








Does Nasal Septal Deviation and Concha Bullosa Have Effect on Maxillary Sinus Volume and Maxillary Sinusitis?: A Retrospective Study

비중격 만곡증과 수포성 비갑개는 상악동 부피와 상악골 부비동염에 있어 관련성을 지니는가?: 후향적 연구

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Purpose This study aimed to determine whether nasal septal deviation and concha bullosa affect the maxillary sinus volume, and whether this effect is associated with the prevalence of chronic sinusitis.

Materials and Methods This study retrospectively reviewed 209 paranasal sinus CT (PNS CT) images of patients with sinonasal symptoms from January 2017 to December 2018. The maxillary sinus volume was measured twice by a radiologist, and statistical analysis was performed using SAS 9.4.

Results Intersex comparison of the maxillary sinus volume (on left and right sides) revealed that the volume was significantly larger on both the sides ($p < 0.0001$) in men compared with that in women. Concha bullosa was found to occur mainly in the concave cavity of the septal deviation ($p < 0.0001$). No significant association was found between nasal septal deviation and maxillary sinusitis ($p = 0.8756$) as well as between concha bullosa and maxillary sinusitis prevalence ($p = 0.3401$) or maxillary sinus volume (both: $p = 0.6289$, Rt.: $p = 0.9522$, Lt.: $p = 0.9201$).

Conclusion Although nasal septal deviation and the location of concha bullosa may affect each other, maxillary sinus volume and maxillary sinusitis were neither associated with nasal septal deviation nor concha bullosa.

Index terms Paranasal Sinuses; Nasal Septum; Turbinates; Maxillary Sinus; Maxillary Sinusitis


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INTRODUCTION

In recent clinical trials, paranasal sinus computed tomography (PNS CT) is used for patients with chronic sinusitis presenting with facial pain, headache, and nasal symptoms for more than 12 weeks. Sinusitis is an inflammation around the ostiomeatal complex (maxillary ostium, infundibulum, uncinata process, hiatus semilunaris, ethmoid bulla and middle meatus) near the antrum of maxillary sinus, which is the common drainage pathway of many sinuses as well as a ventilation pathway. The pathophysiology of sinusitis is related to poor drainage of secretions and impaired ventilation as a result of an obstruction caused by anatomical variation and mucosal thickening around these structures (1). Anatomic variations, such as the nasal septal deviation and concha bullosa, which have a relatively large influence on the air flow around the ostiomeatal complex, can induce sinusitis. Nasal septal deviation causes airflow asymmetry between both nasal passages, leading to a significant nasal obstruction. It is known to occur mainly by trauma, especially during birth. The negative airflow pressure on the concave side of the deviation, produces an ipsilateral compensatory hypertrophy of turbinate, which affects the drainage pathway in addition to the nasal obstruction. This compensatory hypertrophy of turbinate is a physiological phenomenon that prevents intranasal dehydration and crusting due to excessive airflow, which has an important association with the concha bullosa (2, 3). Concha bullosa is the most common anatomical variation that occurs near the ostiomeatal complex, mostly in the middle turbinate in the center of the cavity, which is most affected by airflow. Concha bullosa is caused by the pneumatization of the turbinate and can be classified into lamellar, bulbous, and extensive types depending on the extent and location. Bulbous and extensive types of concha bullosa at the turbinate tips near the middle meatus are thought to be one of the predisposing factors of sinusitis (2). And also these nasal structures affected to forming maxillary sinus volume. Maxillary sinus volume begins to develop at 3 months of intrauterine life and it continues to 15–18 years of age. Maxillary sinus is the most affected by ventilation among nasal sinuses, and is known to have some relation on the progress of sinusitis (4). The purpose of this study was to determine whether deviation of the nasal septum and concha bullosa affect the volume of the maxillary sinus and the prevalence of chronic sinusitis.

MATERIALS AND METHODS

This retrospective, single-institution study was approved by our Institutional Review Board. The requirement for written consent was waived by the board (IRB No. CR319084). We retrospectively analyzed 209 of 759 PNS CT images of patients (male: 130; female: 79) with sinonasal symptoms, who visited the Department of Otorhinolaryngology from Jan 2017 to Dec 2018. We analyzed the duration and history of nasal symptoms with past medical charts to rule out the effects of chronological changes. And also allergic reactions were excluded with analyzing past blood sample such as immunoglobulin E level. We applied the following exclusion criteria: 1) under 18 years of age, 2) previous history of surgery in the sinonasal region such as nasal polyp and recurred mucocele etc. (121 patients), 3) severe systemic disease such as hypertension and diabetes mellitus etc. (95 patients), 3) patients with previous congenital

nasal anomalies, sinonasal diseases like allergic rhinitis and dental problem (20 patients), 4) destroyed nasal cavity and sinus anatomical structures due to malignant tumors or trauma (103 patients), 5) anterior to posterior ‘S’-shaped septum (211 patients). All of the examinations were performed using a 64-slice CT (Brilliance 64, Philips Healthcare, Cleveland, OH, USA). We did not inject CT contrast agents and relied on bone windows for interpretation. Overall measurements including the wall thickness and volume of maxillary sinus in PNS CTs were done with Aquarius iNtuition software 4.4.12 (TeraRecon, Foster City, CA, USA) in the 2 dimensional (2D) view of the whole region creating 3D view of it. After setting maxillary sinus manually in each view of coronal, axial and sagittal of PNS CT, the images were combined and 3D-reconstructed for measuring the volume (Fig. 1). Data were analyzed twice by one radiologist to reduce examiner bias. Septal deviation was measured in a coronal view with the convex part based on the line connecting the anterior nasal spine and crista galli

Fig. 1. Three-dimensional reconstruction of bilateral maxillary sinus volume using Aquarius iNtuition software (version 4.4.12; TeraRecon, Foster City, CA, USA).

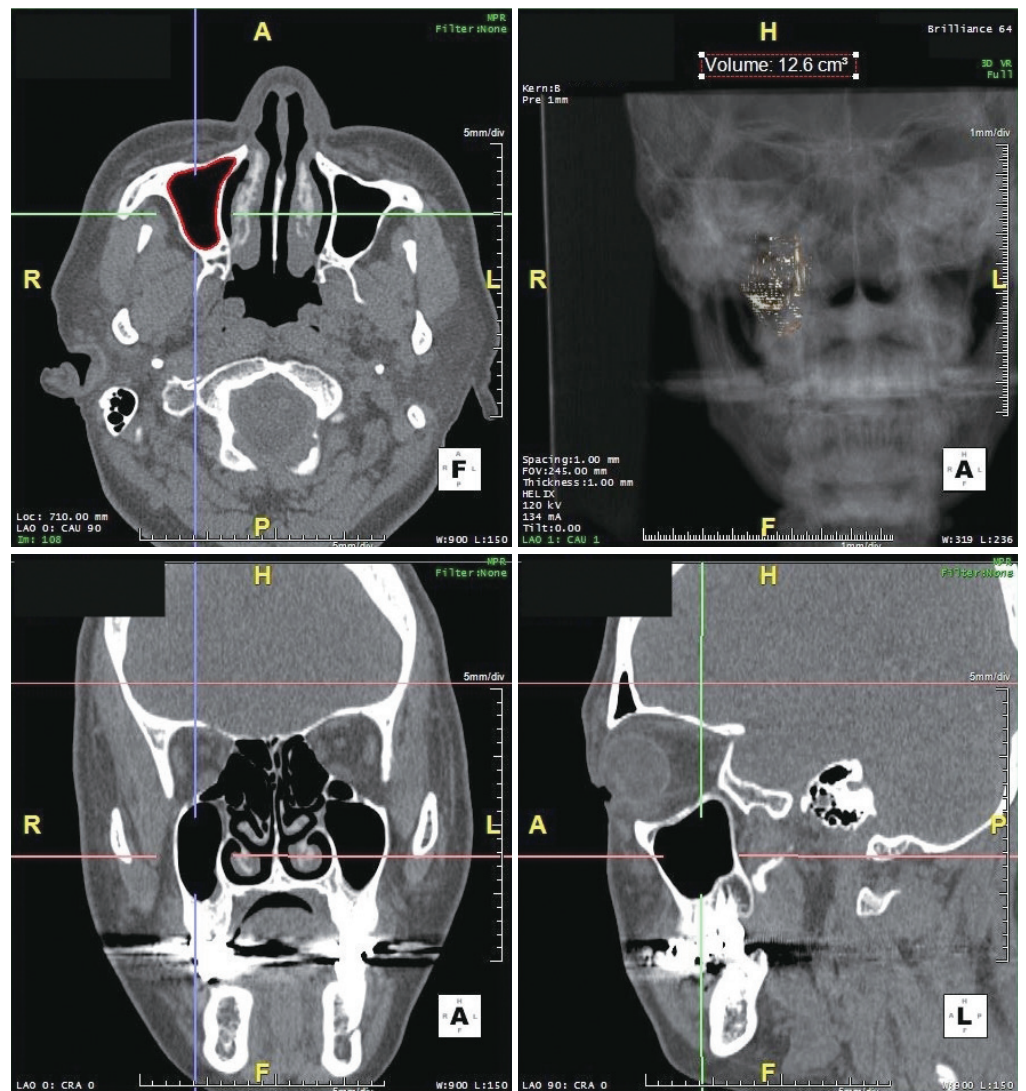


Fig. 2. Evaluation of nasal septal deviation.

A. Baseline for determining the degree of septal deviation—line connecting crista galli and anterior nasal spine (red dotted line).

B. Right deviated nasal septum. Curved nasal septum is observed by referencing the line connecting crista galli and anterior nasal spine (red dotted line).

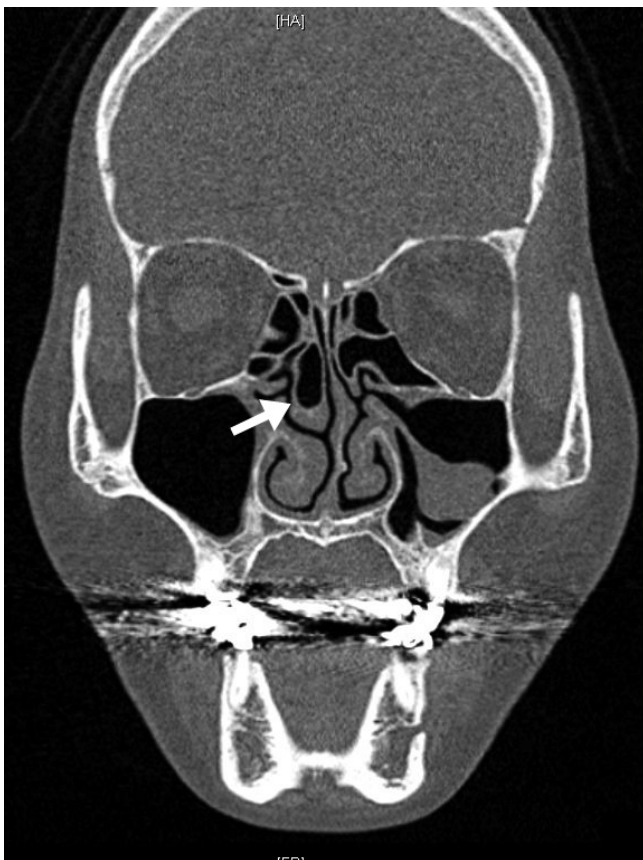
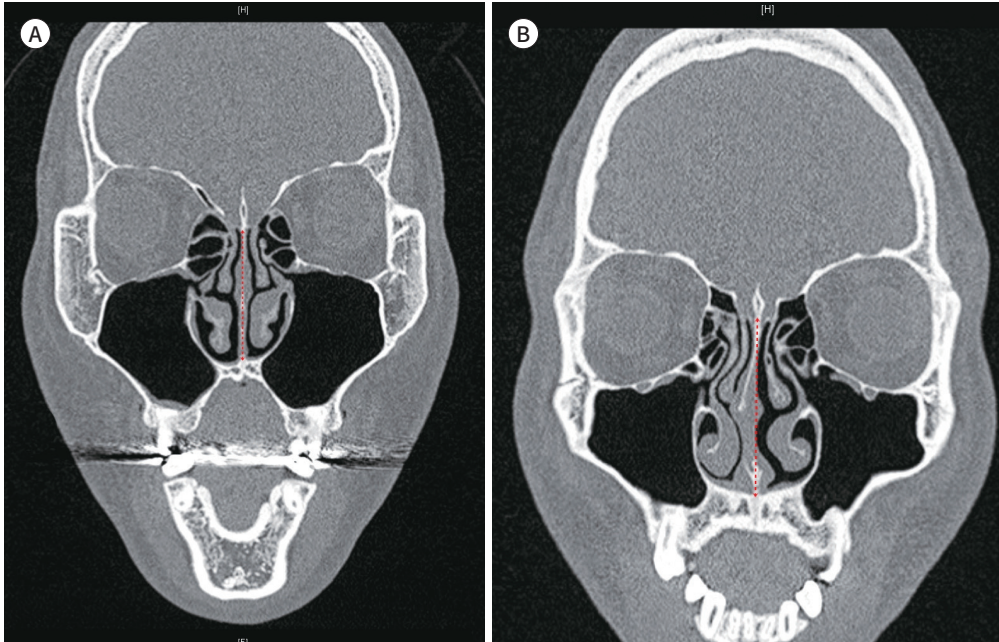


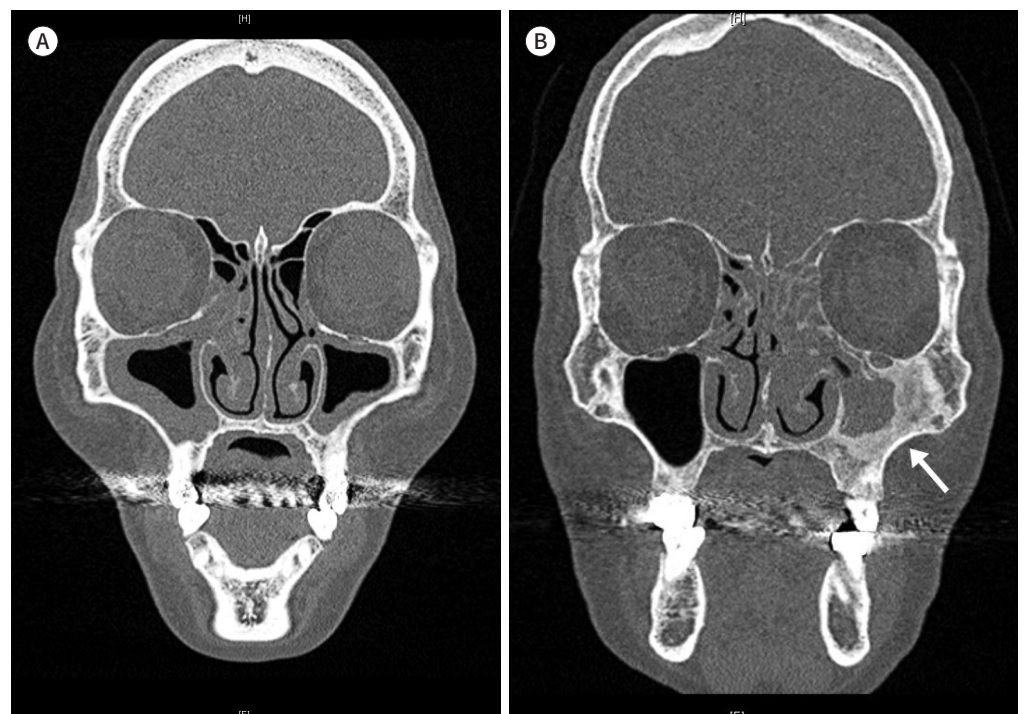
Fig. 3. Left deviated nasal septum with right bulbous-type, middle turbinate concha bullosa (arrow).

(Fig. 2A, B). We analyzed directionality and association of bulbous and extensive types of concha bullosa only, as they have a large effect on the nasal-airway (Fig. 3) (5, 6). Sinonasal symptoms with remarkable anatomical change (over 4 mm sinus mucous membrane thickening and polypoid change, bony wall sclerotic change) detected on the PNS CTs were designated as chronic sinusitis (Fig. 4A, B) (7, 8). Statistical analysis was performed using SAS 9.4 with two-sample *t*-test and chi-square test; results were given as odds ratio (OR) and as estimates of the relative risk with a 95% confidence interval (CI). Statistical significance was set at $p < 0.05$.

RESULTS

A total of 209 patients (male: 130; female: 79) were included in this study and their mean age was 46.39 ± 17.17 years (male: 44.26 ± 18.09 ; female: 49.87 ± 15.01). The proportion of the direction of deviation was straight septum in 103 (49.52%), right (Rt.) deviated septum in 49 (23.56%), and left (Lt.) deviated septum in 56 patients (26.92%). Concha bullosa was characterized as extensive or bulbous type and was present bilaterally in 26 (12.5%), on the Rt. side in 12 (5.77%), on the Lt. side in 21 (10.1%), and absent in 149 (71.63%) patients. An analysis of sinus volume revealed no statistically significant differences between the Rt. and Lt. sides. However, the Rt. sinus volume ($p < 0.0001$) and Lt. sinus volume ($p < 0.0001$) showed significant differences based on sex. The sinus volume on both sides in the male patients was significantly larger than that in the female patients (Table 1). Maxillary sinusitis was present

Fig.4. A major anatomical change in chronic sinusitis.
A. Symmetric thickening of both sinus membranes.
B. Sclerotic change in the left maxillary sinus wall (arrow).



bilaterally in 51 (24.4%), on the Rt. side in 25 (11.96%), on the Lt. side in 31 (14.83%), and absent in 102 patients (48.8%).

RELATIONSHIP BETWEEN SEPTAL DEVIATION AND CONCHA BULLOSA

The relationship between the orientation of septal deviation and concha bullosa was significant ($p < 0.0001$). When septal deviation was on the Rt. side, Lt. concha bullosa was detected in 17 patients (8.17%), and when the deviation was on the Lt. side, Rt. concha bullosa was detected in 12 (5.77%) (Table 2). Thus, in other words, concha bullosa was mainly located

Table 1. Gender Differences in the Maxillary Sinus Volume

	Male (n = 130)	Female (n = 79)	p-Value
Right sinus volume (cm ³)	20.76 ± 6.71*	16.04 ± 5.90*	< 0.0001
Left sinus volume (cm ³)	20.98 ± 6.69*	16.50 ± 5.84*	< 0.0001
p-value	0.7853	0.6180	

*Mean ± standard deviation.

Table 2. Relationship between NSD and CB

NSD/CB	Absence (n, %)	Equal Both (n, %)	Right (n, %)	Left (n, %)	p-Value
Straight	87 (41.83)	15 (7.21)	0 (0.00)	1 (0.48)	
Right	29 (13.94)	3 (1.44)	0 (0.00)	17 (8.17)	< 0.0001
Left	33 (15.87)	8 (3.85)	12 (5.77)	3 (1.44)	

CB = concha bullosa, NSD = nasal septal deviation

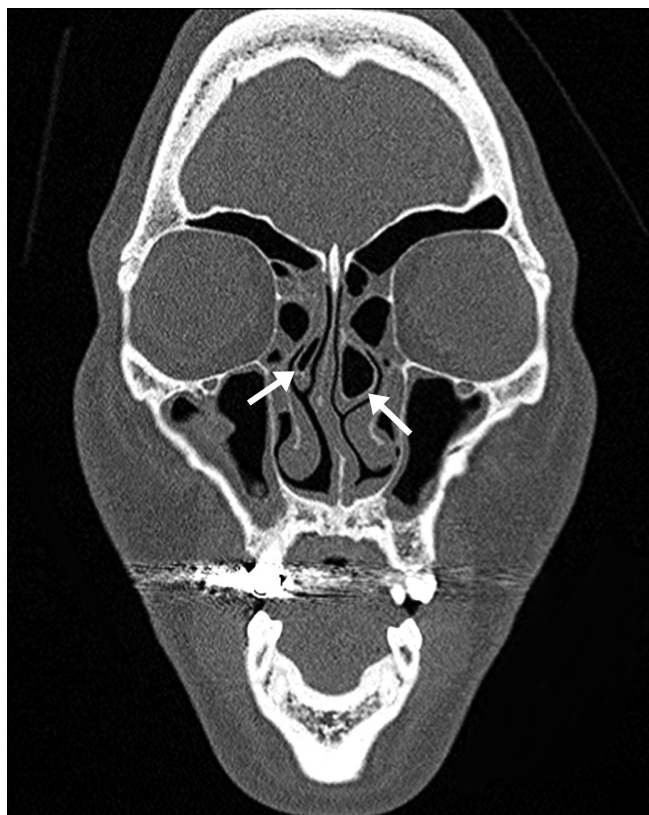


Fig. 5. Dominant proportion of left bulbous-type, middle turbinate concha bullosa and right deviated nasal septum observed simultaneously (arrows).

in the concave cavity of the septal deviation (Figs. 3, 5).

RELATIONSHIP OF SEPTAL DEVIATIONS WITH SINUS VOLUME AND MAXILLARY SINUSITIS

Septal deviation and maxillary sinusitis were not statistically significant when analyzed by direction of deviation (Rt. or Lt.) and disease occurrence ($p = 0.8756$) (Table 3). An analysis of the relationship between the prevalence of maxillary sinusitis and the presence or absence of nasal septal deviation regardless of direction revealed an OR of approximately 1.00 (0.92–1.10), indicating that it was not a significant risk factor. The relationship between the direction of the septal deviation and the maxillary sinus volume was not found to be significant. We also grouped the severity of deviation using the distance away from the mid line which connecting the anterior nasal spine and crista galli. Mean distance was 5.5 mm and there was no statistically significant difference between volumes of maxillary sinus in all the group respectively (Table 4).

RELATIONSHIP OF CONCHA BULLOSA WITH SINUS VOLUME AND MAXILLARY SINUSITIS

No significant relationship between concha bullosa and maxillary sinusitis was found

Table 3. Relationship between NSD with MS

NSD/MS	Absence (n, %)	Bilateral (n, %)	Right (n, %)	Left (n, %)	p-Value
Straight	49 (23.57)	25 (12.02)	15 (7.21)	14 (6.73)	0.8756
Right	25 (12.02)	12 (5.77)	6 (2.88)	6 (2.88)	
Left	28 (13.46)	14 (6.73)	4 (1.92)	10 (4.81)	

MS = maxillary sinusitis, NSD = nasal septal deviation

Table 4. Maxillary Sinus Volume according to the Type of NS

	Straight NS (n = 104)	Rt.-Sided NSD & Dis < 5.5 mm (n = 29)	Rt.-Sided NSD & Dis ≥ 5.5 mm (n = 20)	Lt.-Sided NSD & Dis < 5.5 mm (n = 31)	Lt.-Sided NSD & Dis ≥ 5.5 mm (n = 25)
Rt. sinus volume (cm ³)	18.64 ± 7.27*	19.84 ± 6.13*	18.74 ± 7.13*	19.37 ± 6.63*	19.28 ± 5.76*
Lt. sinus volume (cm ³)	18.73 ± 7.07*	20.23 ± 6.46*	19.31 ± 6.60*	19.77 ± 6.66*	20.19 ± 6.07*
p-value	0.9379	0.8121	0.7297	0.8118	0.5900

*Mean ± standard deviation.

Lt. = left, NS = nasal septum, NSD = nasal septal deviation, Rt. = right

Table 5. Relationship between CB with MS

CB/MS	Absence (n, %)	Bilateral (n, %)	Right (n, %)	Left (n, %)	p-Value
Absence	67 (32.06)	40 (19.14)	21 (10.05)	22 (10.53)	0.3401
Equal both	15 (7.18)	3 (1.44)	4 (1.91)	4 (1.91)	
Right	6 (2.87)	4 (1.91)	0 (0.00)	2 (0.96)	
Left	14 (6.70)	4 (1.91)	0 (0.00)	3 (1.44)	

CB = concha bullosa, MS = maxillary sinusitis

when their orientation was analyzed ($p = 0.3401$) (Table 5). Additionally, further analysis by dividing each of the factor into two groups also did not reveal any relationship between unilateral or dominant concha bullosa and prevalence of maxillary sinusitis ($p = 0.1844$). We also confirmed the relationship between the direction of concha bullosa and the maxillary sinus volume. When there concha bullosa was absent, or was located equally on both sides such that there is a comparable nasal air-flow effect, there was no statistical difference between the maxillary sinus volume on each side ($p = 0.6289$). However, even when a unilateral or dominant concha bullosa was present, which can affect nasal air flow, there was no significant difference in the bilateral sinus volumes (Rt.: $p = 0.9522$, Lt.: $p = 0.9201$) (Table 6). In conclusion, there is no significant relationship between directions of concha bullosa and maxillary sinus volume.

DISCUSSION

AVAILABILITY OF CT IN PARANASAL SINUS DISEASE

In recent clinical trials, PNS CT is frequently used in conjunction with endoscopy in patients with suspected sinusitis or other nasal symptoms. In addition, when performing endoscopic surgery in the nasal area, PNS CT is segmented by each view, which provides a 3D-reconstructed anatomy, thereby becoming more important as a tool to localize accurate lesions and reduce complications (7, 9). Maxillary sinus is clinically more important than any other paranasal sinus, because it is more affected by infections, tumor, or trauma than the other sites. Even though, anatomical changes such as mucosal thickening and opacification of the normally aerated sinus lumen can be evaluated quickly and non-invasively with standard radiographic views (Caldwell, Waters, Base and lateral etc.); however the inability to distinguish between the ethmoid air cell, the upper two-third nasal cavity, and the frontal recess poses as a limitation (10). Beck et al. (11) demonstrated the excellent ability of PNS CT to display bone and soft tissue and its utility as a diagnostic tool for evaluating the ostiomeatal complex, which is a major site where nasal symptoms are triggered. Therefore, presently CT is the most effective method for evaluating PNS.

THE RELATIONSHIP BETWEEN NASAL SEPTAL DEVIATION AND CONCHA BULLOSA

Earwaker (12) showed that nasal septal deviation had a nation-wide incidence of 14% to 80% with a slight Rt. side predominance and an equal gender distribution in 44% of individu-

Table 6. Maxillary Sinus Volume Based on the Presence of CB

	Absence or Equal Bilateral CB	Only Right or Dominant Right CB	Only Left or Dominant Left CB
Right sinus volume (cm ³)	18.98 ± 6.94*	20.28 ± 5.93*	18.46 ± 6.21*
Left sinus volume (cm ³)	19.33 ± 6.85*	20.42 ± 5.51*	18.66 ± 6.65*
<i>p</i> -value	0.6289	0.9522	0.9201

*Mean ± standard deviation.

CB = concha bullosa

als. Wee et al. (13) reported that the prevalence of nasal septal deviation in Koreans was 22.38% and was reported to be higher in men (79%) than in women (68%). In our study, the ratio of nasal septal deviation was 50.23% and the ratio of male to female was slightly higher [male (56.92%) to female (9.24%)], which is similar to results of previous studies. However, the predominant direction of deviation in our study was the Lt. side (Rt. deviated septum was 46.67%, Lt. deviated septum was 53.37%), which is different from the results of previous analyses (14). Concha bullosa which is thought to be related to nasal septal deviation, is reported to have a frequency of 14–53.6% according to previous studies (15). In this study, concha bullosa located bilaterally or unilaterally showed a similar result i.e. 28.37% in total. These two anatomical variations, i.e. that nasal septal deviation and concha bullosa have many effects on the nasal airway, and their relationship has been investigated in several studies. A study by Stallman et al. (16) showed that whether the concha bullosa is dominant or unilateral, a clear association is present regardless of severity of nasal septal deviation. Furthermore, there is preservation of air channels between the dominant concha and the deviated nasal septum. Additionally, Balikci et al. (17) reported that regardless of the concha bullosa type, contralateral nasal septal deviation and unilateral or dominant concha bullosa have a strong association. In this study, we did not analyze the presence of air-channels or the relationship between nasal septal deviation and concha bullosa according to the various types. And similar to previous studies, it was concluded that there was a significant relationship between contralateral nasal septal deviation and unilateral concha bullosa. However, it was the only significant relationship which we analyzed on this study.

EFFECT OF NASAL SEPTAL DEVIATION AND CONCHA BULLOSA ON MAXILLARY SINUS VOLUME AND MAXILLARY SINUSITIS

The maxillary sinus is a pyramidal shaped sinus behind the maxillary bone and the orbital bone, which develops from the third week of gestation to early adulthood. It is a mesodermal structure in the first branchial arch, with an average volume of 15 mL (18). Lorkiewicz-Muszyńska et al. (19) has shown that the differences in growth and development of the sinus are genetically determined, but morphological features also differ as a result of aging of the adjacent structures or environmental adaptive deformation. In addition, according to the anatomical variants associated with the airway in the nasal cavity, such as nasal septal deviation or concha bullosa, maxillary sinus volume is also influenced simultaneously with development. For example, Kapusuz Gencer et al. (18) showed that the contralateral maxillary sinus volume was significantly larger than the ipsilateral maxillary sinus volume in the severe nasal septal deviation group. There are several causes of inflammation in the maxillary sinus, but obstruction of the ostiomeatal complex is known to be the most common. Momeni et al. (1) found that allergy, viral infection, or air pollutants cause local inflammation, resulting in peripheral mucosal swelling and decreased mucocilliary clearance, as well as blockage of sinus ostia. The relationship between sinus volume and sinusitis in nasal septal deviation and concha bullosa has been studied previously. Some examples include the studies by Orlandi et al. (20), which showed that other possible factors such as anatomic narrowing of the frontal recess, as well as nasal septal deviation may affect rhinosinusitis and by Calhoun et al. (21), which showed that a population with symptoms of sinus disease also has

a significantly greater incidence of concha bullosa and septal deviation, and they can affect each other. However, contrary to these findings, Jones et al. (22) concluded that such anatomical variations are potentially predisposing, but not a direct etiological factor of chronic sinusitis. Furthermore, Kucybała et al. (23) reported that the presence of nasal septal deviation is closely related to the increase in bilateral maxillary sinusitis incidence, but both nasal septal deviation and concha bullosa have no effect on the asymmetric development of the maxillary sinus. The results of this study show that nasal septal deviation and concha bullosa are not significantly related to the incidence of maxillary sinus volume or sinusitis. These conflicting findings have been a topic of debate and further investigations are imperative to arrive at any clear conclusions regarding the relationship between nasal septal deviation and concha bullosa.

Our study has several limitations that need to be acknowledged. First, results may have a possibility of bias due to cross-sectional analysis for chronic disease. Second, even if the measuring is performed twice, a bias can be easily introduced because the measurements are performed by the same radiologist. There are several studies that analyze the relationship between the volume of maxillary sinus and the prevalence of sinusitis; however only a few of those studies are based on a Korean or Asian population. In addition, the results are conflicting, and further studies are needed to better treat clinical sinusitis, a common disease that affects many people and causes discomfort.

In conclusion, concha bullosa was significantly present in the contralateral nasal cavity when nasal septal deviation was present. However, except for this one significant finding, no other significant relationships were detected between the nasal septal deviation and concha bullosa and other factors such as incidence of maxillary sinus volume or sinusitis.

Author Contributions

Conceptualization, L.J., K.M.S.; data curation, L.J.; formal analysis, M.J.S.; investigation, L.J., P.S.M.; methodology, L.J., P.S.M., K.M.S.; project administration, C.S., K.M.S.; supervision, K.M.S.; validation, M.J.S.; visualization, L.J.; and writing—original draft, L.J., P.S.M.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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비중격 만곡증과 수포성 비갑개는 상악동 부피와 상악골 부비동염에 있어 관련성을 지니는가? 후향적 연구

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목적 본 연구의 목적은 비중격 만곡증과 수포성 비갑개가 상악동 부피에 영향을 미치는지 그리고 만성 부비동염의 유병률과 관련성 여부를 분석해보는 것이다.

대상과 방법 이 연구는 2017년 1월부터 2년 동안 부비동 증상을 호소하며 본인 이비인후과를 내원한 환자 중 부비동 컴퓨터단층촬영술을 시행한 209명의 환자들을 후향적으로 분석하였다. 부비동의 부피 측정을 포함한 컴퓨터단층촬영술에 대한 판독은 1명의 영상의학과 의사가 2번 반복하여 시행하였고, 통계적 분석은 SAS 9.4를 사용되었다.

결과 상악동 부피는 우측, 좌측 모두 남자가 여자보다 의미 있게 컸다($p < 0.0001$). 또한 수포성 비갑개는 비중격 만곡증의 오목한 부분에서 유의하게 많이 존재하였다($p < 0.0001$). 그러나 비중격 만곡증이나 상악동 부비동염과의 관련성은 방향성을 나누어 분석했을 시 서로 유의하지 않았다($p = 0.8756$). 또한 수포성 비갑개는 상악동 부비동염($p = 0.3401$)이나 상악동 부피와(양측: $p = 0.6289$, 우측: $p = 0.9522$, 좌측: $p = 0.9201$) 연관성이 없었다.

결론 수포성 비갑개는 만곡된 비중격의 반대편에 주로 존재하였다. 그러나 해당 관련성 이외에는, 비중격 만곡증과 수포성 비갑개는 상악동의 부피나 부비동염과는 큰 연관이 없다.

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