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Anatomic Variations of the Paranasal Sinus Region: Evaluation with Multidetector CT

Paranazal Sinüs Bölgesinin Anatomik Varyasyonları: Çok Kesitli BT ile Değerlendirme

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Abstract / Özet

Objective: In this study, we aimed to evaluate the frequency of anatomic variations of the paranasal sinus region by using multidetector computerized tomography (MDCT).

Methods: Between November 2009 and February 2012, 5832 adult patients (2980 females, 2852 males) with a mean age of 39.1±15.4 years (range; 19-85), who underwent MDCT imaging of the paranasal sinus region, were retrospectively evaluated by using the picture archiving and communication system (PACS). All the images were evaluated by three radiologists. Frequency distribution and descriptive statistics of the variants were analysed.

Results: Nasal septal deviation was the most commonly detected variation (59.1%) and most were rightward (26.5%). Middle concha pneumatization was the second most commonly encountered variation (57.2%), whereas nasal septum pneumatization was the third most common one (34.8%). Maxillary sinus aplasia was detected in one patient and it was the least common variation (0.05%). Dehiscence of the maxillary nerve (0.4%) and internal carotid artery (0.5%) and sphenoid sinus aplasia (0.5%) were infrequently encountered variations in our study.

Conclusion: It is important for the radiologist to know the anatomical variations of the paranasal sinus region in order to consider their possible pathological consequences. Guiding the surgeon in the preoperative period is essential to avoid potential complications.

Key Words: Anatomic variation, MDCT, paranasal sinus

Amaç: Bu çalışmada, paranazal sinüs bölgesindeki anatomik varyasyon frekanslarını çok kesitli bilgisayarlı tomografi (ÇKBT) kullanarak değerlendirmeyi amaçladık.

Yöntemler: Kasım 2009-Şubat 2012 arasında paranazal sinüs bölgesine yönelik ÇKBT yapılan, ortalama yaşı 39,1±15,4 (Aralık; 19-85), olan 5832 yetişkin hasta (2980 kadın, 2852 erkek) görüntü arşivleme ve iletişim sistemi (PACS) kullanılarak retrospektif olarak radyologlar tarafından değerlendirildi. Varyasyonların frekans dağılımı ve tanımlayıcı istatistikler analiz edildi.

Bulgular: Nazal septum deviasyonu en sık saptanan varyasyondu (%59,1) ve en sık sağ taraflıydı (%26,5). Orta konka pnömatizasyonu ikinci en sık (%57,2), nazal septum pnömatizasyonu ise üçüncü en sık (%34,8) saptanan varyasyondu. Maksiller sinüs aplazisi bir hastada saptanmıştı ve en az sıklıkta görülen varyasyondu (%0,05). Maksiller sinir dehisansı (%0,4), internal karotid arter dehisansı (%0,5) ve sfenoid sinüs aplazisi (%0,5) çalışmamızda nadir saptanan varyasyonlardı.

Sonuç: Radyologlar için paranazal sinüs bölgesi anatomik varyasyonlarını bilmek olası patolojik sonuçları öngörmek için önemlidir. Ameliyat öncesi cerrahlara rehberlik etmek potansiyel komplikasyonları engellemek için esansiyeldir.

Anahtar Kelimeler: Anatomik varyasyon, ÇKBT, paranazal sinüs

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Introduction

The paranasal sinus region is subject to a large variety of lesions. Congenital anomalies and normal anatomical variations in this region are important as they may have pathological consequences or may be the source of difficulty during surgery (1).

Straying beyond the surgical field may lead to serious complications such as cerebrospinal fluid leak, meningitis, or blindness, so a detailed knowledge of the possible anatomical variations is essential. The development and refinement of computerized tomography (CT) imaging has allowed detailed assesment of each individual's paranasal sinus anatomy, thus providing a map that allows the sinus surgeon to operate safely (2).

In this study we aimed to evaluate the frequency of anatomic variations of the paranasal sinus region by using multidetector computerized tomography (MDCT).

Methods

Patient group

A total of 6224 patients underwent MDCT imaging of the paranasal sinus region, in a tertiary hospital, between November 2009 and February 2012, were retrospectively evaluated by using picture archiving and communication system (PACS). Imaging was usually for investigation of evident or possible sinusitis, rarely for tumors or trauma. The patients whose MDCT images showed any alteration of the paranasal sinus anatomy due to surgery, tumor or facial trauma were excluded from the study. Also the patients whose sinus disease obscured the structures that we planned to evaluate were excluded. The pediatric patients (age<18 years) were excluded also due to the development stages of the paranasal sinuses. 5832 adult patients (2980 females, 2852 males) with a mean age of 39.1±15.4 years (range; 18-85), were included in the study. Informed consent was obtained from the research population.

MDCT protocol

Axial images were obtained using a 16-detector MDCT (Philips Brillance 16 CT scanner, Philips Medical Systems, Cleveland, Ohio, USA) according to those parameters: slice thickness, 0.8 mm; interval, 0.4 mm; kv, 120; mA, 105; pitch, 0.4; rotation time, 0.75 s; collimation, 16x0.75; matrix, 512x512; FOV, 200x200 mm. Coronal images were obtained by reformatting the axial images with 1 mm slice thickness and 2 mm intervals, using a software program (CT Viewer, Philips Medical Systems, Cleveland, Ohio, USA).

Image interpretation

MDCT scans were transferred to PACS workstations in DICOM 3.0 format, and retrospectively evaluated by using software programs (Fusion PACS and eFilm, Merge Healthcare, Chicago, Illinois, USA). All of the coronal reformatted images were reviewed by radiologists and, if needed, axial images were also evaluated too. Any disagreements between radiologists about the type or presence of variation were resolved by consensus. In all cases, the existence of the following variants were İnvestigated: (1) nasal septum (NS): septal deviation (leftward, rightward or S-shape), bony spur, pneumatization; (2) concha (superior, middle, inferior): pneumatization (unilateral or bilateral), paradoxical curvature of middle concha; (3) air cells: Agger nasi cells (ANC), Haller cells (HC), Onodi cells (OC), supraorbital ethmoid air cells (SOEC); (4) sinuses (frontal, maxillary, sphenoid): hypoplasia, aplasia; (5) sphenoid bone: pneumatization of anterior clinoid process (ACP), posterior clinoid process (PCP) and pterygoid process (PP), protrusion and dehiscence of optic nerve (ON), internal carotid artery (ICA), vidian nerve (VN) and maxillary nerve (MN); (6) other variants: pneumatization of uncinate process (UP) and crista galli (CG), asymmetry of the height of ethmoid roof (ER).

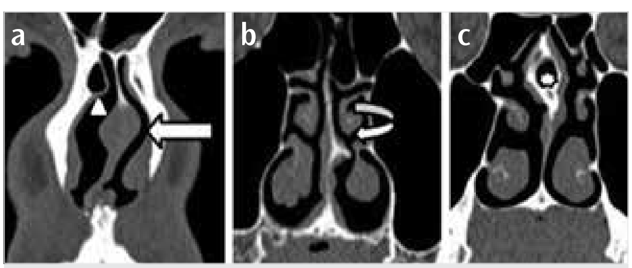

Figure 1. a-c. Coronal CT images of different patients showing: leftward deviation of nasal septum (arrow) and Agger nasi cell (arrowhead) extending to the right frontal recess (a), bony spur of nasal septum (curved arrow) extending to the left inferior concha and narrowing the nasal passage (b), pneumatization of posterior portion of nasal septum (asterisk) (c)
CT: computed tomography

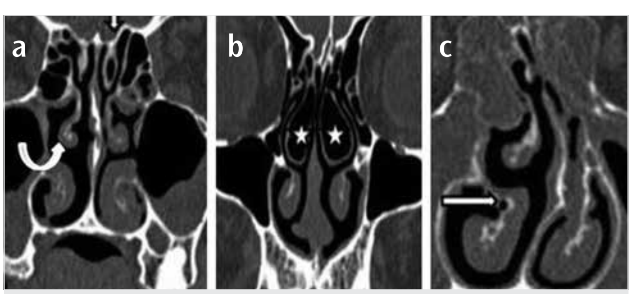

Figure 2. a-c. Coronal CT images of different patients showing: pneumatization of left superior concha (arrow) and paradoxically curved right middle concha (curved arrow) (a), pneumatization of bilateral middle conchae (asterisks) (b), pneumatization of right inferior concha (arrow) (c)
CT: computed tomography

Statistical analysis

The frequency distribution and descriptive statistics were analysed. The relationships between the variants were not analysed. All statistical calculations were performed using a software program (Statistical Package for Social Sciences version 16.0, SPSS Inc., Chicago, Illinois, USA).

Results

Nasal septum

Deviations of NS were found in 3448 (59.1%) patients. Deviations were rightward, leftward and S-shape in 1548 (26.5%), 1460 (25%) and 440 (7.5%) of patients, respectively. Pneumatizations of NS were found in 2032 patients (34.8%). Bony spurs were encountered in 1160 patients (19.9%) (Figure 1).

Concha

Unilateral or bilateral pneumatization either lamellar, bulbous or extensive types (concha bullosa) of the middle, superior and inferior conchae were found in 3336 (57.2%), 1044 (17.9%) and 60 (1%) of patients, respectively. Paradoxial curvatures of middle concha were found in 520 (9%) of patients (Figure 2).

Air cells

ANC were encountered in 1068 (18.3%) of patients (Figure 1). In 864 (14.8%) of patients there was HC, in 788 (13.5%) of patients there was OC. SOEC was found in 552 (9.4%) of patients (Figure 3).

Sinuses

Hypoplasia of frontal, maxillary and sphenoid sinuses was found in 728 (12.5%), 140 (2.4%), 52 (0.9%) of patients, respectively. Aplasia of frontal, maxillary and sphenoid sinuses was ncountered in 104 (1.7%), 4 (0.05%), 32 (0.5%) of patients, respectively.

Sphenoid Bone

Pneumatizations of ACP, PCP and PP were encountered in 1176 (20%), 144 (2.5%), 2044 (35%) of patients, respectively. Protrusions and dehiscences found for ON were seen in 324 (5.5%) and 92 (1.5%), for ICA in 172 (3%) and 24 (0.5%), for VN in 1188 (20.3%)

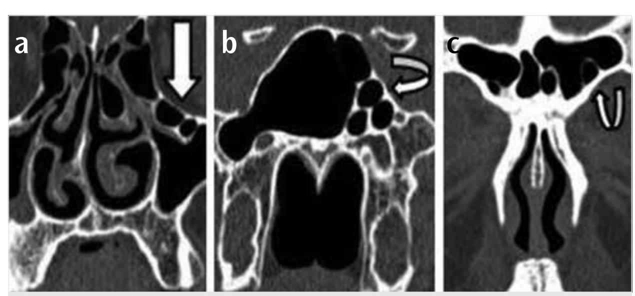

Figure 3. a-c. Coronal CT images of different patients showing: Haller cells (arrow) obstructing the left maxillary sinus ostium (a), Onodi cells (curved arrow) adjacent to the left pterygoid process (b), Supraorbital ethmoid air cell (curved arrow) originating from left orbital plate of frontal bone (c)
CT: computed tomography

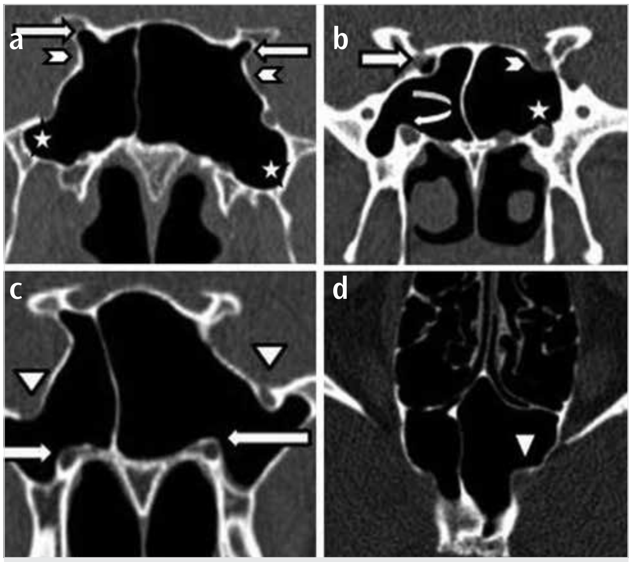

Figure 4. a-d. Coronal CT images of different patients showing: pneumatization of bilateral anterior clinoid processes (arrows) and bilateral pterygoid processes (asterisks) and protrusion of the bilateral internal carotid arteries (arrowheads) (a), protrusion of the right optic nerve (arrow), dehiscence of the left optic nerve (arrowhead), protrusion of the right vidian nerve (curved arrow), dehiscence of the left vidian nerve (asterisk) (b), protrusion of bilateral vidian nerves (arrows), dehiscence of the right maxillary nerve and protrusion of the left maxillary nerve (arrowheads), (c) axial CT image of a different patient showing dehiscence of the left internal carotid artery (arrowhead) (d)
CT: computed tomography

and 64 (1%), for MN were in 280 (4.8%) and 24 (0.4%) of patients, respectively (Figure 4).

Other variants

Pneumatizations of either unilateral or bilateral UP were found in 408 (7%) patients and pneumatizations of CG were found in 548 (9.4%) patients. Asymmetry of the height of ER either left sided or right sided was encountered in 468 (8%) of patients (Figure 5). Numbers of anatomic variations and frequency distribution are shown in Table 1.

Discussion

CT is the modality of choice when assessing inflammatory sinus disease and is routinely performed prior to functional endoscopic sinus surgery (FESS), the aim of which is to restore the normal mucociliary drainage pathways. It is important for the radiologist to understand the anatomy of the drainage pathways and the frequent anatomical variants in this region in order to guide the surgeon. These variants may impair the functional drainage pathways, increase the risk of endoscopic surgery and make access to sites of disease extremely difficult (3).

Deviations represent the most frequent pathological condition in the NS. It has been suggested that the NS is usually a midline structure until the age of 7 and it deviates mostly to the right side thereafter. Deviation of the septum may take the form of a "C" or "S" or may look like a large spur (4). The incidence of septal deviation is varied 20-79% and is of not clinically relevant. However septal deviation can displace the middle turbinate, narrowing the middle meatus, making surgical access difficult (3). In our study, we found nasal septal deviation in 59.1% of patients and most were rightward (26.5%).

Table 1. Number of anatomic variations and frequency distribution

		Number of patients	Frequency (%)
	Total deviations	3448	59.1
	Rightward	1548	26.5
	Leftward	1460	25.1
Nasal septum	*S-shape*	440	7.5
	Bony spur	1160	19.9
	Pneumatization	2032	34.8
	Pneumatization		
	Superior	1044	17.9
Concha	*Middle*	3336	57.2
	Inferior	60	1.1
	Paradoxial curvature of middle concha	520	9.1
	Agger nasi	1068	18.3
Air cells	*Haller*	864	14.8
	Onodi	788	13.5
	Supraorbital ethmoid	552	9.4
	Hypoplasia/aplasia		
	Frontal	728/104	12.5/1.7
Sinuses	*Maxillary*	140/4	2.4/0.05
	Sphenoid	52/32	0.9/0.5
	Pneumatization		
	ACP	1176	20
	PCP	144	2.5
	PP	2044	35
Sphenoid Bone	Protrusion/Dehiscence		
	ON	324/92	5.5/1.5
	ICA	172/24	3/0.5
	VN	1188/64	20.3/1
	MN	280/24	4.8/0.4
	Pneumatization of UP	408	7
Other variants	Pneumatization of CG	548	9.4
	Asymmetry of ER	468	8

ACP: anterior clinoid process; PCP: posterior clinoid process; PP: pterygoid process; ON: optic nerve; ICA: internal carotid artery; VN: vidian nerve; MN: maxillary nerve; UP: uncinate process; CG: crista galli; ER: ethmoid roof

Septal spurs are frequently encountered in association with septal deviation and if prominent may also make surgical access difficult and narrow the middle meatus or ethmoidal infundibulum (3). The incidence of bony spur was reported to be 7.2 and 13.6% by Earwaker (5) and Perez-Pınas et al. (6), respectively. We found an even higher frequency of nasal septal bony spur (19.9%). The pneumatized septum is usually due to extension of air from the sphenoid sinus or crista galli and is usually not significant but may narrow the sphenoethmoidal recess (3). The incidence of pneumatized septum was reported to be 2 and 15% by Chao (7) and Sapci et al. (8), respectively. We found an even higher frequency of pneumatized septum (34.8%).

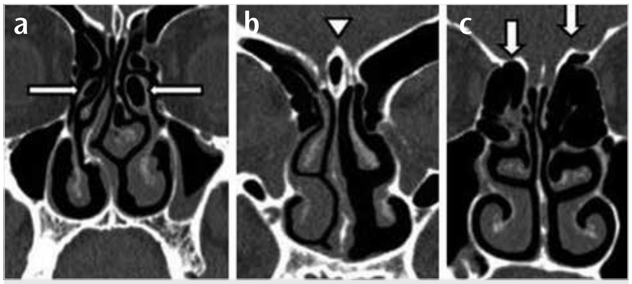

Figure 5. a-c. Coronal CT images of different patients showing, pneumatization of bilateral uncinate processes (arrows) (a), pneumatization of the crista galli (arrow head) (b), asymmetry of the height of the ethmoid roofs (arrows) (c)
CT: computed tomography

Concha bullosa is the pneumatization of the concha and is one of the most common variations of the sinonasal anatomy. A 14-53.6% frequency of concha bullosa was reported by various studies (9). Pneumatization is most commonly seen in the middle concha followed by the superior concha. Pneumatized inferior concha is rare, and most of the papers in the literature appear as case reports (10). Bolger et al. (11) have classified pneumatization of the concha based on the location as lamellar, bulbous and extensive concha bullosa. It usually occurs bilaterally, however the degree of pneumatization varies not only from patient to patient, but also from one side to the other side of a given patient.

If the pneumatization is extensive, a large concha bullosa may cause significant problems by its size alone, such as headaches with accompanying mucosal contact, and/or a marked nasal obstruction (12). In our study, we classified concha bullosa by their locations, did not classify by their sizes, types or sides. We found that the most common pneumatized concha was the middle one (57.2%), and the least common was the inferior one (1%). These findings were consistent with the literature (9-13).

Normally, the convexity of the middle concha is directed medially, toward the NS. When paradoxically curved, the convexity is directed laterally, toward the lateral sinus wall. A 26.1% prevalence of paradoxically curved middle concha has been reported. Although no studies relate this variation to sinus disease, it is a presumed etiologic factor because of the deformity and obstruction or alteration of nasal passage air flow dynamics, especially when associated with other variations (14). In our study, the incidence of middle paradoxial concha was 9%, lower than that of the literature.

ANC are considered the most anterior of all ethmoid cells and can pneumatize posteriorly to narrow the frontal recess. Coronal and sagittal reformatted CT images are most helpful in identifying the ANC (15). Various authors have published the prevalence of ANC from 10% to 98.5%, depending on the method of evaluation (16). In our study we found ANC in 18.3% of patients.

HC or the infraorbital ethmoid cells are the ethmoidal cells that develop into the floor of orbit (i.e. the roof of maxillary sinus) adjacent to and above the maxillary sinus ostium, and which if enlarged can significantly constrict the posterior aspect of the ethmoidal infundibulum and ostium of the maxillary sinus above. It is controversial that the HC are originate from anterior or the posterior ethmoid cells (1). The incidence of HC has been reported to vary from 2-45% (17). Our HC prevalence was 14.8%. It is clinically significant anatomic variation because it has implicated as a possible etiologic factor in recurrent maxillary sinusitis due to their negative influence on maxillary sinus ventilation by narrowing the infundibulum and ostium (1).

OC or sphenoethmoid air cell is a posterior ethmoid cell which pneumatized far laterally and to some degree superiorly to the sphenoid sinus and is intimately associated with the ON (1). The prevalence of Onodi cells on CT studies varies from 8% to 13%. The presence of an OC may possibly contribute to an increased in the risk of injury to the ON and to the ICA, because an unsuspecting surgeon may not expect the ON to be present in a posterior ethmoid cell rather than in the sphenoid sinus. Identification of the OC before surgery may be extremely valuable in decreasing the risk of such complication (18). In our study we found OC in 13.5% of patients.

SOEC are anterior ethmoid air cells that extend superiorly and laterally over the orbit from the frontal recess. These cells represent pneumatization of the orbital plate of the frontal bone posterior to the frontal recess and the frontal sinus. They typically drain into the lateral aspect of the frontal recess. Up to 15% of adults may have one or more SOEC, with approximately 5% of frontal sinuses having multiple SOEC (15). In our study we found SOEC in 9.4% of patients. SOEC can obstruct frontal sinus drainage; preoperative identification is essential because these cells can be readily mistaken for the frontal ostium during endoscopic dissection. SOEC may mimic the appearance of a septated frontal sinus or may give the appearance of multiple frontal sinuses (15).

In addition, there are several other named frontal recess cells, which include frontal cells, frontal bullar cells, suprabullar cells, and inter-frontal sinus septal cells (15). These cells were not investigated in this study.

The underdevelopment or aplasia of the paranasal sinuses is a rare phenomenon that refers mainly to the frontal (12%) and secondarily to the maxillary sinuses (5-6%). This occurs more frequently in syndromes of craniosynostosis, osteodysplasia (Melnick-Needles), as well as in cases of Down's syndrome (hypoplasia of the frontal sinus). Aplasia of the sphenoid sinuses is an extremely rare phenomenon. The diagnosis of sphenoid sinus hypoplasia is potentially important in patients in whom trans-sphenoidal hypophysectomy is contemplated. Maxillary sinus hypoplasia is an uncommon condition that may be misdiagnosed as chronic sinusitis. Maxillary sinus hypoplasia predisposes to orbital penetration during endoscopic sinus surgery; therefore this bony abnormality must be recognized as well as associated anatomic variations, especially prior to sinus surgery (19). Maxillary sinus aplasia is a very rare congenital anomaly. Only a few cases have been reported in the English literature (20). In our study hypoplasia of frontal, maxillary and sphenoid sinuses were found in 12.5, 2.4, 0.9% of patients, respectively. Aplasia of frontal, maxillary and sphenoid sinuses were encountered in 1.7, 0.05, 0.5% of patients, respectively.

On coronal CT, the UP is easily detected as a superior extension of the medial maxillary sinus wall, forming the lateral wall of the middle meatus. The exact mechanism by which uncinate pneumatization occurs is not known. It has been proposed that this process is due to growth of ANC into the most anterosuperior region of the UP. Studies reveal a prevalence of 0.4-2.5%. This variation has been implicated in narrowing of the infundibulum, producing impaired sinus ventilation (14). In our study we found pneumatized UP in 7% of patients, higher than that of the literature.

The CG sits in the midline above the cribriform plate. Embryologically, CG is derived from the ethmoid bone, and as such, it would seem reasonable that any eventual pneumatization of the CG would come from the ethmoid complex. Because sinus pneumatization is known to cross from one bone to another and with the recent observation that most frontal sinus interseptal cells (immediately adjacent to the crista galli) come from the frontal sinuses and not from the ethmoid complex as previously thought, the possibility exists that pneumatization of the crista galli could also come primarily from the adjacent frontal sinuses (21). The incidence of pneumatized CG was reported to be 2.4 and 13% by Basic (22) and Som et al. (21), respectively. In our study we found pneumatized CG in 9.4% of patients. As we aimed to detect the presence of pneumatized crista galli; the extension or origin of the pneumatization were not the subject in the present study.

The level of the fovea ethmoidalis is determined relative to the cribriform plate, and is a function of both the vertical length of the lateral lamella (height) and the angle at which it articulates with the cribriform plate (contour) (23). We considered the height of the fovea to be asymmetric if the CT scan demonstrated a difference in the vertical dimension of the lateral lamella. The incidence of asymmetry of the ER was found to be 9.5% and 10% by Lebowitz (23) and Dessi et al. (24), respectively. In our study, we found asymmetry of the ER in 8% of patients, slightly lower than other studies.

The sphenoid sinus and adjacent bony structures may show various degrees of pneumatization (25). Considerable variations including cavernous sinus, ICA, optic and vidian canals are intimately related to sphenoid sinuses. When the ACP is pneumatized, the ON protrudes against the superior lateral sinus wall. Optic canal is the place where the optic nerve is the least nourished throughout its course; therefore, it is very susceptible to injury through direct inflammatory invasion of the sinus diseases and additionally, there is a risk of blindness if the surgeon damages the nerve within the sinus. In the literature, pneumatization of the ACP, protrusion and dehiscence of the ON were noted as between 6-17%, 8-70% and 4-12%, respectively (26). We found ACP pneumatization in 20% of the patients, higher than that of the literature. In contrast, protrusion and dehiscence of the ON was detected in 5.5% and 1.5% of the patients, respectively. The reported prevelance of PCP pneumatization in a previous study was 1% by Lu et al. (27). We found a higher frequency of PCP pneumatization (2.5%).

The percentage of protrusion and dehiscence of ICA were noted as 7-82% and 4-25% in the literature, respectively (26). In our study, we found protrusion and dehiscence of ICA in 3% and 0.5% of patients, respectively, both of them were lower than that of the literature. A dehiscence in the bone covering the artery may lead to direct contact of the artery with sinus mucosa which may lead infection occuring within the cavernous sinuses (26). On the other hand, if the surgeon is not aware of such variation, operation may result in blindness or even fatal hemorrhage as in the case of carotid artery laceration. In the literature, pneumatization of the PP was reported as between 25-57% (26). Similarly, we found PP pneumatization in 35% of the patients. When pneumatization expands into the plates, the floor of the sinus shows a definite ridge that corresponds to the vidian canal. The reported prevelance of VN protrusion and dehiscence were as 7.5-37.5% and 7.1-10%, respectively (26, 28). In our study, we found protrusion of VN in 20.3% of patients, consistent with other studies, and dehiscence of VN in 1% of patients, lower than that of literature. In the literature, protrusion and dehiscence of MN were reported as 12.7-30.3% and 3.5-4%, respectively (26, 28). In our study, we detected protrusion and dehiscence of MN in 4.8% and 0.4% of patients, respectively, both of them were lower than that of the literature.

There were some limitations in our study. First, our images were obtained with one CT scanner at a single hospital with one ethnic group. Second, we did not compare the CT images with the findings gained from FESS. Third, we could not discuss other rare variations due to the study design.

Conclusion

Multidetector computerized tomography is the modality of choice to evaluate the patients for paranasal sinus disease. There are several anatomic variations in paranasal sinus region which radiologists should know. Guiding the surgeons in the preoperative period is essential to avoid potential iatrogenic complications.

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Informed Consent: Written informed consent was obtained from patients who participated in this study.

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Hasta Onamı: Yazılı hasta onamı bu çalışmaya katılan hastalardan alınmıştır.

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