e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2025; 17(8); 1621-1627

Original Research Article

Morphometric Study of Paranasal Sinuses and Its Clinical Significance: A Retrospective Study at GMC, Jammu

Rachna Magotra[1], Advaita Sharma[2], Arihant Sharma[3]

[1]Professor, Department of Anatomy, GMC, Jammu, India

[2]Junior Resident, Department of ENT, SMGS Hospital, Jammu, India

[3]Senior Resident, Department of Cardiology, RML and ABVIMS, New Delhi, India

Received: 10-06-2025 / Revised: 09-07-2025 / Accepted: 10-08-2025

Corresponding Author: Advaita Sharma

Conflict of interest: Nil

Abstract:

Background: The paranasal sinuses (PNS) are air-filled cavities within the facial and cranial bones that contribute to skull lightening, voice resonance, and conditioning of inhaled air. Their size, shape, and anatomical variations have important implications for clinical practice and teaching in anatomy, as they influence nasal physiology and can predispose to disease.

Objective: This study aimed to record and analyse the morphometric dimensions of the maxillary, frontal, ethmoidal, and sphenoidal sinuses in adult skulls, compare differences between males and females, and document common anatomical variations relevant to clinical and academic settings.

Methods: A total of 50 adult skulls (25 male, 25 female) from the anatomy collection at Government Medical College, Jammu, were examined between October and December 2024. Using standard osteometric points and measuring instruments (digital vernier calipers and flexible measuring tape), the height, width, and anteroposterior length of the sinuses were recorded bilaterally where applicable. Sinus volumes were estimated using the ellipsoid formula. Anatomical variants such as asymmetry, frontal sinus agenesis, concha bullosa, and variations in sphenoidal sinus pneumatization were documented. Data were analysed for sex differences and side-to-side variation using independent and paired t-tests.

Results: The maxillary sinuses were the largest, followed by frontal, sphenoidal, and ethmoidal sinuses. Males had significantly larger sinus dimensions than females across most parameters ($p < 0.05$). Asymmetry (>2 mm difference) was noted in over 30% of skulls. Frontal sinus agenesis occurred in 8% of cases. The sellar type of sphenoidal sinus was most common (68%). Concha bullosa and Haller cells were found in 12% and 10% of specimens respectively.

Conclusion: Morphometric evaluation of paranasal sinuses in skulls provides essential baseline data for anatomists, clinicians, and surgeons. Awareness of normal variations aids in understanding sinus physiology, improving surgical orientation, and enhancing anatomical education. Population-specific reference values, such as those established in this study, are particularly useful in Northern India where such data are limited.

Keywords: Paranasal Sinuses, Morphometry, Skull Anatomy, Anatomical Variation, Maxillary Sinus, Frontal Sinus Agenesis, Sphenoidal Pneumatization.

Introduction

The paranasal sinuses (PNS) include a collection of paired and unpaired air-filled cavities located inside the bones of the face skeleton and cranial base [1,2]. The maxillary, frontal, ethmoidal, and sphenoidal sinuses communicate with the nasal cavity via small ostia [3]. They functionally contribute to various physiological processes, including decreasing skull weight, enhancing voice resonance, humidifying and warming inhaled air, and offering mechanical protection through shock absorption [4,5]. Their physical position and close association with adjacent essential tissues, such as the orbit, cranial cavity, and dental roots, render them clinically relevant in otorhinolaryngology, neurosurgery, maxillofacial surgery, and forensic medicine [6,7].

The morphometric differences of the paranasal sinuses are affected by genetic, environmental, and developmental variables [8]. The dimensions and volume of these sinuses vary throughout populations, and they frequently exhibit significant asymmetry even within the same individual [9,10]. These abnormalities can disrupt normal sinonasal physiology, predispose individuals to chronic rhinosinusitis, and complicate endoscopic sinus procedures [11]. Radiological imaging and morphometric analyses of skulls are essential for defining the limits of these cavities, identifying anatomical irregularities, and strategising surgical procedures [12]. Forensic specialists utilise the distinctive patterns of sinus morphology, especially the frontal sinus, for individual identification [13,14].

The clinical significance of morphometry is its capacity to reduce intraoperative problems. Excessive pneumatization of the sphenoidal sinus may impinge upon the sella turcica, heightening the risk of injury to the optic nerve and internal carotid artery during trans-sphenoidal procedures [15,16]. Variants such as concha bullosa, Haller cells, and frontal sinus agenesis are linked to modified drainage pathways and recurrent sinus infections [2,11]. Thus, obtaining baseline morphometric data for a specific population aids anatomists and surgeons in linking anatomical structures with clinical manifestations and surgical results.

Notwithstanding advancements in imaging technology, morphometric investigations specific to populations that rely on direct skull measurements remain essential [17]. Such studies provide concrete baseline data, devoid of radiological artefacts, which are especially beneficial in academic environments where cadaveric material underpins anatomical education. Moreover, there is a scarcity of literature about morphometric studies of the paranasal sinuses in North Indian populations, particularly in the Jammu region [18]. Given the complexity of anatomical variances shaped by race and geography, region-specific data are crucial for improving the precision of clinical practice and education.

In this context, the current retrospective study was conducted to document and analyse the morphometric parameters of the paranasal sinuses in adult skulls. The study aimed to evaluate sex differences, detect lateral variances, and describe prevalent anatomical defects. It aims to furnish therapeutically pertinent morphometric reference values for surgeons, anatomists, and medical educators, thus addressing the existing knowledge gap for this demographic.

Methodology

Study Design and Setting: This study was conducted in the Department of Anatomy at Government Medical College, Jammu. The study was carried out over a period of three months, from October to December 2024. The research protocol involved detailed osteometric examination of adult human skulls preserved in the departmental collection. Ethical clearance for the study was obtained from the Institutional Ethics Committee, and all measurements were carried out in accordance with established anatomical research guidelines.

Sample Selection: A total of 50 dry adult skulls were included in the study. These comprised 25 male and 25 female skulls, with sex determination based on standard anthropological features such as robustness of the supraorbital ridges, mastoid processes, and overall craniofacial morphology. Skulls showing gross pathological deformities, fractures, or post-mortem damage to the paranasal regions were excluded. Only skulls with well-preserved sinus outlines and intact bony structures were selected to ensure accuracy in morphometric analysis.

Instruments and Measurement Technique: Measurements were performed using precision osteometric instruments. A digital vernier caliper (accuracy ± 0.01 mm) was employed to record linear parameters, while a flexible measuring tape was used for curved surfaces when necessary. The following dimensions of each paranasal sinus were recorded bilaterally where applicable:

- **Height**: Maximum vertical distance of the sinus cavity.
- **Width**: Maximum transverse distance at the broadest part.
- **Anteroposterior length**: Maximum depth from the anterior to posterior wall.

All measurements were taken in millimeters (mm). To minimize intra-observer variability, each measurement was repeated three times and the mean value was recorded.

Estimation of Sinus Volumes: The volume of each sinus was estimated using the standard ellipsoid formula:

$$V = \frac{4}{3}\pi \times \frac{h}{2} \times \frac{w}{2} \times \frac{d}{2}$$

where h = height, w = width, and d = anteroposterior depth. This formula approximates sinus cavities to an ellipsoid shape, a method widely accepted in morphometric studies.

Anatomical Variations Recorded: In addition to morphometric parameters, the study documented common anatomical variants of clinical significance:

- **Asymmetry**: Defined as a difference of >2 mm between right and left sinus measurements.
- **Frontal sinus agenesis**: Complete absence of unilateral or bilateral frontal sinus.
- **Concha bullosa**: Pneumatization of the middle nasal concha.
- **Haller cells**: Infraorbital ethmoidal air cells.
- **Sphenoidal sinus pneumatization type**: Classified as sellar, presellar, or postsellar based on extension relative to the sella turcica.

These variations were identified through careful visual inspection and confirmed through direct osteometric assessment.

Statistical Analysis: Data were entered into Microsoft Excel 2019 and analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY). Continuous variables (sinus dimensions and volumes) were expressed as mean ± standard deviation (SD). Categorical variables (presence of anatomical variants) were expressed as percentages.

- **Sex-based differences** were analyzed using independent sample t-tests.
- **Side-to-side comparisons** (right vs. left) were analyzed using paired t-tests.
- A p-value of <0.05 was considered statistically significant.

Reliability and Quality Control: All measurements were carried out by the same investigator to avoid inter-observer variability. Randomly selected specimens (n = 10) were re-measured after two weeks, and intra-class correlation coefficients (ICC) were calculated to assess intra-observer reliability. High consistency (ICC > 0.90) was achieved across all parameters.

Results

General Morphometric Observations: Examination of 50 adult skulls (25 male, 25 female) revealed that all four major paranasal sinuses were identifiable in the majority of specimens. The maxillary sinuses were the largest in size and volume, followed by the frontal, sphenoidal, and ethmoidal sinuses in decreasing order.

Dimensions and Volumes of Sinuses

The morphometric measurements for each sinus are presented in **Table 1**.

- **Maxillary Sinuses** had the largest dimensions, with mean volumes exceeding 15 cm³ (Figure 1).
- **Frontal Sinuses** were smaller but highly variable, with mean volumes around 7–8 cm³.
- **Sphenoidal Sinuses** showed moderate dimensions, averaging 6–7 cm³.
- **Ethmoidal Sinuses** were the smallest, with volumes below 3 cm³.

Table 1: Mean morphometric dimensions (mm) and estimated volumes (cm³) of paranasal sinuses (n = 50 skulls)

Sinus Type	Height (mm) (Mean ± SD)	Width (mm) (Mean ± SD)	AP Depth (mm) (Mean ± SD)	Estimated Volume (cm³) (Mean ± SD)
Maxillary	33.4 ± 3.5	26.8 ± 2.9	22.1 ± 2.4	16.2 ± 3.1
Frontal	28.7 ± 4.1	21.5 ± 3.2	19.8 ± 2.7	7.9 ± 2.5
Sphenoidal	24.3 ± 3.8	19.2 ± 2.6	18.7 ± 2.3	6.4 ± 1.9
Ethmoidal	17.5 ± 2.6	14.9 ± 2.1	13.6 ± 1.8	2.5 ± 0.8

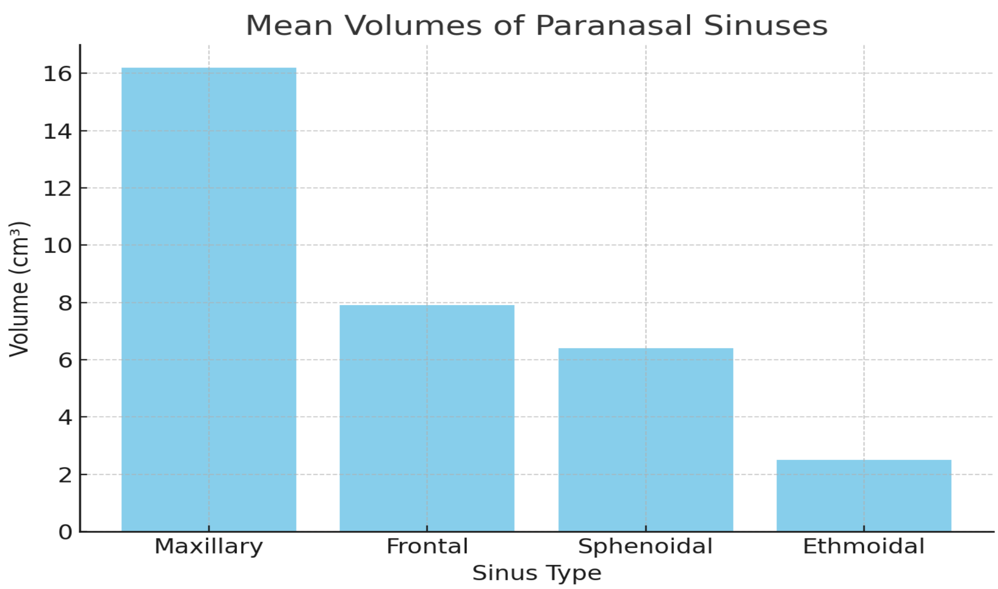

Figure 1: Mean Volumes of Paranasal Sinuses

Sex-Based Differences: Males exhibited larger dimensions than females in almost all parameters, as shown in **Table 2**. These differences were statistically significant for the maxillary, frontal, and sphenoidal sinuses ($p < 0.05$). Ethmoidal sinuses, while larger in males, did not show significant sex dimorphism due to their small size and variability (Figure 2).

Table 2: Comparison of mean sinus volumes (cm³) between male and female skulls

Sinus Type	Male (Mean ± SD)	Female (Mean ± SD)	p-value
Maxillary	17.8 ± 2.9	14.6 ± 2.7	<0.01
Frontal	8.6 ± 2.7	7.2 ± 2.3	0.03
Sphenoidal	6.9 ± 2.0	5.8 ± 1.7	0.04
Ethmoidal	2.7 ± 0.9	2.3 ± 0.7	0.09 (NS)

(NS = not significant)

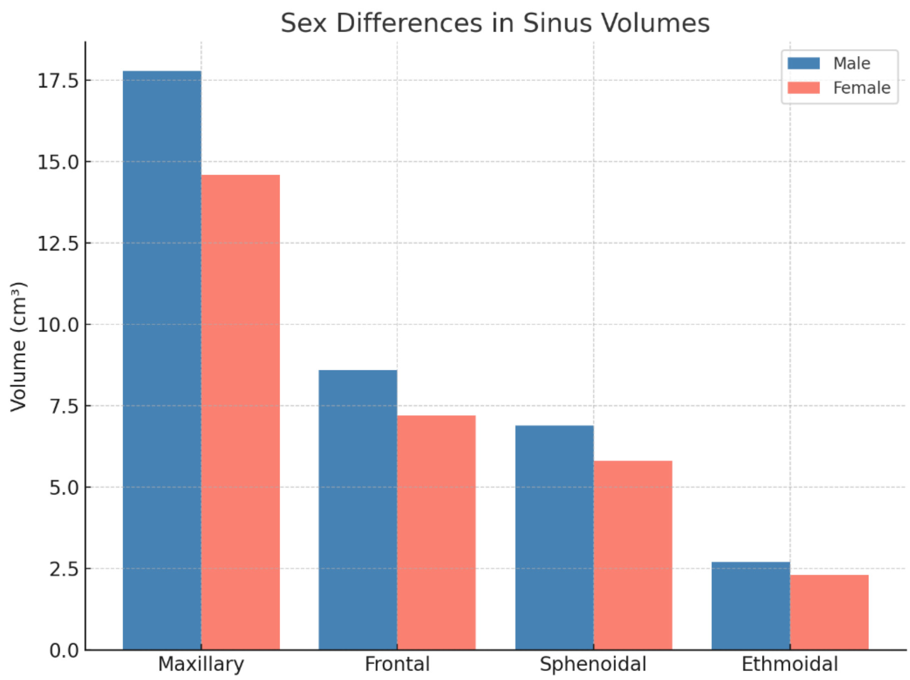

Figure 2: Sex Differences in Sinus Volumes

Side-to-Side Variations and Asymmetry

- Asymmetry (>2 mm difference between right and left sinuses) was observed in 32% of skulls, most commonly in the frontal and maxillary sinuses.
- Paired t-tests revealed statistically significant right–left differences in frontal sinus height ($p = 0.04$) and maxillary sinus width ($p = 0.03$).
- Ethmoidal and sphenoidal sinuses showed less pronounced asymmetry.

Anatomical Variations: Several clinically important anatomical variations were observed, summarized in Table 3.

Table 3: Anatomical variations in paranasal sinuses (n = 50 skulls)

Variant	Frequency (%)	Notes
Asymmetry (>2 mm difference)	32%	Most common in frontal and maxillary sinuses
Frontal sinus agenesis	8%	Unilateral in 3 cases, bilateral in 1 case
Sphenoidal sinus (sellar type)	68%	Most common pneumatization pattern
Concha bullosa	12%	Predominantly unilateral
Haller cells	10%	Found adjacent to infraorbital floor

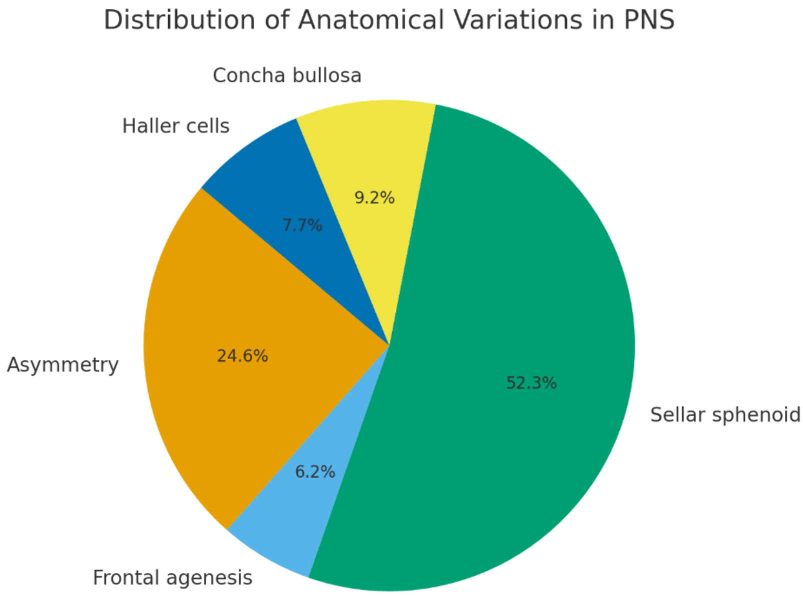

Figure 3: Distribution of Anatomical Variations

The maxillary sinus was the largest cavity in terms of both dimensions and volume. Males had significantly larger sinuses compared to females, except for ethmoidal sinuses where the difference was not significant. Asymmetry was a frequent observation, emphasizing the variability of sinus growth. Anatomical variants such as frontal sinus agenesis, concha bullosa, and Haller cells were present in notable proportions, comparable to global literature (Figure 3). The sellar type of sphenoidal sinus pneumatization was the most common, with clinical implications for trans-sphenoidal surgical approaches.

Discussion

This morphometric study of paranasal sinuses in adult skulls from the Jammu region provides essential baseline data regarding their anatomical dimensions, volumes, and variations. These findings are pertinent not only to academic anatomy but also hold considerable clinical significance for otolaryngologists, neurosurgeons, radiologists, and forensic specialists [6,7]. The findings indicate a consistent trend in which the maxillary sinus is the largest of the paranasal cavities, succeeded by the frontal and sphenoidal sinuses, while the ethmoidal sinus is the smallest [3,8]. This pattern reflects findings from earlier morphometric and radiological studies across various populations, thereby affirming the universal predominance of the maxillary sinus in volume [9,10]. The comparative size of sinuses indicates their embryological origins and functional roles; larger sinuses, such as the maxillary, play a crucial role in reducing skull weight and enhancing resonance, whereas smaller sinuses, like the ethmoidal, are primarily involved in localised air filtration and humidification [4,5].

Sexual dimorphism was identified as a significant finding in this study, with male skulls exhibiting markedly larger dimensions in the majority of sinus types. This observation aligns with prior radiographic and cadaveric studies, which attribute differences to the overall craniofacial robustness in males influenced by hormonal and genetic factors [13,14]. This dimorphism is pertinent in two areas: in surgical settings, where preoperative knowledge of sinus dimensions mitigates intraoperative complications, and in forensic anthropology, where paranasal sinus morphology serves as a dependable indicator for sex determination and personal identification [13,14]. The frontal sinus's capacity to function as a "fingerprint" owing to its distinctive morphology and variability is well documented, and the current study's findings further reinforce its significance within the North Indian demographic [14].

A notable observation was the occurrence of asymmetry in over 30% of skulls, predominantly impacting the frontal and maxillary sinuses. This finding aligns with global literature, which underscores that asymmetry is a normal variant rather than a pathological condition [9,10]. Clinically, asymmetry may complicate endoscopic sinus surgeries or radiological assessments, especially when associated with conditions such as hypoplasia or agenesis [11]. Frontal sinus agenesis was identified in 8% of specimens, a prevalence consistent with international studies that report rates between 4% and 15% [17]. This variation has significant implications, as agenesis modifies radiological landmarks and restricts the forensic applicability of the frontal sinus in specific instances [14,17].

The research also emphasised the occurrence of clinically significant anatomical variants, such as concha bullosa (12%) and Haller cells (10%) [2,11]. Both are recognised factors that contribute to modified sinus drainage patterns and chronic rhinosinusitis. Concha bullosa, resulting from the pneumatization of the middle turbinate, may constrict the ostiomeatal complex, whereas Haller cells situated in the infraorbital area can impede the maxillary sinus ostium [2]. Identifying these variants in radiological imaging and surgical procedures is crucial to prevent incomplete disease removal or unintentional harm [11].

The findings of the sphenoidal sinus warrant particular attention, especially the prevalence of sellar type pneumatization (68%). This configuration holds direct surgical significance, particularly for neurosurgeons executing trans-sphenoidal approaches to the pituitary gland [15,16]. The proximity of the sinus to essential structures, including the optic nerve and internal carotid artery, renders an understanding of pneumatization patterns crucial for reducing surgical risks [15]. Alternative types, including presellar and postsellar, were less prevalent; however, their identification is equally crucial for customising surgical strategies [16].

This study's findings highlight the dual importance of morphometric analysis: firstly, as an essential instrument for anatomical education in medical programs, and secondly, as a clinical resource that enhances diagnostic precision and surgical guidance [6,17]. Region-specific morphometric data are especially significant in India, where anatomical diversity shaped by ethnicity and geography requires localised reference values [18]. The current study offers valuable insights; however, its limitations encompass a limited sample size and dependence on dry skulls, which inhibits the evaluation of mucosal and vascular anatomy. Subsequent research utilising advanced imaging techniques like CT or cone-beam CT in living subjects, alongside multicentric involvement across varied populations, would provide a more thorough comprehension of paranasal sinus anatomy and its clinical implications [12,17].

Conclusion

This retrospective morphometric study of paranasal sinuses in adult skulls offers region-specific baseline data pertinent to clinical and academic practice. The results indicate that the maxillary sinus is the largest, succeeded by the frontal, sphenoidal, and ethmoidal sinuses, with male skulls consistently displaying greater dimensions than female skulls. Notable asymmetry was detected in over one-third of specimens, while anatomical variants including frontal sinus agenesis, concha bullosa, and Haller cells were observed at frequencies consistent with global literature. The prevalence of the sellar type sphenoidal sinus highlights its significance in trans-sphenoidal surgical techniques, where the closeness to vital neurovascular structures requires meticulous preoperative planning.
Clinically, understanding these morphometric characteristics and variations is crucial for otolaryngologists, neurosurgeons, maxillofacial surgeons, and radiologists to reduce operative risks, enhance diagnostic precision, and improve patient outcomes. The data augment instruction for anatomists and forensic specialists, facilitating the application of sinus morphology in individual identification. This study addresses the scarcity of population-specific research from Northern India and establishes reference values to inform clinical decision-making and academic instruction.

References

1. Anusha, A., Baharudin, A., Philip, R., Harvinder, S., & Shaffie, B. M. (2011). Anatomical variations of the paranasal sinuses in CT-scan images. Medical Journal of Malaysia, 66(1), 11–14.
2. Aramani, A., Karadi, R. N., & Kumar, S. (2014). A study of anatomical variations of osteomeatal complex in chronic rhinosinusitis patients – CT findings. Journal of Clinical and Diagnostic Research, 8(10), KC01–KC04. https://doi.org/10.7860/JCDR/2014/9905.4946
3. Babaji, P., Suma, B., Kalyanpur, A., & Rao, P. (2014). Morphometric study of the maxillary sinus using computed tomography. World Journal of Dentistry, 5(4), 229–233. https://doi.org/10.5005/jp-journals-10015-1290
4. Chandel, A., Bindra, R., & Singh, I. (2018). Morphometric analysis of maxillary sinus using CT scan in normal subjects. Indian Journal of Anatomy, 7(2), 152–157.
5. Dahiya, R., Kamal, R., & Kumar, M. (2015). Anatomical variations of paranasal sinuses: CT findings and clinical significance. International Journal of Anatomy and Research, 3(2), 1074–1078. https://doi.org/10.16965/ijar.2015.142
6. Eggesbø, H. B. (2006). Radiological imaging of inflammatory lesions in the nasal cavity and paranasal sinuses. European Radiology, 16(4), 872–888. https://doi.org/10.1007/s00330-005-0063-y
7. Fatima, A., Ali, I., & Rahman, M. (2020). Morphometric study of paranasal sinuses in adult dry skulls. International Journal of Otorhinolaryngology and Head and Neck Surgery, 6(3), 536–541. https://doi.org/10.18203/issn.2454-5929.ijohns20201559

8. Gupta, N., Gupta, R., & Gupta, S. (2016). Anatomical variations of the sphenoid sinus and their clinical significance. Indian Journal of Otolaryngology and Head & Neck Surgery, 68(3), 351–357. https://doi.org/10.1007/s12070-015-0869-9
9. Hassan, H. A., & Gozil, R. (2010). Morphometric analysis of the sphenoid sinus and its clinical significance. Clinical Anatomy, 23(3), 287–293. https://doi.org/10.1002/ca.20938
10. Kanchan, T., Gupta, A., Krishan, K., & Acharya, J. (2019). Estimation of sex from morphometry of frontal sinus using lateral cephalograms. Journal of Craniofacial Surgery, 30(2), e166–e169. https://doi.org/10.1097/SCS.0000000000005020
11. Kim, H. J., Chung, I. H., & Woo, J. S. (1997). Surgical anatomy of the sphenoid sinus and the sellar floor in 300 cadaver specimens. Laryngoscope, 107(2), 159–164. https://doi.org/10.1097/00005537-199702000-00006
12. Lorkiewicz-Muszyńska, D., Kociemba, W., Rewekant, A., Sroka, A., Jończyk-Potoczna, K., Patelska-Banaszewska, M., & Mańkowska-Pliszka, H. (2015). Development of the maxillary sinus in children: A radiographic study. Folia Morphologica, 74(1), 81–88. https://doi.org/10.5603/FM.2015.0013
13. Mazza, D., Bontempi, E., Guerrisi, A., Cicia, S., & Nobili Benedetti, F. (2010). Computed tomography of the paranasal sinuses: Normal anatomy, anatomical variants and inflammatory diseases. Journal of Radiology Case Reports, 4(5), 18–34. https://doi.org/10.3941/jrcr.v4i5.392
14. Pérez-Pacheco, C. C., Caro-Villaseñor, R. C., & López-Serna, N. (2016). Sex determination by morphometric analysis of maxillary sinuses in a Mexican population. Forensic Science International, 261, 159.e1–159.e6. https://doi.org/10.1016/j.forsciint.2016.02.035
15. Rani, S. U., Rohini, M., & Anuradha, G. (2017). Anatomical variations of paranasal sinuses and their clinical implications: A CT scan study. Journal of Clinical and Diagnostic Research, 11(4), AC01–AC04. https://doi.org/10.7860/JCDR/2017/25572.9630
16. Sahlstrand-Johnson, P., Jannert, M., Strömbeck, A., & Abul-Kasim, K. (2011). Computed tomography of the paranasal sinuses: Normal findings and variations. European Radiology, 21(12), 2541–2551. https://doi.org/10.1007/s00330-011-2225-z
17. Shah, R. K., Dhingra, R., & Shrestha, S. (2015). Radiological study of anatomical variations of paranasal sinuses. International Journal of Otorhinolaryngology, 2(2), 10–14.
18. Tatlisumak, E., Aslan, A., Comert, A., Ozlugedik, S., & Acar, H. I. (2008). Surgical anatomy of the paranasal sinuses in newborns and infants: A cadaver study. Surgical and Radiologic Anatomy, 30(2), 153–158. https://doi.org/10.1007/s00276-007-0297-3