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Osteomeatal Complex variations and Maxillary Sinusitis: A CT-Based Cross-Sectional Study

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ABSTRACT

Backgorund The osteomeatal complex (OMC) is the main drainage pathway of the paranasal sinuses, and anatomical variations, such as nasal septal deviation, may disrupt airflow and increase the risk of sinusitis; therefore, a CT Scan is the preferred modality for its evaluation. Objective: To determine the association between OMC anatomical variations and maxillary sinusitis based on head CT Scan results at Ajibarang Regional Hospital in 2024. Methodology: This analytic, observational, cross-sectional study used head CT Scan data, with OMC anatomical variations as independent variables and maxillary sinusitis as the dependent variable. Interobserver agreement was assessed using Fleiss' Kappa, followed by univariate analysis to determine frequency distribution, and bivariate analysis using the Chi-square (χ^2) test with a significance level of $p < 0.05$. Results: Interobserver agreement was substantial to perfect ($\kappa = 0.76–1.00$). Most patients presented with maxillary sinusitis (69.44%), and the most common anatomical variation was nasal septal deviation (52.78%), which was the only anatomical variation to show a significant association with maxillary sinusitis ($p = 0.001$). Conclusion: Nasal septal deviation is the only OMC anatomical variation significantly associated with maxillary sinusitis, while other variations showed no meaningful association.

1. INTRODUCTION

The paranasal sinuses are air-filled cavities that play an important role in ventilation, voice resonance, and the production and drainage of mucus into the nasal cavity through the osteomeatal complex (OMC). The OMC functions as the main drainage pathway of the maxillary, frontal, and anterior ethmoid sinuses. Impairment of OMC patency, whether due to mucosal inflammation or anatomical variations, may cause obstruction of airflow and secretions, thereby triggering the occurrence of sinusitis (Tortora & Derrickson, 2017; Valde et al., 2024).

Maxillary sinusitis is inflammation of the mucosa that occurs in the paranasal sinuses, particularly the maxillary sinus (Inggas et al., 2025). Maxillary sinusitis is the most frequently encountered form of sinusitis in clinical practice. Globally, sinusitis is one of the chronic inflammatory diseases of the upper respiratory tract with high prevalence, reported to affect 10–15% of the adult population. This condition not only causes local symptoms such as nasal obstruction, purulent rhinorrhea, facial pain, halitosis, and olfactory disturbance, but also has a significant impact on patients' quality of life, work productivity, and increases the burden on healthcare services due to recurrent visits, long-term antibiotic use, and the need for surgical intervention (Kennedy et al., 2024). The maxillary sinus is a cavity located within the maxillary bone. It is located on the floor of the orbit and superior to the molar and premolar teeth. Maxillary sinusitis is caused by obstruction due to anatomical variations of the OMC, thereby resulting in impaired drainage that leads to mucus retention and subsequent bacterial proliferation, as well as other factors such as upper respiratory tract infections caused by viruses, bacteria, or fungi, molar tooth infection, local factors including craniofacial anomalies, foreign bodies, trauma, and systemic factors such as asthma, cystic fibrosis, and immunodeficiency. In the long term,

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persistent or recurrent maxillary sinusitis may progress to chronic sinusitis and increase the risk of serious complications, such as orbital cellulitis, subperiosteal abscess, and even intracranial complications. In addition, this condition often indicates functional endoscopic sinus surgery (FESS), particularly in cases with predisposing anatomical factors that are unresponsive to medical therapy (Shetye, 2021; Kennedy et al., 2024).

The osteomeatal complex is the main drainage pathway of the maxillary sinus; therefore, anatomical variations such as nasal septal deviation and concha bullosa have the potential to affect sinus ostial patency. Nasal septal deviation is reported as the most frequently identified anatomical variation, followed by concha bullosa, agger nasi cell, Haller cell, variations of the uncinate process, paradoxical middle turbinate, and Onodi cell. Obstruction of the OMC may lead to accumulation of sinus secretions, which contribute to the development of maxillary sinusitis (Ahmed et al., 2024; Babkina et al., 2020).

Previous research has shown inconsistencies regarding the clinical role of certain OMC anatomical variations in the development of maxillary sinusitis. Several studies report a significant association between concha bullosa or Haller cells and sinusitis, whereas others do not have a significant association. These differences are presumed to be influenced by variations in study design, population characteristics, operational definitions of sinusitis, and imaging methods. This condition indicates a scientific gap that still needs to be examined further, at both the global and regional levels. Computed Tomography is the gold standard modality for evaluating OMC anatomy because it can detect detailed anatomical variations, assess their involvement in sinusitis, and serve as an important guide in planning Functional Endoscopic Sinus Surgery (FESS). In addition to its role in diagnostic and clinical management, the CT scan also plays a role in forensic science. On CT scan examination, hypodense intrasinus lesions with fluid levels and mucosal thickening > 2 mm may be identified (Rudrawadi & Ragupathi, 2024; Usmani et al., 2022).

Although previous studies have been conducted, data regarding the association between OMC anatomical variations and maxillary sinusitis in Indonesia, particularly in the local population at regional hospitals, remain limited. Therefore, research is needed to provide objective findings from CT scans to enrich scientific evidence and support clinical decision-making.

The objective of this study is to determine the association between anatomical variations of the osteomeatal complex and maxillary sinusitis based on head CT scan findings at Ajibarang Regional General Hospital in 2024, with the specific objectives of identifying the types of OMC anatomical variations, determining the proportion of patients with maxillary sinusitis, as well as analyzing the association between each OMC variation and maxillary sinusitis. This study has theoretical benefits in the form of scientific contributions in the fields of radiology and clinical anatomy regarding the role of OMC variations as predisposing factors for sinusitis, as well as practical benefits as a reference for hospital evaluation in assessing sinus drainage function, as a basis for CT scan–based diagnosis formulation, and as a means of public education regarding the importance of comprehensive nasal and sinus examination.

This study has novelty in its comprehensive examination of the association between anatomical variations of the osteomeatal complex and the occurrence of maxillary sinusitis, based on CT scan findings in the patient population at Ajibarang Regional General Hospital, as no similar study has been conducted at this hospital or within the local population. Unlike several previous studies that assessed only a limited number of anatomical variations or were not specific to the maxillary sinus, this study evaluates multiple OMC structures simultaneously, involving three observers to enhance the objectivity and reliability of radiological assessment. In addition, the variation in findings reported in the literature regarding the role of certain anatomical variations, such as concha bullosa, underscores the need for further research to provide comparative data and enrich the evidence useful for clinical practice, diagnostic support, and imaging-based management planning.

2. METHOD

This study was an observational analytic study with a cross-sectional design using secondary data in the form of head CT scan images obtained from the radiology medical records of Ajibarang Regional General Hospital for the 2024 period. The study population included all patients who underwent a head CT scan examination during that period. The study sample consisted of 252 CT scans selected using a simple random sampling technique, with inclusion criteria including patients aged ≥18 years, a field of view covering the nasal cavity, maxillary sinus, and osteomeatal complex structures, and good image quality for anatomical evaluation.

The study sample consisted of 252 head CT scan data that met the inclusion and exclusion criteria. Sample selection was performed using a purposive sampling technique, taking into account the suitability of the field of view and image quality for evaluation of the osteomeatal complex structures and the maxillary sinus. This technique was chosen to ensure that all samples could be optimally assessed in accordance with the study objectives, although it has the potential for selection bias.

The exclusion criteria included a history of paranasal sinus surgery, the presence of sinonasal tumors, massive nasal polyps, or destructive masses that altered the anatomy of the osteomeatal complex, a history of maxillofacial trauma resulting in facial bone or sinus deformities, congenital craniofacial anomalies, as well as CT scan images with severe artifacts or data that did not include the maxillary sinus.

The independent variable in this study was anatomical variations of the osteomeatal complex (OMC), which included agger nasi cell, Haller cell, Onodi cell, concha bullosa, paradoxical middle turbinate, nasal septal deviation, and variations of the uncinate process. The dependent variable was the presence of maxillary sinusitis, as determined by CT scan findings. The instruments used in this study included the PACS (Picture Archiving and Communication System) of Ajibarang Regional General Hospital for image data retrieval, and Horos software as a Digital Imaging and Communications in Medicine (DICOM) viewer. CT scan image assessment was performed by three observers using the Horos application, all of whom were competent in head-and-neck radiological interpretation. Before the image reading process, interobserver calibration was conducted to standardize the assessment criteria for anatomical variations and the radiological terminology used.

CT scan images that met the criteria were subsequently assessed independently, without knowledge of the patients' identities or the assessment results of the other observers. Interobserver agreement was analyzed using Fleiss' Kappa test, with κ values interpreted as follows: $\kappa < 0.40$ (poor), 0.40–0.75 (moderate), and >0.75 (good to very good). The image interpretation results were analyzed to assess interobserver agreement using the Fleiss' Kappa test. The association between anatomical variations of the osteomeatal complex and maxillary sinusitis was analyzed using the Chi-square (χ^2) test. A p-value < 0.05 was considered statistically significant. All data analyses were performed using appropriate statistical software.

3. RESULT AND DISCUSSION

Result

The analysis was performed on 252 CT scan samples that had met the inclusion and exclusion criteria. Interobserver agreement was conducted by three observers to ensure the consistency and reliability of the assessment of OMC anatomical variations. Once the level of agreement was considered adequate, the data were processed for further analysis.

Table 1. Distribution of OMC Variations and the Occurrence of Maxillary Sinusitis

Anatomical Variable	Frequency (n)		Percentage (%)	
	Present	Absent	Present	Absent
Maxillary Sinusitis	175	77	69,44	30,56
Nasal Septal Deviation	133	119	52,78	47,22

Concha Bullosa	120	132	47,62	52,38
Paradoxical Concha Media	23	229	9,13	90,87
Uncinate *Process Variation*	66	186	26,19	73,81
Onodi Cell	3	249	1,19	98,81
Agger Nasi Cell	95	157	37,70	62,30
Haller Cell	108	144	42,86	57,14

In this study, anatomical variations of the osteomeatal complex (OMC) were identified in varying proportions. Maxillary sinusitis was identified in 69.44% of subjects, whereas 30.56% did not experience it. Nasal septal deviation was the most frequently identified variation (52.78%), followed by concha bullosa (47.62%) and Haller cell (42.86%). Other variations, such as the agger nasi cell, were recorded in 37.70% of cases, while variations of the uncinate process were found in 26.19% of cases. The paradoxical middle turbinate and Onodi cell had the lowest percentages at 9.13% and 1.19%, respectively.

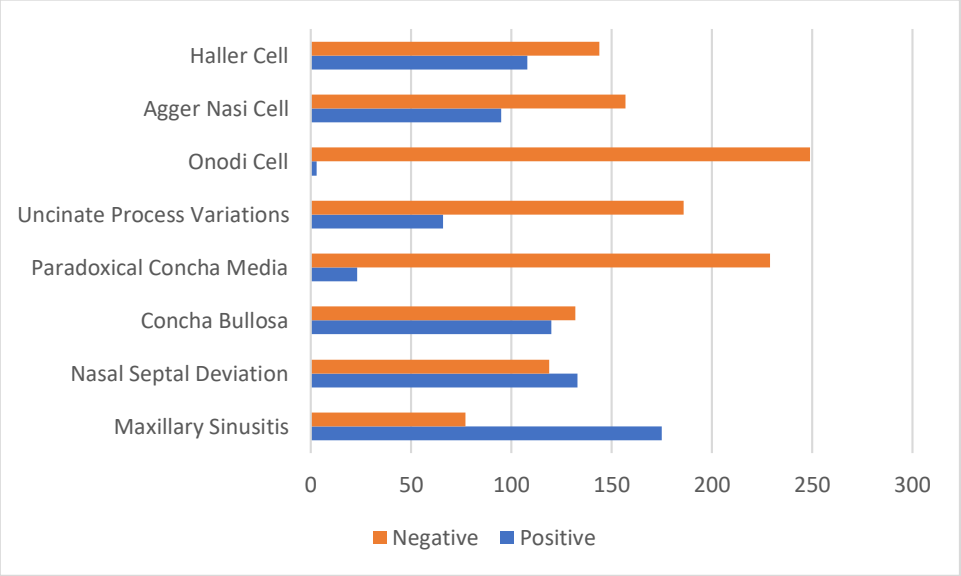

Figure 1. Distribution of OMC Variations and Maxillary Sinusitis

Bivariate analysis was performed to evaluate the association between anatomical variations of the osteomeatal complex and the occurrence of maxillary sinusitis using the Chi-square test, with a significance level of $\alpha = 0.05$. This test aimed to determine whether each anatomical variation significantly affected the risk of developing maxillary sinusitis. The statistical test results were interpreted based on the p-value, where $p < 0.05$ was considered statistically significant, indicating a significant association between anatomical variables and maxillary sinusitis.

Table 2. Association Between OMC Variations and Maxillary Sinusitis

Dependent Variable	Independent Variable	χ^2	*p*-value
Maxillary Sinusitis	Nasal Septal Deviation	11.986	0.001
	Concha Bullosa	2.408	0.121
	Paradoxical Middle Turbinate	0.927	0.336
	Uncinate Process Variation	0.003	0.959
	Onodi Cell	0.011	0.916
	Agger Nasi Cell	0.327	0.567
	Haller Cell	0.305	0.580

Based on the results of the Chi-square test presented in the table above, it can be observed that among all anatomical variations of the osteomeatal complex analyzed, only nasal septal deviation demonstrated a significant association with maxillary sinusitis ($\chi^2 = 11.986$; $p = 0.001$). This finding indicates that septal deviation significantly increases the risk of maxillary sinusitis. Clinically, nasal septal deviation may obstruct airflow and sinus drainage, thereby increasing the likelihood of maxillary sinus inflammation.

Other anatomical variations, including concha bullosa, paradoxical middle turbinate, variations of the uncinate process, Onodi cell, agger nasi cell, and Haller cell, did not demonstrate a statistically significant association with maxillary sinusitis ($p > 0.05$). This finding indicates that although these anatomical variations may influence sinus morphology or drainage pathways, their effect on the risk of maxillary sinusitis is not as substantial as that of nasal septal deviation. This finding is consistent with several previous studies, which emphasize that nasal septal deviation is the most dominant anatomical factor associated with maxillary sinusitis, whereas other anatomical variations tend to have a minor influence or act only as additional predisposing factors.

Discussion

The results of the Fleiss' Kappa test demonstrated good to very good interobserver agreement ($\kappa = 0.76–1.00$), indicating that the assessment of anatomical variations of the osteomeatal complex (OMC) on head CT scans was consistent and reliable. The highest level of agreement was observed for the Onodi cell ($\kappa = 1.00$), which may be attributed to its clearly defined anatomical boundaries on CT imaging, making it readily identifiable by each observer. Conversely, the paradoxical middle turbinate showed the lowest level of agreement ($\kappa = 0.76$), which can be explained by variations in shape and the minimal degree of displacement of the middle turbinate, thereby complicating interpretation in several cases. Overall, these findings indicate that the radiological data used were feasible for further analysis. Based on non-contrast head CT scan findings, maxillary sinusitis was the most common, followed by nasal septal deviation, with 175 cases of maxillary sinusitis and 133 cases of nasal septal deviation among 252 head CT scan patients. Other anatomical variations of the osteomeatal complex included concha bullosa in 120 cases, Haller cell in 144 cases, agger nasi cell in 95 cases, and uncinate process variation in 66 cases, whereas paradoxical middle turbinate was identified in 23 patients. The least frequently identified anatomical variation was the Onodi cell, which was found in only 3 patients.

This study found that only nasal septal deviation was associated with maxillary sinusitis. This finding is consistent with the study by Putra et al. (2022), which showed that 74.1% of patients with nasal septal deviation had concomitant maxillary sinusitis. Other studies have also demonstrated that nasal septal deviation, combined with other anatomical variations of the osteomeatal complex, may further impair sinus drainage and increase obstruction (Baisakhiya et al., 2023).

Nasal septal deviation showed a significant association with maxillary sinusitis due to its pathophysiological effects on ventilation of the nasal cavity and paranasal sinuses, particularly the maxillary sinus. Nasal septal deviation causes imbalance of airflow and alterations in intranasal pressure, which cumulatively may impair sinus ventilation and drainage. This condition has the potential to trigger persistent mucosal inflammation and explains the consistent finding of septal deviation as a significant factor compared with other anatomical variations of the osteomeatal complex (Wardani et al., 2017; Dhingra et al., 2018).

In contrast to the present findings, Mahebbi et al. (2020) reported that nasal septal deviation was not significantly associated with maxillary sinusitis, indicating that nasal septal deviation does not always result in clinically relevant impairment of sinus ventilation. These differences in findings can be due to assessing septal deviation solely by its presence or direction, without evaluating its severity or functional impact on the osteomeatal complex. Ventilation of the maxillary sinus is not determined solely by septal position, but may also be influenced by ostial patency and mucosal balance. Therefore, nasal septal deviation does not always have a direct implication for inflammation of the maxillary sinus.

Differences in study design, population characteristics, and imaging methods also contribute to inconsistent results, particularly in studies using head CT scans or dedicated paranasal sinus CT scans. This finding emphasizes that the role of nasal septal deviation in maxillary sinusitis is context-dependent and cannot be generalized without considering the degree of deviation and other local factors.

Conversely, other anatomical variations of the osteomeatal complex tend to exert limited local effects. The presence of osteomeatal complex variations on CT scan does not always result in functional obstruction, as their effect is influenced by size, degree of pneumatization, and their anatomical relationships with surrounding structures. Therefore, anatomical variations of the osteomeatal complex may be incidental findings and do not necessarily contribute directly to the occurrence of maxillary sinusitis.

The findings of this study have important implications for radiological and otorhinolaryngological practice. For radiologists, nasal septal deviation should be consistently reported because it can have broad functional effects on sinonasal ventilation. Meanwhile, other anatomical variations of the osteomeatal complex should still be documented, even if they do not demonstrate a statistically significant association, as these findings remain relevant for planning functional endoscopic sinus surgery (FESS) and for anatomy-based therapeutic decision-making. Interpretation of CT findings integrated with clinical and endoscopic data is expected to improve diagnostic accuracy and prevent unnecessary interventions.

CT scan, the primary imaging modality for evaluating the paranasal sinuses, has limitations because it assesses only static anatomical structures. This examination cannot evaluate mucociliary function, the dynamics of mucosal edema, or fluctuating mucosal inflammatory activity. Sinusitis is a multifactorial disease with a dominant inflammatory component; therefore, OMC anatomical findings on CT scans should be interpreted cautiously and not considered the sole determinant of diagnosis or disease severity.

This study has several limitations, including its retrospective design, the use of non-contrast head CT scans rather than dedicated paranasal sinus CT scans, and assessment limited to static anatomical features without evaluation of the severity of nasal septal deviation. In addition, patient clinical factors were not comprehensively analyzed. Future studies are recommended to use a prospective design with dedicated paranasal sinus CT imaging and integration of clinical and endoscopic data to evaluate the role of anatomical variations as predisposing factors in the pathogenesis of sinusitis.

4. CONCLUSION

Maxillary sinusitis was the most common finding on a non-contrast head CT scan. Nasal septal deviation showed a statistically significant association with the occurrence of maxillary sinusitis and acts as the primary anatomical factor influencing ventilation and drainage of the maxillary sinus. Other anatomical variations of the osteomeatal complex did not show a significant association; however, they remain clinically relevant as predisposing factors.

The results of this study emphasize the importance of identifying and reporting nasal septal deviation on CT scans as part of the evaluation of maxillary sinusitis and may serve as a basis for clinical consideration in management planning and further research regarding the role of osteomeatal complex anatomical variations in paranasal sinus disease..

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