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UNVEILING SPHENOID SINUS VARIATIONS IN RURAL POPULATION OF KARNATAKA THROUGH CT IMAGING: A STUDY OF ANATOMIC VARIANC

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ABSTRACT

Background: Anatomical variations of the sphenoid sinus are common, and understanding these variations is crucial for safely performing trans-sphenoidal and functional endoscopic sinus surgeries to avoid potential damage to surrounding neurovascular structures. The study was done to identify the different anatomical variations of the sphenoid sinus in rural patients of Karnataka. **Materials and Methods:** This retrospective study was conducted at a tertiary health care centre in rural Karnataka and computed tomography scans of the paranasal sinuses of 214 patients presented with sinonasal symptoms between May 2022 and May 2024 were analysed. The different anatomical variations of sphenoid sinus like type of sphenoid sinus, pneumatization of anterior clinoid process, and pterygoid process, variations of neurovascular structures were studied. **Result:** Sellar pneumatization was seen in most cases (51.40%), 24.77% of cases with pterygoid process pneumatization, 20.09% cases with pneumatized anterior clinoid process and 20.09% of cases had pneumatized greater wing of the sphenoid. Single septation was present in 40.65%, septum attached to the optic nerve in 25.23%, and onodi cell in 28.04% cases. Delano type 1 optic nerve relationship was the most common. **Conclusion:** The study reveals significant anatomical variations of the sphenoid sinus in the rural population of Karnataka, with sellar pneumatization being the most common. The findings emphasize the im-portance of detailed preoperative imaging to ensure safe and effective trans-sphenoidal and endoscopic sinus surgeries by minimizing risks to neurovascular structures.

INTRODUCTION

The sphenoid sinuses are paired air-filled spaces located within the body of the sphenoid bone, communicating with the nasopharynx via a sphenoethmoidal recess through the sphenoid ostium in its anterior wall. It shares close proximity with neurovascular structures like cavernous sinuses, cavernous segments of carotid arteries, optic, oculomotor, trochlear, and 1st and 2nd division of trigeminal nerve and pituitary gland from the nasal cavity and surrounding structures. Sphenoid sinus develops postnatally and reaches adult size usually by the age of 12 years.[1] The sphenoid sinus is the one with the maximum variations among the paranasal sinuses (PNS) based on an ex-tension of pneumatization, the number of septa and their attachments, and its relation to surrounding structures.[2] Knowing about the anatomical variations of the sphenoid sinus and its relation with neurovascular structures will help surgeons plan the surgical procedure and anticipate and reduce intra-operative complications that can occur during trans-sphenoidal and functional endoscopic sinus surgery.

The pneumatization of the sphenoid sinus varies from absent to extensive, which can make the bone that covers the carotid arteries, the optic nerves, and the vidian nerves thin or even missing, resulting in being more susceptible to iatrogenic injury. Safe access to the sella during the trans-sphenoidal route is significantly influenced by the pattern of pneumatization in the sphenoid sinus.[3] Computed tomography (CT) is considered the gold standard for paranasal sinus imaging. Preoperative CT scans provide essential information that aids in the surgical planning process, particularly because the sphenoid sinus serves as a crucial corridor to the skull base.[1] This study aims to identify the incidence of various anatomical variations of the sphenoid sinus using CT imaging of the paranasal sinuses. The increasing use of CT scans in treating sinus-related issues has greatly enhanced our understanding of the relevant anatomical structures and the identification of different anatomical variants.

Having region-specific anatomical data is beneficial ensuring that surgeons are familiar with the typical and atypical anatomy they are likely to encounter in their clinical practice. In conclusion, conducting a sphenoid sinus variant study in rural population of Karnataka is essential to enhance surgical outcomes, improve diagnosis and treatment of sinus diseases, and contribute to the global understanding of anatomical diversity.

MATERIALS AND METHODS

This was a retrospective study on 214 patients who were attending ENT and Head and Neck sur-gery outpatient department with sinonasal symptoms that were evaluated between May 2022 to May 2024. The ethical clearance for the study was taken from the institutional ethics committee.

Inclusion Criteria

Patients who were attending the ENT and Head and Neck Surgery outpatient department with sinonasal symptoms who had undergone a CT scan of PNS as a part of the evaluation.

Exclusion Criteria

Patients with previous surgery involving the skull base/sphenoid sinus, trauma causing hemosinus/ fractures around the skull base, or having space-occupying lesions around the skull base/ sphenoid sinus were excluded from the study.

The studies were performed on a CTScan. The images were obtained in the axial plane with 1 mm thickness and then reconstructed in three planes on axial, coronal, and sagittal planes. The analysis of the different variations of the sphenoid sinus was studied, which includes: 1. Type of sphenoid sinus based on the position of the sinus about the sella turcica, 2. Pneumatization of anterior clinoid process, pterygoid process, and greater wing of sphenoid, 3. Presence of onodi cells,4. Variations of neurovascular structures like optic nerve, maxillary nerve, vidian nerve, internal carotid artery, 5. Variations of intersphenoid septum and its attachment to neighbouring neurovascular structures.

The relation of the optic nerve with the sphenoid sinus was studied based on Delano's classification:

Type 1- Optic Nerve lying adjacent to the lateral or superior wall of sphenoid sinus without im-pression on the sinus wall,

Type 2- Optic nerve causing impression on the lateral sphenoid wall

Type 3- Optic nerve coursing through the sphenoid sinus,

Type 4- Optic nerve coursing immediately lateral to posterior ethmoids and sphenoid sinuses.

Statistical Analysis: Data entry was done in Microsoft Excel and analyzed by SPSS software (ver-sion 25). Categorical data was expressed in count (%).

RESULTS

A total of 214 CT scans of PNS were analyzed in the study. The age of patients ranges from 3 years to 65 years, comprising 130 males and 84 females. [Table 1].

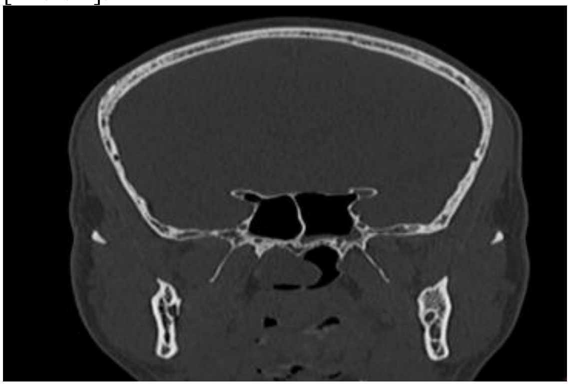

Figure1: Pneumatization of anterior clinoid process

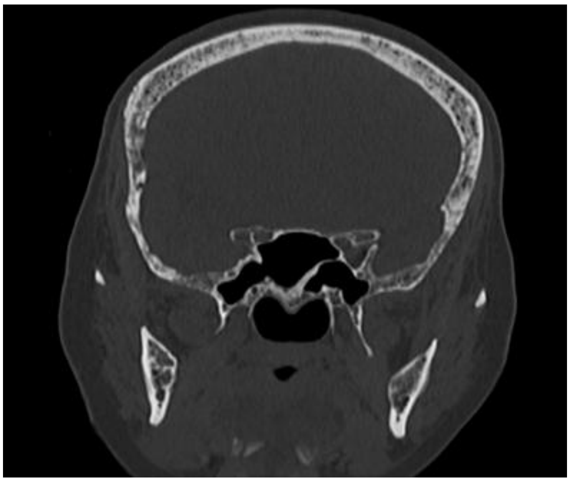

Figure 2: Pneumatization of bilateral pterygoid processes

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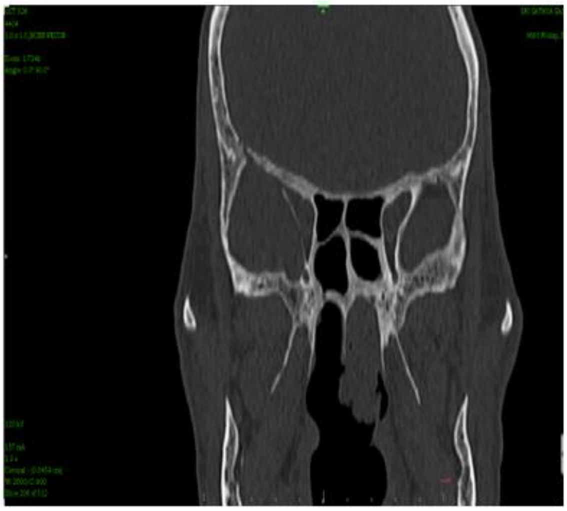

Figure 3: Bilateral Onodi cells

The majority of cases had normal sphenoid sinus (71.40%), 10.28% had right-side sphenoid dis-ease, 9.81% with left side sphenoid disease, and 8.41% with bilateral sphenoid disease [Table 2]. All the diseased cases showed features of sphenoid sinusitis. The analysis of the variations of the sphenoid sinus based on pneumatisation of sella turcica was found to have a predominance of the sellar type, 51.40% and24.77% cases of postsellar type, 22.42% of presellar type and 1.40% cases with conchal type. [Table 3]. Pneumatization of the ante-rior clinoid process was observed in 43 cases, [Figure 1] of which 13, 16, and 14 cases were bilateral, right, and left 43 respectively. Pneumatization of the greater wing of the sphenoid was observed in 43 cases out of which 15, 15, and 13 cases were bilateral, right, and left-sided respectively. Pneumatization of the pterygoid process was observed in 53 cases out of which 27, 15, and 11 were bi-lateral, right and left sides respectively. [Table 4 & Figure 2]

In this study, we observed that the majority had type 1optic nerve relation in 164 cases out of which 143, 9, and 12 were bilateral, right, and left-sided respectively. Type 2 in 27 cases, of which 12, 7, and 8 cases were bilateral, right and left sides respectively. Type 3 in 10 cases, of which 8 were bilateral 1 was right-sided, and 1 left sided. Type 4 was observed in 13 cases, of which 9, 3, and 1 cases were bilateral, right, and left sides respectively. [Table 5].

Variations of neurovascular structures with sphenoid sinus were studied. Optic nerve protrusion was noted in 15 cases and 11 cases with optic nerve dehiscence were observed. The maxillary nerve was found protruded in 43 cases and was observed dehiscent in 4 cases. Protrusion of the internal carotid artery into the sphenoid sinus was observed in 48 cases out of which 15, 17, and 16 cases were bilateral, right and left-sided respectively [Table 6]. Vidian nerve protrusion was noted in 21.49% of our cases.

The onodi cells [Figure 3] were found in 60 cases out of which 18, and 22,20 cases were bilateral, right, and left-sided respectively [Table 7]. Studies on the presence of intersphenoid septum and its attachment to the optic nerve and internal carotid artery were done. Single intersphenoid septum was found in 87 cases, 65 cases with multiple septations, and 62 cases without septations. In-tersphenoid septum was attached to the internal carotid artery in 65 cases and 54 cases had septum attached to the optic nerve [Table 8].

Table 1: Demographics

Age group(in years)	**Number of cases**	**Percentage**
3-20	45	21.03
21-40	115	53.74
41-60	44	20.56
>60	10	4.67
Gender	**Number of cases**	**Percentage**
Female	84	39.25
Male	130	60.75

Table 2: Sphenoid sinus status(present/absent)

Disease status of sphenoid sinus	**Number of cases**	**Percentage**
Normal	153	71.49
Right sided disease	22	10.28
Left sided disease	21	9.81
Bilateral disease	18	8.41

Table 3: Types of sphenoid sinus based on pneumatization

Type of pneumatization	**Number of cases**	**Percentage**
Conchal	3	1.40
Presellar	48	22.42
Sellar	110	51.40
Postsellar	53	24.77

Table 4: Extension of pneumatization of sphenoid sinus

Pneumatization of:	**Right side(n/%)**	**Left side(n/%)**	**Bilateral (n/%)**	**Total**
Anterior clinoid process	16 (7.48%)	14 (6.54)	13 (6.07%)	43 (20.09%)
Pterygoid process process	15 (7.00%)	11 (5.14%)	27 (12.62%)	53 (24.77%)
Greater wing of sphenoid	15(7.00%)	13 (6.07%)	15 (7.00%)	43 (20.09%)

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Table 5: Optic nerve relation based on DeLano classification

Type	Right side(n/%)	Left side(n/%)	Bilateral (n/%)	Total
1	9 (4.21%)	12 (5.61%)	143 (68.82%)	164 (76.64%)
2	7 (3.27%)	8 (3.74%)	12 (5.61%)	27 (12.62%)
3	1(0.47%)	1 (0.47%)	8 (3.74%)	10 (4.67%)
4	3 (1.40%)	1 (0.47%)	9 (4.21%)	13 (6.07%)

Table 6: Variations of optic nerve, maxillary nerve, vidian nerve and internal carotid artery

Variation	Right side(n/%)	Left side(n/%)	Bilateral (n/%)	Total
Optic nerve protrusion	5(2.34%)	6 (2.80%)	4 (1.87%)	15 (7.00%)
Optic nerve dehiscence	5(2.34%)	2 (0.93%)	4(1.87%)	11(5.14%)
Maxillary nerve protrusion	15 (%)	12 (%)	16 (%)	43 (20.09%)
Maxillary nerve dehiscence	2(0.93%)	1 (0.47%)	1 (0.47%)	4 (1.87%)
Internal carotid artery protrusion	17 (7.94%)	16 (7.48%)	15 (7.00%)	48 (22.43%)
Internal carotid artery dehiscence	1(0.47%)	1(0.47%)	0	2 (0.93%)

Table 7: Onodi cell

Side	Number of cases	Percentage
Right	22	10.28
Left	20	9.34
Bilateral	18	8.41
Total	60	28.04

Table 8: Intersphenoid septum characteristics

Characteristics	Number of cases	Percentage
Single	87	40.65
Multiple	65	30.37
Absent	62	28.97
Septum attached to Internal carotid artery	65	30.37
Septum attached to Optic nerve	54	25.23

DISCUSSION

The sphenoid sinus is located within the sphenoid bone at the base of the skull and expands in anteroposterior and lateral directions until age of 10 years, but its full extension occurs only after adolescence.[4,5] It has various extensions that bring it into proximity with important anatomical structures, including the internal carotid artery and the optic nerve.[2] When the sphenoid sinus is well-pneumatized, it is often separated from these adjacent structures by only a thin bonyplate.[6] This close relationship is clinically significant as surgeries involving the sinus or the conditions affecting the sphenoid sinus, such as infections or tumors, can potentially impact or compress the nearby in-ternal carotid artery and optic nerve, leading to serious complications.

Ossama et al,[7] and Guldner et al,[8] classified the sphenoid sinus based on the pneumatization into the following four groups; Type I: conchal, Type II: presellar, Type III: sellar, and Type IV: postsellar. It decides the surgical approach in cases of trans-sphenoidal surgery.[9] The sellar type is the most prevalent pneumatization,[9,10] and the sellar type was the most common (51.4%) in the current study. Sellar type of pneumatization has been reported to be less prone to surgical risk in trans-sphenoidal surgery. Conchal type is the least frequent in most studies and was found only in 2% of cases in the studies conducted by Levine and Clemente,[11] and Sareen et al,[12] In the pre-sent study, 1.4% of cases with conchal type were found. The conchal type was always considered to be a contraindication for a trans-sphenoidal approach to the cellar. However, with recent advances like intra-operative fluoroscopic imaging and navigation devices, the conchal non-pneumatized sphenoid approach can be feasible, and it should, be confined only to small and intra-sellar tumors though it is time-consuming.[13,14]

The prevalence of the anterior clinoid process is well documented in the literature. In the present study, the anterior clinoid process was found pneumatized in 20.09%. The study by Bolger et al. on 202 paranasal sinus CT scans of 3mm thickness showed 13% of anterior clinoid process pneumatization.[15] Delano et al. found anterior clinoid process pneumatization in only 13 of 300 sides (4%).[16] In the study by Hubballi RK et al. Observed 28% of cases with anterior clinoid process pneumatisation. In this study, the researchers examined CT scans with a slide thickness of 1 mm. The pneumatization of the anterior clinoid process forms the opticocarotid recess which is sup-posed to coincide with the ipsilateral protrusion of the optic nerve and/or the internal carotid artery into the sphenoid sinus.[9]

The pterygoid process is said to be pneumatised if it extends beyond a horizontal plane passing the vidian canal.[7] In our present study, 24.77% of cases had pneumatization of the pterygoid process. The studies performed by Hubballi RK et al. and Hewaidi GH et al. showed the pneumatized pterygoid process in 26% and 29% of cases respectively.[9,17] The endoscopic endonasal trans-pterygoid approach utilizes the pneumatization of the pterygoid process to access and treat lesions in the middle and posterior skull base, providing a route for endoscopic biopsies of skull

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base neo-plasms and the endoscopic repair of cerebrospinal fluid leaks.[18]

The greater wing of the sphenoid is said to be pneumatised when the extension pneumatisation of extends sinus extends beyond a vertical line crossing the foramen rotundum. In the present study, we observed 20.9% of cases with pneumatisation of the greater wing of the sphenoid. A study done by Hewaidi GH et al. showed pneumatization of the greater wing of the sphenoid in 20% of cases.[8] A study by Hubballi RK et al. reported 22% of cases with pneumatization of the greater wing of the sphenoid.[9]

The most posterior ethmoidal cell is the onodi cell which develops superolaterally to the sphenoid sinus and pushes the sinus downward. It was seen in 28% of our study population, There are great variations in literature regarding this type of cells with a range of 8%–33.3%.[19] The Onodi cell is closely related to the optic nerve and internal carotid artery, requiring caution in patients with this variant.[20] It shares a wall with the sphenoid sinus, and during the endoscopic endonasal transsphenoidal approach, it can obstruct the sellar floor. Mistaking the onodi cell for the sphenoid sinus can lead to accidental entry into the middle cranial fossa, risking injury to the optic nerve and internal carotid artery.[4]

Delano et al. described the types of optic nerve nerve relation concerning sphenoid sinus into four types and the most common configuration was reported to be type 1, which is reported in 76% of cases.[16] Type 3 and 4 have a close relation of optic nerve with sphenoid sinus and are thus more prone to iatrogenic injury. In the present study, we observed 76.64% of cases with Delano type 1 relation, 12.62% of cases with type 2, 4.67% of cases with type 3, and 6.07% cases with type 4 respectively. The study by Hubballi RK et al. observed 76% of cases with Delano type 1 relation of optic nerve.[9] Kanotra S et al. observed 69.3% with type 1, 20.9% of cases with type 2, 3% with type 3, and 6.8% of cases with type 4 respectively.[21]

Internal carotid artery, optic nerve, vidian nerve, or maxillary nerves can protrude into the sphenoid sinus. Vidian or maxillary nerve protrusions can cause neuralgia in sphenoid sinus disease.[22] The observed rate of optic nerve protrusion was 7%, which is consistent with the literature, where re-ported rates range from 2.3% to 35.6%.[23] In the present study, dehiscence of the optic nerve was found in 5.14% of cases. Fujii et al. and Lupascu et al. found dehiscence of the optic nerve in 4% of cases and 5% of cases respectively.[24,25] In the study by Hubballi RK et al. found 3% of cases with optic nerve dehiscence.[9] The internal carotid artery's proximity to the sphenoid sinus poses a risk of fatal hemorrhage if damaged during surgery, as controlling such bleeding is difficult. Simi-larly, protrusion of the optic nerve can lead to blindness if injured. Infections in the sphenoid sinus can also compress the optic nerve, causing visual impairments. Surgeons must be aware of these risks to avoid serious complications.

In the present study, we observed protrusion of the maxillary nerve in 20.09% of cases and dehis-cence in 1.87% of cases. The study by Hubballi RK et al. found 25% of cases with maxillary `nerve protrusion and 1% of cases with maxillary nerve dehiscence.[9] Hewaidi et al. observed pro-trusion of the maxillary nerve in 24.3% of cases and dehiscence in 13% of cases.[17] A protruding or dehiscent maxillary nerve is susceptible to injury during endoscopic sinus surgery and is also more vulnerable to neuritis when sphenoid sinusitis is present, potentially leading to trigeminal neu-ralgia.[9] Vidian canal protrusion was observed in 21.49% of our cases which is similar to studies conducted by Hewaidi et al. and Hubballi RK et al. in which they observed protrusion of the vidi-an canal in 27% and 22% of cases respectively.[9,17]

In our study, internal carotid artery protrusion into the sphenoid sinus occurred in 22.43% of cases which is in accordance with studies by Dal Secchi et al. (26%) and Sirikci et al. (26.1%).[26,27] Dehiscence of the internal carotid artery was identified in only 2 cases (0.93%). The review of the literature showed internal carotid artery protrusion with a wide range, from 5.2 to 67.0%,[18,24] while its dehiscence ranges from 1.5–5% to 1.5–30%.[17,23,26]

In the present study single intersphenoid sinus septum was found in 40.65%, multiple in 30.37%, and none in 28.97% respectively. Inter sphenoid sinus septum was attached to the carotid artery in 30.37% of cases and to the optic nerve in 25.23% of cases. This was in agreement with the work done by Famurewa et al. who found single septum in 46.9%, multiple in 50.6%, none in 2.5%, and attached to the carotid artery in 31.6% of cases.[20]

CONCLUSION

The study depicts the significant anatomical variations of the sphenoid sinus and its surrounding structures in the rural population of Karnataka. Sellar pneumatization was the most common type, with notable occurrences of pterygoid process and anterior clinoid process pneumatization, as well as variations in septation and neurovascular relationships. These findings necessitate the im-portance of preoperative imaging and careful surgical planning to minimize risks during trans-sphenoidal and functional endoscopic sinus surgeries. Understanding these population-specific var-iations provides valuable information for otolaryngologists and neurosurgeons, ultimately contrib-uting to safer and more effective surgical outcomes. Further studies with larger and more diverse populations could build on these findings to enhance anatomical knowledge and clinical practices.

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