ORIGINAL ARTICLE

Computed Tomography Correlation of Paranasal Sinusitis with its Anatomical Variants and with Oto-Mastoiditis

Zahra Nasrullah[1*], Fatima Azam[1], Sidra Seyal[1], Shumaila Seemi Malik[1] and Safdar Ali Malik[1]

[1]*Department of Radiology, Alnoor Diagnostic Centre, Lahore, Pakistan*

ABSTRACT

Background: The complexity of paranasal sinus anatomy and drainage pathways make computed tomography evaluation of the paranasal sinuses mandatory in all symptomatic patients.

Objective: The study aimed to evaluate the frequency of anatomical variants and the correlation on computed tomography between paranasal sinusitis, its anatomical variants, otitis media and mastoiditis.

Methods: This retrospective cross-sectional study was conducted from July to December 2022 at Alnoor Diagnostic Centre, Lahore. A total 100 symptomatic subjects with sinusitis were included in the study. Computed Tomography scans of the paranasal sinuses were performed following the functional endoscopic sinus surgery protocol. The scans were reviewed to assess the involvement of paranasal sinus as well as anatomical variants such as paradoxical middle nasal turbinate, deviated nasal septum (DNS) and concha bullosa among other anatomical variations. The study also examined the correlation between sinusitis, otitis media and mastoiditis.

Results: Out of 100 subjects, the mean age was 45.27±18.67 years. The most common sinus involved was the maxillary sinus (83%). The most common anatomical variants observed were deviated nasal septum (72%), concha-bullosa (23%) and agger nasi cells (17%). There was a correlation between paranasal sinusitis and OMC widening, as well as between different types of sinusitis. Specifically, ethmoid sinusitis was correlated with concha bullosa. However, other anatomical variants did not show a significant correlation with sinusitis. The correlation between mastoiditis and otitis media was also noted.

Conclusion: This study suggests no significant difference in the prevalence of sinusitis due to these anatomical variants. However, it is important to document them to avoid post-surgical complications.

Keywords: *Functional endoscopic sinus surgery, anatomical variants, ostiomeatal complex, otitis media.*

INTRODUCTION

Sinusitis is the inflammation of the mucosal lining of the sinuses, which are air-filled spaces around the nose. The frontal, ethmoidal, maxillary and sphenoid sinuses are four pairs of paranasal sinuses. Computed Tomography of the paranasal sinuses with Functional Endoscopic Sinus Surgery (CT PNS FESS) protocol has revolutionized the evaluation of paranasal sinus anatomy. It is now the study of choice for preoperative evaluation and the gold standard study to look for the extension of the inflammatory process [1]. Anatomical variants can alter the anatomy of adjacent structures resulting in the retention of secretions and inflammation. Commonly seen anatomical variants include agger nasi cells, infraorbital ethmoidal (Haller) cells seen adjacent to the maxillary ostium, Onodi cells, nasal septal deviation, and concha bullosa [2]. Agger nasi cells are the most anterior ethmoid air cells located anterolateral and inferior to the frontal recess. Onodi cells are the posterior-most ethmoidal air cells that lie superolateral to the sphenoid sinus. Onodi cells are located near the optic nerve, internal carotid artery and pituitary fossa so it's important to identify them in the preoperative CT scan as they can pose obstacles during Transsphenoidal surgery [3]. Mucous retention cysts are benign lesions that form within the sinuses, while polyps soft growths of the nasal cavity. The ostiomeatal complex is a common channel that links the maxillary, ethmoid and frontal sinus to the middle meatus. According to an article by Anita Armani, obstruction of the OMC causes a vicious cycle of events that lead to sinusitis. Its obstruction leads to mucosal congestion, which decreases airflow and leads to further obstruction [4]. Whether a deviated nasal septum is a potential risk factor for sinusitis is still controversial [5]. Concha bullosa is the pneumatization of the middle nasal turbinate. Tiwari R [6] documented that concha bullosa is associated with sinusitis, although it is still debatable. Normally the concavity of the middle turbinate faces laterally, but in paradoxical middle turbinate, the concavity faces medially. The lamina papyracea (LP) is the weakest area of the medial orbital wall and is a vulnerable area during endoscopic surgery [7]. Superadded hyper-densities and bony erosions on CT scans are considered indicators of superadded fungal infection in preoperative studies [8]. A pneumatized crista galli is now considered to originate from the frontal sinus and has surgical implications when disease is present in the crista galli [9]. OM and mastoiditis are conditions characterized by inflammation in the middle ear cavity and mastoid air cells. This study was also

[*]*Corresponding Author: Zahra Nasrullah, Department of Radiology, Alnoor Diagnostic Centre, Lahore, Pakistan, Email: zahra.nasrullah@gmail.com*
Received: June 22, 2024; Revised: August 10, 2024; Accepted: August 12, 2024
DOI: https://doi.org/10.37184/nrjp.3007-5181.1.2

ISSN: 3007-519X (Online)

designed to examine the correlation between paranasal sinusitis and OM as well as mastoiditis.

Certain anatomical variants are expected to be a causative factor in sinusitis. Therefore, the current study is designed to establish a relationship between paranasal sinusitis and anatomical variants, particularly in symptomatic populations. It is important to mention these anatomical variants in preoperative assessment by radiologists as a lack of knowledge in this regard may contribute to post-surgical complications. In this study, CT scans of paranasal sinuses from 100 patients who presented with symptoms of sinusitis during the study duration were reviewed. This study documented the incidence of the above mentioned anatomical variants. A correlation was noted between anatomical variants and sinusitis.

METHODS

A retrospective cross-sectional study was conducted at the Department of Radiology, Alnoor Diagnostic Centre, in Lahore, Pakistan, from July to December 2022. The study received approval from the Ethics Committee of Alnoor Institute of Radiology (Approval no. ANIR-12/02/2024-ERB-1337). The sampling technique used was non-probability convenience sampling. By applying the statistical formula N= 4pq/L2 and considering the most prevalent anatomical variant of agger nasi cells to be 86.4% [10] with a margin of error up to 8%, the calculated sample size was 98.38. The study included 100 symptomatic patients with sinusitis, aged between 18-85 years. Mucosal thickening greater than 1-mm on a CT scan is an indicator of sinusitis. We excluded patients under 18 years old and over 85 years old, as well as those with a history of sinus surgery, malignancy, or facial trauma.

The CT scan of paranasal sinuses with FESS protocol was performed on a Toshiba 128 Slice CT Scanner with 1-mm thick serial axial slices and sagittal and coronal reformat. All symptomatic patients referred by physicians for CT PNS FESS protocol were retrospectively reviewed by three consultant radiologists.

Each CT scan was analyzed for opacification of the paranasal sinuses, indicating sinusitis, as well as the presence and location of normal anatomical variants. Statistical analysis was conducted to determine the association between normal anatomical variations and unilateral & bilateral sinusitis. The frequency of involvement of different paranasal sinuses was studied about each anatomical variant. Additionally, the association of paranasal sinusitis with OM and mastoiditis was noted.

Analyses were conducted using the Statistical Package for the Social Sciences (SPSS) System, Windows version 26. The variables were tabulated and presented as frequencies and percentages. The data was displayed as mean ± standard deviation. The association was established using Pearson Correlation. Statistical significance was set at $p < 0.05$.

RESULTS

Out of 100 subjects, 60 were males and 40 were females with a mean age of 45.27±18.67 years. The most common sinus involved was the maxillary sinus (83%), followed by the ethmoid sinus (49%), sphenoid sinus (48%) and frontal sinus (43%). In most cases, both sinuses (right and left) were involved. OMC widening was noted in 33% of cases, with 18% having bilateral OMC widening. Superadded hyperdensity was noted in 15% only. Erosion of LP was found in 9% only. Retention cysts were found in 26%, while polyps were found in 25% only.

The frequency of involvement of anatomical variants in decreasing order is described in Table **1**. The most common anatomical variants observed were deviated nasal septum (72%), concha bullosa (23%) and agger nasi cells (17%). Out of the 72 % with DNS, 33% had a nasal spur on the left side, 32 % had a nasal spur on the right side and 7% had an S-shaped DNS. Paradoxical nasal turbinate was found in 13% only. Pneumatized crista Galli was found in 4%. Haller and Onodi cells were found in 4% and 3%, respectively.

There was a significant correlation between maxillary sinusitis and ethmoid sinusitis ($r=0.23$, $p=0.02$) as well as sphenoid sinusitis ($r=0.31$, $p=0.001$) as shown in Table **2**. Similarly, ethmoid sinusitis was correlated with sphenoid sinusitis ($r=0.25$, $p=0.01$). Frontal sinusitis showed a correlation with ethmoid sinusitis ($r=0.53$, $p <0.001$) and sphenoid sinusitis ($r=0.31$, $p=0.002$).

OMC widening was associated with maxillary sinusitis ($r=0.26$, $p=0.007$), ethmoid sinusitis ($r=0.16$, $p=0.09$), sphenoid sinusitis ($r=0.25$, $p= 0.01$) and the presence of polyps ($r=0.45$, $p <0.001$).

Hyperdensity was correlated with bony erosion of LP ($r=0.35$, $p <0.001$).

Ethmoid sinusitis was correlated with concha bullosa ($r= -0.20$, $p=0.04$), hyperdensity ($r=0.37$, $p <0.001$), and bony erosion of the LP ($r=0.296$, $p=0.003$) as shown in Table **2**.

There was no gender association with any specific type of sinus involvement, but males were generally more affected than females. There was no significant

correlation of sinusitis with DNS, paradoxical nasal turbinate, pneumatized crista galli, agger nasi, Haller cells, and Onodi cells.

DNS had no correlation with concha bullosa (r=0.16, p=0.87) which is not significant (less than 0.05). DNS also had no correlation with OMC widening, paradoxical nasal turbinate, retention cysts and polyps.

Mastoiditis was present in 15% of subjects, with bilateral mastoids involved in only 4%, right-sided mastoiditis in 7% and left-sided mastoiditis in 4%. Otitis media was present in 9%, with bilateral otitis media seen in 3%, right-sided OM in 4% and left-sided OM in 2% only as shown in Table **3**. OM had a correlation with mastoiditis (r=0.48, p <0.001), but was not associated with sinusitis.

Table 1: Anatomical variants and their incidence listed in order of decreasing frequency, along with their corresponding percentages.

Anatomical Variants	Frequencies	Percentages
DNS	72	72.0
Concha Bullosa	23	23.0
Agger nasi cells	17	17.0
Paradoxical Nasal Turbinate	13	13.0
Pneumatized Crista Galli	4	4.0
Onodi cells	4	4.0
Haller cells	3	3.0

Table 2: Correlation between ethmoid sinusitis and concha bullosa, superadded hyperdensity and erosion of the lamina papyracea.

Ethmoid Sinusitis	Concha Bullosa	Hyper Density	Erosion of Lamina Papyracea
Pearson Correlation	-.026	.377	.296
Sig (2-Tailed)	0.039	<0.001	0.003

DISCUSSION

This study was conducted to establish the correlation and frequency of sinusitis in the presence of anatomical variants. Anatomical variants cause narrowing or obstruction of drainage pathways, impairing airflow and resulting in recurrent sinusitis. Therefore, CT PNS should be advised in patients with recurrent sinusitis who have not responded to treatment, to look for anatomical variants. FESS involves surgically opening the sinus drainage passages which requires careful evaluation and a detailed radiological description of the regional anatomy and anatomical variations in the nose and paranasal sinuses. Although the role of anatomical variations of the OMC in causing sinusitis is still being researched, knowledge of these variations in every patient is important for presurgical planning to avoid damage to surrounding vital structures such as orbit, surrounding nerves and the brain. Hence, the radiologist should have a good grasp of paranasal sinus anatomy and its variants to help doctors with early diagnosis and avoid FESS complications.

In our study of 100 patients, males were more affected than females with a mean age of 45.27 ± 18.67 years. According to a study conducted in China, the prevalence of sinusitis was also slightly higher in males than females [11]. In another study, the average age group of affected by sinusitis patients was 20-50 years [12].

The most common sinus involved in our study was the maxillary sinus (83%), followed by the ethmoid, sphenoid and frontal sinuses respectively. In another study conducted in Nepal, the frequency of sinus involvement was similar to our study; the maxillary sinus was involved in 50.9% of cases, followed by the ethmoid sinus (30%), sphenoid sinus (15.4%) and frontal sinus (11.8%) [13].

In our study, the most common anatomic variant of the sino-nasal cavities was DNS, which was present in 72% of the patients. Out of these patients, 33% had a nasal spur on the left side (as shown in **Fig. 1**), while 32% had a spur on the right side. According to a previous study, DNS (88.5%) is the most common variation, with slight predominance towards the left side, similar to that seen in our study [14].

The second most common variant in our study was concha bullosa (23%) followed by agger nasi cells and paradoxical nasal turbinate. In another study conducted in Pakistan [15], the most common anatomical variants were found to be agger nasi cells (64%), DNS (56%), concha bullosa (46%), Haller cells (10%) and Onodi cells (10%). The prevalence of Haller cells in our study was 3% which was lower than the previously documented range of 10-62% [16]. However, the prevalence of Haller cells has been reported to be highly

Table 3: Frequency of mastoiditis and otitis media.

Mastoiditis & Otitis Media	Frequency of Mastoiditis	Percentage of Mastoiditis	Frequency of Otitis Media	Percentage of Otitis Media
Overall	15	15.0	9	9.0
Bilateral	4	4.0	3	3.0
Right Sided	7	7.0	4	4.0
Left Sided	4	4.0	2	2.0

variable, ranging from 2.7 to 45.1% [17]. The presence of Haller cells can increase the risk of orbital injury during ethmoidectomy [18]. The prevalence of Onodi cells was 4% in our study which is within the range of 1.3-65.3% as previously reported [19]. Additionally, the prevalence of pneumatized crista Galli (4%) was within the previously reported range of 2.4-13% range [9]. The prevalence of concha bullosa at 23.0% in our study is within the range of 14-67.5% as previously reported [5, 20].

In our study, we found no correlation between DNS and sinusitis. The only significant association observed in our study was the occurrence of ethmoid sinusitis and concha bullosa. A study showed no increased incidence of paranasal sinus disease in patients with concha bullosa or nasal septal deviation [20, 21].

The OMC is an important entity to examine for drainage of the frontal, anterior ethmoid and maxillary cells. Our study showed that OMC widening was associated with maxillary, ethmoid and sphenoid sinusitis. It also demonstrated a significant correlation between OMC widening and the occurrence of polyps. Bony erosion is considered a minor criterion for the diagnosis of allergic fungal rhino sinusitis, with the LP being the most frequently involved. In our study, ethmoid sinusitis showed a significant association with the erosion of the LP. These findings are consistent with the results published by Al-Dousary S [22]. Hyper-density is correlated with erosion of the lamina papyracea (r=0.35, p= 0.00).

Our study showed an association of OM with mastoiditis, as seen in one of the CT scans in Fig. **(2)**. Another study stated that mastoiditis was a frequent comorbidity of both acute and chronic otitis media [23]. However, no correlation was found between OM and sinusitis in our study. A study conducted by Raman R reported that sinonasal pathologies and mastoid infections have a close association. Sinus pathologies and DNS were frequently observed in patients with mastoiditis [24].

In our study, we did not find a significant association between anatomical variants and sinusitis. Therefore, the importance of these variants lies primarily in presurgical planning rather than as a causative factor. These results were also noted by Shpilberg KA [2].

LIMITATION OF STUDY

We did not cover all anatomical variants; only the common ones were included. Secondly, this study included a limited number of subjects and was conducted at a single center. This study only included symptomatic subjects, so the incidence and correlation of anatomical variants in healthy individuals were not considered. Previous studies have shown varying results regarding the correlation between paranasal sinusitis and anatomical variants. Therefore, more

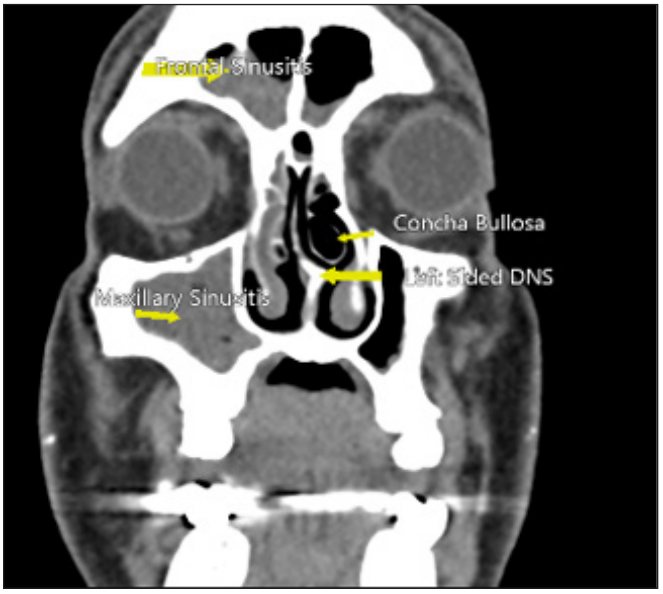

Fig. (1): Coronal view CT of the paranasal sinuses shows the presence of normal anatomical variants, such as a left concha bullosa and a deviated nasal septum towards the left. The right maxillary sinus is completely opacified, and there is mild mucosal thickening in both frontal sinuses consistent with maxillary and frontal sinusitis.

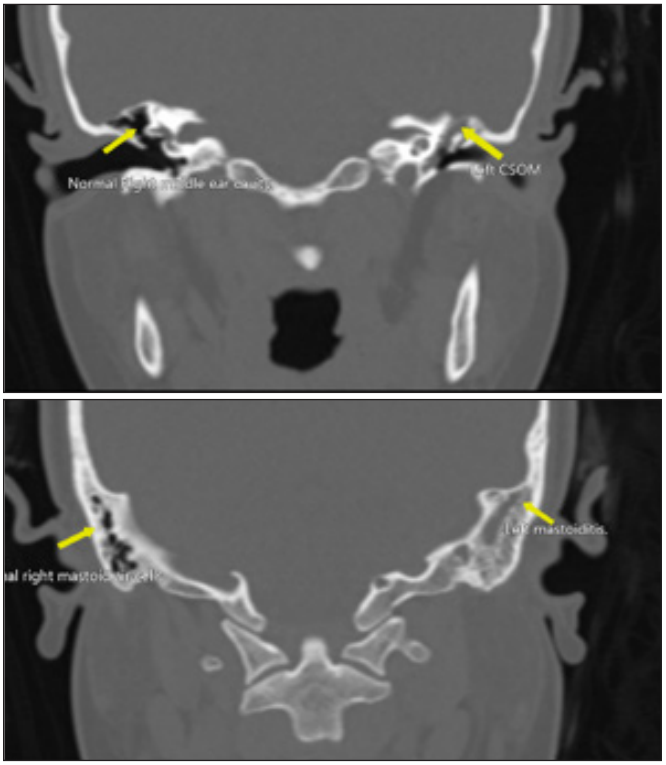

Fig. (2): Two coronal sections through a CT scan of the paranasal sinuses of the same patient show the presence of opacification in the left middle ear cavity completely encasing the ossicular chain suggesting otitis media. The left mastoid air cells are also completely opacified demonstrating fluid density consistent with acute left mastoiditis.

comprehensive research is needed with a metacentric, multiregional approach in the future to better understand this correlation.

CONCLUSION

Several anatomical variants were noted in this study but correlation was only established with a few. Whether a CT PNS is performed for pre-surgical evaluation or not, it is important to mention any anatomical variants in the report to prevent potential surgical complications.

ETHICS APPROVAL

This study was approved by the Alnoor Institute of Radiology, Lahore, Pakistan (Approval no. ANIR: 12/02/2024-ERB-1337). All procedures performed in studies involving human participants were following the ethical standards of the institutional and/ or national research committee and the Helsinki Declaration.

CONSENT FOR PUBLICATION

Informed consent was obtained from the participants of the study.

AVAILABILITY OF DATA

Supporting data is available from the corresponding author's email address on request.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGMENTS

The completion of this research paper would not have been possible without the support and guidance of Dr. Muhammad Zubair, Consultant Radiologist at Alnoor Diagnostic Centre.

AUTHORS' CONTRIBUTION

Zahra Nasrullah, Fatima Azam and Sidra Seyal designed and prepared the manuscript.

Shumaila Seemi Malik and Safdar Ali Malik reviewed and conducted a critical analysis of the manuscript.

REFERENCES

1. Kandukuri R, Phatak S. Evaluation of sinonasal diseases by computed tomography. J Clin Diagn Res 2016; 10(11): 9-12. DOI: https://doi.org/10.7860/JCDR/2016/23197.8826
2. Shpilberg KA, Daniel SC, Doshi AH, Lawson W, Som PM. CT of anatomic variants of the paranasal sinuses and nasal cavity: Poor correlation with radiologically significant rhinosinusitis but importance in surgical planning. AJR Am J Roentgenol 2015; 204(6): 1255-60. DOI: https://doi.org/10.2214/AJR.14.13762
3. Shin JH, Kim SW, Hong YK, Jeun SS, Kang SG, Kim SW, *et al.* The Onodi cell: An obstacle to sellar lesions with a transsphenoidal approach. Otolaryngol Head Neck Surg 2011; 145(6):1040-2. DOI: https://doi.org/10.1177/0194599811418040
4. Aramani A, Karadi RN, Kumar S. A study of anatomical variations of osteomeatal complex in chronic rhino sinusitis patients-CT findings. J Clin of Diagn Res2014; 8(10): 1-4. DOI: https://doi.org/10.7860/JCDR/2014/9323.4923
5. Alsaggaf ZH, Almadfaa AO, Marouf AA, Alfawaz KS, Niyazi RA, Ibrahim NK, *et al.* Sinusitis and its association with deviated nasal septum at a tertiary hospital: A retrospective study. J Taibah Univ Med Sci 2022; 17(6):1065-9. DOI: https://doi.org/10.1016/j.jtumed.2022.06.001
6. Tiwari R, Goyal R. Role of concha bullosa in chronic rhino sinusitis. Indian J Otolaryngol Head Neck Surg 2019; 71(1): 128-31. DOI: https://doi.org/10.1007/s12070-018-1497-y
7. Xu J, Qin L, Wang D. Analysis of the lamina papyracea dehiscence based on computed tomography findings. J Craniofac Surg 2022; 33 (6): 580-3. DOI: https://doi.org/10.1097/SCS.0000000000008557
8. Çankal F, Sarı N. Radiological evaluation of allergic fungal sinusitis: Novel findings. J Contemp Med 2021; 11(6): 919-23. DOI: https://doi.org/10.16899/jcm.1020505
9. Som PM, Park EE, Naidich TP, Lawson W. Crista galli pneumatization is an extension of the adjacent frontal sinuses. AJNR Am J Neuroradiol 2009; 30: 31-3. DOI: https://doi.org/10.3174/ajnr.A1291
10. Ras AB, Farok HM, Abdel Khalik EF, Shalaby AM. Anatomic variations of para-nasal sinuses in patients undergoing CT scan: Spectrum, prevalence and implications. BJAS 2022; 7(3): 89-99. DOI: https://doi.org/10.21608/bnas.2022.244903
11. Shi JB, Fu QL, Zhang H, Cheng L, Wang YJ, Zhu DD, *et al*. Epidemiology of chronic rhino sinusitis: Results from a cross-sectional survey in seven Chinese cities. Allergy 2015; 70(5): 533-9. DOI: https://doi.org/10.1111/all.12577
12. Gouripur K, Kumar U, Janagond AB, Elangovan S, Srinivasa V. Incidence of sino nasal anatomical variations associated with chronic sinusitis by CT scan in Karaikal, South India. Int J Otorhinolaryngol Head Neck Surg 2017; 3 (3): 576-80. DOI: https://doi.org/10.18203/issn.2454-5929.ijohns20172291
13. Shrestha MK, Ghartimagar D, Ghosh A, Jhunjhunwala AK. Sensitivity of sinus radiography compared to computed tomogram: A descriptive cross-sectional study from Western Region of Nepal. JNMA J Nepal Med Assoc 2020; 58(224): 214-7. DOI: https://doi.org/10.31729/jnma.4824
14. Farhan N, Naqvi SU, Rasheed B, Sattar A, Khan M, Rahim A, Murtaza G. Identification of significant anatomical variations in the nose and anterior skull base using computed tomography: A cross-sectional study. Cureus 2020; 12(6): e8449. DOI: https://doi.org/10.7759/cureus.8449
15. Qureshi MF, Usmani A. A CT-scan review of anatomical variants of sinonasal region and its correlation with symptoms of sinusitis (nasal obstruction, facial pain and rhinorrhea). Pak J Med Sci 2021; 37(1): 195-200. DOI: https://doi.org/10.12669/pjms.37.1.3260
16. Fadda GL, Rosso S, Aversa S, Petrelli A, Ondolo C, Succo G, *et al*. Multiparametric statistical correlations between paranasal

sinus anatomic variations and chronic rhino sinusitis. Acta Otorhinolaryngol Ital 2012; 32: 244-51.

17. Mahapatra S, Hebbale M, Manjula, Tepan M, Halli R, Singh S, *et al*. Prevalence of haller cell and accessory maxillary ostium: A cone-beam computed tomographic study. JIAOMR 2022; 34(4): 466-9.
DOI: https://doi.org/10.4103/jiaomr.jiaomr_154_22

18. Nouraei SA, Elisay AR, Dimarco A, Abdi R, Majidi H, Madani SA, *et al*. Variations in paranasal sinus anatomy: implications for the pathophysiology of chronic rhino sinusitis and safety of endoscopic sinus surgery. J Otolaryngol Head Neck Surg 2009; 38: 32-7.
DOI: https://doi.org/10.2310/7070.2008.070266

19. Tomovic S, Esmaeili A, Chan NJ, Choudhry OJ, Shukla PA, Liu JK, *et al*. High-resolution computed tomography analysis of the prevalence of Onodi cells. Laryngoscope 2012; 122: 1470-73.
DOI: https://doi.org/10.1002/lary.23346

20. Smith KD, Edwards PC, Saini TS, Norton NS. The prevalence of concha bullosa and nasal septal deviation and their relationship to maxillary sinusitis by volumetric tomography. Int J Dent 2010; 2010: 404982.
DOI: https://doi.org/10.1155/2010/404982

21. Stallman JS, Lobo JN, Som PM. The incidence of concha bullosa and its relationship to nasal septal deviation and paranasal sinus disease. AJNR 2004; 25: 1613-8.

22. Al-Dousary S, Alarifi I, Bin Hazza'a A, Sumaily I. Paranasal sinus wall erosion and expansion in allergic fungal rhinosinusitis: An image scoring system. Cureus 2019; 11(12): e6395.
DOI: https://doi.org/10.7759/cureus.6395

23. Bhalla AS, Singh A, Jana M. Chronically discharging ears: Evalution with high resolution computed tomography. Pol J Radiol 2017; 82: 478-89.
DOI: https://doi.org/10.12659/PJR.901936

24. Raman R, Murthy N, Galag S, Diwakar S. Mastoiditis and sinonasal pathologies on cranial computed tomography imaging: A correlative study. Int J Sci Stud 2016; 4(1): 165-8.
DOI: https://doi.org/10.17354/ijss/2016/210