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ORIGINAL RESEARCH

A study of anatomical variations in sphenoid sinus and their association with extent of disease using modified lund mackay staging system

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Abstract
Objectives: The objective of this study is to detect the incidence of anatomical variations of sphenoid sinus and its association with the extent of disease using the Modified Lund Mackay staging system.
Method: Cross-sectional study conducted at a tertiary care medical college in South India. Participants included 201 patients with chronic rhinosinusitis who attended the outpatient department of otorhinolaryngology from November 2021 to May 2023.
Main Outcome Measures: CT paranasal sinus was performed using a 16-slice CT machine. The radiological findings of the sphenoid sinus were characterized by the Modified Lund-Mackay staging system, with points awarded on both sides separately.
Results: The mean age of the study participants was 37.6 (SD=11.4). Incidences of anatomical variations in the sphenoid sinus were observed, including hypoplasia, agenesis, and various forms of pneumatization and protrusion. There was a statistically significant association between the pneumatization of the pterygoid process, anterior clinoid process, greater wing of sphenoid, and protrusion of the Vidian canal with sphenoid sinusitis.
Conclusion: It is crucial to know the variations of the sphenoid sinus to avoid complications during surgery on patients with these variations.
Keywords: Anatomical variations, chronic rhinosinusitis, sphenoid sinus, CT paranasal sinus, modified Lund Mackay staging.

Introduction

Knowledge of the anatomic variations of paranasal sinuses reduces surgical complication rates during Functional Endoscopic Sinus Surgery (FESS). It also helps reduce disease recurrence and allows surgeons to adjust operative techniques accordingly. The posterior ethmoids and sphenoid sinuses can be accessed via the anterior ethmoid cells. Any anatomical variations of the sinuses make the approaches to FESS more complex.[1].

Not all anatomical variants are responsible for the development of rhinosinusitis, but knowledge of their presence is necessary. Cerebrospinal fluid leak, meningitis, or blindness can occur as complications during FESS, so detailed knowledge of possible anatomical variations is essential.[2,3] CT PNS is a mandatory investigation for patients with chronic rhinosinusitis undergoing FESS. CT PNS helps identify these anatomical variations of the paranasal sinuses.[4]

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Okushi et al. described a volumetric analysis technique to measure mucosal thickening of each paranasal sinus cavity and calculate a quantitative modification to the LM score, a "modified Lund-Mackay" (MLM) score, on a continuous scale.[5] Certain anatomical variations are thought to predispose individuals to sinus disease, making it necessary for surgeons to be aware of these variations, especially if the patient is a candidate for FESS.[6]
Of all the paranasal sinuses, the sphenoid sinus is the most inaccessible to surgeons. Coronal sections of CT scans show progressively deeper structures as they are encountered by the surgeon during FESS. Knowledge of the anatomic variations of the sphenoid sinus and its related structures is important to avoid surgical complications and explain unusual symptoms arising from sphenoid sinus disease.[7]

Objectives of the Study

1. To determine the incidence of variations in the sphenoid sinus using the Modified Lund Mackay staging system.
2. To determine the association of anatomical variations of the sphenoid sinus with the extent of disease using the Modified Lund Mackay staging system.

Materials and Methods

Source of Data

Patients with chronic rhinosinusitis who attended the outpatient department of otorhinolaryngology head and neck surgery (ENT-HNS) at a tertiary medical college in South India for 18 months from November 2021 to May 2023.

Method of Collection of Data

A Cross-sectional study with 201 patients with chronic rhinosinusitis were subjected to CT-PNS. CT paranasal sinuses were performed with a 16-slice CT machine (Siemens Somatom) by direct axial, sagittal, and coronal sections. The study was conducted between November 2021 to May 2023. The radiological findings of the sphenoid sinus were characterized by the Modified Lund-Mackay staging system, and points were awarded on both sides separately.
The study was approved by the Institutional Ethics Committee of our institute and conformed to the ethical standards laid down in the Declaration of Helsinki. Manuscript preparation followed the principles of the Committee on Publication Ethics (COPE) and guidelines of The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement. Informed consent was taken from all patients recruited for the study.

Inclusion Criteria

- Patients subjected to CT PNS scan with CRS.
- All patients undergoing endoscopic sinus surgery for chronic rhinosinusitis with sphenoid sinus variations.

Exclusion Criteria

- Pregnant patients.
- Patients below 15 years of age.
- Patients with a history of previous nasal surgery or trauma.
- Patients with severe degenerative disease of the cervical spine or cervical spinal trauma.

Sample Size Estimation

Sample size calculated based on the study conducted by Bolger WE et al. [17] It showed a prevalence of one of the anatomical variations of paranasal sinus was 13.3%.The minimum

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sample size required for the study is 185. For the present study, 201 patients with chronic rhinosinusitis were selected.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 16.0. Descriptive statistics such as mean, standard deviation, and percentage were used to summarize the demographic and clinical characteristics of the study population. The Chi-square test was employed to assess the association between anatomical variations of the sphenoid sinus and the presence of sphenoid sinusitis. Pearson correlation test was utilized to determine the strength and direction of the relationship between different variables. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 201 patients were included in the study, all of whom met the inclusion and exclusion criteria. The key findings and observations are summarized below.

Distribution of Sphenoid Sinusitis

The analysis of sphenoid sinusitis among the patients revealed varied stages of disease severity. On the right side, 60.2% of patients showed no signs of sphenoid sinusitis. Mild sinusitis, with involvement ranging from 1% to 25%, was observed in 28.4% of patients. Moderate sinusitis, involving 26% to 50% of the sinus, was found in 9% of the patients. Severe stages of sinusitis, with involvement between 51% and 75%, were seen in 1.5% of patients, and very severe sinusitis, involving 76% to 100% of the sinus, was observed in only 0.5% of patients.

Similarly, on the left side, 61.2% of patients showed no signs of sphenoid sinusitis. Mild sinusitis was observed in 30.3% of patients, while moderate sinusitis was present in 5.5% of patients. Severe stages of sinusitis were seen in 2% of patients, and very severe sinusitis was found in 1% of the patients.

Incidence of Anatomical Variations

The study observed various anatomical variations in the sphenoid sinus among the patients. Hypoplasia was noted in 0.5% of patients on the right side and 2.5% on the left side. Agenesis of the sphenoid sinus was rare, observed in 0.5% of patients on the right side and not observed on the left side. Pneumatization of the pterygoid process was the most common variation, seen in 49.3% of patients on the right side and 40.3% on the left side.

Pneumatization of the anterior clinoid process was observed in 27.4% of patients on the right side and 15.9% on the left side. Pneumatization of the greater wing of the sphenoid was less common, found in 5% of patients on the right side and 4.5% on the left side.

Protrusion and dehiscence of significant anatomical structures were also recorded. Protrusion of the internal carotid artery was seen in 3.5% of patients on the right side and 1% on the left side, while dehiscence was observed in 1.5% of patients on the right side and 2.5% on the left side. Protrusion of the optic nerve was noted in 4% of patients on both sides, and dehiscence was also observed in 4% of patients on both sides.

Maxillary nerve protrusion was found in 4% of patients on both sides, while dehiscence was seen in 1% of patients on both sides. Vidian canal protrusion was observed in 37.3% of patients on the right side and 33.3% on the left side, with dehiscence noted in 1.5% of patients on both sides. Onodi cells were present in 7% of patients on both sides.

The pneumatization of the sphenoid sinus was categorized into conchal, sellar, presellar, and postsellar types. The conchal type was rare, found in 0.5% of patients on both sides. The sellar type was the most common, observed in 85.1% of patients on the right side and 82.1%

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on the left side. The presellar type was noted in 6% of patients on the right side and 4% on the left side, while the postsellar type was observed in 7.5% of patients on the right side and 5.5% on the left side. The intersphenoid septum was absent in 1.5% of patients, single in 77.6%, and accessory septum was found in 16.9% of patients on the right side and 4.5% on the left side.

Association with Sphenoid Sinusitis

Statistical analysis using the Chi-square test revealed significant associations between certain anatomical variations and sphenoid sinusitis. There was a significant association between the pneumatization of the pterygoid process and sphenoid sinusitis on both sides. Similarly, the pneumatization of the anterior clinoid process and the protrusion of the Vidian canal were significantly associated with sphenoid sinusitis on both sides. Additionally, there was a significant association between the pneumatization of the greater wing of the sphenoid and left sphenoid sinusitis.

These findings highlight the importance of recognizing anatomical variations in the sphenoid sinus, as they are significantly associated with the presence and severity of sphenoid sinusitis. This knowledge is crucial for improving surgical outcomes and reducing complications during endoscopic sinus surgeries.

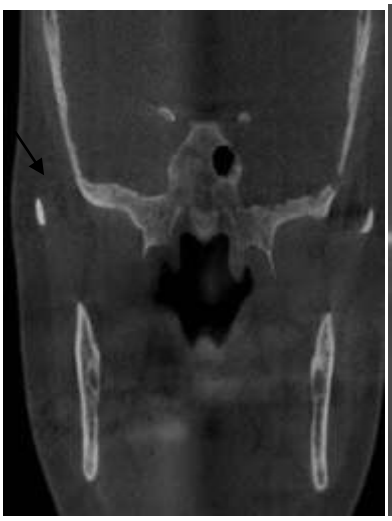

Fig 1: Agenesis of sphenoid

Fig 2:Hypoplasia of sphenoid

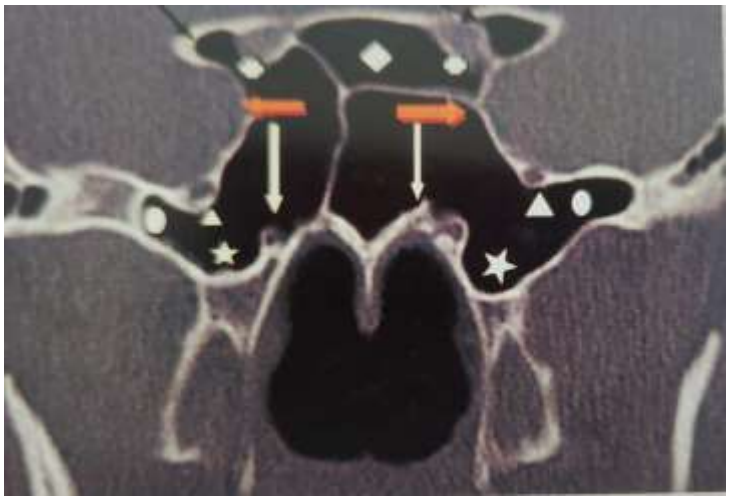

Fig 3:CT PNS showing pneumatization of bilateral pterygoid processes(stars) and anterior clinoid processes(black arrows), bilateral greater wing of sphenoid(white

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dot)with protrusion and dehiscence of vidian nerves(white arrow), protrusion and dehiscence of optic nerve(cross), protrusion and dehiscence of maxillary nerve(arrow head), protrusion of internal carotid artery(orange arrow),onodi cell(diamond)

Table 1: Percentage distribution of the sample according to Computerized tomography of paranasal sinus findings -sphenoid sinus

Computerized tomography of paranasal sinus right		Count	Percent
Sphenoid sinusitis right	0%	121	60.2
	1 % - 25 %	57	28.4
	26% - 50%	18	9.0
	51% - 75%	3	1.5
	76% - 99%	1	0.5
	100%	1	0.5
Sphenoid sinusitis left	0%	123	61.2
	1%-25%	61	30.3
	26%-50%	11	5.5
	51%-75%	4	2.0
	76%-99%	2	1.0

Table 2: Percentage distribution of the sample according to variations of sphenoid sinus in right

Variations of sphenoid sinus		Count	Percent
Hypoplasia		1	0.5
Agenesis		1	0.5
Pneumatization of pterygoid process		99	49.3
Pneumatization of anterior clinoid process		55	27.4
Pneumatization of greater wing of sphenoid		10	5.0
Internal carotid artery	Dehiscence	3	1.5
	Prominent	7	3.5
Optic nerve	Dehiscence	8	4.0
	Prominent	7	3.5
Maxillary nerve	Dehiscence	2	1.0
	Prominent	8	4.0
Vidian nerve	Dehiscence	3	1.5
	Prominent	75	37.3
Onodi cell		14	7.0
Pneumatization	Conchal	1	0.5
	Selar	171	85.1
	Presellar	12	6.0
	Postsellar	15	7.5

Table 3: Percentage distribution of the sample according to variations of sphenoid sinus in left

Variations of sphenoid sinus	Count	Percent
Hypoplasia	5	2.5
Agenesis	0	0.0
Pneumatization of pterygoid process	81	40.3
Pneumatization of anterior clinoid process	32	15.9
Pneumatization of greater wing of sphenoid	9	4.5

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Internal carotid artery	Dehiscence	5	2.5
	Prominent	2	1.0
Optic nerve	Dehiscence	8	4.0
	Prominent	6	3.0
Maxillary nerve	Dehiscence	2	1.0
	Prominent	8	4.0
Vidian nerve	Dehiscence	3	1.5
	Prominent	67	33.3
Onodi cell		14	7.0
Pneumatization	Conchal	1	0.5
	Sellar	165	82.1
	Presellar	8	4.0
	Postsellar	11	5.5

Discussion

In our study the incidence of anatomical variations in sphenoid sinus observations (fig 1and 2) were hypoplasia (right-0.5%, left-2.5%) and agenesis (right-0.5%). These findings corresponds with the retrospective study conducted by Binal C et al who looked into 384 patients and found unilateral agenesis in 0.26%, unilateral sphenoid sinus hypoplasia in 0.26% and bilateral sphenoid sinus hypoplasia in 0.26%. Bilateral sphenoid sinus agenesis was not seen. [8]

In our study pneumatization of pterygoid process was right-49.3% and left-40.3%. The study by Hiremath et al showed 31% of the patients with pneumatized pterygoid process.[7] Bolger et al. identified pneumatization of the pterygoid process in 43.6% of the patients.[1] Both studies findings correspond with our study.

Bolger et al., found pneumatization of the anterior clinoid process in 13% of 202 patients, whereas De Lano et al. found it in 13 of 300 patients (04%).[1,9] Similarly, Birsen et al., encountered pneumatization of the anterior clinoid process in 24.1% of 260 patients and Hewaidi GH et al. identified it in 15.3% patients.[10,11] In our study pneumatization of anterior clinoid process was encountered in right-27.4% and left-15.9% patients, which was similar to the findings of the studies which were conducted by Hewaidi GH et al. and Bolger et al.[11,1]

In our study, pneumatization of greater wing of sphenoid (fig 3) is seen in right-5% patients and left-4.5% patients. A study which was conducted by Jhon Earwaker showed pneumatization of the greater wing of the sphenoid in 10.7% of the patients, whereas Hewaidi GH et al., identified it in 20.0% patients. [12]

Hewaidi GH et al., found protrusion of the internal carotid artery into the sphenoid in 41% of the patients and dehiscence of the artery in 30% patients.[12] Hiremath et al found, protrusion of the internal carotid artery into the sphenoid in 7% patients and dehiscence of the artery was found in 3% patients. [7] As compared to this in our study, protrusion (right-3.5%, left-1%) and dehiscence (right-1.5%, left-2.5%) of internal carotid artery was less common. Sareen et al. assessed the sagittal sections of 20 dried skulls and found dehiscence of the internal carotid artery in 0.5% skulls. [13]

In our study protrusion of optic nerve was seen in right-3.5% and left-3% while dehiscence of optic nerve was seen in right-4% and left-4%. Hewaidi GH et al., encountered the protrusion of the optic nerve in 35.6% patients and dehiscence of the nerve in 30.6% patients.[11] Various studies which were conducted showed a wide range of protrusion rates (from 8% to 70%).[11]

A study which was assessed by Hewaidi GH et al.,showed that maxillary nerve protrusion was noted in 24.3% patients and that dehiscence of the nerve was noted in 13% patients. [11] Birsen et al. encountered the maxillary nerve protrusion in 30.3% patients and dehiscence in 3.5% patients. [10] Hiremath et al. showed maxillary nerve protrusion was noted in 12.25%

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patients and dehiscence of the nerve was noted in 2.75% patients. [7] In our study, maxillary nerve protrusion was 4% and the maxillary nerve dehiscence was 1%.

Our study showed Vidian canal protrusion in right-37.3% and left-33.3% and Vidian canal dehiscence in right-1.5% and left-1.5% of patients. Hiremath et al showed, Vidian canal protrusion was seen in 31% patients and dehiscence was seen in 7.75% patients which is similar to our findings. [7] Lang and Keller reported 18% patients with a protruded Vidian canal.[14]In our study Onodi cell found in 7% of patients. According to Sumailey et al. Onodi air-cell were found to be present in 31.4%.[15]

Baskin et al.; Carter et al.; and Hammer & Radberg reported that in their previous studies, the incidence of conchal type is reported to be none to 3%. [16] In the studies conducted by Baskin et al.; Bruneton et al.; Carter et al.; and Hamid et al. incidence of presellar type was reported to be 5.5% to 27% ,incidence of the sellar type of sphenoid ranges from 59% to 86%.[17] Hamid O., El Fiky L., Hassan O., Kotb A. and El Fiky S. provide the following values for the types of pneumatization: 2% conchal pneumatization, 21% preselar, 54.7% selar, and 22.3% postselar.[17] This finding corresponds with our study conchal (right-0.5%,left-0.5%),sellar (right-85.1%,left-82.1%), presellar (right-6%, left-4%) and postsellar (right-7.5%,left-5.5%).

In the present study, there was statistically significant association between right pneumatization of pterygoid and right sphenoid sinusitis ($p < 0.05$), right protrusion of Vidian nerve and right sphenoid sinusitis ($p < 0.05$) and left pneumatization of pterygoid and left sphenoid sinusitis ($p < 0.05$), left protrusion of Vidian nerve and left sphenoid sinusitis ($p < 0.05$), left pneumatization of greater wing of sphenoid and left sphenoid sinusitis ($p<0.05$). The pterygoid process pneumatization might cause a potential space for occurrence of focal infection as it will have preponderance, in order to gravity, to contain purulent exudates which is associated with sinusitis.[18]

In the present study, there was statistically significant association between right pneumatization of anterior clinoid and right sphenoid sinusitis ($p<0.05$), left pneumatization of anterior clinoid and left sphenoid sinusitis ($p<0.05$). The knowledge on association of these variations with sinusitis helps in improving the results and in decreasing the complications of the endoscopic sinus surgeries. Kazkayasi et al noticed that as the size of the pterygoid recess increases, the VC protrusion occurs simultaneously and they detected statistically significant correlations between pterygoid process pneumatization and both protrusions of VC ($p < 0.001$).[18] Anatomic variations are claimed to have a predisposing effect on the formation of sinus disease and mucosal disease is claimed to occur more in these .[18]

Conclusion

Sphenoid sinus has numerous anatomical variations, some of which are significantly associated with sinonasal mucosal disease. Recognizing these variations is essential to avoid complications during surgery on patients with these variations. Proper understanding and identification of these variations can lead to better surgical outcomes and reduced complications.

Conflicts of Interest

The authors declare no conflicts of interest.

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