Normal anatomic variants of paranasal sinus region studied by computed tomography

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Abstract

Background and objective: Variation in paranasal sinus anatomy, as shown on computed tomographic scans, is of potential significance as it may pose risks during surgery or predispose to certain pathologic conditions. This study aimed to investigate the frequency of anatomic variants of the nasal cavity and paranasal sinuses in our population and determine their relationship with gender and find out the association of these variants with mucosal abnormalities.

Methods: This was a cross-sectional study conducted at the College of Medicine, Hawler Medical University from October 2017 to January 2019. A review of computed tomography scans of the paranasal sinuses of 300 patients was done; special attention was directed toward identifying bony anatomic variants and mucosal abnormalities.

Results: Frequent variants were: Agger nasi cells (72%), nasal septal deviation (71.7%), Haller cells (70.7%), concha bullosa (61%), elongation of uncinate process (69.7%) and different variants of the sphenoidal sinus (78.8%). The frequency of variants did not differ significantly with respect to gender, except for sphenoidal variants along with Keros types and asymmetry of the ethmoidal roof. A significant association was found between middle concha variants and inferior turbinate enlargement (P <0.001).

Conclusion: Anatomic variants of the paranasal sinus region were common in our population; the most frequent ones were those involving the nasal septum, ethmoid air cells, sphenoid sinuses, and middle turbinates. The study of these variants is important for the management of paranasal sinus region disease.

Keywords: Anatomic variants; Paranasal sinuses; Computed tomography.

Introduction

Paranasal sinus (PNS) region anatomy differs significantly among individuals; certain anatomic variants are frequently seen on sinus computed tomography (CT) scans. The most common ones are Agger nasi cells, infraorbital ethmoidal (Haller) cells, sphenoethmoidal (Onodi) cells, nasal septal deviation (NSD), septal bony spur, concha bullosa (CB) and paradoxical middle turbinate.[1-10] Less common anatomic variants of the PNS region include pneumatization of the uncinate process, large ethmoidal bulla, superior turbinate pneumatization, and pneumatized crista galli.[3,5,11-14] Some of the anatomic variants have been reported to be associated with chronic rhinosinusitis, possibly leading to inflammation by obstructing drainage pathways from the sinuses and nasal cavity.[2-5] However, a number of other studies did not show a significant association between these anatomic variants and rhinosinusitis.[1,4,9,10,15,16] Moreover, it has been reported that failure to recognize certain anatomic variants such as asymmetry of the ethmoidal roof, Onodi cells, pneumatization of anterior clinoid processes, supraorbital cells, Haller cells, pneumatization of the dorsum sella and dehiscence of the lamina papyracea may lead to complications during surgery due to proximity of blood vessels, nerves, brain,

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and orbits.[17-20] The frequency of these variants may differ among the different ethnic groups.[21]There is no data on anatomic variants of the PNS region in our population in the literature review. This study aimed to investigate the frequency of a number of anatomic variants of the PNS region in our population, find out their gender distribution and the association of these variants with mucosal abnormalities, and compare the results with previous investigations conducted in different populations. The end goal was to gather this knowledge in an effort to reduce the rate of complications of endoscopic sinus surgery.

Methods

This was a cross-sectional study conducted at the College of Medicine, Hawler Medical University from October 2017 to January 2019. The study protocol was approved by the Research Ethical Committee of the college. It comprised a review of 350 cases with unenhanced PNS CT scans at Rizgary teaching hospital using Siemens SOMATOM Emotion16-slice multidetector CT scanner. All scans were performed for evaluation of a symptom related to the PNS region. After excluding those below 18 years, previous nasal or paranasal sinus surgery, neoplastic disease, a history of nasal trauma or facial anomaly, and extensive opacification of PNSs that distorted the normal anatomy, the CT findings of the remaining 300 patients were analyzed. All scans were obtained using a bone algorithm in axial complemented by coronal and sagittal reconstructions with a slice thickness of 0.6mm in most cases and kept 3 mm at maximum. Two independent observers assessed the scans. In cases of discrepancy between them, a third observer participated in the discussion to obtain an agreed decision. In all cases, the existence of the following variants was investigated: (1) nasal septum: septal deviation, septal bony spur, and pneumatization; (2) turbinates: middle turbinate pneumatization or concha bullosa

(CB), paradoxical (false) middle concha, hypoplasia; (3) ethmoid air cells: Agger nasi cells, Haller cells, and Onodi cells; (4)ethmoid uncinate process: elongation of the upper edge, pneumatization; (5) sphenoid sinus variants and (6) other variants: maxillary or frontal sinus septa or hypoplasia. The depth of olfactory fossa was classified according to the grading system proposed by Keros into three types.[22] The asymmetry of ethmoidal roof and incidence of aerated crista galli was also investigated. The summation of the unilateral and bilateral abnormalities has been reported as the prevalence of variants without considering the "half-head" as a separate entity. The images were also analyzed for the presence of mucosal abnormalities, including PNS mucosal thickening and inferior turbinate enlargement indicative of rhinosinusitis.

Statistical Analysis

The statistical package for the social sciences software, version 21 (Chicago; IL, USA) was used for data entry and analysis. A descriptive approach was used to determine frequency and percentages while in analytic approach (Chi-square test) was used for categorical variables. A P value of <0.05 was considered statistically significant. The results were compared with studies published in the literature that aimed to detect the same anatomic variants using the CT scan. Images of some interesting cases were illustrated.

Results

Of the initial 350 scans, 50 were excluded for not meeting the inclusion criteria. The final sample size, as such, was 300. The mean age of the patients was 33.36±13.15 years, ranging from 18 to 69 years. There were 161 females (53.7%) and 139 males (46.3%). In all scans studied, one or more anatomic variants were identified. Asymmetry of the sphenoid cavities corresponding to the sphenoid sinus was observed in all, so it was not considered as an anatomic variant. The frequencies of
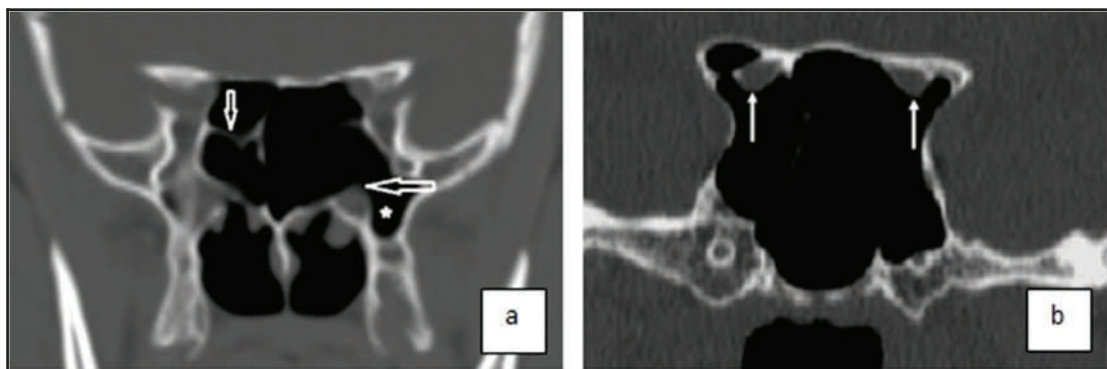
a number of the anatomic variants are shown in Table 1. Frequent variants were Agger nasi cells (72%), NSD (71.7%), Haller cells (70.7%), CB (61%) and different forms of sphenoid variants (78.7%) as shown in Figures 1 and 2.

Table 1: Frequency of certain anatomic variants in the studied sample.

Anatomic Variants	Number	% (N=300)
Nasal septal variants		
NSD	215	71.7
Septal spur	102	34.0
Septal pneumatization	50	16.7
Middle turbinate variants		
CB	183	61.0
Paradoxical turbinate	57	19.0
Hypoplastic turbinate	3	1.0
Aggernasi cells	216	72.0
Haller cells	212	70.7
Onodi cells	134	44.7
Ethmoid Uncinate process		
Elongation	209	69.7
Pneumatization	9	3.0
Frontal sinus agenesis or hypoplasia	35	11.7
Keros classification		
Type I	93	31.0
Type II	200	66.7
Type III	7	2.3
Ethmoidal roof asymmetry	130	43.3
Sphenoidal variants	236	78.7
Crista galli pneumatization	17	5.7
Maxillary sinus		
Hypoplasia	4	1.3
Septum	75	25.0

Figure 1: Coronal non-contrast computed tomography images in the bone window. (a) Bilateral Agger nasi cells (white arrows) and nasal septal deviation to the right (yellow arrow); (b) Bilateral concha bullosa (stars) and Haller cell (white arrow); (c) Nasal septal deviation to the right with spur; (d) Septal pneumatization (white star) and bilateral inferior turbinate enlargement more severe at the left (yellow stars).

Figure 2: Coronal CT images of sphenoid sinus variants: (a) pneumatization of the left pterygoid processes (star) with protrusion and partial dehiscence of the left vidian nerve (horizontal arrow) and septum deviated to the right (vertical arrow); it is seen to insert over the bone covering the right internal carotid artery; (b) protrusion and partial dehiscence of the optic nerves (arrows).

The frequency of anatomic variants did not differ significantly with respect to gender, except for sphenoidal variants along with Keros types and ethmoidal roof asymmetry (P <0.001), as shown in Table 2.

Table 2: Prevalence of certain anatomic variants by gender.

Variables	Gender		Total (N=300)	P value
	Male No. (%)	**Female** No. (%)		
Nasal septal deviation				
Absent	37(26.6)	48 (29.8)	85(28.3)	0.54
Present	102(73.4)	113 (70.2)	215(71.7)	
Nasal septal spur				
Absent	88(63.3.)	110(68.3)	198(66.0)	0.36
Present	51(36.7)	51(31.7)	102(34.0)	
Septal pneumatization				
Absent	114(82)	136(84.5)	250(83.3)	0.569
Present	25(18)	25(15.5)	50(16.7)	
Concha bullosa				
Absent	55(39.6)	62(38.5)	117(39.0)	0.851
Present	84(60.4)	99(61.5)	183(61.0)	
Agger nasi cells				
Absent	37(26.6)	47(29.2)	84(28.0)	0.621
Present	102(73.4)	114(70.8)	216(72.0)	
Haller cells				
Absent	41(29.5)	47(29.2)	88(29.3)	0.954
Present	98(70.5)	114(70.8)	114(70.8)	
Onodi cells				
Absent	71(51.1)	95(59.0)	166(55.3)	0.168
Present	68(48.9)	66(41.0)	134(44.7)	
Sphenoidal variants				
Absent	19(13.7)	45(28)	64(21.3)	0.003
Present	120(86.3)	116(72)	236(78.7)	
Keros classification				
Type I	54(38.8)	39(24.2)	93(31.0)	*<0.001
Type II	78(56.1)	122(75.8)	200(66.7)	
Type III	7(5.0)	0(0.0)	7(2.3)	
Ethmoidal roof asymmetry				
Absent	66(47.5)	104(64.6)	170(56.7)	0.003
Present	73(52.5)	57(35.4)	130(43.3)	

*Fisher ́s Exact Test used

Mucosal abnormalities representing rhinosinusitis were detected in 268 (89.3%) of 300 patients, including inferior turbinate hypertrophy and mucosal thickening of the sinuses. The prevalence of mucosal thickening was significantly higher in males than females. The relationship between certain anatomic variants and mucosal abnormalities is shown in Tables 3 and 4. A significant association was found between the middle turbinate variants and the presence of mucosal abnormalities.

Table 3: Association of certain anatomic variants with mucosal thickening of the sinuses.

Variables	Mucosal thickening of the sinuses		Total (N=300)	*P* value
	Absent	**Present**		
	No. (%)	**No. (%)**	**No. (%)**	
Gender				
Male	54(38.8)	85(61.2)	139(100)	0.001
Female	94(58.4)	67(41.6)	161(100)	
Nasal septal deviation				
Absent	37(43.5)	48 (56.5)	85(100)	0.206
Present	111(51.6)	104 (48.4)	215(100)	
Concha bullosa				
Absent	52(44.4)	65(55.6)	117(100)	0.176
Present	96(52.5)	87(47.5)	183(100)	
Agger nasi cells				
Absent	39(46.4)	45(53.6)	84(100)	0.53
Present	109(50.5)	107(49.5)	216(100)	
Haller cells				
Absent	39(44.3)	49(55.7)	88(100)	0.263
Present	109(51.4)	103(48.6)	212(100)	
Onodi cells				
Absent	83(50)	83(50)	166(100)	0.797
Present	65(48.5)	69(51.5)	134(100)	

Table 4: Association of certain anatomic variants with inferior turbinate enlargement.

Variables	Inferior Turbinate Enlargement		Total	*P* value
	Absent	**Present**	No. (%)	
	No. (%)	**No. (%)**		
Gender				
Male	20(14.4)	119(85.6)	139(100)	0.024
Female	40(24.8)	121(75.2)	161(100)	
Nasal septal deviation				
Absent	17(20.5)	66 (79.5)	83(100)	0.897
Present	43(19.8)	174(80.2)	217(100)	
Concha bullosa				
Absent	34(29.1)	83(70.9)	117(100)	0.002
Present	26(14.2)	157(85.8)	183(100)	
Agger nasi cells				
Absent	20(23.8)	64(76.2)	84(100)	0.304
Present	40(18.5)	176(81.5)	216(100)	
Haller cells				
Absent	11(12.5)	77(87.5)	88(100)	0.036
Present	49(23.1)	163(76.9)	212(100)	
Onodi cells				
Absent	36(21.7)	130(78.3)	166(100)	0.41
Present	24(17.9)	110(82.1)	134(100)	

Discussion

The paranasal sinus region is subject to a large variety of lesions. Normal anatomic variants in this region are important as they may have pathological consequences or maybe the source of difficulty/ complication during surgery. Certain anatomic variants are thought to be predisposing factors for the development of sinus diseases, and thus it becomes necessary for the radiologist to be aware of these variants, especially if the patient is a candidate for functional endoscopic sinus surgery (FESS).[23] The most common anatomic variant in this study was Agger nasi cell (72%), similar to a study done in Turkey.[6] Other authors have reported prevalence rates of 88%,[24] 96.5%,[25] and 94.1%.[26] The Aggernasi cell (Figure 1 a) is the most anterior of the anterior ethmoid cells, found anterior and superior to the middle turbinate attachment to the lateral wall.[27] Enlargement of Agger nasi cells has been found to correlate with a decrease in CT in the anterioposterior size of the nasofrontal recess, involved in the frontal sinus drainage pathway. Failure to address Agger nasi disease can contribute to the failure of the primary surgery.[28] The second most common anatomic variant was the deviation of the nasal septum. The NSD (Figure 1 a) is an asymmetric bowing of the nasal cartilaginous septum. Such bowing may compress the middle turbinate in a lateral fashion, which may lead to the narrowing of the middle meatus.[27] In this study, any deviation from the midline was regarded as NSD without considering the degree of deviation determined by connecting the lines being drawn downward from the crista galli and upward from the nasal eminence, and it was found in 71.7% of the scans. Earlier studies reported different rates, for example, 89.7% by Kaya et al.,[6] 81.8% by Kaplanoglu et al.,[29] 68.2% by Sharma et al.,[30] 60% by Reddy et al.,[31] and 48.8% by Alsowey et al.[32] Other variants of the nasal septum included septal spur (34%) and pneumatized septum (17.3%). In literature, the frequency of pneumatization of the nasal septum is (0-18) %.[6,29,33] Haller cells (Figure 1 b) are ethmoid air cells that extend laterally over the medial aspect of the roof of the maxillary sinus; they may cause narrowing of the infundibulum.[27] In the present study, Haller cells were frequent variants and found in 70.5% of the scans (Figure), but other authors have reported a wide variation in the prevalence rates such as 25%,[1] 9.1%,[33] 8%,[34] and 33%.[31,35] Onodi cell was found in 44.7% of the scans in the current study. Other studies reported Onodi cell in 8%[1] and 14%[6] of their samples. Onodi cell is the most posterior ethmoid air cell that extends laterally. This extension is near the carotid canal and close to the optic nerve, which emphasizes the clinical importance of considering this anatomic variation prior to any attempt for invasive intervention.[27] Middle turbinate or middle concha variants were common in the present study (81.7%). Concha bullosa (CB) is one of the most frequently found anatomic variants. The incidence of CB in the population ranges from 13 to 73% in literature;[36] the differences reported may have been influenced by the aeration degree, and lower rates suggest that only large turbinates may have been taken into consideration. The present study has adopted the definition by Zinreich et al.,[37] who have considered any pneumatization degree as CB and was found in 61.4% of the scans (Figure 1 b). Other studies have found a prevalence of 30.6% by Alsowey et al.,[32] 31.7% by Kalaiarasi et al.,[36] 30% and 51% by two different studied in Turkey.[6,29] The middle turbinate usually curves medially toward the nasal septum. However, the resultant anatomic variant is known as a paradoxical middle turbinate when the turbinate curves laterally. Such a variant can narrow or obstruct the nasal cavity, middle meatus, or infundibulum.[27] Again, the prevalence reported by different authors may diverge because some consider any involved portion of the turbinate as paradoxical curvature.

In contrast, others may consider this variation only in cases where the whole turbinate is unusually curved towards the opposite side. In the present study, 57 patients were found with paradoxical middle turbinates (19%) near to a study done in India 18%.[31] Roman et al.[1] have found this variant in 8% of their cases, Adeel et al.[2] in 14.3% and Kaya et al.[6] in 4.3%. The uncinate process (UP) is a structure that has multiple variations between individuals. The superior attachment of the UP has three major variations that help determine the anatomic configuration of the frontal recess and its drainage.[27] The present study investigated the shape and pneumatization of the UP. Elongation of the UP was frequent (69.7%). Regarding the depth of olfactory fossa, the most frequent type in this study was Keros Type II in agreement with Keros[22] and Yadav et al.[38] According to Keros classification, the depth of the olfactory fossa is 1-3 mm in Type I, 4-7 mm in Type II, and 8-16 mm in Type III based on the height of the lateral lamella, the greater the height of the lateral lamella, the higher the risk of its penetration into the anterior cranial fossa.[22] Asymmetry in the anterior of the skull base and especially in the ethmoid roof is important for ESS. Intracranial complications appear more frequently on the side in which the ethmoid roof is low. This low-hanging roof may cause cerebrospinal fluid fistula and recurrent meningitis postoperatively.[39] This study showed asymmetry of the ethmoidal roof in 43.3% of the 300 scans. The sphenoid bone may be affected by different variants of pneumatization (Figure 2), these have a relevant importance from a clinical and surgical point of view.[40] Of the 300 scans in the current study 78.7% showed a form of anatomical variant of the sphenoid sinuses with statistically significant differences between males and females (P <0.01). The current study showed rudimentary or absence of at least one side of the frontal sinuses in 11.7% of the scans in agreement with Kaya et al.[6]

There were other uncommon variants with crista galli pneumatization in 5.7%, maxillary sinus hypoplasia in 1.3%, and uncinate process pneumatization in 3% of cases. The dissimilarities observed between our findings and the results of previous investigations may be attributed to racial, geographic, and hereditary disparities, differing sensitivity of data acquisition, and discrepant definitions for a few diagnostic variants. In this study, the frequency of variants did not differ significantly with respect to gender (P >0.05) in agreement with Reddy et al.[31] and Yadav et al.[38] except for sphenoidal variants along with Keros types and ethmoidal roof asymmetry (P <0.00). Males had a higher prevalence of Keros type III and asymmetry of the ethmoid roof, which makes them more susceptible to operative complications. Therefore, extra care must be taken during surgeries on males the same as in the neighbor Turkish population reported by Kaplanoglu et al.[29] Mucosal abnormalities were detected in 268 (89.3%) of 300 patients, including inferior turbinate hypertrophy and mucosal thickening of the sinuses. The term 'turbinate hypertrophy' was first coined in the late 1800s to describe enlargement of the inferior turbinate, and it remains in common use today.[41] In the present study, a significant association was found between mucosal abnormalities with each of the gender and middle concha variants, including CB. There are limitations of the present study, mainly because the studied population does not accurately represent the general population. All patients were referred to PNS CT for suspected sinus disease. This is difficult to overcome because a study with a truly randomized population would require subjects to undergo unnecessary radiation exposure and thus contradict the ALARA principle, "as low as reasonably achievable." Some studied used patients referred for the brain, orbit, or dental evaluation as control groups, but this was not done in the current study.

Conclusion

Anatomic variants of the paranasal sinus region were common in our population; the most frequent ones were those involving the nasal septum, ethmoid and sphenoid sinuses. The study of these variants is important for the management of paranasal sinus region disease.

Competing interests

The author declares no competing interests.

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