

Anatomical variations of human sphenoid sinus in terms of volume and septation pattern in a subset of Pakistani population using computed tomographic images

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Abstract

Objectives: To compare the sphenoid volume between the genders and to analyse variations in septal insertions on bony wall of optic nerve and internal carotid artery.

Methods: The prospective study was conducted from October 2020 to February 2021 at the Radiology Department of Dow University of Health Sciences, Karachi, and comprised paranasal sinus patients of either gender aged 20-60 without any bony deformity of sphenoid sinus who were analysed for sphenoid volume, number of septa and variable septal insertions using computed tomography of paranasal sinus. On the basis of septal insertions, the scans were categorised into Group 1 with no risky septal insertion, Group 2 with septal insertion on bony wall of optic nerve, Group 3 with septal insertion of internal carotid artery, and Group 4 with septal insertion on both optic nerve and internal carotid artery. Differences in sphenoid volume were analysed between males and females and among the four groups. Data was analysed using Graph Pad Prism 9.

Results: Of the 300 patients, 171(57%) were males and 129(43%) were females. The overall mean age was 39.28±10.9 years. Multiple septa were found in 208(69.3%) of the sinuses. There were 129(43.7%) patients in Group 1, 34(11.3%) in Group 2, 119(39%) in Group 3 and 18(6%) in Group 4. Significant difference was found between volume and gender as well as among the four groups ($p<0.001$).

Conclusion: The sphenoid volume between the genders and the variations in septal insertions on bony wall of optic nerve and internal carotid artery were significantly different.

Keywords: Optic nerve, Internal carotid artery, Sphenoid sinus, Computed tomography, Sphenoid bone.

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Introduction

Paranasal sinus (PNS) plays a vital role in making the skull light-weight, humidifying the inspired air, giving resonance to voice and acting as buffer against facial trauma.¹ Among all the nasal sinuses, sphenoid sinus (SS) occupies the most strategic location sitting deeply in the centre of the skull.² This paired and highly variable sinus is asymmetrical and is divided into right and left cavities by a bony inter-sinus septum.^{1,2} It has important relationships with vital neurovascular structures; worth mentioning among them being optic nerve (ON) and internal carotid artery (ICA).³ Moreover, pneumatization also affects this relationship dangerously as a highly pneumatized sinus shows greater degree of protrusion and dehiscence of these neurovascular structures into the sinus cavity.⁴ Hence, the relationship of sinuses with vital structures place them at the risk of iatrogenic injury during endoscopic trans-sphenoidal (ETS) surgery.^{3,4} Besides, the inter-sinus septum is of utmost importance as it guides the midline of SS.¹ Normally, a single inter-sinus septum divides the cavity into two halves, but multiple

septa may present with risky septal insertions on the bony wall of ON and ICA. In such cases, accidental avulsion of these septa may cause lethal injury to ON and ICA, resulting in blindness and fatal haemorrhage.⁵ This necessitates pre-operative computed tomography (CT) evaluation of inter-sinus septa and sphenoid volume in order to predict and avoid surgical complications.

The inter-sinus septum usually runs in the midline anteriorly, but its posterior part often deviates laterally to get attached to the anterior wall of sella, or the bony covering of ICA and ON.^{4,5} This means that midline of SS may not be exactly guided by the inter-sinus septum in endoscopic sinus surgery. Literature has reported loss of vision in 1.8% cases and ICA injury with catastrophic haemorrhage in 0.4-1.1% cases of ETS surgery, with mortality and morbidity rates of 14% and 24% respectively.⁶ These risky septal insertions must be carefully evaluated on CT scans to plan a safe surgical route.⁷ The presence of multiple septa within the sinus cavity represents a serious surgical issue as they reduce the space for collocation and free movement of surgical instrumentation which requires them to be removed. In order to host the endoscope and other instruments, a single rectangular cavity needs to be created within the SS. For correct positioning of endoscope and handling of

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instruments, adequate visualisation is mandatory which is achieved by the removal of multiple septa.^{6,7}

Volumetric measurements of PNS by CT scan provide a better understanding of the morphometry and available field of work. Some studies have used 2-dimensional (2D) CT scans to estimate volume of the sinus by using different formulas,^{8,9} while others have used 3D models for volumetric calculation and understanding of the surrounding anatomical relations.¹⁰

With advances in ETS surgery in recent years, the knowledge of SS anatomy has gained importance. It helps to plan the surgical pathway to SS not only in diseases of sinus, but also to approach pituitary gland for its various pathologies and tumours involving the anterior skull base, para-sellar region, clivus and cavernous sinus.^{5,11} However, variable anatomy of SS limits the surgical approach and increases the risk of dreadful complications.¹²

The frequency of multiple septation has been explored in different populations^{2,13-17} and risky septal insertions onto bony coverings of ON and ICA have been analysed.^{5,13,18,19} Accounts in the relationship between volume of SS and septation pattern in Pakistani population are scarce. The current study was planned to fill the gap by comparing the sphenoid volume between the genders and by analysing variations in septal insertions on bony wall of ON and ICA.

Patients and Methods

The prospective study was conducted at the Radiology Department of Dow University of Health Sciences (DUHS), Karachi, from October 2020 to February 2021. After approval from the institutional ethics review board, the sample size was calculated using OpenEpi calculator,²⁰ taking the prevalence of PNS variations to be 52%²¹ while keeping power 80% and confidence level 95%. The sample size was inflated by >10% to increase the study power. The sample was raised using convenience sampling technique.

Those included were PNS patients of either gender aged 20-60 years and without any bony SS deformity. Individuals with extensive sino-nasal disease causing bony deformity of SS, nasal polyposis, nasal and PNS tumours and prior history of trauma or surgical procedures around the nose were excluded.

After taking informed consent, the patients were subjected to CT scan of PNS which was performed (General Electric [GE] Healthcare Computed Tomography Optima 660 system), as per departmental protocol using 3mm slice thickness with scan parameters of kV 120,

beam collimation 20 mm, rotation time 0.5s, mA 60-220 in both bony and soft tissue algorithms. Axial sections were performed in a plane parallel to the hard palate from the upper dental arch to the roof of frontal sinuses. The coronal and sagittal images were obtained by multiplanar reconstructions which were made using Digital Imaging and Communications in Medicine (DICOM) (RadiAnt, Poland), and reporting was done on Health Information and Management System (HIMS). A detailed analysis of the scans was done by a consultant radiologist with clinical experience of around 7 years. Any query or confusion was resolved with departmental consultation.

The scans were analysed for the numbers of inter-sinus septa and their possible insertions on the bony wall of ICA and ON. The sinuses with more than one inter-sinus septa were considered to have multiple septa. For volumetric measurements, carniocaudal height, width and antero-posterior length were measured on sagittal and axial planes, respectively. All measurements were taken at points of maximum dimensions of the sinus. The volume was calculated using formula $\text{height} \times \text{width} \times \text{length} \times 0.52$.⁹ To analyse the association between volume and variable septal insertion, the sample was categorised into Group 1 with no risky septal insertion, Group 2 with septal insertion on the bony wall of ON, Group 3 with septal insertion of ICA, and Group 4 with septal insertion on both ON and ICA.

Data was analysed using Graph Pad Prism 9. Quantitative variables, like age and sphenoid volume, were expressed as mean and standard deviation, while qualitative variables, like inter-sinus septa and variable septal insertions, were expressed as frequencies and percentages. Normality of data was determined using Shapiro-wilk test. Three variables were normally distributed, while one variable, septal insertion on ICA, was non-normally distributed. Statistically significant difference between volume and gender was calculated using independent t-test, while sphenoid volume and four groups of septal insertion were assessed by one-way analysis of variance (ANOVA). Post-hoc analysis was done by Tukey honest significant difference (HSD). $P < 0.05$ was considered significant. The correlation between sphenoid volume, number of septa and variable septal insertions on bony wall of ON, ICA or both were calculated using Pearson's correlation coefficient.

Results

Of the 300 patients, 171(57%) were males and 129(43%) were females. The overall mean age was 39.28 ± 10.9 years. Multiple septa were found in 208(69.3%) cases. Most of

Table: Descriptive statistics of septal variants (n=300).

Variables		Frequency (%)
Number of septa	1	92(30.6%)
	2	125(45.8%)
	3	62(17.6%)
	4	18(5.1%)
	5	3(0.9%)
Inter-sinus septa	Single	92(30.6%)
	Multiple	208(69.4%)
Risky septal insertions	No risky septal insertions	129(43.7%)
	On bony wall of ON	34(11.3%)
	On bony wall of ICA	119(39%)
	On bony wall of both ON and ICA	18(6%)

ON: Optic nerve, ICA: Internal carotid artery.

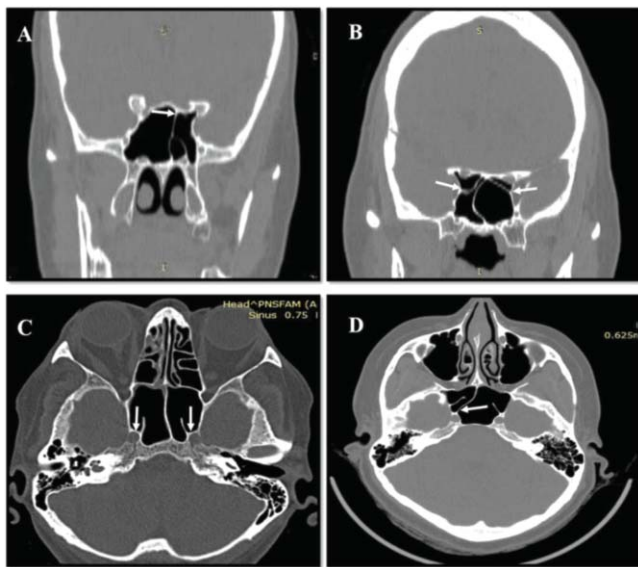


Figure-1: Septal variations of sphenoid sinus (SS) on computed tomography (CT). A: Coronal CT image showing septal insertion on bony wall of left optical nerve (ON) (white arrow). B: Coronal CT image showing multiple septa with bilateral protrusion plus septal insertions on bony wall of internal carotid artery (ICA) (white arrows). C: Axial CT scan showing multiple septa with bilateral protrusion and septal insertion onto the bony wall of both ICAs (white arrows). D: Axial CT image revealing multiple septa with septal insertion on the right ICA (white arrow).

the sinuses 125(45.8%) presented two septa. There were 129(43.7%) patients in Group 1, 34(11.3%) in Group 2, 119(39%) in Group 3 and 18(6%) in Group 4 (Table).

The septal variations of SS were noted (Figure-1). A single inter-sinus septum was found in 92(30.6%) participants.

A significant difference ($p < 0.001$) was observed in SS volume between males $11.01 \pm 3.5 \text{ cm}^3$ and females $7.70 \pm 2.13 \text{ cm}^3$, with males showing a higher volume compared to the females (Figure-2). The difference in volume among the four groups of risky septal insertions on bony wall was statistically significant in both males

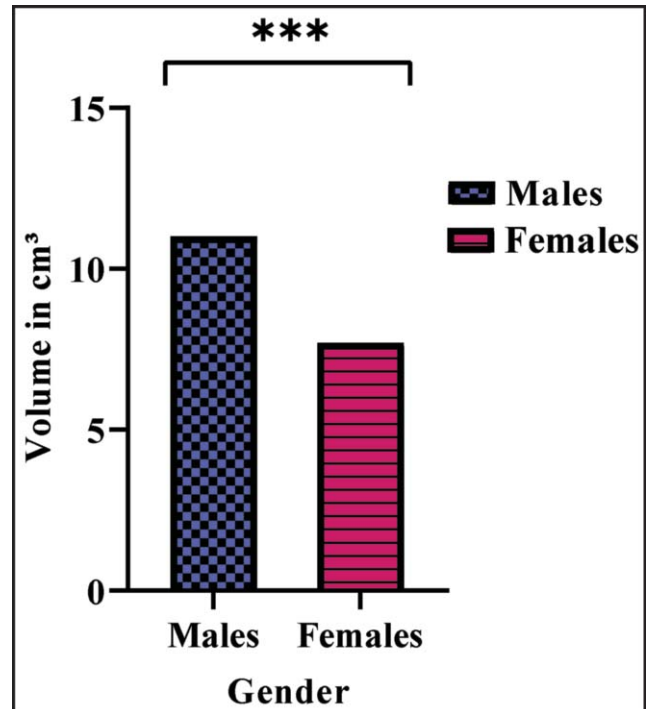


Figure-2: Graphical representation of volume of sphenoid sinus in males and females with significant p-value $*** < 0.001$.

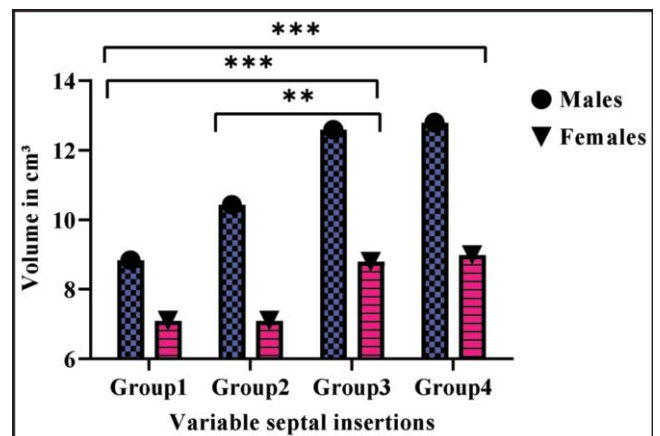


Figure-3: Graphical representation of relationship of volume with four groups of variable septal insertions. Posthoc Turkey HSD analysis: p-value $*** < 0.001$, $** = 0.001$.

Group 1: No risky septal insertions.

Group 2: Septal insertions on bony wall of ON

Group 3: Septal Insertions on bony wall of ICA

Group 4: Septal Insertions on bony walls of both ON and ICA

ON (optic nerve), ICA (Internal carotid artery)

HSD: Honest significant difference ON: Optic nerve. ICA: Internal carotid artery.

and females ($p < 0.001$) (Figure-3).

There was significant difference in volumes between Group 1 compared to Group 3 and Group 4 ($p < 0.001$), and Group 2 compared to Group 3 ($p = 0.001$). In Group 3 and Group 4, the SS volume was higher compared to the other

groups. However, no differences were found between either Group 1 and Group 2, or between Group 3 and Group 4 ($p>0.05$).

There was an intermediate positive correlation between volume and number of septa ($r=0.452$, $p=0.001$) and between volume and Group 3 ($\rho=0.512$, $p=0.001$), confirming that larger sinuses were more likely to have multiple septa as well as risky septal insertions on bony wall of ICA.

Discussion

The present study is the first to highlight significant association between sphenoid volume and variable septation pattern in a subset of Pakistani population.

As the applications of endoscopic trans-sphenoidal surgery are gradually advancing to approach the skull base, a detailed knowledge of anatomical variants of SS has gained significant importance. For safe surgical procedure, a detailed analysis of all anatomical variants must be done on pre-operative CT, among which number and location of inter-sinus septa are critical because of their intimate relationship with ON and ICA.⁵⁻⁷

Multiple septa were observed in the current study in 69.4% cases, out of which 45.8% had two septa within the sinus cavity. The results are consistent with the findings in Malaysian¹⁴ and Polish populations,¹⁷ reporting two septa per sinus in 32.9% and 30% cases, respectively.

We found risky septal insertions on bony wall of ICA in 39% subjects which is consistent with the findings of Abdullah et al. (31.5%).¹⁴ Our findings are somewhat greater than reported by Unal et al. (26.7%), Elwany et al. (12.9%), Gibelli et al. (23.8%) and Farhan et al. (13.1%),^{5,13,19,22} but somewhat lower than Fernandez-Miranda et al. (89%).¹⁸ We found risky septal insertions on bony wall of ON in 11.3% subjects which is nearly consistent with the findings of Farhan et al (8.5%) and Gibelli et al. (7.7%),^{19,22} but much lower than Lupasco et al. (65%) and Unal et al. (27.3%).^{5,23} The findings and comparison with literature accentuate that risky variations in septation pattern of SS are not rare and must be carefully evaluated on pre-operative CT scans.

The association between volume and variable septal insertions on bony wall of ON and ICA has significance in surgical planning. As volume of SS increases, the number of inter-sinus septa also increases. The frequency of ICA septal insertions also increases along with the sphenoidal volume, but it is not true for ON septal insertions. A large SS is expected to have more than one septa and risky ICA septal insertion which must be carefully checked before the surgical procedure to prevent fatal haemorrhage. On

the contrary, ON insertions can be found in small sinuses which is also important to be considered during surgical intervention on SS.²

The results of the current study add to the knowledge in the field of ETS surgery by emphasising important association between volume and septation pattern of SS in our population which will be helpful for neurosurgeons and rhinolaryngologists while performing endoscopic sinus surgery.

The limitation of the present study is that it was performed at a single centre. To obtain generalisable results with maximum authenticity, multi-centred approach with large sample size should be employed. The frequency of surgical complications is not known, therefore there should be confirmatory endoscopic correlation with CT scans.

Conclusion

The sphenoid volume between the genders and the variations in septal insertions on bony wall of ON and ICA were significantly different. The critical association between sphenoid volume and variable septation pattern requires detailed morphometric assessment prior to planning of endoscopic trans-sphenoidal surgical procedure and also plays an important role in reducing the rate of intra-operative and post-operative complications.

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