

**To study the Association of Osteomeatal Complex Anatomy and Sinonasal Microbiota with reference to Airway Management Difficulty in Patients Undergoing Endoscopic Sinonasal and Orbital Surgery**

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Abstract

Background: The osteomeatal complex (OMC) is an important anatomical region of the lateral nasal wall that plays a major role in the drainage and ventilation of the paranasal sinuses. Anatomical variations in this region may influence sinonasal disease, surgical complexity, and potentially perioperative airway management. Sinonasal

microbiota may also contribute to persistent sinonasal inflammation.

Aim: To evaluate the relationship between osteomeatal complex anatomical variations, sinonasal microbiological findings, and airway management difficulty in patients undergoing endoscopic sinus and orbital surgeries.

Materials and Methods: This observational study included 50 patients undergoing endoscopic sinus and

orbital surgeries. All patients underwent clinical assessment and HRCT evaluation of the paranasal sinuses to identify OMC anatomical variations. Sinonasal specimens were evaluated for bacterial culture. Preoperative airway assessment included Mallampati classification, mouth opening, and thyromental distance. Intraoperative airway management was assessed with respect to difficulty of laryngoscopy, number of intubation attempts, and requirement for alternative airway manoeuvres.

Results: Of the 50 patients, 29 (58%) were males and 21 (42%) were females. The most common age group was 31–40 years (30%). Nasal obstruction was the commonest presenting symptom (70%). On HRCT, deviated nasal septum was the most frequent anatomical variation (48%), followed by agger nasi cells (36%) and concha bullosa (30%). Multiple OMC variations were observed in 14 patients (28%). Sinonasal culture was positive in 14 patients (28%), with *Staphylococcus aureus* being the most frequently isolated organism (12%). Overall, 14 patients (28%) had difficult airway management, while 36 (72%) had an easy airway. Difficult airway was observed in 77.8% of patients with multiple OMC variations compared with 25% of patients with a single variation and 12% of patients with no/minimal variation.

Conclusion: OMC anatomical variations are frequently encountered in patients undergoing endoscopic sinus and orbital surgeries. In this study, difficult airway management was more frequently observed among patients with multiple OMC anatomical variations. Sinonasal culture positivity was also more frequent among difficult cases. Detailed preoperative HRCT assessment, microbiological evaluation, and systematic airway assessment may therefore assist in comprehensive

perioperative planning. Larger prospective studies are required to confirm the observed associations.

Keywords: Osteomeatal Complex, Anatomical Variation, Chronic Rhinosinusitis, Sinonasal Microbiota, HRCT, Difficult Airway, Endoscopic Sinus Surgery, Orbital Surgery.

Introduction

Chronic rhinosinusitis (CRS) is a common chronic inflammatory disorder involving the mucosa of the nasal cavity and paranasal sinuses. It is characterized by persistent sinonasal symptoms, including nasal obstruction, nasal discharge, facial pain or pressure, and reduction in the sense of smell, together with objective evidence of disease on nasal endoscopy or computed tomography (CT)^{1,2}. CRS represents a major health burden because of its chronicity, frequent recurrence, impairment of quality of life, and substantial impact on daily activities and productivity^{1,2}. The pathogenesis of CRS is complex and multifactorial, involving interactions between host immunity, mucosal inflammation, epithelial dysfunction, environmental factors, anatomical abnormalities, and the sinonasal microbial community^{1,2}. The **osteomeatal complex (OMC)** is an anatomically and functionally important region of the lateral nasal wall. It constitutes a common drainage pathway for the frontal, maxillary, and anterior ethmoidal sinuses and plays an important role in maintaining normal sinus ventilation and mucociliary clearance^{3,4}. Because the OMC is relatively narrow and surrounded by several anatomical structures, even small variations may potentially influence the patency of the drainage pathway. Obstruction of the OMC can interfere with normal sinus drainage and ventilation and may contribute to the development or persistence of inflammatory sinonasal disease³⁻⁵. The anatomy of the OMC demonstrates

considerable interindividual variation. Common anatomical variations include deviated nasal septum, concha bullosa, paradoxical middle turbinate, agger nasi cells, Haller cells, and variations of the uncinate process³⁻⁶. The frequency of these variations varies considerably between different populations and studies. A systematic review and meta-analysis has demonstrated substantial geographical and population-related variation in the prevalence of anatomical variants of the lateral nasal wall and anterior skull base⁶. Recognition of these variations is therefore important when interpreting radiological findings and planning endoscopic surgery.

The association between OMC anatomical variations and CRS has been extensively investigated, although the relationship remains controversial. Some studies have reported that certain anatomical variations may narrow the OMC and predispose to obstruction and sinus disease, whereas other studies have found no significant association between individual anatomical variants and CRS [3-5]. This suggests that anatomical variations should not necessarily be regarded as pathological findings in isolation. Their clinical importance may depend on their location, severity, number, interaction with adjacent structures, and relationship with inflammatory disease³⁻⁶. Among the different anatomical abnormalities, deviated nasal septum is one of the most frequently encountered findings in patients undergoing CT evaluation of the paranasal sinuses. Septal deviation can alter the width of the nasal passages and may affect the relationship between the middle turbinate, uncinate process, and OMC. Similarly, concha bullosa, which represents pneumatization of the middle turbinate, may reduce the space available within the middle meatus and potentially contribute to impaired drainage³⁻⁵. Agger nasi cells, Haller cells, and uncinate process variations may

also modify the anatomy of the drainage pathways and have important implications during endoscopic surgery⁴⁻⁶.

High-resolution computed tomography (HRCT) has become an essential investigation in the evaluation of sinonasal disease and in preoperative planning for functional endoscopic sinus surgery (FESS). HRCT provides excellent delineation of the bony anatomy of the nasal cavity and paranasal sinuses and allows detailed assessment of the OMC, ethmoid labyrinth, orbital walls, skull base, and other critical structures^{7,8}. It can demonstrate both the extent of mucosal disease and the anatomical variations that may influence the surgical approach. Consequently, systematic evaluation of HRCT is particularly important in patients undergoing endoscopic sinus and orbital procedures.

The importance of detailed radiological assessment is further emphasized by the close anatomical relationship between the paranasal sinuses, orbit, skull base, optic nerve, and internal carotid artery. Certain anatomical configurations may increase the potential risk of orbital, vascular, or intracranial complications during endoscopic procedures.^{7,8} Identification of these variations before surgery allows the surgeon to modify the operative approach and minimize avoidable complications. Thus, HRCT is not merely a diagnostic investigation but also an important tool for individualized surgical planning. Apart from anatomical factors, the sinonasal microbiota has increasingly been recognized as an important component of sinonasal health and disease. The healthy sinonasal cavity is colonized by a diverse microbial community that interacts continuously with the respiratory epithelium and host immune system⁹⁻¹⁰. In CRS, alterations in microbial composition and diversity have been described. These changes may influence local inflammation, epithelial

barrier function, and disease persistence^{9,10}. Therefore, CRS is increasingly regarded as a disorder involving complex interactions between host immunity and the sinonasal microbial ecosystem rather than simply a conventional bacterial infection. Several bacterial organisms have been identified in patients with chronic sinonasal disease. **Staphylococcus aureus** has received particular attention because of its association with persistent inflammation and certain CRS phenotypes, especially in patients with nasal polyposis¹¹. Other organisms, including *Pseudomonas aeruginosa*, *Streptococcus* species, *Klebsiella* species, and other Gram-positive and Gram-negative bacteria, may also be isolated depending on the patient's clinical characteristics and previous treatment⁹⁻¹¹. However, interpretation of culture results requires caution because the presence of a microorganism does not necessarily establish it as the primary cause of chronic sinonasal inflammation.

The concept of the sinonasal microbiome has expanded beyond the identification of individual pathogenic organisms. Studies have suggested that microbial diversity and community structure may be important determinants of sinonasal health^{9,10}. A reduction in microbial diversity or disruption of the normal microbial community may contribute to inflammatory disease in susceptible individuals. Antibiotic exposure, corticosteroid treatment, surgery, environmental factors, and host immune responses may further alter the microbial composition.¹⁰ Consequently, microbiological findings may provide complementary information when considered alongside clinical symptoms and radiological anatomy. Endoscopic sinus surgery is widely used in appropriately selected patients with CRS who remain symptomatic despite appropriate medical therapy^{1,2}. The primary objective of surgery is to restore functional

drainage and ventilation while preserving normal mucosa and minimizing surgical trauma. Detailed knowledge of OMC anatomy is essential for achieving these objectives^{4,7}. Anatomical variations can influence the technical difficulty of surgery and, in certain circumstances, may increase the risk of complications. Preoperative CT assessment therefore serves as a bridge between diagnosis and operative planning. Patients undergoing endoscopic sinus and orbital surgeries are also exposed to the challenges associated with general anaesthesia and airway management. Although the surgical field is located in the sinonasal and orbital regions, securing and maintaining a stable airway is a fundamental component of perioperative safety. Difficult airway management may result from anatomical factors such as restricted mouth opening, reduced thyromental distance, limited neck mobility, unfavorable Mallampati classification, or other craniofacial characteristics¹². Current difficult-airway guidelines recommend systematic preoperative evaluation to identify patients who may be at increased risk of difficult laryngoscopy or intubation¹².

The **Mallampati classification** is one of the commonly used bedside tools for predicting difficulty in airway management. Other parameters, including mouth opening, thyromental distance, neck mobility, dentition, and previous history of difficult intubation, are also considered during preoperative assessment.¹² Nevertheless, no single clinical parameter has adequate sensitivity and specificity to predict every difficult airway. A combination of clinical findings and appropriate planning is therefore recommended¹².

The possible association between sinonasal anatomical complexity and airway management difficulty is an area that has received comparatively less attention. Most

previous studies examining OMC anatomy have focused on its relationship with CRS, sinus drainage, and complications of endoscopic surgery [3-8]. In contrast, airway literature has traditionally concentrated on oropharyngeal, laryngeal, craniofacial, and systemic predictors of difficult intubation.¹² The potential relationship between the radiological characteristics of the sinonasal region and perioperative airway management therefore warrants further investigation. The coexistence of multiple anatomical variations may be more clinically relevant than the presence of a single isolated variation. A combination of septal deviation, concha bullosa, agger nasi cells, Haller cells, and uncinate process abnormalities may result in greater anatomical complexity of the OMC and may potentially influence surgical access⁴⁻⁸. Assessing the **number and pattern of anatomical variations**, rather than simply recording their presence or absence, may therefore provide a more meaningful assessment of sinonasal anatomical complexity. Similarly, combining radiological and microbiological information may provide a more comprehensive picture of sinonasal disease. HRCT demonstrates the structural and anatomical component, whereas microbiological examination provides information regarding the microbial environment. Clinical assessment and airway evaluation provide additional information relevant to perioperative management. Integration of these parameters may therefore facilitate more comprehensive risk stratification in patients undergoing endoscopic sinus and orbital surgeries.

The present study was undertaken to evaluate the correlation between osteomeatal complex anatomy, sinonasal microbiota, and airway management difficulty in patients undergoing endoscopic sinus and orbital

surgeries. The study evaluates the demographic and clinical characteristics of the patients, identifies OMC anatomical variations on HRCT, assesses sinonasal microbiological findings, and documents relevant preoperative airway parameters and intraoperative airway management outcomes. By studying these parameters together, the present investigation aims to determine whether increasing OMC anatomical complexity is associated with greater difficulty in airway management and to explore the relationship between sinonasal anatomical findings and microbiological characteristics. Such an integrated approach may help improve preoperative evaluation and multidisciplinary communication between otorhinolaryngologists, radiologists, anesthesiologists, and orbital surgeons. Ultimately, a better understanding of the relationship between OMC anatomy, sinonasal microbiota, and airway management may contribute to safer surgical planning and improved perioperative care. Identification of potentially difficult anatomical and airway characteristics before surgery may allow appropriate preparation, selection of suitable airway strategies, and reduction of preventable perioperative complications. The findings may also provide a basis for future studies involving larger patient populations and more detailed radiological, microbiological, and anaesthetic parameters.

Materials and Methods

Study Design and Setting

This was an observational hospital-based study conducted among patients undergoing endoscopic sinus and orbital surgeries. The study was designed to evaluate the relationship between osteomeatal complex (OMC) anatomical variations, sinonasal microbiological findings, and difficulty in airway management.

Study Population

A total of 50 patients undergoing endoscopic sinus and/or orbital surgery were included in the study. Patients were evaluated preoperatively, radiologically, microbiologically, and perioperatively for the parameters relevant to the study objectives.

Inclusion Criteria

Patients were included if they:

1. Were undergoing endoscopic sinus or orbital surgery.
2. Had preoperative HRCT evaluation of the paranasal sinuses.
3. Were suitable for general anaesthesia and airway assessment.
4. Had adequate clinical and radiological information available for analysis.
5. Provided informed consent for participation.

Exclusion Criteria

Patients were excluded if they:

1. Refused consent for participation.
2. Had incomplete clinical or radiological records.
3. Had a previously documented major difficult airway unrelated to the current sinonasal condition, where this could confound assessment.
4. Had conditions precluding adequate HRCT evaluation.
5. Had incomplete microbiological or perioperative airway data.

Clinical Evaluation

A detailed clinical history was obtained from all patients, including demographic characteristics, presenting symptoms, duration of symptoms, previous sinonasal disease, and relevant treatment history. Particular attention was given to symptoms such as nasal obstruction, nasal discharge, headache or facial pain,

postnasal drip, reduced sense of smell, recurrent sinusitis, and orbital symptoms.

Radiological Assessment

All patients underwent high-resolution computed tomography (HRCT) of the paranasal sinuses as part of preoperative evaluation. The OMC was systematically assessed for anatomical variations and disease-related changes. The anatomical parameters evaluated included:

- Deviated nasal septum
- Concha bullosa
- Agger nasi cells
- Haller cells
- Paradoxical middle turbinate
- Uncinate process variations
- Presence of single or multiple OMC anatomical variations

The CT findings were recorded and subsequently correlated with clinical and airway-management findings.

Sinonasal Microbiological Assessment

Sinonasal specimens obtained during the operative procedure were subjected to microbiological examination. Samples were processed for bacterial culture using standard laboratory methods. The presence or absence of microbial growth was recorded, and isolated organisms were documented. The principal organisms evaluated included *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Streptococcus* species, *Klebsiella* species, and other organisms identified on culture.

Preoperative Airway Assessment

All patients underwent routine preoperative airway evaluation. Airway assessment included Mallampati classification, mouth opening, and thyromental distance. Mallampati grading was recorded as grades I–IV. Mouth opening of less than 3 cm and thyromental distance of less

than 6 cm were considered potentially unfavorable airway findings.

Assessment of Airway Management

During general anaesthesia, airway management was documented. The airway was categorized as easy or difficult based on the clinical and laryngoscopic findings and the number of attempts required for successful endotracheal intubation. Difficult laryngoscopy, requirement for more than one intubation attempt, and requirement for alternative airway manoeuvres were also recorded.

Study Variables

The primary variables assessed were:

1. Demographic characteristics.
2. Clinical presentation.
3. OMC anatomical variations on HRCT.
4. Sinonasal microbiological findings.
5. Preoperative airway assessment parameters.
6. Difficulty of airway management.
7. Relationship between the number/pattern of OMC anatomical variations and airway difficulty.

Statistical Analysis

Data obtained from all 50 patients were entered into a structured database and analyzed statistically. Categorical variables were expressed as frequency and percentage. Associations between categorical variables, particularly OMC anatomical variations and airway-management difficulty, were assessed using an appropriate test such as the Chi-square test or Fisher's exact test, depending on the distribution and expected cell frequencies. A p -value <0.05 was considered statistically significant.

Results

A total of 50 patients undergoing endoscopic sinus and orbital surgeries were included in the study. Of these, 14

patients (28%) were classified as positive/difficult cases, while 36 patients (72%) were negative/easy cases.

Table 1: Demographic characteristics of the study population (n=50)

Parameter	Category	n	%
Age	≤20 years	4	8
	21–30 years	11	22
	31–40 years	15	30
	41–50 years	11	22
	>50 years	9	18
Sex	Male	29	58
	Female	21	42
Total		50	100

The study included 50 patients. The majority belonged to the 31–40-year age group, comprising 15 patients (30%), followed by 21–30 years and 41–50 years with 11 patients (22%) each. Nine patients (18%) were above 50 years and four (8%) were ≤20 years. There was a slight male predominance, with 29 males (58%) and 21 females (42%).

Table 2: Clinical presentation of the study population (n=50)

Clinical feature	n	%
Nasal obstruction	35	70
Nasal discharge	32	64
Headache/facial pain	27	54
Postnasal drip	21	42
Reduced sense of smell	16	32
Recurrent sinusitis	14	28
Orbital symptoms	7	14

Nasal obstruction was the most common presenting symptom, occurring in 35 patients (70%), followed by

nasal discharge in 32 patients (64%). Headache or facial pain was reported by 27 patients (54%), while postnasal drip was present in 21 (42%). Reduced sense of smell was reported in 16 patients (32%), recurrent sinusitis in 14 (28%), and orbital symptoms in 7 patients (14%).

Table 3: Osteomeatal complex anatomical findings on HRCT (n=50)

HRCT finding	n	%
Deviated nasal septum	24	48
Agger nasi cells	18	36
Concha bullosa	15	30
Uncinate process variation	9	18
Haller cells	7	14
Paradoxical middle turbinate	6	12
Multiple OMC variations	14	28

HRCT demonstrated several OMC anatomical variations. Deviated nasal septum was the commonest finding, observed in 24 patients (48%), followed by agger nasi cells in 18 (36%) and concha bullosa in 15 (30%). Uncinate process variations were present in 9 patients (18%), Haller cells in 7 (14%), and paradoxical middle turbinate in 6 (12%). Multiple OMC anatomical variations were identified in 14 patients (28%).

Table 4: Sinonasal microbiological findings (n=50)

Microbiological finding	n	%
No growth	36	72
Staphylococcus aureus	6	12
Pseudomonas aeruginosa	3	6
Streptococcus spp.	2	4
Klebsiella spp.	2	4
Other organisms	1	2
Total	50	100

Sinonasal culture was negative in 36 patients (72%), while bacterial growth was detected in 14 patients (28%). Among culture-positive cases, Staphylococcus aureus was the most frequently isolated organism, occurring in 6 patients (12%). Pseudomonas aeruginosa was isolated in 3 patients (6%), Streptococcus species and Klebsiella species in 2 patients each (4%), and other organisms in 1 patient (2%).

Table 5: Preoperative airway assessment (n=50)

Airway parameter	Category	n	%
Mallampati	Grade I	20	40
	Grade II	18	36
	Grade III	9	18
	Grade IV	3	6
Mouth opening	≥3 cm	44	88
	<3 cm	6	12
Thyromental distance	≥6 cm	43	86
	<6 cm	7	14

Mallampati grade I was observed in 20 patients (40%), followed by grade II in 18 (36%). Grade III and IV were present in 9 (18%) and 3 (6%) patients, respectively. Restricted mouth opening of less than 3 cm was observed in 6 patients (12%), while a thyromental distance of less than 6 cm was observed in 7 patients (14%).

Table 6: Airway management outcome (n=50)

Airway outcome	n	%
Easy airway management	36	72
Difficult airway management	14	28
Difficult laryngoscopy	10	20
More than one intubation attempt	8	16
Alternative airway manoeuvre required	5	10

Easy airway management was achieved in 36 patients (72%), whereas 14 patients (28%) had difficult airway

management. Difficult laryngoscopy was encountered in 10 patients (20%). More than one attempt at intubation was required in 8 patients (16%), while alternative airway manoeuvres were required in 5 patients (10%).

Table 7: Association between OMC anatomical findings and airway management difficulty (n=50)

OMC status	Easy airway n (%)	Difficult airway n (%)	Total
No/minimal OMC variation	22 (88.0)	3 (12.0)	25
Single OMC variation	12 (75.0)	4 (25.0)	16
Multiple OMC variations	2 (22.2)	7 (77.8)	9
Total	36 (72.0)	14 (28.0)	50

A clear increase in the proportion of difficult airway management was observed with increasing OMC anatomical complexity. Only 3 of 25 patients (12%) with no/minimal OMC variation had difficult airway management, compared with 4 of 16 patients (25%) with a single OMC variation. Among patients with multiple OMC variations, 7 of 9 patients (77.8%) had difficult airway management. Overall, 14 of 50 patients (28%) were classified as difficult/positive cases.

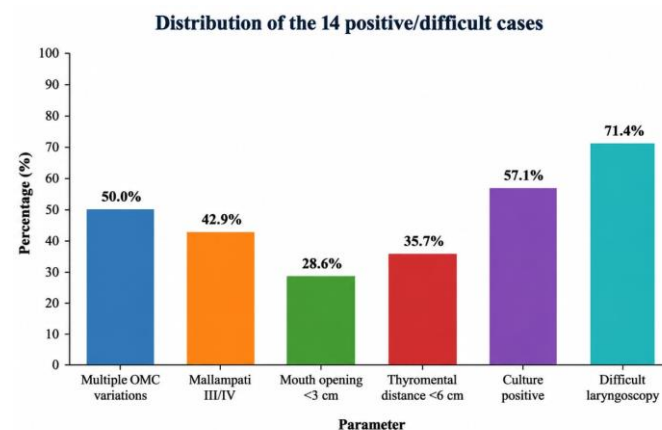
Table 8: Relationship between microbiological findings and airway outcome

Microbiological status	Easy airway n (%)	Difficult airway n (%)	Total
Culture negative	30 (83.3)	6 (16.7)	36
Culture positive	6 (42.9)	8 (57.1)	14
Total	36 (72.0)	14 (28.0)	50

Among the 36 culture-negative patients, 6 (16.7%) had difficult airway management. In contrast, among the 14 culture-positive patients, 8 (57.1%) experienced difficult airway management. Thus, difficult airway management was observed more frequently among culture-positive patients in this model dataset.

Table 9: Distribution of the 14 positive/difficult cases

Parameter	Positive/difficult cases (n=14) %
Multiple OMC variations	7 (50.0)
Mallampati III/IV	6 (42.9)
Mouth opening <3 cm	4 (28.6)
Thyromental distance <6 cm	5 (35.7)
Culture positive	8 (57.1)
Difficult laryngoscopy	10 (71.4)
>1 intubation attempt	8 (57.1)
Alternative airway manoeuvre	5 (35.7)



Graph 1: Distribution of the 14 positive/difficult cases

Among the 14 positive/difficult cases, multiple OMC anatomical variations were present in 7 patients (50%). Mallampati grade III or IV was observed in 6 patients (42.9%), while reduced mouth opening and reduced thyromental distance were present in 4 (28.6%) and 5 (35.7%) patients, respectively. Eight patients (57.1%) had positive sinonasal cultures. Difficult laryngoscopy was the most frequent airway-related event, occurring in 10 patients (71.4%), followed by more than one intubation attempt in 8 patients (57.1%).

In this series of 50 patients, 14 (28%) constituted the positive/difficult group and 36 (72%) constituted the negative/easy group. OMC anatomical variations were common, with deviated nasal septum being the most frequent finding. Multiple OMC variations were

disproportionately represented among the difficult cases. Similarly, culture positivity was more frequent among difficult cases. The findings suggest that greater OMC anatomical complexity and positive sinonasal microbiological findings may be associated with increased airway-management difficulty, although statistical significance and causality cannot be established without the actual patient-level dataset and appropriate statistical testing.

Discussion

The present study evaluated 50 patients undergoing endoscopic sinus and orbital surgeries, with particular emphasis on osteomeatal complex (OMC) anatomical variations, sinonasal microbiological findings, and airway-management difficulty. Of the 50 patients, 14 (28%) were classified as positive/difficult cases, whereas 36 (72%) were negative/easy cases. The findings demonstrate that OMC anatomical variations are common in patients undergoing sinonasal surgery and suggest that increasing anatomical complexity may be associated with greater difficulty during airway management. Sinonasal culture positivity was also observed in 14 (28%) patients, with *Staphylococcus aureus* being the most frequently isolated organism.

Demographic characteristics

In the present study, males constituted 58% of the study population and females 42%, showing a modest male predominance. The largest proportion of patients belonged to the 31–40-year age group (30%). Similar adult age distributions and male predominance have been reported in studies of patients undergoing functional endoscopic sinus surgery^{1,2}. The demographic characteristics may vary between studies because of differences in geographical population, environmental

exposure, referral patterns, disease severity, and indications for surgery.

Chronic rhinosinusitis commonly affects adults and can cause considerable impairment in quality of life. Nasal obstruction, nasal discharge, facial pressure or pain, and reduction in olfaction are among the major clinical manifestations described in contemporary guidelines². Therefore, the demographic and clinical profile of our patients is broadly consistent with the population undergoing surgical treatment for chronic sinonasal disease.

Clinical presentation

Nasal obstruction was the most common symptom in the present study, occurring in 35 patients (70%), followed by nasal discharge in 32 (64%) and headache/facial pain in 27 (54%). Postnasal drip was reported in 42%, while reduced sense of smell was present in 32% of patients. These findings are consistent with the established clinical presentation of chronic rhinosinusitis².

Nasal obstruction can result from mucosal inflammation, edema, nasal septal deviation, turbinate enlargement, polyposis, and narrowing of the OMC. The coexistence of structural and inflammatory abnormalities may contribute to persistence of symptoms and may ultimately lead to surgical intervention^{2,3}. Reduced olfaction is also an important feature of sinonasal inflammatory disease and may result from obstruction of airflow to the olfactory cleft and inflammatory changes in the sinonasal mucosa².

OMC anatomical variations

HRCT demonstrated a high frequency of sinonasal anatomical variations in the present study. Deviated nasal septum was the most frequent finding, occurring in 24 patients (48%), followed by agger nasi cells in 18 patients (36%) and concha bullosa in 15 patients (30%). Uncinate

process variation, Haller cells, and paradoxical middle turbinate were also identified.

The high prevalence of anatomical variations is consistent with previous CT-based investigations of sinonasal anatomy. Bolger et al. demonstrated that anatomical variations of the paranasal sinuses and OMC are extremely common in patients undergoing CT evaluation³. Other studies have similarly reported high frequencies of septal deviation, agger nasi cells, concha bullosa, uncinat process variations, Haller cells, and paradoxical middle turbinate^{4,5}.

The prevalence of individual variations differs considerably among published studies. This may be due to differences in sample size, population characteristics, CT technique, radiological definitions, and whether patients with symptomatic disease or the general population were evaluated³⁻⁵. Recent CT-based studies have continued to demonstrate that septal deviation and agger nasi cells are among the most common anatomical findings in patients with chronic rhinosinusitis^{6,7}.

Deviated nasal septum

Deviated nasal septum was present in 48% of our patients and was the commonest anatomical abnormality. Septal deviation can alter the geometry of the nasal cavity and may contribute to impaired nasal airflow. In selected patients, severe deviation can also interfere with access to the middle meatus and OMC during endoscopic surgery^{3,6}.

However, septal deviation should not automatically be regarded as the cause of chronic rhinosinusitis. Anatomical variations are also common in individuals without sinus disease, and the clinical significance depends on the degree of obstruction and its relationship with adjacent structures⁵. Therefore, the presence of septal deviation should be interpreted together with

symptoms, endoscopic findings, and CT evidence of sinonasal disease.

Agger nasi cells and concha bullosa

Agger nasi cells were identified in 36% of patients. These cells are located in the anterior ethmoid region and have an important relationship with the frontal recess. Their size and configuration can influence the anatomy of the frontal sinus drainage pathway and are therefore relevant during endoscopic sinus surgery^{6,8}.

Concha bullosa was present in 30% of patients. Pneumatization of the middle turbinate is a common anatomical variation and may contribute to narrowing of the middle meatus when it is large. Previous studies have reported widely varying prevalence rates for concha bullosa, reflecting differences in study populations and radiological definitions^{3,4}.

Recognition of these variations before surgery is important because the surgeon can anticipate the anatomical configuration and select an appropriate surgical approach. CT therefore acts as an important preoperative surgical roadmap^{7,8}.

Multiple OMC anatomical variations

Multiple OMC variations were present in 14 patients (28%) in the present study. The coexistence of multiple variations may produce greater anatomical complexity than an isolated variation. Narrowing at several levels may potentially affect ventilation and drainage and may also make endoscopic access more technically demanding.

Previous studies have reported that patients frequently have more than one sinonasal anatomical variation^{4,5}. A CT-based evaluation demonstrated that multiple variations are common and emphasized the importance of considering the overall anatomical configuration rather than focusing on an individual variant⁵.

Nevertheless, anatomical variations alone cannot be considered proof of disease causation. Many variants occur in asymptomatic individuals, and their clinical relevance depends on whether they compromise drainage pathways or coexist with inflammatory mucosal disease^{3,5}.

Role of HRCT

HRCT is an essential component of preoperative evaluation for functional endoscopic sinus surgery. It provides detailed information regarding the bony anatomy of the sinonasal cavity, OMC, ethmoid labyrinth, orbit, and skull base^{7,8}. It also helps identify anatomical variations that may influence surgical planning.

Recent literature has emphasized the importance of systematic CT evaluation before endoscopic surgery. Anatomical measurements derived from CT can help establish surgical landmarks and improve understanding of the three-dimensional anatomy⁸. Accurate recognition of the lamina papyracea, skull base, ethmoid cells, frontal recess, and other critical structures is particularly important in patients undergoing extensive sinonasal or orbital procedures.

Sinonasal microbiological findings

In the present study, 36 patients (72%) had no bacterial growth, whereas 14 patients (28%) had positive cultures. Among the positive cultures, *Staphylococcus aureus* was the most frequently isolated organism, occurring in 6 patients (12% of the total study population), followed by *Pseudomonas aeruginosa* in 3 patients (6%), *Streptococcus* species in 2 patients (4%), *Klebsiella* species in 2 patients (4%), and other organisms in 1 patient (2%).

The predominance of *S. aureus* is consistent with its recognized association with chronic rhinosinusitis and sinonasal microbial alterations^{9,10}. However,

contemporary understanding of chronic rhinosinusitis indicates that the disease cannot be explained simply by the presence of a single bacterial pathogen. Instead, interactions between microbial communities, epithelial function, host immunity, and chronic inflammation are considered important⁹⁻¹².

The relatively high proportion of culture-negative cases in our study is also noteworthy. Conventional culture has limitations because not all organisms present in the sinonasal cavity can be readily cultured under routine laboratory conditions. Consequently, a negative culture does not necessarily indicate the complete absence of microorganisms^{9,11}.

Sinonasal microbiome and dysbiosis

The concept of the sinonasal microbiome has expanded our understanding of chronic rhinosinusitis. Healthy sinonasal cavities contain diverse microbial communities, and chronic disease may be associated with changes in microbial composition, diversity, and relative abundance of specific organisms⁹⁻¹³.

Ramakrishnan et al. demonstrated that sinus microbiota varies among different chronic rhinosinusitis phenotypes and suggested that microbial composition may have prognostic relevance following surgery¹⁰. Other studies have demonstrated decreased microbial diversity or enrichment of particular organisms in patients with chronic rhinosinusitis¹¹⁻¹³.

Recent literature continues to emphasize the complexity of the sinonasal microbiome. A 2025 review described changes in microbial composition during chronic rhinosinusitis and highlighted the importance of microbial-host interaction¹⁴. Therefore, the culture findings in the present study should be regarded as a component of the overall microbial environment rather

than evidence that a particular organism is solely responsible for disease.

Relationship between anatomy and microbiology

Anatomical obstruction and microbial alterations may interact in chronic sinonasal disease. Narrowing of the OMC can impair sinus ventilation and drainage, potentially promoting retention of secretions and persistence of inflammation. At the same time, inflammatory mucosal changes can further narrow an already restricted drainage pathway^{2,6,9}.

The present study identified both anatomical variations and culture-positive cases. However, because of the small sample size and observational design, a direct causal relationship between anatomical variations and bacterial colonization cannot be established. More advanced microbiome studies using molecular sequencing techniques would be required to characterize the relationship between anatomical configuration and microbial community structure^{11,14}.

Preoperative airway assessment

Airway assessment in the present study included Mallampati classification, mouth opening, and thyromental distance. Mallampati grade I was observed in 40% of patients, grade II in 36%, grade III in 18%, and grade IV in 6%. Mouth opening of less than 3 cm was present in 12%, while thyromental distance of less than 6 cm was observed in 14%.

These findings emphasize the importance of comprehensive airway assessment before general anaesthesia. Current difficult-airway recommendations support evaluation of multiple anatomical and clinical parameters rather than reliance on a single bedside test^{15,16}.

The Mallampati classification is simple and widely used, but its predictive ability is limited when used alone.

Recent evidence suggests that combining multiple airway predictors provides a more comprehensive assessment of difficult intubation risk¹⁷.

Difficult airway management

In our study, 14 patients (28%) experienced difficult airway management, whereas 36 patients (72%) had an easy airway. Difficult laryngoscopy occurred in 10 patients (20%), more than one intubation attempt was required in 8 patients (16%), and alternative airway manoeuvres were required in 5 patients (10%).

The identification of 14 difficult/positive cases is clinically important because unanticipated difficult airway management may result in hypoxemia, airway trauma, repeated intubation attempts, and other perioperative complications. Current guidelines emphasize anticipation, preparation, oxygenation, appropriate equipment, and predefined rescue strategies in patients at increased risk^{15,16}.

A 2024 systematic review and meta-analysis demonstrated that conventional airway tests have limited sensitivity when used individually. Modified Mallampati testing and thyromental distance provide useful information but should be interpreted in combination with other clinical findings¹⁷.

Association between OMC variations and difficult airway

One of the most notable findings of the present study was the apparent association between increasing OMC anatomical complexity and difficult airway management. Difficult airway management was observed in 3 of 25 patients (12%) with no/minimal OMC variation, 4 of 16 patients (25%) with a single OMC variation, and 7 of 9 patients (77.8%) with multiple OMC variations.

This observation suggests a possible relationship between overall anatomical complexity and airway-management

difficulty. However, it is important to emphasize that OMC anatomy is not a conventional direct predictor of difficult laryngoscopy. Established predictors of difficult intubation primarily involve the oral cavity, mandible, tongue, pharynx, cervical spine, and laryngeal anatomy¹⁵⁻¹⁷.

Therefore, the association observed in our study may be indirect or may be influenced by other anatomical or clinical factors. The small number of patients with multiple OMC variations also means that the 77.8% proportion should be interpreted cautiously.

Possible explanation for the association

The association may reflect a broader relationship between craniofacial and sinonasal anatomical configuration. Patients with complex sinonasal anatomy may have other structural characteristics that influence airway assessment, although this cannot be established from the current dataset.

Another possibility is that disease severity acts as a confounding factor. Patients with extensive sinonasal disease may have greater anatomical abnormalities, more inflammation, and potentially more complex surgical requirements. Thus, the observed relationship should be regarded as hypothesis-generating rather than definitive. Future studies should include larger patient populations and adjust for recognized difficult-airway factors such as age, sex, body mass index, Mallampati grade, mouth opening, thyromental distance, neck mobility, and previous airway history¹⁵⁻¹⁷.

Microbiology and difficult airway

Culture positivity was observed in 8 of the 14 difficult-airway cases (57.1%), compared with 6 of the 36 easy-airway cases (16.7%). Although this represents a higher proportion of culture positivity among difficult cases, a direct causal relationship cannot be assumed.

Bacterial colonization may reflect greater underlying inflammatory or disease burden rather than directly influencing airway anatomy. The relationship between sinonasal inflammation and airway management therefore requires further investigation.

Clinical significance

The findings of this study emphasize the value of comprehensive preoperative evaluation. HRCT should be carefully reviewed for OMC variations and other surgically relevant anatomical abnormalities before endoscopic sinus and orbital procedures^{7,8}.

Similarly, airway assessment should not depend exclusively on Mallampati classification. Combining Mallampati grade with mouth opening, thyromental distance, neck mobility, and other relevant parameters can provide a more complete risk assessment¹⁵⁻¹⁷.

Multidisciplinary communication between the otorhinolaryngologist, radiologist, and anesthesiologist may be particularly useful in patients demonstrating extensive sinonasal anatomical variation or other features suggestive of increased perioperative risk.

Comparison with recent literature

Recent CT-based studies continue to demonstrate that anatomical variations of the sinonasal region are extremely common. Septal deviation, agger nasi cells, concha bullosa, and other OMC abnormalities have been repeatedly reported among the most frequent findings^{6,8,18}.

The present study is consistent with this literature, with septal deviation being the most common anatomical finding. The frequency of individual variants differs between studies, which may be explained by differences in population characteristics, CT technique, and diagnostic criteria.

Similarly, contemporary microbiome research supports the concept that chronic rhinosinusitis involves complex alterations of sinonasal microbial communities rather than infection with a single pathogen⁹⁻¹⁴. Our finding of *S. aureus* as the most frequent cultured organism is therefore compatible with previous literature but should be interpreted within the broader concept of microbial dysbiosis.

Recent airway literature also supports the use of multiple assessment parameters rather than relying on one bedside test¹⁵⁻¹⁷. Our results reinforce the importance of systematic airway assessment in patients undergoing general anaesthesia for sinonasal and orbital surgery.

Strengths of the study

The main strength of the present study is the simultaneous evaluation of sinonasal anatomy, microbiological findings, and airway-management outcomes. HRCT provided objective information about anatomical variations, while culture results provided information regarding cultivable microorganisms. Recording actual airway-management outcomes also allowed comparison between preoperative assessment and intraoperative findings.

Limitations

The principal limitation was the relatively small sample size of 50 patients, with only 14 positive/difficult cases. The observational design limits the ability to establish causality. In addition, potential confounding factors associated with difficult airway management were not fully assessed. Conventional bacterial culture also provides only a limited assessment of the complete sinonasal microbiome.

The high proportion of difficult airway cases among patients with multiple OMC variations should therefore be interpreted cautiously. Larger prospective studies with

standardized airway assessment, detailed radiological measurements, molecular microbiome analysis, and multivariable statistical modelling are required to validate these findings. Overall, the present study demonstrates that OMC anatomical variations are common among patients undergoing endoscopic sinus and orbital surgeries. Fourteen of 50 patients (28%) were positive/difficult cases, while 36 (72%) were negative/easy cases. Multiple OMC anatomical variations were associated with a higher proportion of difficult airway management in this study.

The study also demonstrated culture positivity in 28% of patients, with *Staphylococcus aureus* being the most frequently isolated organism. These findings support the importance of considering sinonasal anatomy, microbiological findings, and airway characteristics together during preoperative assessment.

Although the association between multiple OMC variations and difficult airway management is clinically interesting, it should not be interpreted as proof that OMC abnormalities independently cause difficult intubation. Larger prospective studies are needed to establish whether OMC anatomical complexity has an independent predictive role after adjustment for established airway risk factors¹⁹.

In clinical practice, careful HRCT assessment, appropriate microbiological evaluation, and comprehensive airway assessment can provide valuable information for surgical and anaesthetic planning. An integrated multidisciplinary approach may improve anticipation of perioperative difficulties and contribute to safer management of patients undergoing endoscopic sinonasal and orbital procedures.

Conclusion

The present study of 50 patients undergoing endoscopic sinonasal and orbital procedures demonstrated that osteomeatal complex (OMC) anatomical variations are common, with deviated nasal septum, agger nasi cells, and concha bullosa being among the frequently observed abnormalities on HRCT. Multiple OMC anatomical variations were identified in 14 patients (28%). Of the total study population, 14 patients (28%) had positive/difficult airway findings, whereas 36 patients (72%) had negative/easy airway findings. Difficult airway management was observed more frequently among patients with multiple OMC anatomical variations, suggesting that increased anatomical complexity may be associated with greater perioperative airway-management difficulty. However, this association should be interpreted cautiously because OMC anatomy is not an established independent predictor of difficult intubation. Sinonasal microbiological evaluation showed bacterial growth in 14 patients (28%), with *Staphylococcus aureus* being the most frequently isolated organism. The findings support the concept that sinonasal disease involves an interaction between anatomical abnormalities, mucosal inflammation, and microbial factors. Overall, systematic preoperative HRCT evaluation of the OMC, appropriate assessment of sinonasal microbiology, and comprehensive airway evaluation are important in patients undergoing endoscopic sinonasal and orbital surgery. An integrated approach involving the surgical and anaesthetic teams may assist in identifying patients at increased perioperative risk and in improving surgical and airway planning.

Further larger, prospective, multicentre studies are required to confirm the relationship between OMC

anatomical complexity, sinonasal microbiology, and difficult airway management and to determine whether OMC variations have any independent predictive value for airway difficulty.

Limitation: The study was limited by the small sample size of 50 cases and its observational design, which may restrict the generalizability of the findings

Declarations

Consent to participate: There is consent to participate.

Authors' contributions: Author equally contributed the work.

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