RESEARCH ARTICLE

Anatomical variations in pneumatization types and volume of sphenoid sinus in a subset of Pakistani people

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Abstract

Objective: To evaluate the relationship between volume and pneumatization pattern of sphenoid sinus using computed tomography images.

Method: The prospective, cross-sectional study was conducted at the Radiology Department of Dow University of Health Sciences, Karachi, from October 2020 to February 2021, and comprised patients of either gender aged 20-70 years who were subjected to computed tomography of paranasal sinuses. The scans were analysed for sphenoid volume and four pneumatization types of sphenoid sinus, including Type-I conchal, Type-II presellar, Type-III sellar and Type-IV postsellar. Significant differences in sphenoid volume and pneumatization pattern were noted. Data was analysed using GraphPad Prism 9.

Results: Of the 300 patients with mean age 39.28±10.99 years171(57%) were males and 129(43%) were females. The mean sphenoid volume in males was 11.01±3.50cm3 compared to 7.7±2.13cm3 in females. The majority of sinuses presented postsellar pneumatization type 192(64%), followed by sellar 84(29%), presellar 26(8.7%) and conchal pneumatization 2(0.7%). Significant difference in volume was observed with respect to gender and typology of the sphenoid sinus ($p<0.001$).

Conclusion: There was a significant relationship of sphenoid volume with and gender and pneumatisation variants, confirming the significance of ethnic heterogeneity.

Key Words: Paranasal sinuses, Sphenoid bone, Sphenoid sinus, Computed tomography.

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Introduction

With the introduction of endoscopic trans-sphenoidal surgery (ETS) and advancement in techniques of imaging, the anatomy of paranasal sinuses (PNS), especially sphenoid sinus (SS), has gained importance. This procedure permits surgeons to utilise SS as a surgical corridor to explore the inside of skull like perisellar regions, anterior cranial base, cavernous sinuses, pituitary gland and the petroclival region. However, surgical procedures may be complicated by the considerable variety in its kinds of pneumatization, septation pattern, and association with neighbouring important neurovascular relations. As a result, a detailed morphological examination of SS on preoperative computed tomography (CT) scan is critical for predicting intraoperative and postoperative lesions.[1]

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The SS begins to develop in the 3rd month of intrauterine life. At the time of birth, SS is present as a recess between sphenoid concha and sphenoid body which later starts to expands postero-inferiorly. In the second or third year of life, the SS cavity starts forming when sphenoid concha fuses with pre-sphenoid.[2] It is visible between the ages of 8 and 10 years. By the time a child reaches puberty at the age of 14, the sinus cavity has fully developed. However, adulthood is thought to be the point at which pneumatization is fully accomplished.[3] Some studies have reported the first appearance of sinus cavity in the first and second year, which increases over time and by the end of third decade of life, it occupies the full extent of sphenoid bone with gradual decrease of the size of the sinus cavity subsequent to sphenooccipital synchondrosis.[4] Some studies have reported the fourth foetal month as the beginning of SS development. Studies on SS volume (Sv) have also shown discordant findings. A recent study shows that Sv decreases with age,[5] but one study has reported contradictory evidence.[1]

There are different theories postulating the mechanism of pneumatization, but the exact process is not fully understood. According to invasive tissue hypothesis, the complex process of pneumatization is triggered by decreased oxygen tension and temperature changes that allow the conversion of haematopoietic red marrow to

fatty yellow marrow. Mucous epithelium then invades adjacent bone stabilising the complex sinus system.[6] Studies on humans at different altitudes have not shown significant differences in Sv.[7] The ethmoidal expansion theory states that aeration of SS is secondary to expansion of ethmoidal air cells into the adjacent sinuses. The variation in blood supply could be the other factor that promotes this transformation.[1]

Two adjacent neurovascular structures, the internal carotid artery and the optic nerve, have their bony protrusion and dehiscence greatly impacted by the pneumatization pattern of SS. Large sinuses with extended pneumatization exhibit increased neighbouring critical neurovascular structure protrusion and dehiscence. Sv and sinus types have a strong relationship. It provides anatomical information about SS, making it a crucial criterion for surgical intervention and planning.[7] It is an important parameter to identify optic nerve (ON) and internal carotid artery (ICA) bony protrusions and dehiscence as well as hazardous septal insertions on their bony coverings.[8] Sv can be calculated manually[7] as well as digitally by three-dimensional (3D) reconstruction of CT images.[8,9]

Currently, ETS is used more commonly because it is less invasive, has better visibility, and has fewer complications than open surgery. This technical advancement requires a preliminary evaluation of all measures of SS to plan the path of endoscopic procedure and surgery, as the anatomical variations of SS may lead to problems of guidance during endoscopic surgery.[10] Hence, a comprehensive knowledge of anatomy of SS and its variations ensures safe surgical procedure is essential.

Guldner et al. classified SS into four types as conchal, presellar, sellar and postsellar in association with sella turcica (ST).[11] Type-I conchal has little to no SS cavity and a 10mm mass of spongy bone separating the sinus with ST, Type-II presellar has the posterior wall of SS in front of the anterior sellar wall, Type-III sellar has posterior sinus wall halfway between the anterior and posterior sellar walls, and Type-IV postsellar includes the posterior wall of the sinus behind the posterior wall of ST. The conchal and presellar types are contraindication for ETS approach to ST because the amount of bone present between the sphenoid bone and ST needs a lot of drilling of thick bone and may lead to dreadful bleeding, while the sellar and postsellar types are most acquiescent for ETS.[8] Hence, the pneumatization configuration is of utmost importance for the surgeons to select the safest route to access the SS, and needs careful preoperative CT evaluation.

Studies have reported ethno-geographical variability in size and morphology of SS in different population.[1,3,7,8,10] Several local studies have also highlighted pneumatisation variants of SS.[12,13] The current study was planned to evaluate the relationship between Sv and pneumatization pattern of SS using CT images.

Patients and Methods

The prospective, cross-sectional study was conducted at the Radiology Department of Dow University of Health Sciences (DUHS), Karachi, from October 1, 2020, to February 22, 2021. After approval from the institutional ethics review board, the sample size was calculated using OpenEpi calculator[14], assuming the prevalence of PNS variants to be 52%,[15] with 80% power and 95% confidence level. The sample was raised using convenience sampling technique. Those included were patients of either gender aged 20-70 years who were subjected to PNS CT scans. Those with a history of nose surgery, any trauma around the nose, PNS tumours, nasal polyposis, and chronic illnesses of the PNS producing bony deformities of SS were excluded.

After furnishing informed consent, the patients underwent a PNS CT scan (Optima 660, 64-slice CT scanner General Electric Healthcare Computed Tomography system- California, United States) in accordance with departmental regulations, utilising 3mm slice thickness with scan parameters of kV 120, 0.5s rotation time and 60-220mA in both soft tissue and bony algorithms. A plane from the roof of frontal sinus to upper dental arch was used to provide axial sections. Radiant application was used to obtain multiplanar reconstructions. The scans were analysed in detail by a consultant radiologist.

The Guldner classification was used to analyse the pneumatisation types of SS (Figure 1).[11] The width, height

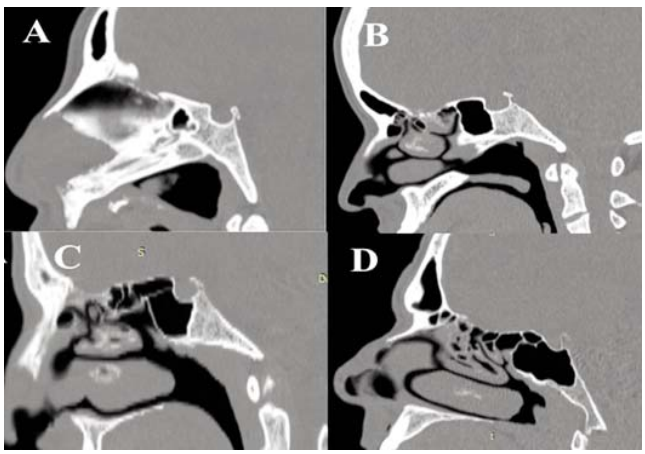

Figure-1: Radiological presentation of the different sphenoid sinus pneumatization variants. A: Type-I conchal, B: Type-II presellar, C: Type-III sellar, D: Type-IV Postsellar

and antero-posterior length were measured for Sv measurements in the sagittal and axial planes. All measurements were taken from the widest area of sinus, and the formula height*width*length*0.52 was used to calculate Sv.[7]

Data was analysed using GraphPad Prism 9. Quantitative variables were expressed as mean +/- standard deviation (SD), while qualitative data was expressed as frequencies and percentages. Data normality was checked using Shapiro-Wilk test. Independent t-test was used to compute significance of difference between Sv and gender, while Sv and four pneumatization types were analysed using one-way analysis of variance (ANOVA). Post-hoc analysis was performed using the Tukey honest significant difference (HSD). P<0.05 was considered significant.

Results

Of the 300 patients with mean age 39.28±10.99 years 171(57%) were males and 129(43%) were females. The majority of sinuses presented postsellar pneumatization type 192(64%), followed by sellar 84(28%), presellar 26(8.7%) and conchal pneumatization 2(0.7%). The mean sphenoid volume in males was 11.01±3.50cm3 compared to 7.7±2.13cm3 in females. Significant difference in volume was observed with respect to gender and typology of the sphenoid sinus (p<0.001) (Table 1).

Posthoc analysis revealed that the the difference between conchal and presellar types was statistically significant (p-value<0.05) and highly significant difference was observed between conchal vs sellar, conchal vs postsellar, presellar vs sellar , presellar vs postsellar and sellar vs postsellar (p-value≤0.001), with men having higher volume than women through all the types (Figure).

Discussion

The variable anatomy of SS and its relationship with surrounding noble structures, like ICA, ON, maxillary nerve, vidian nerve and pituitary gland, has given it a unique importance in endoscopic sinus surgery.[1] Information regarding the development of this highly variable sinus cavity is conflicting in literature.[1]

The volumetric analysis is a crucial measure for PNS assessment. SS type and basic dimensions can be used to determine the likelihood of inadvertent harm during sinus surgery.[8] In order to reduce intraoperative and postoperative complications following ETS, a thorough understanding of anatomical variations of SS is required.

In addition to presenting novel knowledge on pneumatization types and Sv in Pakistani population, the current volumetric study, to our knowledge, is the first to establish a substantial correlation between the two variables, which is helpful for the anatomical description of SS. To show the possible influence of ethnicity on the structural development of SS, a comparison was made between the results of comparable investigations carried out in other ethnicities.

The most frequently observed pneumatization type in Pakistani population was postsellar (63.5%) which was also reported in other populations, like Iranian (83.5%), Turkish (57.8%), Brazilian (63%), Americans (54%) and Nepalese (52%).[1,16-19] Alternatively, the sellar pattern of pneumatization was prevalent in Chinese, Malaysian, Indian, Italain and Croatian populations.[16,18]

When comparing Sv with gender, a significant difference (p<0.001) was observed, making this method useful in assessing dimorphism, which was consistent with the

Table-1: Association between sphenoid volume and gender according to the pneumatization types of the sphenoid sinus.

Variable		Pneumatisation types					
		Type-I Conchal	Type-II Presellar	Type-III Sellar	Type-IV Postsellar	Total	p-value
Volume (cm^3)	Males	----	4.21± 1.55	8.5±2.18	12.76±1.95	11.01±3.50	<0.001*
	Females	0.56 ± 0.77	3.52 ± 0.77	6.91±1.10	8.88±1.56	7.7 ± 2.13	<0.001*

Table-2: Comparison of sphenoid sinus volume in different populations.

Studies	Sample size	Population	Volume (cm^3)
Present study	300	Pakistani	9.59±3.4
Tuang GJ et al[21]	304	Indian	11.5±3.97
Tusng GJ et al[21]	304	Chinese	12.96±4.62
Tuang GJ et al[21]	304	Malaysian	10.68±4.13
Ramos et al[24]	268	Brazilian	11.36±4.23 (M) 10.00±3,61(F)
Gibelli et al[8]	100	Italian	10.00±5.101 (M) 7.920±3.176 (F)
Selcuk et al.[7]	115	Turkish	
		Agri district	7.03±1.8(M), 6.00±0.5(F)
		Antalya district	9.00±3.6(M) 7.20±4.3(F)
Pirner et al[19]	50	German	11.2

M=Males, F=Females

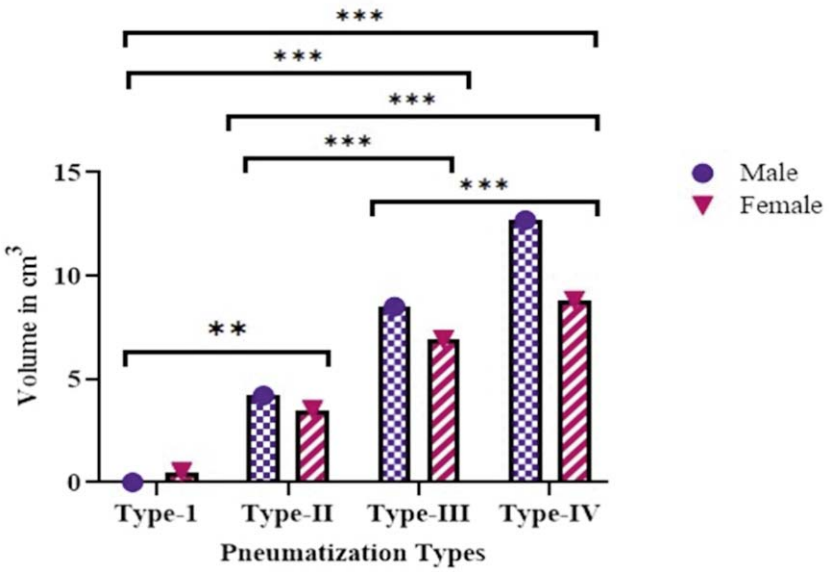

Figure-2: Association between volume of sphenoid sinus and its pneumatization type. **p<0.05=significant difference, ***p<0.001=highly significant difference, Type I: Conchal, Type II: Presellar, Type III: Sellar, Type IV: Postsellar

earlier findings.[5,8,20] However, other studies showed no difference between gender and Sv.[1, 21]

The present study illustrated that racial differences existed in the size of SS in different populations. The highest volume was found in postsellar type in both males and females, followed by sellar and presellar types. This was in agreement with earlier findings.[1,8] When comparing Sv with the types of pneumatization pattern in different ethnic populations, it was observed that Brazilian had a higher volume in presellar type compared to Italian and Pakistani populations, while a higher volume of postsellar type was found in Pakistani population compared to Brazilian and Italian populations. The sellar type in Italians had a higher volume than Brazilian and Pakistani populations.[1,8] These findings indicated that there were ethnic differences not only in size of SS, but also in the sinus type. This underscored the need to obtain further data in specific geographical contexts.[19]

When comparing the sphenoid volume among Asian countries (Table 2), mean Sv in Chinese was found to be higher (12.96cm^3) compared to Pakistani (9.59cm^3), Indian (11.5cm^3), Malaysian (10.68cm^3) and Israeli (4,55cm^3) pouplations.[22] The western countries displayed a mean Sv not more than 12cm3 and a maximum Sv of not more than 25cm^3.[22,23] These findings support the manifestation of racial difference in the size of the sinus.

The current study has limitations as it has a small sample size from a single centre. Large-scale, multicentre approaches are recommended for future research.

Conclusion

Sv was found to be significantly influenced by the type of pneumatization. For each type, men had a greater volume than women. There existed ethnic differences in sinus dimensions and pneumatization types among Asian countries, with Chinese individuals possessing a greater volume compared to their counterparts elsewhere in the region.

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Authors' Contribution:
AA: Concept, data acquisition, analysis, interpretation, drafting, revision and final approval.
NK: Drafting, revision and final approval.