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Is There a Coexistence Between Smaller Maxillary and Frontal Sinus Volume and Narrow Internal Nasal Valve Angle? Three-Dimensional Computed Tomography Assessment

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ABSTRACT

Objective: Pneumatization of paranasal sinuses varies greatly between patients, and certain pneumatization variants have been associated with specific clinical conditions. The present research aimed to evaluate the presence of coexistence smaller maxillary and frontal sinus volume and narrow internal nasal valve angle and whether this association is significant.

Methods: Sixty patients aged above 18 years old who underwent surgery for caudal septal deviation at the ear nose throat department of a tertiary care hospital between 2018 and 2021 were included in this retrospective cross-sectional study. The internal nasal valve angle was measured from reformatted coronal computed tomography scans. The maxillary sinus volume and frontal sinus volume were calculated using a workstation. The maxillary sinus and frontal sinus volumes were classified as narrow side and wide side according to the internal nasal valve angle measurements. The narrow- and wide-side maxillary sinus and frontal sinus volumes were compared within each other.

Results: There was a statistically significant difference between the maxillary sinus volumes of the narrow internal nasal valve angle side and wide internal nasal valve angle side (mean ± SD: 14.47 ± 5.45 and 15.21 ± 5.31 mL, respectively, $P = .014$). There was a statistically significant difference between the frontal sinus volumes of the narrow internal nasal valve angle side and wide internal nasal valve angle side (median: 2.85 and 3.08 mL, respectively, $P < .001$).

Conclusion: The maxillary sinus and frontal sinus volumes ipsilateral to the narrow internal nasal valve angle sides were significantly decreased. This coexistence may be significant. Further studies are needed to explain the significance of this association.

Keywords: Internal nasal valve angle, frontal sinus, maxillary sinus, paranasal sinus volume, pneumatization

Introduction

Paranasal sinuses are spaces inside the cranial bones. The paranasal sinuses comprise the maxillary, frontal, and sphenoid sinuses.[1] They form hollow, air-filled cavities lined by a thin respiratory mucosa with virtually no glands or vascularization.[1] A simple contact with the atmospheric environment is maintained through a small ostium.[1] The ethmoid labyrinths are currently considered as sinuses. Despite being described as sinuses for centuries, the ethmoid labyrinths may be regarded instead as remnants of the olfactory nose.[1,2] The ostium of the maxillary sinus (MS), frontal sinus (FS), and anterior ethmoid cells is in the middle meatus.[3] The MS, which is settled under the orbita in the maxillary bone, continues to develop from the third month of intrauterine life until the age of 15-18 years.[3] The average volume of the MS in adults is 15 mL.[3] The FS is a cone-shaped space settled in the frontal bone. The development of the FS also continues until late adolescence.[3] Its mean capacity in grown-ups is 6-7 mL.[3] The growth mechanisms of paranasal sinuses are still not clearly understood.[4] Pneumatization of paranasal sinuses varies greatly between patients, and certain pneumatization variants have been associated with specific clinical conditions.[5,6] Nasal airflow plays a significant part in the improvement of the paranasal sinuses.[7] Various studies have assessed the relationship between nasal septum deviation affecting nasal airflow and paranasal sinus volumes.[8-11]

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The internal nasal valve (INV) area comprises 3 structures, namely, the inferior turbinate, nasal septum, and lateral nasal wall. The INV is the most resistant area throughout the whole airway from the nostril to the alveoli. Small alterations in the INV size can significantly change the resistance of airflow, which, in turn, affects nasal function.[12,13] We speculate that deviations of the caudal septum involving the INV area may affect the development of paranasal sinuses by altering nasal airflow.

The present research aimed to evaluate the presence of coexistence between smaller maxillary and FS volume and narrow INV angle and whether this association is significant by multislice computed tomography (CT).

Methods

Study Design

This was a single-center, cross-sectional, retrospective research conducted at the ear nose throat department of a tertiary care hospital. The study was approved by the Haydarpaşa Numune Training and Research Hospital Clinical Research Ethics Committee (Approval number: 2021/157, Date: 24.05.2021) and conducted in accordance with the ethical principles for medical research involving human subjects outlined in the Declaration of Helsinki. Informed consent was waived due to the retrospective design of the study.

Study Population

The medicinal archives and CT scans of individuals who were operated due to caudal septum deviation between January 2018 and December 2021 were retrospectively scanned. Only patients aged above 18 years were included to achieve standardization in the development of the paranasal sinuses. Thus, we aimed to include patients with narrow INV angles during the paranasal sinus development period. The exclusion criteria were septal deviations other than the INV area (such as posterior and/or inferior deviation), nasal polyposis, concha bullosa, adenoid hypertophy, tumors, a history of maxillofacial trauma, and history of sinonasal surgery or any acute or chronic inflammatory mucosal disease that had destroyed the anatomic structures.

Radiologic Examinations

Paranasal sinus CT scans were obtained from the Picture Archiving Communication Systems (PACS) (Marotech, Seoul, Korea) retrospectively. Scans were performed utilizing a 128 SL Optima CT 660 scanner (General Electric Medical Systems, Milwaukee, Wis, USA) in the supine position. The scanning parameters utilized were as follows: 2 × 0.625 mm detector configuration, 0.625-1.0 mm slice thickness, 160 × 160 field of view, 180 mAs, 120 kVp, and 512 matrix. The patients' heads were fixed in a cephalostat to prevent INV measurements from being affected by the head position.

Reformatted coronal CT scans of the INV angle were requested at a plane vertical to the front view of the acoustic axle, which is determined on a sagittal reformatted image based on a study conducted by Cakmak et al.[14] who revealed that the axis passes through the center of nasal passage in an arc. The INV angle was evaluated through a standardized section (1 mm cut, immediately anterior to the head of inferior turbinate) from reformatted images.[15] The INV angle was evaluated throughout the medial and lateral edges of the airway averaging the contour irregularities, with the apex extending to the anterior-superior edge of the soft tissue (Figure 1). The INV angle was retrospectively measured by the same radiologist (A.O.B.).

The MS and FS volumes were calculated separately for each side utilizing Vital's Vitrea™ Advanced Visualization-postprocessing software (Version 7.0, Canon Medical Systems Cooperation, Otawara, Tochigi, Japan) (Figure 2). The volume of the ethmoid labyrinths was not evaluated because it has a complicated nature and it is formed of many cells disunited into anterior and posterior groups.

The MS and FS volumes were classified as narrow side and wide side according to the INV angle measurements. The narrow- and wide-side MS and FS volumes were compared within each other. Also, the correlation between the INV angle and the MS and FS volumes was investigated.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) for Windows version 22.0 software (SPSS for Windows Inc., Chicago, Ill, USA) was used for statistical analyses. The suitability of the quantitative data for normal distribution was

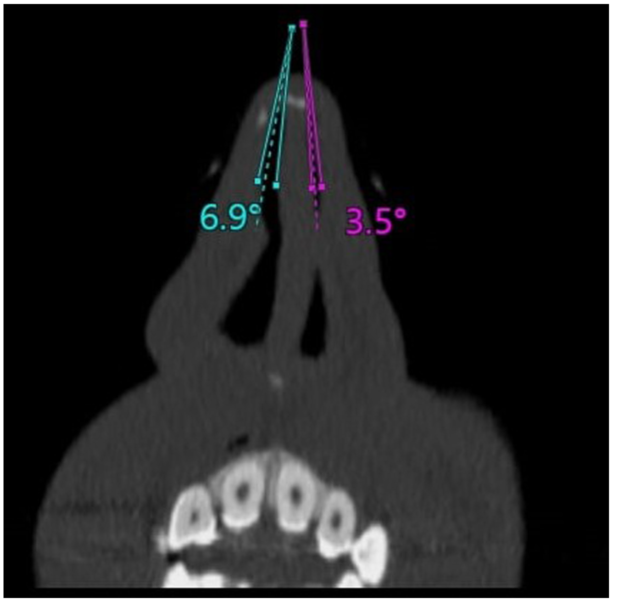

Figure 1. Measurement of the internal nasal valve angle on reformatted coronal computed tomography scans.

Main Points

- We noticed a coexistence between smaller maxillary sinus (MS) and frontal sinus (FS) volume and narrow internal nasal valve (INV) angle.
- Maxillary and FS volumes ipsilateral to narrow internal valve were significantly decreased.
- The coexistence between smaller MS and FS volume and narrow INV angle may be significant.
- There may be an association between the paranasal sinus volumes and internal nasal valve angle.

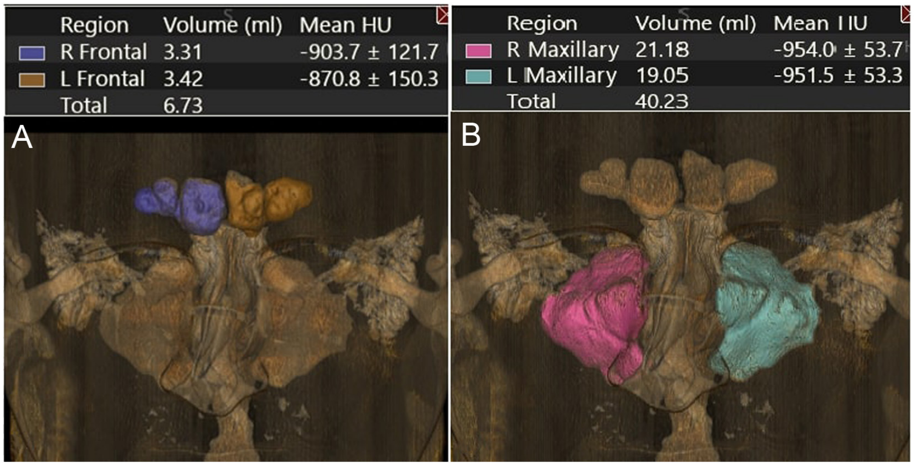

Figure 2. Calculation of frontal sinus (A) and maxillary sinus (B) volumes using Vital's Vitrea™ Advanced Visualization-postprocessing software.

tested using the Shapiro–Wilk test. Categorical characteristics are described using frequency and proportions. Continuous outcomes are defined as means (SD) or median [first (Q1) and third quartiles (Q3)] and compared using either the paired-samples *t*-test or Wilcoxon's signed-rank test, depending on normality. Correlation analysis was performed utilizing Spearman's correlation test. Statistical significance was accepted as $P < .05$.

Results

This retrospective study included 60 patients. Thirty of the participants were female, 30 were male, and all were aged above 18 years.

°Right-side INV angles were measured narrower in 58.3% (n = 35) of the patients, and left-side INV angles were measured narrower in 41.7% (n = 25) of the patients. The median INV angles measured on the narrow sides and wide sides were 4.2° and 6.5°, respectively. A statistically significant difference was found among the narrow-side and wide-side INV angles of the patients ($P < .001$) (Table 1).

The mean MS volumes on the narrow INV angle side and wide INV angle side were 14.47 ± 5.45 mL and 15.21 ± 5.31 mL, respectively. The MS volumes on the narrow INV angle side were statistically significantly smaller than the MS volumes on the wider side ($P = .014$) (Table 2).

The median FS volumes on the narrow INV angle side and wide INV angle side were 2.85 mL and 3.08 mL, respectively. The FS volumes on the narrow INV angle side were statistically significantly smaller than the FS volumes on the wider side ($P < .001$) (Table 2).

There was no significant correlation between the INV angle and the MS volume ($r = 0.072$, $P = .436$). There was no significant correlation between the INV angle and the FS volume ($r = -0.011$, $P = .909$).

Discussion

The present research evaluated the presence of coexistence between smaller MS and FS volume and narrow INV angle and whether this association is significant. The MS and FS volumes on the narrow INV angle side were statistically significantly smaller. There was no significant correlation between the INV angle and the MS and FS volumes. This is a pioneer study in the field of otorhiolaryngology, and few studies have been conducted on this topic.

The normal INV angle in the Caucasian population is between 10° and 15°.[16] Berry[17] described the airflow through the nasal cavity as a parabolic graph that passes through the nostrils and narrows as it reaches the INV. According to Berry and another study, up to two-thirds of all nasal resistance occurs in the inaugural of the INV area.[17,18] Given that patients who underwent surgery due to caudal septum deviations involving the INV area were assessed in the present study, the results of the INV angle measurement we obtained were found to be narrower than the normal population reported in previous studies.

The average volumes of the MS and FS in adults are 15 mL and 6-7 mL, respectively.[3] The MS volumes we obtained were found to be compatible with the literature. However, it was noteworthy that the FS volumes were lower than those in the literature data.

Table 1. The INV Angle Measurements

	Narrow Side	Wide Side	
	Median (Q1, Q3)	Median (Q1, Q3)	*P*
INV angle, degree	4.20 (3.30-5.33)	6.55 (5.33-7.80)	<.001

Wilcoxon's signed-rank test.
INV, internal nasal valve.

Table 2. The MS and FS Volume Measurements

		Narrow Side	Wide Side	*P*
MS volume, mL	Mean ± SD	14.47 ± 5.45	15.21 ± 5.31	.014[a]
FS volume, mL	Median (Q1-Q3)	2.85 (1.27-4.55)	3.08 (1.81-5.57)	<.001[b]

[a]Paired-samples *t*-test, [b] Wilcoxon's signed-rank test.
MS, maxillary sinus; FS, frontal sinus.

Different methods have been used in the literature to evaluate the pneumatization of the paranasal sinuses, and different results have been obtained, accordingly.[19] Paranasal sinuses do not have smooth boundaries, and linear measurements may differ from the reality.[19] Injectable materials can be used to measure sinus volume, but this cannot be performed in vivo and the procedure is difficult.[19] Anatomic measurements made on cadavers will cause misleading and false results due to soft tissue loss.[19] Computed tomography scan is the best method for assessing the size of the paranasal sinuses. Computer-based 3-dimensional (3D) volume reckoning can be performed more precisely, efficiently, and readily with the invent of 3D restoration and settlement techniques. Three-dimensional area, length, angle, and volume measurements in CT scans have been made probable by using sophisticated computer equipment and program technologies. The nearest valuations to inherent measures can be acquired with volume and surface treatment techniques for volume calculation, internal nature, tissue intensity changes, and texture volumes. Computed tomography is less expensive than magnetic resonance imaging, and 3D reconstruction with multidetector CT ensures an excellent assessment of nasal and paranasal spaces.[20] In this study, 3D segmentation was performed on CT images using Vitrea software to measure the volume of MS and FS bilaterally. It has been reported that Vitrea software measurements are highly correlated with actual organ volumes.[21]

The mechanism of paranasal sinus pneumatization is not clearly understood, and the role of sinonasal pathologies in this process is unclear. Previous studies have been conducted on sinus volumes and maxillofacial and sinonasal pathologies. Cho et al[22] found no relation among dental problems and MS volume. It has been stated that cleft palate does not affect MS volume.[23] There is a study reporting that the presence of concha bullosa and septum deviation has no relationship with MS volume.[24] However, different studies suggest that concha bullosa may predispose to maxillary sinusitis and damage the development of the MS by occluding the osteomeatal complex and blocking MS drainage.[25,26] Kapusuz et al[8] suggested that serious septal deviation importantly affected MS capacities and rhinosinusitis complaints. Karataş et al[9] reported that modest septum deviations had a substantial effect on MS sizes, but slight and serious septal deviations did not affect these sizes. In the present study, the MS volumes on the narrow INV angle side were found to be significantly smaller than the wide INV angle side.

The FS size is too changeable, and moreover, right and left FS volumes can vary importantly owing to their sovereign development. It has further been shown that the FS volume is affected by nasal airflow and pneumatization.[10] However, Karataş et al[9] could not define any impact of nasal septum deviation on the FS size. Unlike the literature, we assume that the INV angle may have had an effect on FS volumes in this study. The FS volumes on the narrow INV angle side were significantly smaller than the FS volumes on the wide INV angle side.

In line with the datum acquired from preceding papers, it has been determined that the location of the septum deviation can affect nasal resistance, nasal airflow, and the incidence and solemnity of paranasal sinus ailment.[27,28] Septum deviation straitens the ipsilateral nasal passage and middle meatus. This impact produces oppression on neighbor structures, and accordingly equilibrating alterations happen in the paranasal structure to compensate the nasal airflow on the opposite side of the deviation.[28] Our results can be explained by this compensation mechanism.

We also believe that the results of the present study can be explained by Bernoulli's principle, which defines that when the velocity of a moving fluid rises, press within the fluid diminishes.[29] Several authors studied the relation among septal deviation and airflow features using computational liquid dynamics. In their studies, higher airflow rates and pressures were shown on the narrower side of the nasal cavity.[30,31] It is speculated that INV changes the airflow through the nose, giving the shape, velocity, and resistance of the airflow.[32] Accordingly, the airflow rate may be expected to be higher in the narrow INV angle side. The narrow INV angle can cause an increase in the airflow rate, which, in turn, produces a negative pressure on the ipsilateral side. We hypothesize that the force exerted by this negative pressure might prevent the air entry into the paranasal sinuses via ostiomeatal complex, which could lead to a reduction in paranasal sinus pneumatization during the development period.

The main limitations of the present study were its retrospective design and the small sample size. As another limitation, although all the patients were above 18 years, it is not possible to know how long patients have been exposed to a narrow INV angulation. Another limitation is that the pneumatization of the paranasal sinuses may not have been completed for some of the subjects included in the study. Also, the size of the ethmoid labyrinths was not reckoned because of the complicated anatomy and obscure boundaries of the sinuses.

In conclusion, we noticed a coexistence between smaller maxillary and FS volume and narrow INV angle. The MS and FS volumes ipsilateral to the narrow INV angle sides were significantly decreased. This association does not mean causality. However, this coexistence may be significant. Further studies are needed to explain the significance of this association.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of Haydarpaşa Numune Training and Research Hospital (Approval No: 2021/157, Date: 24.05.2021).

Informed Consent: Informed consent was waived due to the retrospective design of the study.

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