlated with ipsilateral anterior ethmoid sinuses ($Rho = 0.578, p < 0.01$) and sphenoid ($Rho = 0.460, p < 0.01$) sinuses; left DNS correlated with anterior ethmoid ($Rho = 0.463, p < 0.01$) and maxillary ($Rho = 0.311, p < 0.05$). Chi-square the line analysis showed significant associations for all right-sided sinuses and for left anterior ethmoid and maxillary sinuses. OMC obstruction was linked to markedly higher LM scores across ipsilateral sinuses.

Conclusion

DNS severity and OMC obstruction significantly affect sinus disease, especially anterior ethmoid and maxillary regions. Common anatomical variants did not independently predict severity. Preoperative CT evaluation should emphasize DNS and OMC for optimal CRS management.

Keywords

Deviated Nasal Septum; Ostiomeatal Complex; Chronic Rhinosinusitis; Lund-Mackay; CT PNS

Nasal cavities and paranasal sinuses are characterized by high inter-individual anatomical variability.¹ The ostiomeatal complex (OMC) serves as a crucial drainage pathway for frontal, maxillary, and anterior ethmoid sinuses. Disruption in mucociliary clearance at this region predisposes patients to chronic rhinosinusitis (CRS).² Several anatomical variations, including deviated nasal septum (DNS), concha bullosa, and others, have been implicated in impaired sinus ventilation and drainage and the incidence of these anatomic variations varies among different populations.³

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Despite extensive literature, the impact of DNS severity on sinus involvement, particularly at the OMC, remains debated. This study aims to assess the relationship between anatomical variations and mucociliary clearance using Lund-Mackay scoring in the population of North Karnataka.

Materials and Methods

It is a hospital based retrospective observational study done in the Department of Otorhinolaryngology at a tertiary care centre in North Karnataka for a period of 1 year. 73 patients above 18 years of age who underwent coronal CT scan of paranasal sinuses were taken into study. Any patients with conditions which adversely influence anatomy of nasal cavity like previous surgical history, invasive fungal sinusitis, malignancy of PNS and trauma etc. were excluded from the current study. CT scan was performed by a 128-slice GE machine. Contiguous axial and coronal scans of 3mm slice thickness were taken from frontal sinus to sphenoid sinus. All films are taken without contrast.

Deviated nasal septum (DNS) severity was graded as: Grade I ($<5^\circ$), Grade II ($5-10^\circ$), Grade III ($10-15^\circ$), Grade IV ($>15^\circ$). Anatomical variations (Aggar nasi, concha bullosa, etc.) were documented. Lund Mackay (LM) scoring was applied for sinuses and OMC. Statistical analysis included descriptive statistics, Spearman correlation for DNS vs LM scores, and Chi-square tests for DNS grades vs LM subscores. A p-value <0.05 was considered significant.

Results

A total of 73 patients were included in this observational study, with a mean age of 38.8 ± 13.6 years. The gender distribution was 40 males and 33 females. DNS was observed on the right side in 43 patients (58.9%) and on the left side in 30 patients (41.1%). When graded based on the degree of deviation:

- Right DNS: Grade I: $n = 12$, Grade II: $n = 29$, Grade III: $n = 2$.

- Left DNS: Grade I: $n = 7$, Grade II: $n = 15$, Grade III: $n = 8$.

Table I : Distribution of Deviated Nasal Septum (DNS) by Side and Severity

	RIGHT DNS (43)	LEFT DNS (30)
Grade I ($<5^\circ$)	12	7
Grade II ($5-10^\circ$)	29	15
Grade III ($10-15^\circ$)	2	8
Grade IV ($>15^\circ$)	0	0

Anatomical Variations:

The most prevalent variation was concha bullosa (right: 38.4%, left: 39.7%). Followed by Aggar nasi and bulla ethmoidalis. Combined frequencies for key variations were Aggar Nasi ($n = 20$), Concha Bullosa ($n = 57$), Bulla Ethmoidalis ($n = 28$), Paradoxical MT ($n = 19$), Pneumatized Uncinate Process ($n = 4$), Onodi Cell ($n = 16$), Haller Cell ($n = 4$), Pneumatized Crista Galli ($n = 4$).

Lund-Mackay Score Analysis:

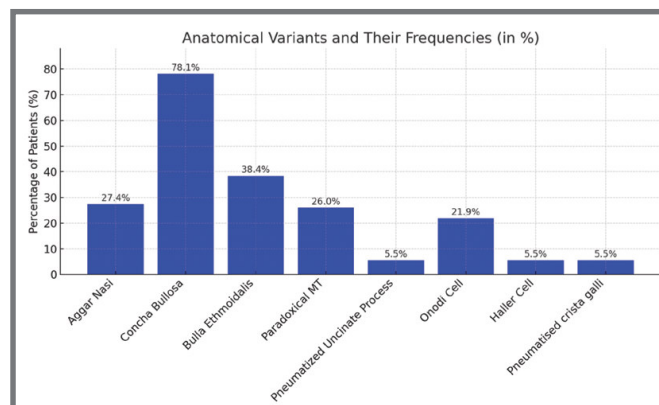


Fig. 1. . Frequency of Anatomical Variations in the Ostiomeatal Complex

The Lund-Mackay (LM) score was evaluated for all paranasal sinuses, with a particular emphasis on the ostiomeatal complex (OMC). In this study, the mean OMC score was approximately 1.07 ± 1.00 on the right and 1.15 ± 1.00 on the left, indicating that around half of the patients exhibited some degree of obstruction at this level. Among all measured regions, OMC showed the highest mean scores, followed by the maxillary sinuses, whereas frontal and ethmoid regions generally had lower scores.

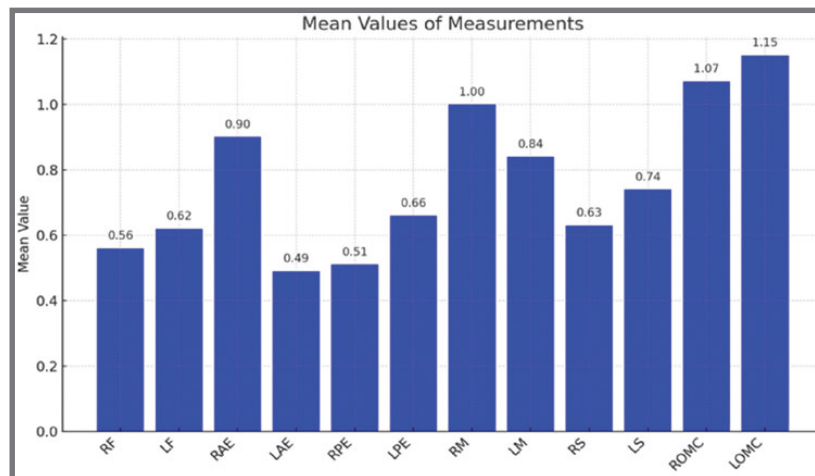


Fig. 2. Mean Lund-Mackay Scores Across Paranasal Sinuses

Correlation Between DNS and LM Scores:

Spearman's rank correlation revealed strong, statistically significant positive correlations between DNS severity and ipsilateral sinus involvement, particularly for the right side:

- Right DNS: RAE ($\tilde{n} = 0.578$, $p < 0.01$), LAE ($\tilde{n} = 0.505$, $p < 0.01$), RS ($\tilde{n} = 0.460$, $p < 0.01$), and RF ($\tilde{n} = 0.392$, $p < 0.05$).

- Left DNS: LAE ($\tilde{n} = 0.463$, $p < 0.01$) and LM ($\tilde{n} = 0.311$, $p < 0.05$).

Contralateral correlations were weak and did not reach statistical significance.

Chi-square Analysis:

A Chi-square test was performed to evaluate the association between DNS grades (I–IV) and Lund-Mackay subscores for individual sinuses:

- Right DNS demonstrated a significant association with ipsilateral sinus involvement, including the frontal, anterior ethmoid, posterior ethmoid, maxillary, and sphenoid sinuses ($p < 0.05$ for all).

- Left DNS also showed significant associations with anterior ethmoid and maxillary sinuses ($p < 0.05$), confirming that severe deviation on the left side influences disease in these regions.

Table II : Association Between DNS Severity and Lund-Mackay Sinus Scores (Chi-square Analysis)

SIDE OF DNS	SINUS	CHI2	DF	P-VALUE
Right	RF	13.22	4	0.010
Left	LF	6.31	4	0.177
Right	RAE	14.42	6	0.025
Left	LAE	18.71	4	0.0009
Right	RPE	10.52	4	0.032
Left	LPE	3.37	4	0.496
Right	RM	10.25	4	0.036
Left	LM	16.08	4	0.002
Right	RS	16.21	4	0.002
Left	LS	6.84	4	0.144

Correlation of OMC Obstruction with Ipsilateral Sinus Scores

The mean LM scores for ipsilateral sinuses were significantly higher when the ostiomeatal complex (OMC) was obstructed (score = 2) compared to when it was patent (score = 0). For the right side, OMC obstruction resulted in mean scores of Frontal: 1.4, Anterior Ethmoid: 1.8, Maxillary: 1.9, whereas these values were markedly lower when the OMC was patent (Frontal: 0.3, Anterior Ethmoid: 0.6, Maxillary: 0.4). A similar trend was observed on the left side (Frontal: 1.2 vs 0.4; Anterior Ethmoid: 1.7 vs 0.5; Maxillary: 1.8 vs 0.6). Spearman correlation analysis revealed a moderate to strong positive correlation between OMC obstruction and ipsilateral sinus involvement:

- Right side: $r = 0.45-0.68$ (strongest for anterior ethmoid and maxillary).
- Left side: $r = 0.40-0.62$ (strongest for anterior ethmoid and maxillary).

This indicates that OMC blockage is strongly associated with higher LM scores and more severe sinus disease.

Discussion

The present study investigated anatomical variations of the ostiomeatal complex (OMC) and their impact on mucociliary clearance using LM Scores. Our findings confirm that DNS severity significantly correlates with ipsilateral sinus involvement, particularly the anterior ethmoid and maxillary sinuses. This is consistent with the pathophysiological understanding that septal deviation can alter nasal airflow, compromise ventilation, and impair mucociliary clearance.⁴

Several studies have demonstrated a significant association between DNS and chronic rhinosinusitis (CRS) severity. Zahraa H Alsaggaf et al,⁵ reported that marked septal deviations are often associated with ipsilateral maxillary and ethmoid sinus disease, which aligns with our observation of a strong positive correlation between DNS grade and anterior ethmoid involvement ($\tilde{r} = 0.578, p < 0.01$). Similarly, Elahi MM et al.⁶ and E Scribano et al.⁷ highlighted that severe DNS ($>10^\circ$)

predisposes patients to obstruction at the OMC, increasing LM scores for the maxillary and ethmoid sinuses.

In the present study, right-sided DNS demonstrated stronger and more frequent significant associations compared to the left. However, after targeted analysis, we observed that severe left-sided DNS also significantly affected the left anterior ethmoid and maxillary sinuses, supporting the role of deviation severity rather than side dominance and we attribute this association to nasal anatomical asymmetry.

Our data confirm the importance of the OMC as a critical site for disease progression. Nearly 50% of our cohort exhibited obstruction at the OMC (LM = 2), emphasizing its role as a functional bottleneck, in agreement with Aramani A et al⁸ and Kennedy D⁹ who described the OMC as the primary drainage pathway whose obstruction leads to widespread sinus involvement.

Our findings demonstrate that obstruction of the OMC significantly increases ipsilateral sinus involvement. Patients with OMC blockage had substantially higher LM scores across all ipsilateral sinuses, with the greatest effect observed in the anterior ethmoid and maxillary regions. Obstruction at this level acts as a critical point of failure, resulting in muco-stasis and widespread disease. This reinforces the clinical principle that restoring OMC patency should be a primary surgical goal in functional endoscopic sinus surgery (FESS).

The frequency of anatomical variants in our population mirrors findings by Bolger et al.,¹⁰ where concha bullosa and Aggar nasi were the most common. However, in our multivariate analysis, these variations did not independently predict sinus disease severity, consistent with Fadda et al.,¹¹ who concluded that while common, these variants act as contributory rather than primary etiological factors. Some authors, such as Daniel Aliyu et al.,¹² have reported significant associations between concha bullosa and CRS severity, which contrasts with our findings. This discrepancy may be attributed to differences in study populations, sample size, or classification criteria for variations. Our data suggest that septal deviation and OMC obstruction play a more dominant role than isolated variants.

Conclusion

This study highlights the significant influence of anatomical variations on sinus disease patterns. Deviated nasal septum (DNS) severity demonstrated strong correlations with ipsilateral sinus involvement, particularly affecting the anterior ethmoid and maxillary sinuses. Although common variations like concha bullosa and Aggar nasi were frequently noted, they did not independently correlate with disease severity. This may be due to differences in study populations, as these variations have been reported to significantly influence outcomes in populations of other ethnic groups. Most importantly, obstruction of the ostiomeatal complex (OMC) showed a strong association with increased Lund-Mackay scores across all ipsilateral sinuses, confirming its critical role in mucociliary clearance. These findings highlight the need for thorough preoperative evaluation tailored to different populations and ethnic groups, along with functional surgical approaches that focus on correcting DNS and restoring OMC patency to optimize outcomes in the management of chronic rhinosinusitis.

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