Original Article

Role of Anatomic Variations of Paranasal Sinuses on the Prevalence of Sinusitis: Computed Tomography Findings of 350 Patients

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ABSTRACT

Objective: The aim of this study was to determine the frequency of anatomic variations of the paranasal sinuses and their roles in the development of sinusitis. **Materials and Methods:** Computed tomography of paranasal sinuses of 350 patients was assessed in terms of anatomic variations and inflammatory sinus pathology. The coexistence of anatomic variations with sinusitis was statistically investigated.**Results:** At least one anatomical variation of paranasal sinuses was detected in 325 patients (92.9%). In 297 (91.4%) of these patients, sinusitis was observed at rates varying depending on the types of anatomic variations. A statistically significant relationship was found between agger nasi cells, Onodi cells, hypertrophy of middle concha, concha bullosa, uncinate bulla, and the medial and lateral deviations of uncinate process and sinusitis. On the other hand, there was no statistically significant relationship between septal deviation, paradoxical middle concha, secondary middle concha, great ethmoidal bulla, and sinusitis. **Conclusion:** Certain types of paranasal sinus variations create a susceptibility to sinusitis.

Keywords: *Computed tomography, endoscopic sinus surgery, secondary middle concha, uncinate process, variation*

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Introduction

The diseases of the nasal cavity and paranasal sinuses are among the most common disorders encountered in clinics of the ear, nose, and throat. Anatomic variations of this region are also frequently seen, and they have an important role in dysfunctional drainage of sinuses, generally resulting in chronic sinusitis.[1,2]

Functional endoscopic sinus surgery (FESS) has become a popular technique being applied in chronic and recurrent sinusitis cases in recent years.[3] Preoperative use of imaging techniques is essential for evaluating the neighboring structures of paranasal sinuses. By evaluating these structures, such as the carotid artery and optic nerve, the surgeon does not only see the critical points for applying the surgical treatment but also avoids complications that can develop during surgery.[4,5] Imaging techniques make clear the vision of very important points in surgeon's perspective. Since the introduction of computed tomography (CT) in this area, hardly evaluated regions of sinonasal pathologies and variations of ostiomeatal complex can be examined carefully.[6]

In this study, it was primarily aimed to review the anatomical variations of paranasal sinus playing a role in the development of sinusitis. In addition, the neighboring structures of this region were evaluated in terms of their relations to complications of FESS.

Materials and Methods

CT images of the paranasal sinus of 350 patients (184 males, 166 females; mean age, 35 years; age range 18–62 years) were studied. CT evaluation had been performed for the suspicion of inflammatory sinus pathology in all patients. Our study

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group consisted of retrospective data of patients' CT images which were collected between October 2000 and June 2002. The patients had no history of a previous facial trauma or operation and had no detected serious polyposis.

Interpretation of computed tomography images

The images were obtained in the prone position using a Siemens Somatom Balance VA10D apparatus (Siemens Healthcare GmbH, Erlangen, Germany) with 130 kV and 100 mAs bone protocol in 3-mm cross-sections at 3-mm intervals in coronal sections. To assess the ethmoid and sphenoid sinuses, the images in axial sections were in supine position in 4-mm cross-sections at 4-mm intervals. Then, the images were also analyzed in soft-tissue window. The coronal sections were obtained applying a perpendicular angle to the hard palate, and axial images were obtained in a parallel plane to orbitomeatal line.

In this study, as similar to previous studies,[7,8] the following radiological findings were considered as sinusitis.

- Diffuse mucosal thickening with 5 mm or more than 5 mm, which was in the maxillary, frontal, and sphenoid sinuses
- Air-fluid level, with diffuse mucosal thickening <5 mm or without mucosal thickening, which was in the maxillary, frontal, and sphenoid sinuses
- Partial opacifications, more than 5 mm, were polypoid, without diffuse mucosal thickening or total opacification, which were in the maxillary, frontal, and sphenoid sinuses
- Partial and total opacifications of the ethmoid cells consisting of the ethmoid sinuses
- The reactive changes such as sclerosis, decalcification, and erosion leading to sinusitis on the sinus bones.

All the CT images were examined by a senior radiologist in terms of inflammatory changes and anatomic variations of paranasal sinuses (e.g., septal deviation, agger nasi cells, hypertrophy of middle concha, concha bullosa, paradoxical middle concha, secondary middle concha, Haller cells, great ethmoidal bulla, uncinate bulla, and medial and lateral deviation of uncinate process) and neighboring structures (e.g., situation of lamina papyracea, aplastic and hypoplastic maxillary sinus, Onodi cells, bulla galli, pneumatization of anterior clinoid process, pneumatization of pterygoid recess, optic nerve in sphenoid sinus, hypoplasic uncinate process, protrusion of internal carotid artery and Vidian nerve, and position of fovea ethmoidalis) [Figures 1-6].

To determine septal deviation, the lines being drawn downward from the crista galli and upward from the nasal eminence were connected, and all deviations were noted without taking the degree of deviation into consideration [Figure 1]. Seven-hundred middle conchae were evaluated in 350 patients with respect to hypertrophy of middle concha. Conchae with mucosal thickness greater than neighboring middle and shared air column were accepted to be hypertrophic [Figure 1]. Middle conchae of the patients were evaluated with respect to their air content and the localization of the content (lamellar, bulbous, and lamellar and bulbous ones together [true]) [Figure 2]. Protrusion of lamina papyracea was classified in 3 degrees as protrusion of the lamina papyracea at 1/3 and less, at 1/3–2/3, and at more than 2/3 of the medial wall of the orbita [Figure 3]. Onodi cells are known as the protrusion of the ethmoidal cells into the sphenoid sinus [Figure 5]. For bulla galli, minimal pneumatization and prominent bulla appearance were evaluated [Figure 5]. The pterygoid recesses that were extending through the lateral margin of anterior clinoid process were regarded as pneumatic [Figure 6].

The midline structures were evaluated solely while lateral nasal wall variations were evaluated with the inflammatory pathologies located at the same side.

Sphenoid sinus septum was asymmetrically located in all patients.

Statistical analysis

The role of anatomic variations of paranasal sinuses on the prevalence of sinusitis were analyzed by Chi-square test. The level of statistical significance was set to $P < 0.05$.

Results

The rate of sinusitis without taking into consideration any anatomic variation in our study group is 82.3%. At least one of the anatomic variations of paranasal sinuses was identified in 325 of 350 patients (92.9%). The most common variation was septal deviation (89.7% of patients) followed by agger nasi cells (72% of sides) and concha bullosa (51% of sides) [Figures 1 and 2]. The frequencies of the anatomic variations of paranasal sinuses were summarized in Table 1.

Role of anatomic variations of paranasal sinuses on the prevalence of sinusitis

The prevalence of sinusitis was highest in patients with septal deviation (91.7%). Other anatomic variations of paranasal sinuses were also associated with high

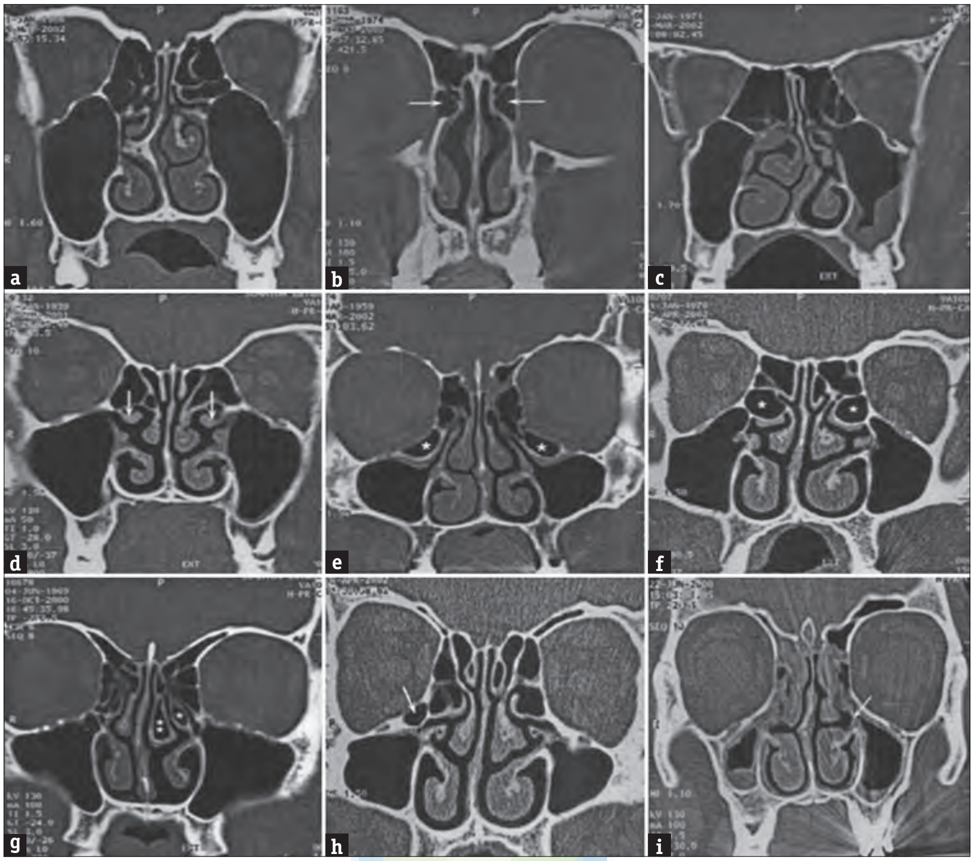

Figure 1: Anatomic variations such as the septal deviation and spur formation on the right side (a), bilateral agger nasi cells (b, arrow), parodoxical middle concha on the left, nasal concha hypertrophies on the right side (c), bilateral secondary middle concha (d, arrow), bilateral Haller cells (e, asterisk), bilateral great ethmoidal bulla (f, asterisk), uncinate bulla (g, asterisk) and concha bullosa (g, double asterisk) on the left side, bilateral medial deviations of uncinate process (h, asterisk) and Haller cell on the right side (h), and lateral deviation of uncinate process (i, arrow)

Figure 2: Coronal computed tomography images of paranasal sinuses with bulbous concha bullosa on the left (a, asterisk) and true concha bullosa on the right side (a, double asterisk) and lamellar concha bullosa on the right side (b, asterisk)

rate of sinusitis affecting 46.7%–87.9% of sides with variations [Table 1]. However, on statistical analysis, the presence of septal deviation, paradoxical middle concha, secondary middle concha, and great ethmoidal bulla has no significant role on the prevalence of sinusitis ($P > 0.05$ for all), [Table 2]. On the other hand, patients with any of the remaining anatomic variations of paranasal sinuses had significantly higher rate of sinusitis than those without corresponding anatomic variation ($P < 0.001$ for all), [Table 2].

Table 1: Prevalence of anatomic variations of paranasal sinuses and that of sinusitis with respect to corresponding variations

Anatomic variations of paranasal sinuses	CT images (350 patients, 700 sides), *n* (%)	Sinusitis, *n* (%)[a]
Septal deviation	314[b] (89.7)	288 (91.7)
Septal spur with septal deviation	26[b] (8.2)	-
Agger nasi cells	504[c] (72)	383 (76)
Hypertrophy of middle concha	182[c] (26)	160 (87.9)
Concha bullosa (total)	357[c] (51)	240 (67.2)
Lamellar concha bullosa	203[c] (29)	142 (69.9)
Bulbous concha bullosa	98[c] (14)	61 (62.2)
True concha bullosa	56[c] (8)	37 (66.1)
Paradoxical middle concha	30[c] (4.3)	14 (46.7)
Secondary middle concha	6[c] (0.86)	4 (66.6)
Haller cells	175[c] (25)	144 (82.3)
Great ethmoidal bulla	49[c] (7)	23 (46.9)
Uncinate bulla	29[c] (4.1)	22 (75.9)
Medial deviation of uncinate process	59[c] (8.4)	40 (67.8)
Lateral deviation of uncinate process	40[c] (5.7)	34 (85)

[a]Percentage of patients with sinusitis among those with corresponding anatomical variation, [b]Number of patients, [c]Number of sides. CT=Computed tomography

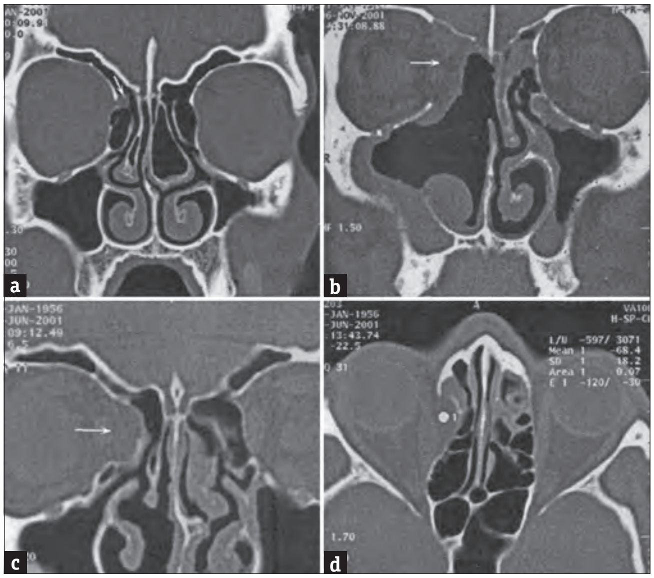

Figure 3: Computed tomography images of paranasal sinuses with dehiscence at lamina papyracea on the right side and ethmoidal protrusion of the orbital content (a, arrow), iatrogenic defect at the lamina papyracea and prominent prolapsus (b, arrow) and prominent prolapsus (c and d, coronal and transverse sections, respectively, - 68 HU fat tissue)

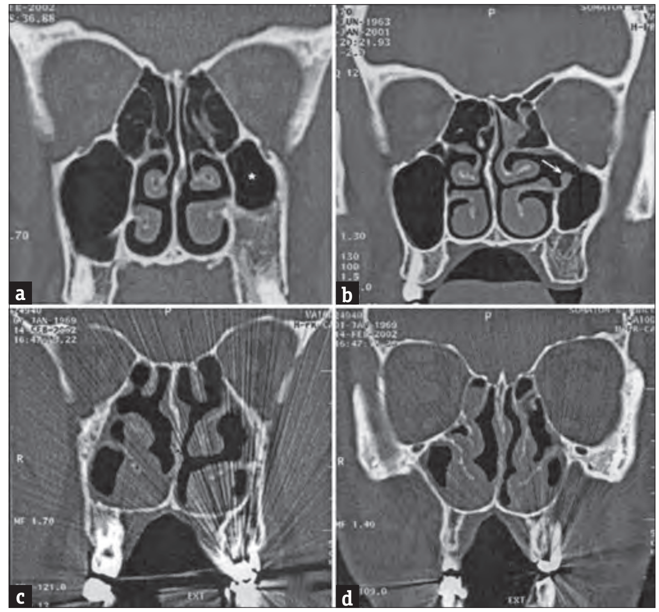

Figure 4: Computed tomography image of paranasal sinuses with hypoplastic maxillary sinus on the left side (a, asterisk), hypoplastic maxillary sinus on the left side and associated hypoplastic uncinate process (b, arrow), and bilateral maxillary sinus agenesis (c and d, anterior and posterior views of the same patient, respectively)

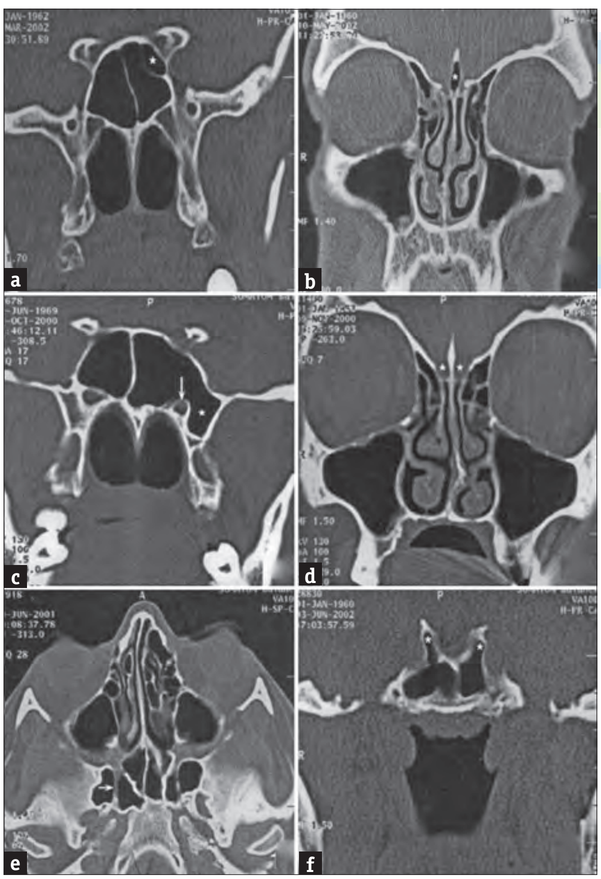

Figure 5: Computed tomography image of paranasal sinuses with Onodi cell (a, asterisk), bulla galli (b, asterisk), prominent pneumatization of pterygoid recess (c, asterisk) and protrusion of Vidian nerve into sphenoid sinus (c, arrow), bilateral inferior extension of fovea ethmoidalis (d, asterisk), Vidian nerve extension in the sphenoid sinus (e, arrow, axial section), and bilateral pneumatization of posterior clinoid process (f, asterisk)

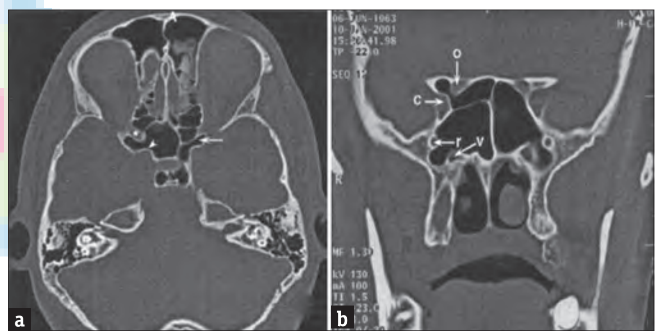

Figure 6: On axial computed tomography image of paranasal sinuses (a), bilateral pneumatization of anterior clinoid process (a, arrow), protrusion of right optic nerve (a, asterisk), and internal carotid artery (a, arrowhead) into the sphenoid sinus were noted. On coronal image (b), pneumatization of right anterior clinoid process and large pterygoid recess were seen. Important structures protruding into the sphenoid sinus were optic nerve (o), internal carotid artery (c), foramen rotundum (r), and Vidian nerve (v)

Role of anatomic variations of neighboring structures on the prevalence of bone dehiscence

The most common anatomic variation of the adjacent structure was pneumatization of crista galli, which was detected in CT images of 143 patients (40.3%) [Table 3 and Figures 3-6]. However, of these patients, only three had bone dehiscence. On the other hand, much more rarely seen anatomic variations, such as protrusion of lamina papyracea, inferior extension of fovea ethmoidalis, or protrusion of internal carotid artery/optic nerve/Vidian nerve into sphenoid sinus, were associated with high rate of bone dehiscence ranging from 20% to 50% [Table 3].

Table 2: The relation between anatomic variations of paranasal sinuses and prevalence of sinusitis

Anatomic variations of paranasal sinuses	CT images (350 patients, 700 sides), *n*	Sinusitis, *n* (%)[a]	*P*
Septal deviation			
Positive	314[b]	288[b] (91.7)	0.121
Negative	36[b]	6[b] (83.3)	
Agger nasi cells			
Positive	504[c]	383[c] (76)	<0.001
Negative	196[c]	80[c] (40.8)	
Hypertrophy of middle concha			
Positive	182[c]	160[c] (87.9)	<0.001
Negative	518[c]	220[c] (42.4)	
Concha bullosa (total)			
Positive	357[c]	240[c] (67.2)	<0.001
Negative	343[c]	140[c] (40.8)	
Lamellar concha bullosa			
Positive	203[c]	142[c] (69.9)	<0.001
Negative	497[c]	293[c] (41)	
Bulbous concha bullosa			
Positive	98[c]	61[c] (62.2)	<0.001
Negative	602[c]	247[c] (41)	
True concha bullosa			
Positive	56[c]	37[c] (66.1)	<0.001
Negative	644[c]	264[c] (40)	
Paradoxical middle concha			
Positive	30[c]	14[c] (46.7)	0.572
Negative	670[c]	274[c] (40.9)	
Secondary middle concha			
Positive	6[c]	4[c] (66.6)	0.235
Negative	694[c]	284[c] (40.9)	
Haller cells			
Positive	175[c]	144[c] (82.3)	<0.001
Negative	525[c]	215[c] (40.9)	
Great ethmoidal bulla			
Positive	49[c]	23[c] (46.9)	0.454
Negative	651[c]	267[c] (41)	
Uncinate bulla			
Positive	29[c]	22[c] (75.9)	<0.001
Negative	671[c]	275[c] (41)	
Medial deviation of uncinate process			
Positive	59[c]	40[c] (67.8)	<0.001
Negative	641[c]	262[c] (40.8)	
Lateral deviation of uncinate process			
Positive	40[c]	34[c] (85)	<0.001
Negative	660[c]	270[c] (40.9)	

[a]Percentage of patients with sinusitis among those with corresponding anatomical variation, [b]Number of patients, [c]Number of sides. CT=Computed tomography

Table 3: Prevalence of anatomic variations of the neighboring structures and that of bone dehiscence with respect to corresponding variations

Anatomic variations of the neighboring structures	CT images (350 patients, 700 sides), *n* (%)	Bone dehiscence, *n* (%)[a]
Protrusion of lamina papyracea	24[c] (3.4)	8 (33.3)
Pneumatization of crista galli	143[b] (40.3)	3[d] (2.1)
Hypoplastic maxillary sinus	18[c] (2.6)	
Aplastic maxillary sinus	2[c] (0.28)	
Onodi cells	49[b] (14)	

Contd...

Table 3: Contd...

Anatomic variations of the neighboring structures	CT images (350 patients, 700 sides), *n* (%)	Bone dehiscence, *n* (%)[a]
Inferior extension of fovea ethmoidalis	22[b] (6.3)	5 (22.7)
Pneumatization of ACP	148[c] (21.1)	
Pneumatization of pterygoid recess	98[c] (14)	
Pneumatization of posterior clinoid process	2[c] (0.28)	
Protrusion of internal carotid artery into sphenoid sinus	64[c] (9.1)	32 (50)
With pneumatization of ACP	33[c] (22.3)	
Protrusion of optic nerve into sphenoid sinus	57[c] (8.1)	21 (36.8)
With pneumatization of ACP	36[c] (24.3)	
Protrusion of Vidian nerve into sphenoid sinus	25[c] (3.6)	5 (20)
With pneumatization of pterygoid recess	18[c] (2.6)	

[a]Percentage of patients with bone dehiscence among those with corresponding anatomical variation, [b]Number of patients, [c]Number of sides, [d]Bulla galli. CT=Computed tomography; ACP=Anterior clinoid process

Discussion

In human anatomy, anterior frontal sinuses and nasal fossa are one of the most common regions that show anatomic variations.[9] In our series of 350 patients, the ratio of the anatomic variations of paranasal sinuses was 92.9%.

The rates of septal deviation and septum derived spur were 18.8%–58% and 7.2%–13.6%, respectively, in earlier reports.[4,9] Studies by Calhoun *et al.*[1] revealed septal deviation to be directly related to sinusitis regardless of the degree of deviation. Moreover, Elahi *et al.*[2] mentioned that spur formation also took place in the etiology of sinusitis. In our study, septal deviation and bony spur were observed at the rates of 89.7% and 8.2%, respectively. We found no statistically significant relationship between septal deviation and sinusitis. Because septal deviation is a very common variation, thus it can have a role in the development of sinusitis in association with other anatomic variations. Albayrak and Guleryuz[10] reported a statistically significant relationship between septal deviation and concha bullosa, which together had a role in the development of sinusitis.

Agger nasi is the prominence at the middle half of the crista ethmoidalis located in the frontal process of the sinus maxillaris. In our study, the rate of the ethmoidal cells extending to this region was 72%. The agger nasi cells were associated with high rate of sinusitis, which was attributed to the drainage of frontal recess. In previous surgical and imaging studies, agger nasi had been shown to be in the etiology of frontal sinusitis.[9,11] In these studies, the frequency of agger nasi cells varied in a broad range from 10% to 100%.

The other important anatomic variation that facilitates the development of sinusitis by affecting the drainage of ostiomeatal units is the uncinate process and the middle nasal concha.[2] In our study, the frequencies of hypertrophic middle concha and concha bullosa cases were found to be 26% and 51%, respectively. There was sinusitis in 88% of the hypertrophic middle concha and 67.2% of concha bullosa cases. The prevalence of concha bullosa was 4%–80% in previous studies.[4,9,12] Joe *et al.*[12] suggested that CT was more effective than endoscopy for showing concha bullosa.

The deviation at the superior pole of the uncinate process could be misinterpreted as secondary middle concha.[13] Khanobthamchai *et al.*[14] interpreted this appearance as a different entity rather than as a secondary middle concha and miscalled this structure as accessory middle concha. They also suggested that secondary middle concha was derived from the lateral wall of the middle concha.[14] In some studies, this variation was found to be present in 1.5%–6.8% of the studied population, but in some other studies, no cases were reported.[14,15] In our study, the prevalence of secondary middle concha was 0.8%. As reported in previous studies, no relation with inflammatory pathologies was found in our study.

The medial convexity that middle concha normally possesses has a paradoxical configuration in some cases. This variation that was observed in 4.3% of our cases was recorded in 3%–26% of cases in earlier reports.[4,12] As in other studies, a clear association with sinusitis was not detected in our study.

In the studies conducted by Perez-Pinas *et al.*[9] and Joe *et al.*,[12] the deviation of uncinate process was not classified as medial or lateral and present in 3%–15% of the cases. Mafee[5] considered medial deviation as the obstruction to the middle meatus and the lateral one as the obstruction to the infundibulum. Medial and lateral deviations were seen in 8.4% and 5.7% of our cases, respectively. The uncinate bulla, which was the increase in the volume of the uncinate process due to air content, was seen in 4.1% of the paranasal sides. The greatest cell of the ethmoid complex is ethmoidal bulla. Extension of its borders obstructing the ostiomeatal unit is named as great ethmoidal bulla and was noted in 7% of the paranasal sides. In earlier reports,[4,9] uncinate bulla and great ethmoidal bulla were encountered in 0.4%–2.5% and 0%–9% of patients, respectively. The rate of sinusitis in cases with medial deviation of uncinate process was 67% and with lateral deviation 85%, with uncinate bulla 76%, and with great ethmoid bulla 46.9% in our study. Although it is considered that great ethmoidal bulla narrows ostiomeatal unit and causes sinusitis, we did not find any statistically significant relationship between sinusitis and great ethmoidal bulla. On the other hand, uncinate bulla and deviations of uncinate process had significant effect on the prevalence of sinusitis. Yousem *et al*.[16] also suggested that the angle of the deviation of the uncinate process is related to maxillary and ethmoidal sinusitis.

Although Haller cells were first described by Albert von Haller in the beginning of the 19th century as the cells extending out from the ethmoidal labyrinth to the maxilla and palatine bone, many other investigators made different definitions. We used the description of Haller in our study. Perez-Pinas *et al*.[9] and Stammberger and Wolf.[13] showed that this variation had a wide range of prevalence (2.7%–45%) and important in the etiology of maxillary sinusitis. The reason for the wide range of prevalence may be the presence of different definitions of the Haller cells in the literature. In the present study, Haller cells were recorded in 25% of the paranasal sides, coexisted with inflammatory changes at the same side at the rate of 82.3%, having a significant effect on the prevalence of sinusitis.

The prevalence of Onodi cells was reported to be 10%–98% in the literature.[9,17] In the present study, it was recorded in 14% of the paranasal sides. Onodi cells can be a mistaken point in evaluating the anatomical landmarks during endoscopic sinus surgery. Hence, its presence must be reported since it can result in penetration into the middle cranial fossa, and if it is together with a dehiscence causing pneumatization of crista galli, it can result in penetration into the anterior fossa during FESS.[18]

The most common orbital complications that can develop during FESS are a hematoma and emphysema formation. Optic nerve and extraorbital muscle damage were also reported in the previous studies.[6,19,20] The most important variations predisposing to these complications are the dehiscence of lamina papyracea forming the medial wall of the orbita and prolapsus of the orbital content into ethmoidal cells. These variations can be congenital, traumatic, or iatrogenic. In the previous studies, the frequency of the mentioned protrusion and dehiscence was reported as 0.5%–6.5% and 0.76%–13.5%, respectively.[17,21-23] In the present study, the prevalences of these variations were 3.4% and 1.1%, respectively.

We noted that an increase in the airing of the sphenoid sinus eased the protrusion of the neighboring structures into the sphenoid sinus. In the earlier reports, the pneumatization made the bony structure thinner.[17] Out of three structures that we analyzed, the frequency of protrusion was 9.1% for internal carotid artery, 8.1% for the optic nerve, and 3.5% for the Vidian nerve. For the cases with these variations, dehiscence rate was 4.6%, 3.0%, and 0.7%, respectively. The prevalences of protrusion of the internal carotid artery and associated dehiscence were reported as 14%–53% and 5%–8%, respectively, in the previous studies.[17,21] The protrusion of optic nerve was encountered in 75%–88% and an associated dehiscence in 3.6%–8% in these studies.[16,21] In these studies, 18% of patients had protrusion of Vidian nerve and an associated dehiscence was present in 10%.[17,21] In our study, there was no dehiscence in any of the patients with bilateral pneumatization of the posterior clinoid process. To the best of our knowledge, there is no study on the frequency of pneumatization of the posterior clinoid process and its clinical importance. The asymmetric sphenoid septum must be reported by the radiologist since it has an important role for the surgeon to localize the internal carotid artery during FESS.[5] As understood from the variations mentioned above, the positions of these structures must be evaluated in detail before performing a sphenoid sinus oriented surgery.

The hypoplastic maxillary sinus was reported in 2.1%–10.4% of the studied populations in literature.[4,9,17] The data obtained from our study were close to the lower limit of the range (2.5%). The aplastic maxillary sinus was observed only in one patient. The hypoplastic uncinate process was accompanying the hypoplastic maxillary sinus cases. Inferior location of fovea ethmoidalis, which increased the risk of penetration to anterior cranial fossa during surgery, was seen in 6.2% of our cases. The dehiscence was recorded in 1.4% of these cases. Meloni *et al*.[21] compared the location of fovea ethmoidalis with the cribriform plate and pointed that fovea ethmoidalis on the right side was more inferiorly located than the one on the left side. In a study by Meyers and Valvassori,[17] the position of fovea ethmoidalis was evaluated by considering orbita in three parts, and it was found that fovea ethmoidalis was extending to superior part at a ratio of 88%, to the middle part 10%, and to inferior part 2%. In the same study, it was also shown that inferiorly located fovea ethmoidalis was predisposing to intracranial penetration during FESS.

The correlation between anatomic variations of paranasal sinuses and inflammatory pathologies has been reported in many previous studies.[4,16,24] However, they had relatively small population sizes and focused on specific anatomic variations. In the previous studies, the frequency of the anatomic variations of paranasal sinuses and nasal cavity was reported in a broad range, probably due to the difference in the definition criteria of these variations. Our study has particular importance for presenting CT findings of a large series of patients and evaluating a wide range of anatomic variations.

Conclusion

Most of the anatomic variations of paranasal sinuses are associated with high prevalence of sinusitis. Considering the guidance of these variations in clinical and surgical interventions, the anatomic variations of paranasal sinuses and neighboring structures need to be evaluated radiologically in clinical practice. CT is the most effective imaging technique for the assessment of these variations.

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Conflicts of interest

There are no conflicts of interest.

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