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ORIGINAL ARTICLE

Retrospective Study

Evaluation of variations in sinonasal region with computed tomography

Ufuk Dasar, Erkan Gokce

Ufuk Dasar, Erkan Gokce, Department of Radiology, School of Medicine, Gaziosmanpaşa University, 60100 Tokat, Turkey

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Correspondence to: Erkan Gokce, MD, Associate Professor, Department of Radiology, School of Medicine, Gaziosmanpaşa University, Kaleardi Quarter, Muhittin Fisunoglu Street, 60100 Tokat, Turkey. erkangokce@mynet.com
Telephone: +90-542-3798986
Fax: +90-362-2309105

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Abstract

AIM: To investigate the frequency of anatomical variations in sinonasal region and association of these variations with mucosal diseases.

METHODS: The study included 400 cases (191 female and 209 male) who were considered to have preliminary diagnoses of sinonasal pathology and who had paranasal sinus computed tomography (CT) examination in axial plane. Reformatted CT images were studied in all planes.

RESULTS: Age range of the patients was 20-83 (mean 40.26 ± 14.85). Most commonly detected anatomical variation was Agger nasi cell (74.8%). There was a significant association between clinoid process pneumatization and protrusion of internal carotid arteries and optic nerves into sphenoid sinus (*P* < 0.001). Besides, the relationships between pterygoid process pneumatization and protrusion of vidian nerve into sphenoid sinus, and between pneumatization of large sphenoid wing and protrusion of maxillary nerves into sphenoid sinus were also significant (*P* < 0.001). Uncinate bulla and giant ethmoid bulla were found to be significantly associated with sinonasal mucosal diseases (*P* = 0.004 and *P* = 0.002, respectively).

CONCLUSION: Sinonasal region has a great number of variations, and some of them have been determined to be associated with sinonasal mucosal disease. It is necessary to know that some of these variations are associated with protrusion of significant structures such as carotid artery or optic nerve into the sinus and care should be observed in surgeries on patients carrying these variations.

Key words: Anatomical variations; Paranasal sinuses; Computed tomography; Sinonasal region; Agger nasi cell

Core tip: Currently paranasal sinus computed tomography is routinely used to detect anatomy and pathologies of nasal cavity and paranasal sinuses. Sinonasal region has a great number of variations, and some of them have been determined to be associated with sinonasal mucosal disease. It is necessary to know that some of these variations are associated with protrusion of significant structures such as carotid artery, optic nerve, vidian nerve and maxillary nerve into the sphenoid sinus and care should be observed in surgeries on patients carrying these variations.

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INTRODUCTION

Currently endoscopic nasal examination and paranasal sinus computed tomography (CT) are routinely used to detect anatomy and pathologies of nasal cavity and paranasal sinuses. Anatomical variations in paranasal sinuses, which are significant in existing soft tissue pathologies and for surgery, can also be detected through CT, their possible association with the pathology can be evaluated, and thus an operational plan is developed. While some of the anatomical variations such as concha bullosa, big Agger nasi cell, pneumatized uncinate process (UP), haller cell, septum deviation could play roles in the etiology of the disease, others such as Onodi cell, optic nerve (ON) and proximity of internal carotid artery (ICA) to sphenoid sinus are important for determination of limits during functional endoscopic sinus surgery (FESS)[1].

Aim of the present study was to investigate the frequency of variations in sinonasal region and to reveal the association of these variations with neighboring anatomical structures and mucosal diseases.

MATERIALS AND METHODS

The present study included a total of 400 patients older than 20 years of age (209 male and 191 female) who were examined using sinus CT at Radiology Department of Gaziosmanpaşa University, Faculty of Medicine during the period from 2010 to 2015. After taking the approval of local ethic committee (No. 14-KAEK-100), CT scanning images of the patients in Picture Archiving and Communication System (PACS, GE) were studied retrospectively. Anatomical variations of sinonasal cavity and their associations with mucosal diseases were investigated using CT examinations. The patients who had massive nasal polyposis, previous sinonasal surgical operation, sinonasal malignancies, serious sinonasal congenital variations and who were younger than 20 years of age were excluded.

All CT examinations were performed at eight-slice multi-detector CT scanners (LightSpeed Ultra; GE, Milwaukee, United States). CT examinations were taken in 1.25 mm thick axial plane while the patient was on supin position giving gantry an angle parallel to hard palate. Coronal and sagittal reformats were made over these images. Anatomical variations were evaluated in both bone (window width: 2000 HU, window level: 350 HU) and soft tissue (window width: 200 HU, window level: 40 HU) frames in CT slices.

A case was considered positive when at least one of the following anatomical variations evaluated was present: Nasal septal deviation, nasal septal spur, nasal septal pneumatization, concha bullosa (CB), paradoxical middle turbinate, secondary middle turbinate, pneumatized superior turbinate, pneumatized inferior turbinate, paradoxical lower concha, curved UP, atelectatic UP, pneumatized UP, lamina papyracea dehiscence, Agger nasi cell, Haller cell, giant ethmoid bulla, Kuhn cells, Supraorbital ethmoidal cell, frontal bullar cell, frontal intersinus septal cell, onodi cell, ethmomaxillary sinüs, maxillary sinus hypoplasia, septated maxillary sinus, accessory ostium, frontal sinus aplasia, frontal sinus hypoplasia, crista galli pneumatization, sphenoid sinus agenesis, sphenoid sinus hypoplasia, anterior clinoid process pneumatization (ACPP), ON protrusion into sphenoid sinus, ICA dehiscence, ICA protrusion into sphenoid sinus, septum related to ICA, vidian nerve (VN) protrusion into sphenoid sinus, pterygoid process pneumatization (PPP), greater sphenoid wing pneumatization (GSWP) and maxillary nerve (MN) protrusion into sphenoid sinus.

Nasal septum's deviation to any direction was evaluated in favor of septal deviation. Cells located on Agger nasi cells were classified considering their numbers and locations based on Kuhn cell classification. Maxillary sinus inferior wall over maxillary alveolar arch was considered in favor of maxillary sinus hypoplasia.

Any level of pneumatization of UP, frontal intersinus septum, nasal septum, crista galli and anterior clinoid process were evaluated in favor of pneumatization. When the pneumatization was below the imaginary line joining VN and MN, it was considered PPP, but it was considered GSWP when the imaginary line extended to VN lateral. Lack of a bone cover over ICA was considered as ICA dehiscence. Any level of indentation of ON, ICA, MN and VN into sphenoid sinus was considered in favor of protrusion. CB was considered extensive when the whole segment was pneumatized, inferior bullosa when the lower part was pneumatized, and lamellar CB when the vertical plate was pneumatized. Presence of one or all of pathological mucosal thickening, retention cyst and secretory fluid was taken the criteria for sinonasal mucosal disease evaluation.

Statistical analysis

The statistics were reviewed and analyzed by a bio-

Table 1 All anatomical variations, frequency and significance of the relations with mucosal diseases

Anatomical variations	NO. (n = 400)	Frequency (%)	P value
Deviated nasal septum	238	59.5	0.318
Nasal septal spur	169	42.3	0.248
Nasal septum pneumatization	8	2	0.150
Concha bullosa	270	67.5	0.910
Paradoxical middle turbinate	63	15.8	0.821
Secondary middle turbinate	4	1	0.999
Superior concha bullosa	52	13	0.950
Inferior concha bullosa	7	1.8	0.461
Paradoxical inferior turbinate	10	2.5	0.760
Curved uncinate process	5	1.3	0.381
Atelectatic uncinate process	2	0.5	0.999
Uncinate process pneumatization	55	13.8	0.004
Lamina papyracea dehiscence	1	0.3	-
Agger nasi cell	299	74.8	0.962
Haller cell	31	7.8	0.167
Giant ethmoid bulla	25	6.3	0.002
Fronto-ethmoidal (Kuhn) cell	274	57.7	0.171
Supraorbital ethmoidal cell	36	9	0.298
Frontal bulla cell	98	24.5	0.846
Frontal intersinus septal cell	14	3.5	0.298
Onodi cell	101	25.3	0.610
Ethmomaxillary sinüs	11	2.8	0.744
Maksiller sinüs hipoplazisi	32	8	0.959
Septalı maksiller sinüs	21	5.3	0.999
Accessory maxillary ostium	87	21.8	0.575
Frontal sinus agenesis	29	7.2	0.918
Frontal sinus hypoplasia	87	21.8	0.206
Crista galli pneumatization	13	3.3	0.245
Sphenoid sinus agenesis	10	2.5	0.523
Sphenoid sinus hypoplasia	58	14.5	0.879
Anterior clinoid process pneumatization	102	25.5	0.399
Protrusion of the optic nerve into sphenoid sinus	141	35.3	0.472
Protrusion of internal carotid artery	184	46	-
Dehiscence of internal carotid artery	8	2	-
Septum related to the internal carotid artery	52	13	-
Pterygoid process pneumatization	207	51.7	0.457
Protrusion of the vidian nerve into sphenoid sinus	222	55.5	-
Greater wing of the sphenoid pneumatization	73	18.2	0.161
Protrusion of the maxillary nerve into sphenoid sinus	99	24.7	-

statistician. Descriptive analyses were made to gain information about general features of working groups. Data regarding continuous variable were given as mean (±) standard deviation but data regarding categorical variables were given as n (%). To evaluate the correlations between variables, cross-tabs 2 and χ^2 tests were used. P values lower than 0.05 were considered significant. Statistical software was used in statistical analyses (IBM SPSS Statistics 19, SPSS Inc., IBM Co., Somers, NY).

RESULTS

The age of the patients in the study ranged from 20 to 88 (mean 40.26 ± 14.85). Sinonasal variation was found in 399 (99.8%) of cases. The most common anatomical variation was Agger nasi (74.8%), while sinonasal mucosal disease was observed in 29.25% of the patients. All observed variations, their frequencies and significance of the relations between them and mucosal diseases were given in Table 1. Different sinonasal variation images were given in Figures 1-4.

Maxillary sinus aplasia, inferior turbinate agenesis and bifid inferior turbinate variations were not observed in the present study.

CB variation was found to be bilateral in 60% of cases and unilateral in 40% of cases. CB types and their frequencies were given in Table 2.

Septal spur was observed in 58.8% of 238 patients having septum deviation and significant association was found between two variables (P < 0.001). UP was asymmetrical in 10.5% of all cases, and type 2 was the most common type in both sides. UP attachment types on both sides and their frequencies were indicated in Table 3.

Fronto-ethmoidal (Kuhn) cell was detected in 57.7% of the patients and 37.6% of them were bilateral (Figure 5). Types and frequencies of Kuhn cells were given in Table 4.

ACPP was observed in 25.5% of the patients, and a significant correlation was found between ACPP and ICA's protrusion to sphenoid sinus (P < 0.001). Frequencies of

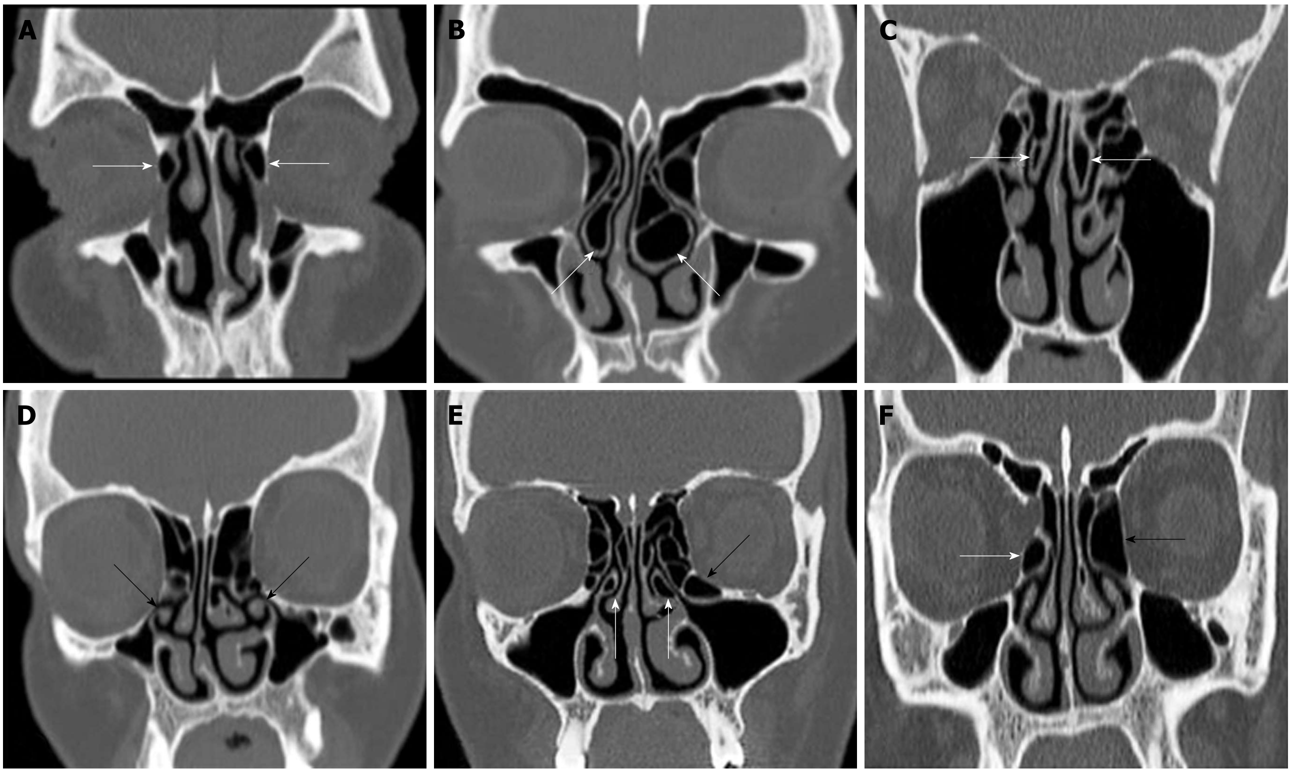

Figure 1 Coronal reformatted computerized tomography images shows different variations. A: Bilaterally Agger nasi cells (arrow); B: Bilaterally extensive concha bullosa (arrows); C: Bilaterally pneumatized superior turbinates (arrows); D: Bilaterally curved uncinate process (black arrows); E: Bilaterally uncinate bulla (white arrows) and left Haller cells (black arrow); F: Left giant bulla ethmoidalis (black arrow) and right bulla ethmoidalis (white arrow).

Table 2 Concha bullosa types and frequencies

Type	NO. (n = 431)	Frequency (%)
Right vertical lamellar	102	23.6
Right inferior bulbous	29	6.7
Right extensive	90	20.8
Left vertical lamellar	104	24.1
Left inferior bulbous	25	5.8
Left extensive	81	18.7

Table 3 Uncinate process binding types and frequencies

	Type	No. of patients (n = 400)	Frequency (%)
Right uncinate process	Type 1	83	20.8
	Type 2	257	64.3
	Type 3	60	15
Left uncinate process	Type 1	88	22
	Type 2	251	62.8
	Type 3	61	15.3

ACPP and ICA protrusion were given in Table 5.

When the association between ACPP and the protrusion of ON into sphenoid sinus was examined, 31 cases with ACPP on the right had ON protrusion on the right, 26 cases with ACPP on the left had ON protrusion on the left, and all 45 cases with bilateral ACPP had bilateral ON protrusion (Figure 6). Consequently, there was significant association between the two variables (P < 0.001). In terms of the relation between PPP and VN protrusion, all 44 cases with PPP on the right had VN protrusion on the right, 98.1% of 54 cases with PPP on the left had VN protrusion on the left, and all 96.3% of 109 cases with bilateral PPP had bilateral VN protrusion. As a result, association between PPP and VN was significant (P < 0.001). In terms of the association between GSWP and MN protrusion, 35% of 20 cases with GSWP on the right had MN protrusion on the right, 69.6% of 33 cases with GSWP on the left had MN protrusion on the left, and 60% of 20 cases with bilateral GSWP had bilateral MN protrusion, and the association between the two variables was significant (P < 0.001) (Figure 7).

Table 4 Fronto-ethmoid (Kuhn) cells types and frequencies

Type	n	Frequency (%)
Type 1	119	43.4
Type 2	80	29.2
Type 3	66	24.1
Type 4	9	3.3
Total	274	100

DISCUSSION

Sinonasal region is one of the regions of the body in which most anatomical variations are seen. An understanding of the variations, their pathologies and relations in this region is necessary for accurate diagnosis and

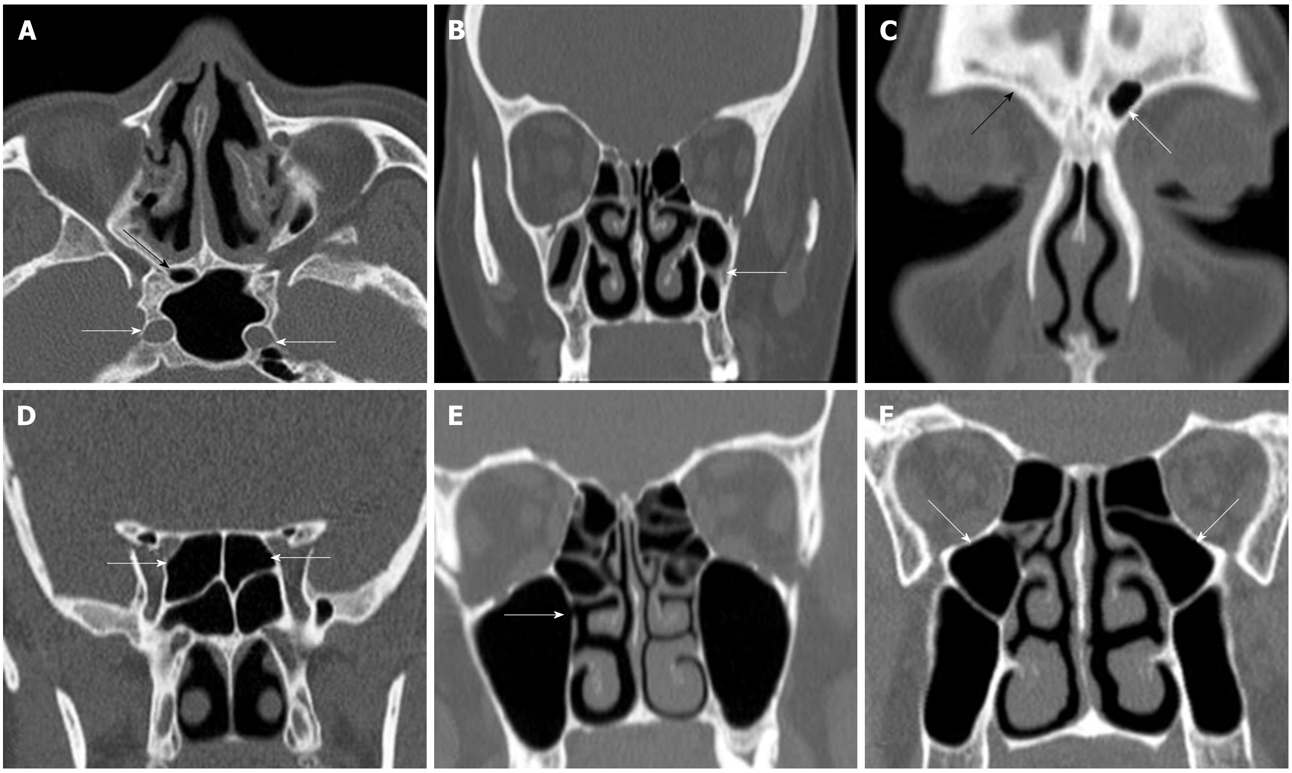

Figure 2 Axial plane (A), coronal reformatted (B-F) computerized tomography images shows different variations. A: Right sphenoid sinus hypoplasia (black arrow) and bilaterally internal carotid artery protrusion into left sphenoid sinus; B: Bilaterally maxillary sinus hypoplasia and left intersinus septa (white arrow); C: Right frontal sinus aplasia (black arrow) and left frontal sinus hypoplasia (white arrow); D: Bilaterally Onodi cells (white arrows); E: Right maxillary sinus accessory ostium (white arrow); F: Bilaterally ethmomaxillary sinus.

Table 5 Anterior clinoid process pneumatization and internal carotid artery protrusion frequencies *n* (%)

Anterior clinoid process pneumatization	Internal carotid artery protrusion				
	None	Right	Left	Bilateral	Total
None	188 (63.1)	15 (5)	23 (7.7)	72 (24.2)	298 (100)
Right	11 (35.5)	4 (12.9)	3 (9.7)	13 (41.9)	31 (100)
Left	8 (30.8)	3 (11.5)	5 (19.2)	10 (38.5)	26 (100)
Bilateral	9 (20)	5 (11.1)	3 (6.7)	28 (62.2)	45 (100)
Total	216 (54)	27 (6.8)	34 (8.5)	123 (30.8)	400 (100)

treatment. Due to the variations in sinonasal region, sinus ostiums or meatus can be narrowed or obliterated. In these situations, patients are considered to have tendency for especially mucosal diseases of sinonasal region. Anatomical variation rate in sinonasal region was reported to vary from 64.0% to 98.5%[2,3]. In the present study, on the other hand, anatomical variation rate of 99.8% was higher than the reported ones in the literature. Such different anatomical variation rates could be due to the differences in anatomical variation classification and population differences.

Agger nasi cell is a structure located in lateral nasal wall in front of or over a place where middle turbinate is situated. It is generally located bilaterally, and it narrows the frontal recess depending upon its pneumatization level. Its morbidity has been reported to vary widely from 3.0% to 98.5%[2,4-6]. Agger nasi was the most common variation in our study with a frequency rate of 74.8%, which was in accordance with studies reporting higher frequencies. Many studies reported that when its size is large, Agger nasi could narrow the drainage way of frontal sinus and impair its drainage[7,8]. There are also some studies which reported no association between frontal sinus infection and Agger nasi cell[9]. No significant relationship was determined between Agger nasi cell and sinonasal mucosal disease in the present study.

One of the most common variations of sinonasal region is septum deviation, referring to opening of nasal septum to left or right. Prevalence of nasal septum deviation has been reported to vary from 20% to 79%[10,11]. In the present study, a moderate frequency of 59.5% was observed for septum deviation. There are studies[12,13], reporting that nasal septum deviation could lead to infection of all sinuses through contacting with hypertrophic or bullous concha, narrowing meatus or impairing normal mucociliary activity and mucus drainage, while there are many other studies[14-16] mentioning lack of any association between septum deviation and

Figure 3 Coronal reformatted computerized tomography images shows different variations. A: Pneumatized nasal septum (arrow); B: Left paradoxical middle turbinate (arrow) and deviated nasal septum; C: Bilaterally paradoxical middle turbinates (arrows) and right vertical lamellar concha bullosa (arrow head); D: Bilaterally secondary middle turbinate (white arrows) and bilaterally Haller cells (black arrows); E: Right pneumatized inferior turbinate; F: Bilaterally inferior bulbous concha bullosa (white arrows) and bilaterally Haller cells (black arrows).

sinus infection. No significant association was found between septum deviation and sinonasal mucosal disease in the present study. Septal spur has been mentioned to have frequencies of up to 78%[3]. Frequency of septal spur was 42.3% in the present study. It was reported that 34% of the cases with Earwacker septal deviation had septal spur[3]. In the present study, 58.8% of the cases with septal deviation were found to have septal spur. When septum deviation and septal spur coexist, narrowing in nasal passage can increase and secondary to this, difficulties could be experienced in endoscopic examination and FESS. About half of the patients with septal spur had sinonasal mucosal disease, but no significant association was found between septal spur and sinonasal mucosal disease.

CB, one of the common variations of paranasal region, is defined as partial or fully pneumatization of middle turbinate which normally is void of pneumatization and is generally observed as bilaterally[17,18]. As the pneumatization level in concha increases, severity of the disease symptoms also increases. In bulbous and extensive types, it could lead to edema in middle meatus, obstruct normal air flux and create disease tendency *via* changing mucus drainage ways. On the other hand, no symptom is seen in lamellar type[9,19]. In the present study, on the other hand, 54.4% of the cases with CB were found to have sinonasal mucosal disease. However, there was no significant association between CB and sinonasal mucosal disease. Morbidity of CB has been reported to vary between 17.0% to 67.5%[2,6,16,20-22]. Frequency of CB was 67.5% in the present study and this value is in accordance with the higher morbidity rates reported in the literature. Different CB subtypes of lamellar, bullous and extensive were reported to have morbidities of 42.3%, 27.0% and 30.7%, respectively[6]. Similar morbidity rates of 47.7%, 12.5% and 39.5% were found in the present study.

Paradoxical middle turbinate is the condition in which convexity of middle turbinate is towards the lateral[23]. Its morbidity has been reported to vary between 3% to 32%[24-27]. Frequency of paradoxical middle turbinate was 15.8% and this frequency was similar to ones reported in the literature. Paradoxical middle turbinate has been reported to lead to recurrent infindibular disease and sometimes headache[28]. In the present study, however, no significant association was found between paradoxical middle turbinate and sinonasal disease.

Secondary middle turbinate is a rare variation. It originates between lateral nasal wall and middle meatus, and is an accessory turbinate observed between superior and middle turbinate. It could be falsely evaluated as osteoma or polyp in endoscopic examination[29]. Its morbidity has been reported to vary from 1.5% to 2.5%[7,29]. Secondary middle turbinate frequency was 1% in our study, which was similar to the lower morbidity reports. No significant association was found between secondary middle turbinate and sinonasal mucosal

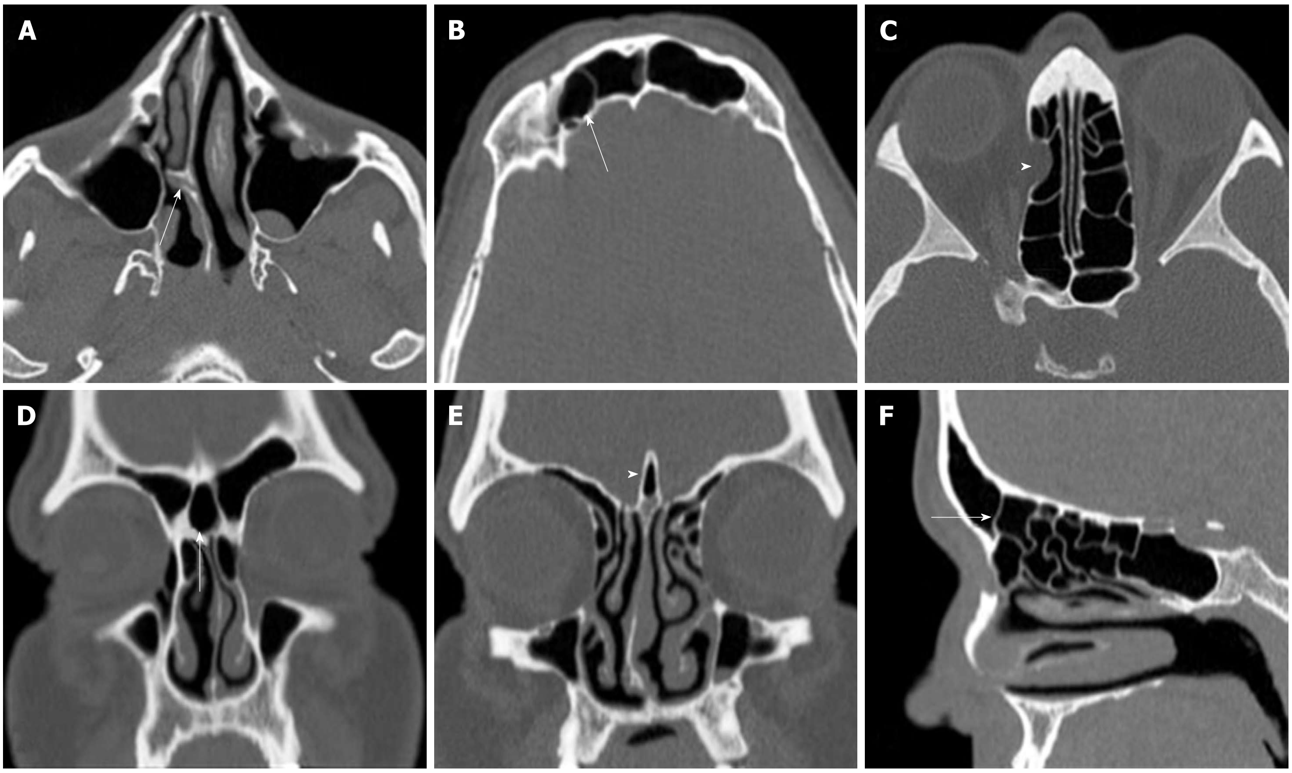

Figure 4 Axial plane (A-C), coronal reformatted (D and E), sagittal reformatted (F) computerized tomography images shows different variations. A: Nasal septal spur (arrow) and deviated septum; B: Right supraorbital ethmoidal cell (arrow); C: Right lamina papyracea dehiscence (arrow head); D: Frontal intersinus septal cell (arrow); E: Crista galli pneumatization (arrow head) and deviated nasal septum; F: Frontal bulla cell (arrow).

diseases in the present study.

It has been reported that hypertrophy of superior turbinate or superior CB could lead to headache and lower sense of smelling[9]. It has been also reported that larger superior turbinate or superior CB could lead to headache and nasal obstruction together with mucosal contact without sinonasal infection, and in patients without sinonasal infection, nasal endoscopy is recommended to determine the reason of complaints due to mucosal contact[7]. Al-Qudah reported a frequency of 17% for superior CB[9]. Superior CB frequency was found to be 13% in the present study, which was slightly lower compared to literature, and no association was detected between superior CB and mucosal disease.

UP is a significant anatomical determinant for the surgeon during the operation. During FESS, the first procedure to display maxillary sinus is generally uncinectomy[27,30]. Pneumatization of UP (uncinate bulla) could lead to osteomeatal unit obstruction and recurrent sinusitis through impairing the drainage of sinuses along with infundibulum as a result of the mucosal contact with neighboring ethmoid bulla or middle turbinate. Various studies in the literature reported morbidity rates of 0.4%-6.0% for uncinate bulla[2,3,31]. Frequency of uncinate bulla in the present study was 13.8%. A significant association was found between uncinate bulla and sinonasal mucosal disease (P = 0.004).

Impact of Haller cells, front ethmoid cells extending towards maxillary ostium in superior or medial part of orbita base, on sinusitis is still debated in the literature. Although their existence was found higher in patients with sinusitis, no significant association was found between Haller cells and sinus infection[8,9,15,32]. Frequency of Haller cells was reported to be 2.5%-45.9%[8,9,15,32]. In the present study, Haller cell frequency was 7.8%, which was among the lower levels reported in the literature. Presence of Haller cells was not significantly associated with mucosal disease.

Cells superior to Agger nasi are called fronto-ethmoidal (Kuhn) cells. They can enter towards frontal recess and affect sinus drainage[33]. Meyer *et al*[34] reported a frequency of 20.4% for fronto-ethmoidal cells. Meyer *et al*[34] reported that the most common type observed was type 1. On the other hand, frequencies of types 1, 2, 3 and 4 were reported to be 20.0%, 48.8%, 14.1% and 1.3%, respectively, by Lee *et al*[35]. Similar to the literature, frequency of fronto-ethmoidal cell appearance was 57.7%, and the most common type was type 1 (43.4%) in the present study. No significant association was found between fronto-ethmoidal cells and mucosal disease.

Hyperpneumatized ethmoid bulla is excessive pneumatization of ethmoid bulla, the largest and least varying cell of frontal ethmoid cells. Hyperpneumatized ethmoid bulla is located between middle concha and UP, and could displace UP towards medial[36,37]. Lloyd[25] reported a frequency of 35% for ethmoid bulla. In the present study, frequency of ethmoid bulla was 6.3% and it was significantly associated with mucosal disease (P = 0.002).

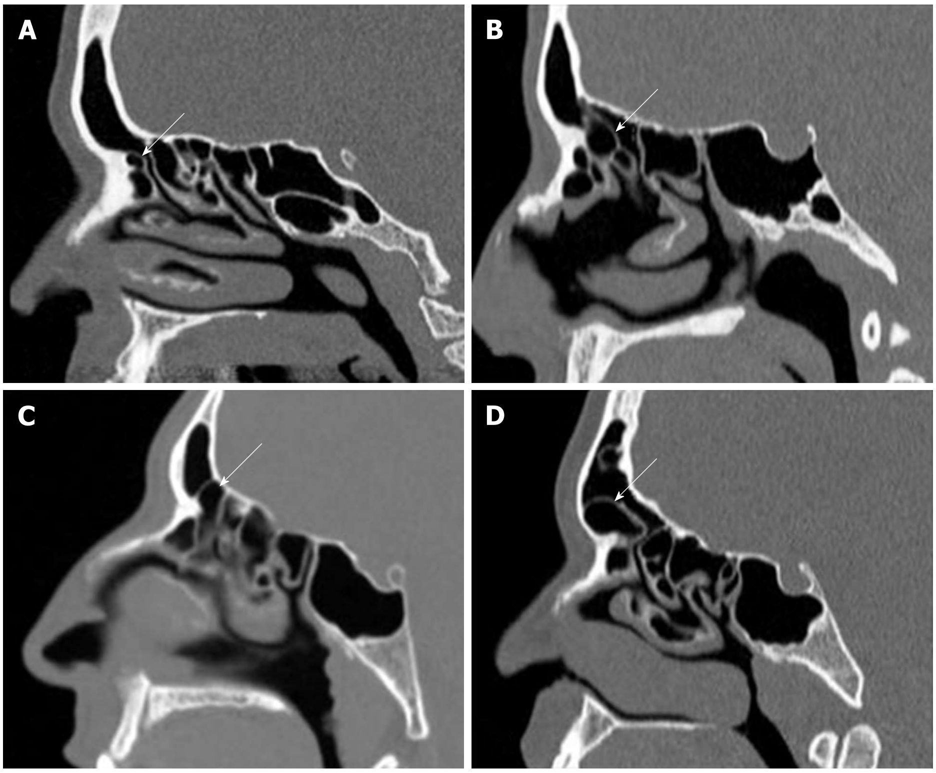

Figure 5 Sagittal reformatted computerized tomography images shows fronto-ethmoidal cells (Kuhn cells). A: Type 1; B: Type 2; C: Type 3; D: Type 4.

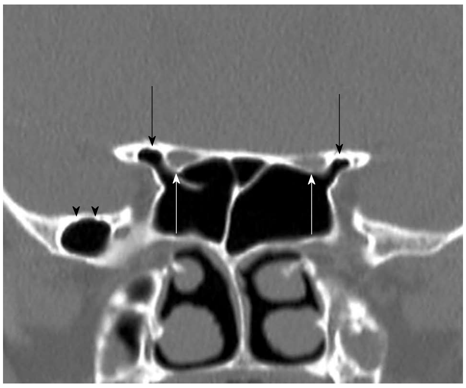

Figure 6 Coronal reformatted computed tomography image shows bilaterally anterior clinoid process pneumatization (black arrows) and optic nerves protrusion (white arrows) into sphenoid sinuses. Additionally shows right greater sphenoid wing pnematization (black arrow heads).

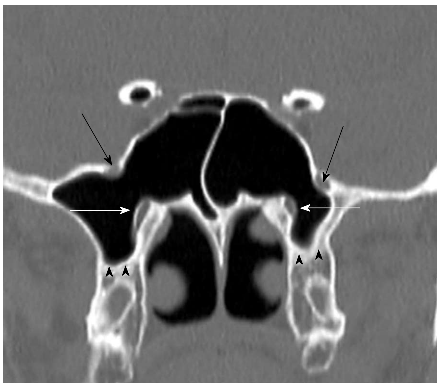

Figure 7 Coronal reformatted computerized tomography image shows bilaterally maxillary nerves (black arrows) and vidian nerves (white arows) protrusion into sphenoid sinus. Additionally shows bilaterally pterygoid process pnematization (black arrow heads).

Apart from ON damage during the surgery, infections in Onodi cell could also press on ON and lead to retro orbital pain[38]. Onodi cell frequency was reported to be 1.4%-96.0%[3,6,39-41]. Frequency of Onodi cell was 25.3% in the present study and this was within the limits reported in previous investigations.

Knowing the presence of serious maxillary sinus hypoplasia and accompanying hypoplasic UP before FESS would lower orbital penetration risk during surgery[42]. Bolger *et al*[42] reported a maxillary sinus hypoplasia incidence of 10.4%. Maxillary sinus hypoplasia incidence was 8.0% in the present study, and 46.9% of them were unilateral and 53.1% were bilateral.

In FESS and transsphenoidal approaches to sphenoid sinus and hypophysis gland pathologies, damages could occur in nerves and veins protruding into sphenoid sinus. Hemorrhages that could lead to high mortality and morbidities can arise in ICA injuries, blindness can develop in ON injuries, and sense defects can occur in MN injuries[7,43,44]. Beale *et al*[30] reported that trigeminal neuralgia can develop in sphenoid sinus pathologies in patients with MN protrusion. It has been determined that as the pneumatization of sphenoid sinus increases, vein and nerve structures next to sinus stay inside the sinus. When this enlargement continues to anterior clinoid processes, injury risk for ON arises during the surgery.

In a region where anatomy has such a high level of variability, it is extremely important to have preliminary information about the variations before the surgery[45]. ACPP incidence was reported to be 0.5%-29.3%[6,41,43,44]. Similarly, an incidence rate of 25.5% was found for ACPP in the present study. ON protrusion into sphenoid sinus has been reported to be 31.5%-35.6%[43,44]. This value was 35.3% in the present study. There was a significant association between ACPP and ON protrusion into sphenoid sinus (P < 0.001).

ICA could result in significant complications during FESS either by protruding into sphenoid sinus, or by lack of bone cover over it (ICA dehiscence), or by depending upon its association with septas in sphenoid sinus. For the elimination of these complications, it is necessary to know sphenoid sinus anatomy well and to specify these variations. Incidence of ICA protrusion into sphenoid sinus was reported to vary widely between 10.5% and 93.0%[8,44,46,47]. ICA dehiscence morbidity was reported to be in the range of 2%-25%[39,48-50]. These frequencies were found to be 46.0% and 2.0% in the present study, respectively, and these results were in accordance with the ones reported earlier. Septum-related ICA frequency was mentioned to be 5.4%[43]. We found a similar rate of 13.0% in the present study.

Reported incidence of PPP in the literature is 15.5%-43.6%[2,43,44,50]. Slightly higher incidence rates of 51.7% for PPP were observed in the present study. There are studies reporting significant associations between PPP and foramen rotundum or VN protrusion[44]. VN protrusion frequency was reported to vary from 18% to 27%[44,51]. A quite higher incidence rate of 96.3%-100% was observed for VN protrusion in patients with unilateral or bilateral PPP in the present study. In addition, there was a very significant association between PPP and VN protrusion (P < 0.001).

GSWP frequency was reported to vary from 10.7% to 20.0%[3,44]. Incidence of MN protrusion into sphenoid sinus was mentioned to be 24.3%[44]. In the present study, on the other hand, GSWP frequency was 18.3% and frequency of MN protrusion into sphenoid sinus was 24.8%, and these results were in accordance with the previously reported ones. Besides, in our cases with GSWP, frequency of unilateral or bilateral MN protrusion into sphenoid sinus was 35.0% on the right, 69.9% on the left and 60.0% on bilateral position. There was a very significant association between the two variables (P < 0.001).

In conclusion, sinonasal region carries a great number and different kinds of variations, some of which were determined to be associated with sinonasal disease. It is necessary to know that protrusion of significant structures such as carotid artery and ON could be involved in some variations and to be extremely careful in the surgery on patients who have these kinds of variations. Therefore, radiologists should evaluate CT images obtained at axial plane along with other planes, and should report the anatomical variations ant their interrelationships in detail.

COMMENTS

Background

Sinonasal region has many variations, some of which could be associated with mucosal disorders. In order to prevent possible complications in surgical interventions involving sinonasal region, associations between these variations and various vital neighboring structures should be known. Computed tomography (CT) is a useful radiological imaging technique used to evaluate anatomic structures, variations and mucosal disorders of sinonasal region. In this study, we used CT to evaluate the frequency of variations in sinonasal region and to reveal the association of these variations with neighboring anatomical structures and mucosal diseases.

Research frontiers

Adjacent to sphenoid sinus are vital vascular structures such as internal carotid artery and nerves of significant functions such as optic nerve (ON), maxillary nerve and vidian nerve. There could be associations between the protrusion of these structures into sphenoid sinus and variations such as clinoid process pneumatization, pterygoid process pneumatization (PPP), greater sphenoid wing pneumatization (GSWP). In addition, there could also be associations between some sinonasal variations and sinonasal mucosal diseases.

Innovations and breakthroughs

In this study, sinonasal variation was found in almost all patients (99.8%). There was a significant association between clinoid process pneumatization and protrusion of internal carotid arteries and ONs into sphenoid sinus (P < 0.001). Besides, the relationships between PPP and protrusion of vidian nerve into sphenoid sinus, and between GSWP and protrusion of maxillary nerves into sphenoid sinus were also significant (P < 0.001). Uncinate bulla and giant ethmoid bulla were found to be significantly associated with sinonasal mucosal diseases (P = 0.004 and P = 0.002, respectively).

Applications

The present study showed that CT examination consisting of unprocessed CT images obtained at axial plane and coronal and sagittal reformat images is beneficial in detection of variations in sinonasal region and evaluation of associations between these variations and significant structures, and that sinonasal region should be evaluated by CT before surgical intervention.

Terminology

Sinonasal variation: It is a situation in which one or a few of the paranasal sinus and nasal cavity structures developed insufficiently or overly, or did not develop at all, or in which extra structures existed in these areas; functional endoscopic sinus surgery: It is a functional surgical procedure for sinuses using nasal endoscope to restore impaired nasal cavity ventilation and drainage of paranasal sinuses which are secondary to pathologies of sinonasal region.

Peer-review

It is a well designed and written study.

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