Original Article

Anterior Clinoid Process Pneumatisation and the Optic Nerve

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Abstract

Background: The anterior clinoid process of the sphenoid bone exhibits intricate anatomical relationships with the optic nerve, internal carotid artery, and oculomotor nerve, with considerable variations including pneumatisation, bony bridges, and dehiscence. These variations carry significant surgical implications, as anterior clinoidectomy procedures carry visual morbidity risks ranging from 4.8% to 20%. Understanding population-specific anterior clinoid process anatomy is paramount for preoperative risk assessment and surgical planning in endoscopic skull base approaches. The aim is to determine the prevalence of anterior clinoid process pneumatisation and its association with optic nerve. 2.To assess the distribution and laterality of anterior clinoid process pneumatisation stratified by age and sex. **Material and Methods:** This retrospective cross-sectional study was conducted over 18 months at the Department of Anatomy and Radiodiagnosis, Government Medical College, Kottayam, Kerala, India. CT images of head, paranasal sinuses, and orbits from 300 adults (≥20 years) were analysed using a 128-slice GE Optima 660 multidetector CT scanner with multiplanar reconstructions in bone window (width 2000 HU; level 300 HU). The anterior clinoid process was analysed and pneumatisation noted.Theprevalence of anterior clinoid process pneumatisation and its association with optic nervewas also studied. **Results:** Among 300 participants (175 males, 125 females; mean age 45–69 years in 59.7%), anterior clinoid process pneumatisation prevalence was 11.0% (right), 13.0% (left), and 7.0% bilaterally. ACP pneumatization was strongly associated with Type 3 optic nerve configuration: 75.8% of right-sided and 74.4% of left-sided Type 3 cases exhibited ACP pneumatization ($\chi^2 = 159.945$, $p < 0.001$ right side; $\chi^2 = 206.115$, $p < 0.001$ left side). No Type 1 cases demonstrated ACP pneumatization. **Conclusion:** Anterior clinoid process pneumatisation is significantly associated with surgically hazardous Type 3 optic nerve configurations in this South Indian population, providing a predictive framework for preoperative risk stratification. High-resolution CT with multiplanar reconstruction is essential for all patients undergoing sphenoid sinus or anterior clinoidectomy procedures to identify at-risk anatomical variants and enhance surgical safety.

Keywords: Anterior Clinoid Process, Pneumatisation, Optic Nerve, Sphenoid Sinus.

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INTRODUCTION

The clinoid process (Origin: Greek, clini meaning “bed” and oidos meaning “similar to) described by Alexander Monro (primus, 1726) is part of a polymorphous skull bone- The Sphenoid.[1,2] The clinoid process of the sphenoid bone—two anterior, two middle, and two posterior-constitute essential landmarks surrounding the hypophyseal fossa. Of these, the anterior clinoid process (ACP) is of particular interest due to its intricate architecture and proximity to critical neurovascular structures. The ACP represents the posterior and medial continuation of the lesser wing of the sphenoid and is anchored to the basisphenoid by superior and inferior roots.[3] The superior root forms a flat structure contributing to the roof of the optic canal and extending into the planum sphenoidale, whereas the inferior root, or optic strut, establishes the lateral and ventral margins of the optic canal, linking the lesser wing with the sphenoid body. Based on its surrounding anatomical relationships, the ACP is described as having six distinct surfaces: frontal, temporal, optic nerve, internal carotid artery, oculomotor nerve, and optic strut.[4]

The anatomy of the suprasellar and parasellar region is complex and exhibits considerable variability. Reported variations include partial or complete pneumatisation, bony bridges, kissing clinoids, venous canals, and accessory spicules.The relationship between anterior clinoid process (ACP) pneumatisation and optic nerve (ON) safety is a critical consideration in transsphenoidal endoscopic surgery.Since variations were recognized in the anatomy of sphenoid sinuses, DeLano et al proposed a classification of the relations of ON with sphenoid and posterior ethmoid sinuses into four types.[5]In Type 1, the course of optic nerve was adjacent to sphenoid sinus, there was no indentation of its wall,In Type 2, the nerve passed adjacent to sphenoidal sinus, causing an indentation to its wall.In Type 3, course of the nerve was through the sphenoid sinus with pneumatization of anterior clinoid process (ACP).In Type 4, the nerve passed immediately adjacent to the sphenoid

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sinus and the posterior ethmoidal air cell Recent literature emphasizes that extensive pneumatisation often renders the bony covering of the optic nerve thinner or dehiscent, thereby increasing the risk of iatrogenic injury during endonasal maneuvers. Anterior clinoidectomy remains a cornerstone neurosurgical procedure to decompress the optic nerve, mobilize the internal carotid artery, or widen the retro carotid corridor. Nevertheless, the surgery carries risks, including rhinorrhoea, optic and oculomotor nerve injury, vascular damage, aneurysm rupture, and pneumocephalus, with reported visual morbidity ranging from 4.8% to 20%. Given these clinical implications, in our study we aimed to assess the relation between optic nerve and anterior clinoid process pneumatisation. The sphenoid bone, well recognized for its variable pneumatisation, can influence the degree of optic nerve protrusion into the sphenoid sinus.[5] Thus, understanding the prevalence of ACP pneumatisation and its association with optic nerve variants in our populations is of paramount importance for surgical planning and risk mitigation.

Materials and Methods

Study design and setting: This retrospective cross-sectional observational study was conducted at the Department of Anatomy and Department of Radiodiagnosis, Government Medical College, Kottayam, Kerala, India, over an 18-month period following Institutional Ethics Committee approval. Waiver of informed consent was granted due to the retrospective nature and use of anonymized imaging data, with no additional radiation exposure to participants. From the Picture Archiving and Communication System (PACS) database, 600 consecutive non-contrast Computed Tomography (CT) scans of the head, brain, paranasal sinuses, and orbits (performed for various clinical indications in the Department of Radiodiagnosis, Government Medical College, Kottayam) were screened.

Study Population: Scans from adult patients referred by clinicians from emergency, neurology, ENT, and neurosurgery departments aged ≥25 years were eligible. Inclusion criteria: diagnostic-quality images covering the sphenoid sinus bilaterally without motion artifacts. Exclusion criteria: neoplastic lesions (e.g., pituitary tumours, meningiomas), fractures or trauma involving sphenoid/optic canal, prior paranasal sinus or skull base surgery, craniofacial anomalies, age <25 years; incomplete scan coverage. Final analysis included 300 patients (600 sides), yielding a representative sample of the local South Indian population attending a tertiary care centre.

Objectives

1. To determine the prevalence of anterior clinoid process pneumatisation and its association with optic nerve.
2. To assess the distribution and laterality ofanterior clinoid process pneumatisation stratified by age and sex.

Data collection procedure and Statistical analysis

CT was performed on GE 660 OPTIMA 128 multislice CT SCANNER. The axial examination was performed in routine protocol with the patient supine, the hard palate perpendicular to the table top and the scanning plane parallel to the orbitomeatal line. The cranial and caudal limits of the average scan (vertex and hard palate, respectively) localized from the lateral scout view. The scan extent from the hard palate to above the end of the frontal sinus. The technical parameters adopted for acquisition of tomographic images included a 120 kV tube voltage and auto mAs (160mAs), 0.8 second rotation time, section thickness of 0.625-1.0mm, a field of view of 140-160mm. Images were then transferred into the computer workstation for interpretation. Sequential axial images were obtained and processed to form volume data. From volume data, multiplanar reconstructions were made in axial, coronal and sagittal planes and analysed. All images were evaluated in coronal planes in bone (window width 2,000 Hounsfield units; window level 300 Hounsfield units). Right and left sides were considered separately. Optic nerve, sphenoid sinus, pneumatisation of the ACP was evaluated from the obtained images. The data collected were entered into Microsoft Excel Work sheet and statistical analysis of the data was performed using SPSS 20.0. The categorical variables were presented as frequency and percentage. Association between the categorical variables were performed using Chi square test. A p value <0.05 was considered statistically significant.

Results

Among the 300 participants analysed, 175 were male (58.3%) and 125 individuals were female (41.7%). The majority fell within the middle age group of 45-69 years, comprising 179 (59.7%) individuals. This was followed by the 25-44 years age group accounting for 76 (25.3%) individuals, the remaining 45 participants (15.0%) belonged to the age group of 70-94 years.

Distribution of ACP pneumatisation on right side

Out of the 300 observations, 33 cases (11.0%) demonstrated pneumatisation of the ACP on the right side, while the majority, 267 cases (89.0%), exhibited an absence of pneumatisation. Distribution of ACP pneumatisation on left sideAmong the total of 300 observations, 39 cases (13.0%) demonstrated pneumatisation of the ACP on the left side, while the majority, 261 cases (87.0%), exhibited an absence of pneumatisation. [Table 1]

Table 1: Frequency distribution of ACP pneumatisation

	Frequency	
	Right side	**Left side**
Present	33	39
Absent	267	261
Total	300	300

Frequency distribution of total ACP pneumatisation in the study population

Among the total of 600 observations, 72 cases (12.0%) demonstrated pneumatisation of the ACP, while the majority, 528 cases (89.0%), exhibited an absence of pneumatisation. [Figure 1]

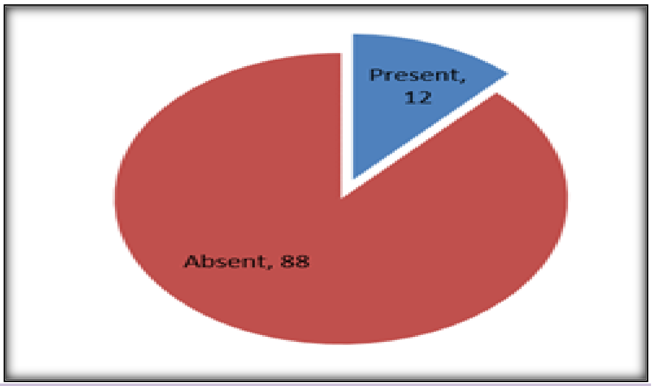

Figure 1: Frequency distribution of total ACP pneumatization

Cross tabulation of Age and ACP pneumatisation on the right side.

For individuals aged 25-44 years, 11 (14.5%) exhibited ACP pneumatisation, the majority (85.5%) of individuals in this age range did not demonstrate ACP pneumatisation. Among individuals aged 45-69 years, 16 cases (8.9%) demonstrated ACP pneumatisation and the majority (91.1%) exhibited its absence. In the age group of 70-94 years, the percentage of individuals with ACP pneumatisation was 13.3%, representing 6 cases, while 39 cases (86.7%) do not show pneumatisation of the ACP. [Figure 2]

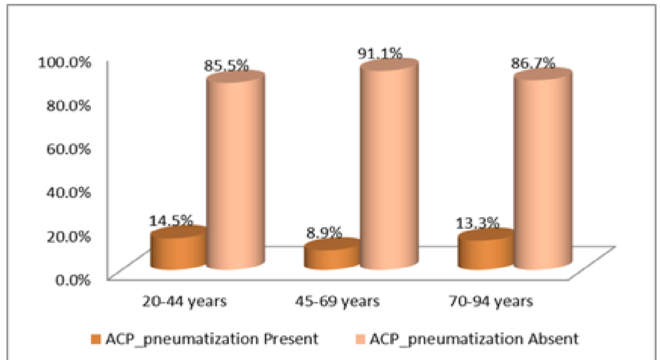

Figure 2: Age and ACPpneumatisation (right side).

Table 2: Cross tabulation of Age and ACP pneumatisation

Age	ACP Pneumatisation	
	Left side	Right Side
25-44 years	13	11
	17.1%	14.5%
45-69 years	20	16
	11.2%	8.9%
70-94 years	6	6
	13.3%	13.3%
Total	39	33
	13.0%	11.0%

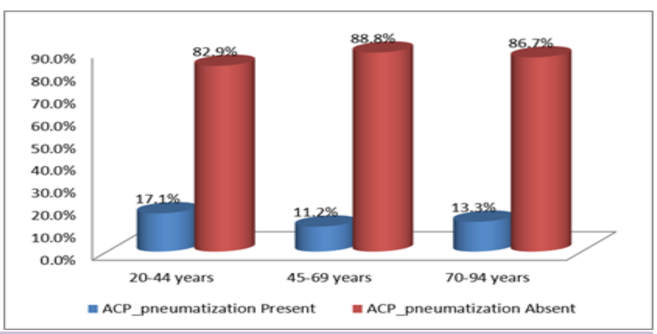

Figure 3: Age and ACPpneumatisation (left)

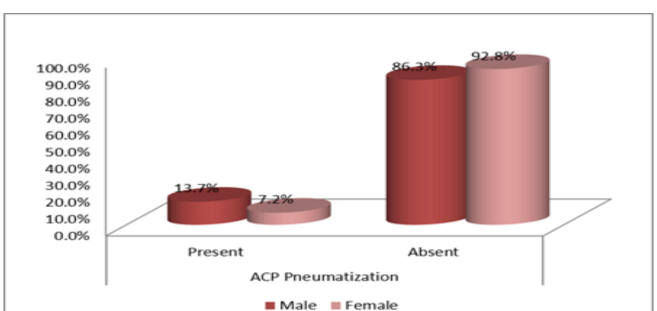

Figure 4: Genderand ACP pneumatisation on the right side.

Cross tabulation of Age and ACP pneumatisation on the left side: Among individuals aged 25-44 years, 13 exhibited ACP pneumatisation, representing 17.1% of this age group. The majority (82.9%) of individuals in this age range did not show ACP pneumatisation. For individuals aged 45-69 years, 20 cases (11.2%) demonstrated ACP pneumatisation, while the remaining 159 cases (88.8%) did not show pneumatisation. In the age group of 70-94 years, the percentage of individuals with ACP pneumatisation was 13.3% (6 cases). [Table 2, Figure 3]

Cross tabulation of Gender and ACP pneumatisation on the right side.

Among males, 24 cases exhibit ACP pneumatisation, accounting for 13.7% of the male population, while the majority (86.3%) show its absence. For females, 9 cases demonstrate ACP pneumatisation, representing 7.2% of the female population, with the majority (92.8%) showing its absence. [Figure 4]

Cross tabulation of Gender and ACP pneumatisation on the left sideAmong males, 23 cases exhibited ACP pneumatisation, accounting for 13.1% of the male population, while the majority (86.9%) did not demonstrate pneumatisation. For females, 16 cases demonstrated ACP pneumatisation, representing 12.8% of the female population, with the majority (87.2%) showing its absence. [Table 3, Figure 5]

Table 3: Cross tabulation of sex and ACP pneumatisation on the left side

Sex	ACP Pneumatisation	
	Left	**Right**
Male	23	24
	13.1%	13.7%
Female	16	9
	12.8%	7.2%
Total	39	33
	13.0%	11.0%

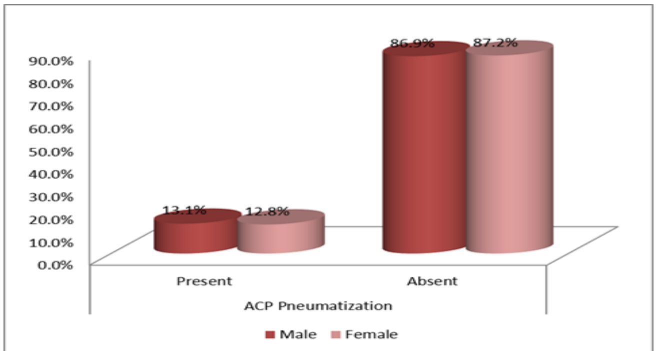

Figure 5: sex and ACP pneumatisation on the left side.

Association between ACP pneumatisation and the optic nerve on the right side.

The crosstabulation analysis reveals a significant relationship between optic nerve (ON) Type on the right side and the presence or absence of ACP pneumatisation. The chi-square test yields a highly significant result ($\chi^2 = 159.945$, $p < 0.001$), indicating that the distribution of ACP pneumatisation varies significantly depending on the ON classification. Majority of cases classified under ON Type1 exhibited no ACP pneumatisation (71.2%), whereas ON type 3 demonstrated a notably higher prevalence of ACP pneumatisation (75.8%). [Table 4, Figure 6]

ACP Pneumatisation -left side

Table 4: Association between ACP pneumatisation and the optic nerve on the right side.

Right		ACP Pneumatisation		Total	Chi square	p value
		Present	**Absent**			
ON Types	ON -Type 1	0	190	190	159.945	p<0.001
		0.0%	71.2%	63.3%		
	ON-Type 2	5	51	56		
		15.2%	19.1%	18.7%		
	ON-Type 3	25	9	34		
		75.8%	3.4%	11.3%		
	ON -Type 4	3	17	20		
		9.1%	6.4%	6.7%		
Total		33	267	300		
		100.0%	100.0%	100.0%		

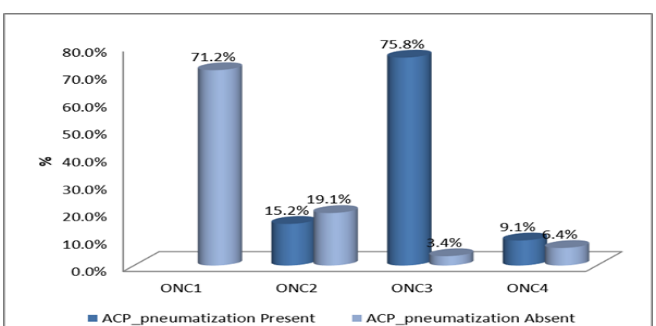

Figure 6: ACP pneumatisation and the optic nerve on the right side

Association between ACP pneumatisation and optic nerve on left side.

The crosstabulation analysis revealed a significant relationship between ON classification on the left side and the presence or absence of ACP pneumatisation. The chi-square test yielded a highly significant result ($\chi^2 = 206.115$, $p < 0.001$), indicating the majority of cases categorized under ON Type1 and ON Type 2 exhibited an absence of ACP pneumatisation, with proportions of 74.3% and 19.9%, respectively. [Table 8, Figure 7]

Table 5: Association between ACP pneumatisation and ON on left side.

Left		**ACP Pneumatisation**		**Total**	**Chi square**	**p value**
		Present	**Absent**			
ON Types	ON- Type1	0	194	194	206.115	p<0.001
		0.0%	74.3%	64.7%		
	ON- Type2	0	52	52		
		0.0%	19.9%	17.3%		
	ON- Type3	29	9	38		
		74.4%	3.4%	12.7%		
	ON -Type4	10	6	16		
		25.6%	2.3%	5.3%		
Total		39	261	300		
		100.0%	100.0%	100.0%		

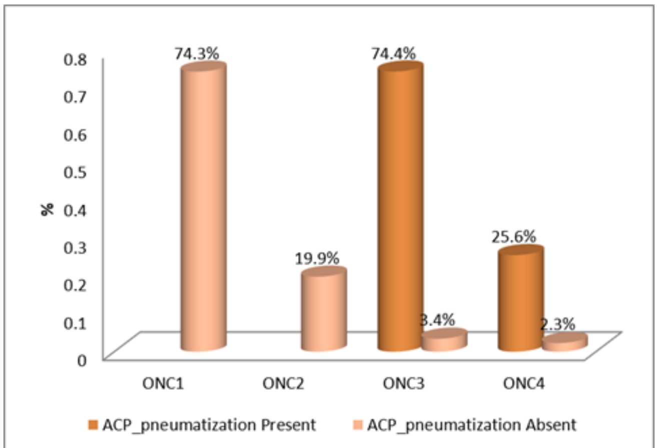

Figure 7: ACPpneumatisation and the optic nerve on the left side.

Figure 8: Bilateral ACP Pneumatisation

Discussion

The present study, conducted in a population of 300, identified a prevalence of ACP pneumatization of 11.0% on the right side, 13.0% on the left, and 7% bilaterally, with slight male predominance and majority representation from the middle-aged group. On detailed analysis there was a statistically significant association between ACP pneumatization and Type 3 ON on both sides. The prevalence of ACP pneumatization observed in our study demonstrated significant findings when compared to similar studies from Indian and global populations. A comprehensive study by Hiremath et al. examining sphenoid sinus variations in the Indian population documented ACP pneumatization prevalence ranging from 20.4% to 23.5% depending on the extent of sphenoid pneumatization. He also concluded that the sphenoid sinuses were extensively pneumatized in Indian population compared to the Chinese and Caucasian population.[6] Sagar et al. reported ACP pneumatization in 26.3% of cases from their North Indian population, while Itagi et al. found pneumatization in 14.3% of cases.[7,8]

However international studies have reported lower prevalence rates. Mikami et al. documented ACP pneumatization in only 9.2% of cases in their Japanese population, while Szmuda et al. reported 9.7% prevalence in their European cohort.[9,10] However, recent studies from Pakistan by Aijaz et al. found ACP pneumatization in 31.33% of cases, suggesting possible regional variations within the South Asian population. The observed variations in prevalence rates across different populations likely reflect ethnic and genetic influences on cranial pneumatization patterns.[11] Extensive pneumatization of the sphenoid complex, including the ACP, appears to be more prevalent in the Indian subcontinent compared to East Asian and Caucasian populations.

The most significant finding of our study is the strong statistical association between ACP pneumatization and Type 3 ON configuration. Our analysis revealed that 75.8% of cases with ACP pneumatization on the right side and 74.4% on the left side demonstrated Type 3 optic nerve patterns. This association was statistically significant with $p<0.001$, indicating a highly reliable correlation. When the ACP becomes pneumatized, it creates a direct pathway for the optic nerve to protrude into or course through the sphenoid sinus, resulting in the Type 3 configuration. Chen et al. demonstrated that the presence of ACP pneumatization significantly increases the likelihood of ON protrusion, with a predictive value that enhances surgical risk assessment.[12] The clinical significance of this association becomes apparent when considering surgical complications. Studies have consistently shown that Type 3 optic nerve configurations carry the highest risk for iatrogenic injury during endoscopic sinus procedures. Kanotra et al. emphasized that Type 3 and Type 4 variants are considered surgically hazardous due to heightened risk of ON injury.[13] The close association between pneumatized ACP and Type 3 ON can cause dehiscence of the bony optic canal making the ON to pass directly within the surgical field.

The association between ACP pneumatization and Type 3 ON configuration directly correlates with increased surgical morbidity. Beer Furlan et al. reported that cerebrospinal fluid rhinorrhea remains a frequent complication of paraclinoid surgery, particularly when the optic strut is pneumatized.[14] The creation of communication between the subarachnoid space and sphenoid sinus during anterior clinoidectomy makes defect closure particularly challenging in pneumatized cases. Son et al. documented that permanent visual morbidity occurred in 4.2% of their cases, with heat injury and mechanical trauma to the optic nerve being primary concerns.[15]

However recent advances in surgical technique have attempted to address these complications. The use of ultrasonic bone curettes instead of traditional drills has shown promise in reducing thermal injury risk. However, the fundamental anatomical relationship between pneumatized ACP and ON protrusion remains a constant surgical challenge requiring meticulous preoperative planning.

Conclusion

In practical terms, these findings highlight the importance of anatomical evaluation before sphenoid sinus procedures—especially as endoscopic techniques become increasingly common in India. Our findings emphasize the importance of taking high-resolution CT imaging with multiplanar reconstruction for all patients undergoing sphenoid sinus surgery. Understanding these population-specific variations is crucial for developing appropriate surgical strategies and training programs. The strong statistical correlation between ACP pneumatization and Type 3 ON configuration provides a predictive framework for preoperative risk assessment, enhanced surgical preparation and patient counselling. The finding that both unilateral and bilateral pneumatization patterns show similar correlations with ON variants suggests a systematic anatomical relationship rather than random variation.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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