Originial Article

Sinonasal Anatomical Variations: A Multidetector Computed Tomographic Study

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ABSTRACT

Background and Aim: The paranasal sinuses are known for their complex anatomy and significant difference in size and shape. This study aimed to determine the prevalence of anatomical variations of the paranasal sinuses in computed tomography (CT).
Materials and Methods: In this cross-sectional study, patients over 18 years of age, who had undergone CT imaging in a private clinic, were screened for eligibility of participation. After excluding the patients with evident sinus pathology in CT, 501 cases were included. An experienced maxillofacial radiologist evaluated the CT images and extracted the frequency of variations using a standardized data collection sheet. Kolmogorov-Smirnov test, independent samples t-test, and chi-square test were used for the statistical analysis.
Result: Among the studied variations, septal deviation and Agger nasi, each with 336 cases (67.1%), and concha bullosa, with 240 cases (47.9%), were identified as the most common anatomical variations of the paranasal sinuses. The uncinate bulla showed a significant correlation with gender (P=0.036).
Conclusion: Considering the remarkable prevalence of some important variations, which may increase the risk of complications in sinus surgery, CT evaluation of patients is recommended before surgical interventions in the sinuses.

Keywords: Anatomy, Paranasal Sinuses, Multidetector Computed Tomography

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Introduction:

The anatomy of the paranasal sinuses has always been an important area of research. According to previous studies, the proximity of these sinuses to adjacent anatomical structures can lead to considerable complications.[1,2] Complete knowledge of anatomy can prevent potential complications during a nasal endoscopy. Surgeons must be aware of the anatomical variations of the paranasal sinus.

The paranasal sinuses are developed by gradual pneumatization of the solid tissue, resulting from nasopharyngeal positive pressure created through the Eustachian tube.[3]

It seems that anatomical variations of the sinuses appear early in life as a part of sinonasal development.[4] Genetic diseases, environmental conditions, and previous infections may affect the development of the paranasal sinuses.[5,6]

There is considerable variation in the size and shape of the paranasal sinuses. These differences are even seen between the right and left sinuses of a single individual. [7]

Sinonasal imaging is often ordered due to infections and allergic reactions in the area. Awareness of natural pneumatization and development course of the sinuses allows for proper investigation and treatment.

The limitation of plain radiography is in the depiction of three-dimensional (3D) structures on a 2D screen. Nowadays, the widespread use of computed tomography (CT) and magnetic resonance imaging (MRI) has allowed the more precise evaluation of these anatomical structures in the sagittal, coronal, and axial planes. CT of the paranasal sinuses is the gold standard imaging modality in the diagnosis of the severity and extent of inflammatory sinus diseases and the investigation of anatomical details and variations.[8] CT scans provide valuable information in the diagnosis of unusual sinus infections, malignancies, and rhinosinusitis-associated complications. [9]

Another advantage of CT in sinonasal imaging is the ability to display posterior structures that are not visible using direct endoscopy.[10]) The anatomical position of the ethmoid cells inhibits the endoscopic evaluation of deeper structures, including the posterior ethmoid sinus, the sphenoid sinus, and the ostiomeatal complex (OMC), while a CT scan can provide precise information of these areas in the coronal and axial sections.[11]

It is common to find anatomical variations on a CT scan. According to previous studies, two-thirds of the CT scans of these areas report one or more of these variations.

Anatomical variations of the paranasal sinuses, especially in the OMC, have been emphasized as a predisposing factor for sinus diseases.[4,6-9] These variations can lead to significant obstructions by narrowing fine drainage canals. However, as emphasized by Stammberger and Wolf, variations do not themselves are an indicator of disease. [4]

It is worth mentioning that anatomical variations have a controversial role in the development or persistence of paranasal sinus diseases.[9] Certain anatomical variations of this area are of great importance due to their potential ability to obstruct the OMC and ventilation canals because they can increase the risk of mucosal diseases of the sinuses.[12] Consequently, the lack of sufficient knowledge of these anatomical conditions may lead to disease persistence or recurrence.[13]

Adjacent to the paranasal sinuses are vital structures, such as the skull base, the optic nerve, and the internal carotid artery. Certain anatomical variations can potentially endanger patients' safety during surgeries in this area, especially when the surgeon is inexperienced.[14]

There are differences in the prevalence of anatomical variations of the paranasal sinuses in different ethnicities and populations.[4,6,15] Therefore, it is beneficial to evaluate the prevalence of these variations in the Iranian population.

The present study intended to investigate the frequency of certain anatomical variations of the paranasal sinuses using CT in Mashhad, Iran, in 2015.

Materials and Methods:

The Ethics Committee of Mashhad University of Medical Sciences approved the study protocol (approval date: October 14, 2015, approval code: 94/492259). All ethical considerations were observed. The information was collected anonymously from the archived images of our radiology center.

The sinonasal CT scans were taken at a private radiology center using a Siemens SOMATOM 16-slice CT scanner (Siemens Healthineers, Germany) with the following settings: 3mm thickness, 0.5mm interval, and 120-kilovoltage peak (kVp). Axial imaging was performed with the gantry in a neutral position and the patient in a supine position, while coronal imaging was performed with the patient in a supine or prone position with an extended neck and a gantry angle close to the coronal plane of the sinus.

Anatomical variations:

In our study, the presence of nasal septum deviation was measured by a 4mm deviation from the midline.[4]

A concha bullosa (middle turbinate pneumatization) is a common finding on CT scans. It is usually of slight clinical significance even though it is associated with nasal septum deviation.[4,5]

Agger nasi air cells are the furthermost anterior ethmoidal cells located anterolateral and inferior to the frontal recess and anterosuperior to the middle turbinate attachment.[4,5]

Haller's cells are air cells underneath the ethmoid bulla on the roof of the maxillary sinus and the inferior portion of the lamina papyracea and include air cells inside the ethmoid infundibulum.[4,5]

The Onodi cell is a posterior ethmoid air cell that is located superior to the sphenoid sinus and close to at least one optic nerve or internal carotid artery.[7,8,10]

Paradoxical middle turbinate (usually bilateral), which is an infrequent cause of nasal blockage, refers to an inferomedially curved edge of the middle turbinate with the concave surface fronting the nasal septum.[7,8,10]

The depth of the olfactory fossa is indicative of the difference between the height of the cribriform plate and the ethmoid roof (the vertical height of the lateral lamella of the cribriform plate).[13]

Statistical analysis:

The statistical analyses were performed in predictive analytics software (PASW, version 18; SPSS Inc., Chicago, IL, USA) using one-sample Kolmogorov-Smirnov test (the normality of age distribution), independent samples t-test, and chi-square test. A p-value less than 0.05 was considered significant.

Results:

The study participants included 501 patients with a mean age of 39.19±14.61 years (age range: 18-90 years). The study sample consisted of 276 males (55%) with a mean age of 39.33±14.61 years (age range: 18-90 years) and 225 females (45%) with a mean age of 39.01± 14.64 years (age range: 20-87 years). One-sample Kolmogorov-Smirnov test showed that the age of the participant had a normal distribution (P=0.17). An independent t-test showed no mean age difference between the two genders (P=0.81).

According to previous studies, the statistical results of each anatomical variation were expressed separately based on the location (right or left), unilaterally or bilaterally, and other characteristics.

Nasal septum deviation of more than 4mm from the midline was observed in 336 cases (67.1%), with 23 cases (4.6%) having a bilateral septum deviation, 117 cases (35.3%) having a right-sided nasal septum deviation, and 182 cases (36.3%) having a left-sided nasal septum deviation.

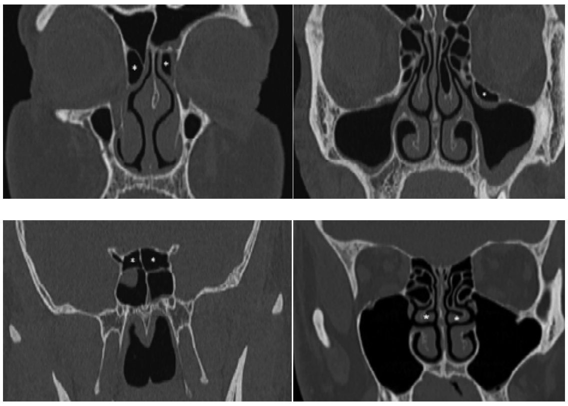
A concha bullosa was observed in 240 patients (47.9%), with unilateral concha bullosa in 120 (24%) patients and bilateral concha bullosa in another 120 (24%) patients. Also, 169 (33.7%) patients had a concha bullosa on the left side, while 191 (38.1%) patients had a concha bullosa on the right side. In the classification of the concha bullosa by location, the total number of right and left concha bullosa was 360, of which lamellar concha bullosa was the most common type with 208 cases (57.8%). Also, bulbous and extensive types, with 109 (30.3%) and 43 (11.9%) cases, were the next common types, respectively. A typical view of the three types of concha bullosa is presented in Figure 1.

Figure 1. Three types of concha bullosa in coronal multidetector computed tomography (MDCT). (A) Lamellar† type. (B) Bulbous‡ type. (C) Bilateral extensive* type.

Agger nasi cells, Haller's cells, Onodi cells, and paradoxical middle turbinate are shown in Figure 2. Agger nasi pneumatization was observed in 336 cases (67.1%), with bilateral Agger nasi in 319 patients (63.7%). Right Agger nasi was seen in 68 cases (13.6%), while left Agger nasi was seen in 75 cases (15%). A typical view of Agger nasi is presented in Figure 2. Haller's cells were observed in 98 patients (19.6%), of which 45 cases (9%) were bilateral. The variation was observed on the right side in 68 cases (13.6%) and on the left side in 75 cases (15%).

A typical view of this variation is shown in Figure 2. Pneumatization of the most posterior ethmoid cells (Onodi cells) was observed in 84 cases (16.8%). A typical view of the Onodi cells is presented in Figure 2. Paradoxical middle turbinate was reported in 67 cases (13.4%), which was unilateral in 44 patients (8.8%) and bilateral in 23 (4.6%) cases. A typical view of this variation is presented in Figure 2. The depth of the olfactory fossa was determined based on the Keros classification.

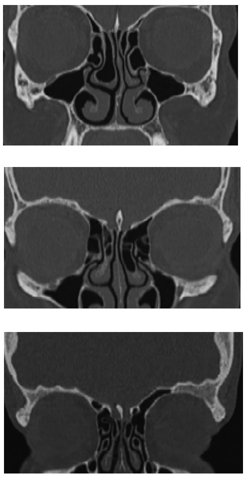
2A 2B



2C 2D

Figure 2. Other anatomical variations in coronal views. (A) Agger nasi cells. (B) Haller's cells. (C) Onodi cells. (D) Bilateral paradoxical curvature of the middle turbinate.

The depth of the olfactory fossa was 1-3mm in 44 cases (8.8%; Keros I, Figure 3), 4-7mm in 371 cases (74.1%; Keros II, Figure 3), and more than 8mm in 86 cases (17.2%; Keros III, Figure 3).



3A 3B 3C

Figure 3. Depth of the olfactory fossa according to the Keros classification (coronal views). (A) Keros I. (B) Keros II. (C) Keros III.

The frequency of each variation by gender is presented in Table 1 along with the correlation of the variation with gender. According to these findings, there is a correlation between the frequency of the uncinate bulla and gender (P=0.036)

Table 1. Association of sinonasal anatomical variations with gender

Anatomical variation	Frequency within gender Male N (%)	Female N (%)	χ^2	*p*
Deviated nasal septum	194 (70.3%)	142 (63.1%)	2.576	.108
Concha bullosa	138 (50.0%)	102 (45.3%)	.903	.342
Agger nasi cell	182 (65.9%)	154 (68.4%)	.247	.619
Haller's cell	54 (19.6%)	44 (19.6%)	.000	1.000
Paradoxical curvature of the middle turbinate	38 (13.8%)	29 (12.9%)	.024	.876
Uncinate bulla*	34 (12.3%)	44 (19.6%)	4.403	.036*
Onodi cell	50 (18.1%)	34 (15.1%)	.601	.438
Depth of the olfactory fossa (Keros classification)			.501	.778
Keros I (1-3mm)	25 (9.1%)	19 (8.4%)		
Keros II (4-7mm)	201 (72.8%)	170 (75.6%)		
Keros III (more than 8mm)	50 (18.1%)	36 (16.0%)		

Discussion:

In recent decades, the therapeutic approach to sinonasal diseases has undergone tremendous advances. The progressive development of minimally invasive surgical procedures, especially endoscopic sinus surgery, is one of these important advances. The therapeutic application of this method has already shown brilliant outcomes.[16,17] Nevertheless, surgical complications can lead to permanent and dangerous consequences due to the proximity of the paranasal sinuses to the vital structures, including the orbit and the skull base.[18]

The paranasal region has a variety of anatomical variations. The role of these variations in the development or progression of many regional diseases is not well understood; however, being aware of their presence, especially preoperatively, is of great importance. Therefore, in the present study, we intended to evaluate the anatomical variations of the paranasal sinuses using spiral CT scans in an Iranian population of 501 patients that presented to a private imaging facility.

Nasal septum deviation is a relatively common variation, which can be congenital or traumatic. The rate of this variation was 67.1% in the present study, which was relatively comparable to the results of the study by Talaiepour et al, in Iran, with a rate of 63%.[19] The prevalence of this variation has been reported to be 12%-58% in other populations.[20-22] Demographic differences and different diagnostic criteria can explain some of these differences. Nasal septum deviation can be mild, asymptomatic, and without any complications; however, severe septum deviation can block the airflow and manifest as nasal congestion, noisy breathing during sleep, or epistaxis. Moreover, severe septum deviation can lead to hypoplasia of the ipsilateral turbinate or hyperplasia of the contralateral turbinate.[23]

Another important variation evaluated in the present study was the concha bullosa, with a prevalence of 47.9% in our study. However, the prevalence was 14%-80% in the literature with a remarkable variation.[9] Although some authors only identify the vertical lamina pneumatization or the lower bulb in the middle turbinate as a real concha bullosa, we have considered all the cases with this variation, regardless of the extent and the location. The significance of the concha bullosa is that it limits the surgical field and may lead to sinus diseases through the obstruction of the OMC.

The Onodi cells are defined as the most posterior ethmoid air cells, with a prevalence of 16.8% in our study. However, the prevalence of this variation was reported to be 7%-10.9% in other studies.[18,19,22,24] Given the proximity of this structure to the carotid canal and the optic nerve and its relatively high prevalence in our study, it is recommended to consider the presence of Onodi cells before surgical interventions in this area to prevent complications.

The study by Badawi et al, in a Sudanese population, involved 29 males (47.5%) and 32 females (52.5%) with a mean age of 37 years. They also did not find any correlation between gender and the distribution of Onodi cells.[25]

The Agger nasi cell is the most anterior ethmoid air cell and is located anterosuperiorly relative to the middle turbinate.[23] This variation is a landmark through which the surgeon enters the frontoethmoidal recess during endoscopic sinus surgery. The prevalence was 67.1% in our study population; however, the prevalence of this variation was greatly different in various populations and has been reported to be 3%-100%. [6,11,19,20,26]

Among the several variations evaluated in this study, only the presence of a bulla in the uncinate process was significantly related to gender, with 34 males cases (12.3% of male patients) and 44 female cases (19.6% of female patients). Our findings were comparable to the results of the study by Kayalioglu et al, indicating no significant difference in the prevalence of major anatomical variations between genders.[20]

On the other hand, the compatibility of our results with another study of an Iranian population confirms the potential role of ethnicity in the prevalence of paranasal sinus variations.[19]

The differences in the prevalence of some anatomical variations among different ethnicities have already been proven, including the difference between Caucasian and Chinese ethnicities and among the three main racial groups in Malaysia, including Malaysian, Indian, and Chinese. [4,6]

In 1962, Keros studied the relationship between the olfactory fossa and the ethmoid roof in 450 skulls.[27] Keros generated a three-category classification system for the depth of the olfactory fossa in relation to the ethmoid roof. This depth is measured by “the vertical height of the lateral lamella of the cribriform plate”, which is the difference between the height of the cribriform plate and the ethmoid roof. This depth is 1-3mm, 4-7mm, and 8-16mm in Keros type I, type II, and type III, respectively.[27] In our study, Keros type II was observed in 74.1% of cases. This finding was similar to the results of studies performed by Babu et al (74.6%) and Madani et al (53.2%). [28,29]

Conclusion:

1.Nasal septum deviation of more than 4mm from the midline was observed in 67% of cases, with 4.6% patients having a bilateral septum deviation, 35.3% patients having a right-sided nasal septum deviation, and 36.3% patients having a left-sided nasal septum deviation.

2.A concha bullosa was observed in 47.9% of patients. The lamellar concha bullosa was the most common type (57.8%). The bulbous and extensive types, with 30.3% and 11.9% cases, were the next common types, respectively.

3.There was a correlation between the frequency of the uncinate bulla and gender. This association was not found between gender and the frequency of other anatomical variations.

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