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ORIGINAL ARTICLE

Anatomical correlation between existence of concha bullosa and maxillary sinus volume

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Abstract
Purpose The objective of this study was to assess the effects of concha bullosa variation on maxillary sinus volume and uncinate angle.
Method The study group included 169 patients (338 sides) who underwent either surgical or medical treatment with the diagnosis of chronic rhinosinusitis. The paranasal sinus computed tomography of these patients was analyzed to measure maxillary sinus volume, uncinate angle and existence of concha bullosa. Subsequently, these variables were evaluated to find out possible relationship inbetween.
Results Mean maxillary sinus volume and uncinate angle at right and left sides were 15.21 ± 0.47 and 15.51 ± 0.48 mm^3, $30.57 \pm 0.62°$ and $30.20 \pm 0.68°$, respectively. There was no difference between patients with or without concha bullosa in regard to maxillary sinus volume and uncinate angle at both sides. Maxillary sinus volume and degree of uncinate angle did not show any significant correlation at both sides; $r = -0.124$, $p = 0.107$ and $r = -0.136$, $p = 0.078$.
Conclusion In conclusion, concha bullosa is a common anatomical variation at nasal cavity. The existence of concha bullosa does not have any association with the volume of maxillary sinus and angle of uncinate process.

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Keywords Concha bullosa · Maxillary sinus volume · Uncinate process

Introduction

The maxillary sinus has a biphasic growth pattern with two peaks; first 3 years after birth and between 7 and 12 years [22]. After reaching adulthood, maxillary sinus grows slowly until it gains its maximal pneumatization at 2nd decade in women and at 3rd decade in men [14]. It has an average volume of 14–18 cm^3 in adults. The mean volume of maxillary sinus decreases with aging in both sexes [9, 11, 14, 16, 27]. Furthermore, males have larger maxillary sinus volume in all ages compared to women [14, 16]. There are also other pathological conditions which change maxillary sinus volume, such as: [developmental sinus hypoplasia, silent sinus syndrome, congenital disorders, iatrogenic (postsurgical or postradiation), traumatic, neoplastic and systemic diseases (hematologic or osteopetrosis)] [22]. Chronic rhinosinusitis was shown to have negative impacts on maxillary sinus volume and bony walls of the sinus were found significantly thicker in those patients [9, 18]. A significant relation between severe septal deviation and contralateral maxillary sinus volume was also reported recently [15].

Concha bullosa, an aerated middle turbinate is among the most common anatomical variants of nasal apparatus [8, 25, 32]. Since middle turbinate is a part of middle meatus, some authors suggested that a pneumatized and enlarged concha may predispose to osteomeatal narrowing and a subsequent sinus infection [1, 8, 21, 25, 26]. However, the previous studies showed contradictory results regarding the relation between concha bullosa and chronic sinusitis. Although some investigators reported a significant association between concha bullosa and sinusitis [7, 8], some did not [1, 19, 21, 25, 32, 33]. Pneumatized middle turbinate is classified as: [lamellar (small), bulbous (moderate) or extensive (large) types] up to its morphology [6, 32]. The clinical significance of the type of concha bullosa on osteomeatal complex and sinus disease is also another debated issue. Some authors reported that bulbous and extensive types were more likely to cause osteomeatal disease predisposing to sinusitis [25, 33].

There are some proposed theories that indicated the importance of available nasal airflow and normal oxygen pressure for the development of paranasal sinus [20, 28]. We suggested that if middle turbinate is large enough to obstruct maxillary sinus ostium, it may restrict normal development of the sinus and eventually leads to a small sinus. To the best of our knowledge, there is no other study which assessed the relation between the concha bullosa and maxillary sinus volume. In addition, an enlarged middle turbinate may influence deflection of uncinate process due to anatomical proximity. Thus, the aim of this study is to determine the role of concha bullosa on volume of maxillary sinus, position of uncinate process.

Materials and method

This retrospective study was conducted at the University of Uludag Medical Faculty, Departments of Otolaryngology and Radiology. The paranasal sinus computed tomography (CT) findings of patients who admitted to otolaryngology clinic between May 2012 and June 2014 were retrospectively analyzed. The study group included patients who underwent endoscopic sinus surgery or medical treatment with the diagnosis of chronic rhinosinusitis with or without nasal polyps. Exclusion criteria were determined as (1) previous sinonasal surgery, (2) history of radiotherapy, (3) maxillofacial trauma and fracture, (4) sinonasal tumor, (5) granulomatous disease, (6) sinonasal fungal infections, (7) <18 years of age and (8) diffuse nasal polyposis. Finally, 169 patients (338 sides) were included in the study group. This study was approved by the ethical committee of the medical school.

The patients images were acquired by high resolution CT scanner (Siemens Medical System, Germany) at 3 mm slice thickness (110 kV, 130 mA) in supine position. The images were analyzed at Syngo Multimodality workstation by using VE36A program. The volume was measured via volume rendering technique (VRT) for region of interest in each side. To measure the total volume inside the maxillary sinus bony walls, the lower and upper Hounsfield unit values were defined as −2500 and −200, respectively (Fig. 1a, b). The images with motion artifacts were excluded from data analysis. To assess the angle of deflection in uncinate process, we measured the angle between two lines; first line passes from crista galli to anterior nasal spine (vertical line) and the second line connects the starting point of uncinate process to the most medial point and the vertical line (Figs. 2, 3). CT images were assessed simultaneously by a senior otolaryngologist and a radiologist.

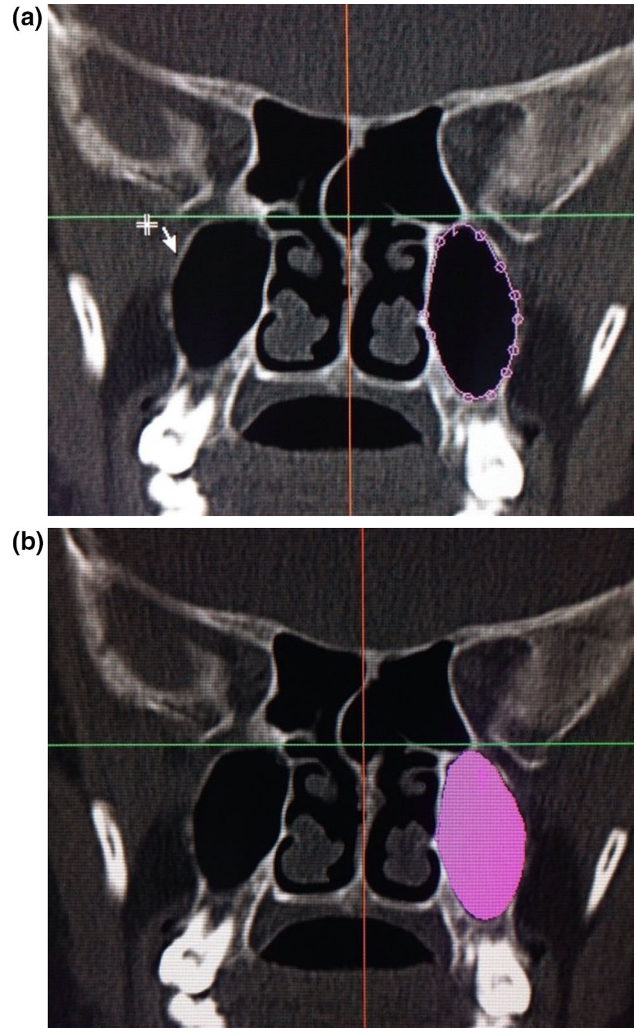

Fig. 1 **a**, **b** These figures show the program used to measure the sinus volume at workstation

After the volumetric measurement of maxillary sinus at both sides was completed, we noted existence of concha bullosa and its morphological type [25] (lamellar, bulbous and extensive) for each patient (Figs. 4, 5, 6). Furthermore, the angle of deflection at uncinate process was measured [24]. Subsequently, we compared the difference in maxillary sinus volume and uncinate angle between patients with or without concha bullosa variants. We also assessed the possible relationship between maxillary sinus volume and uncinate angle.

Statistical analysis was carried out using SPSS v.21 (SPSS Inc, IBM, USA). The continuous variables were presented as mean ± standard error and categorical variables were presented as numeral and associated percentage values. Independent samples *t* test or ANOVA test were

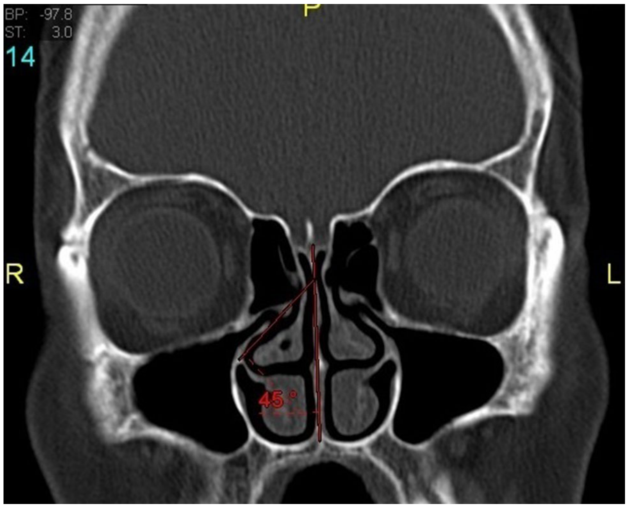

Fig. 2 The figure shows the method used to measure a wide-angled uncinate process

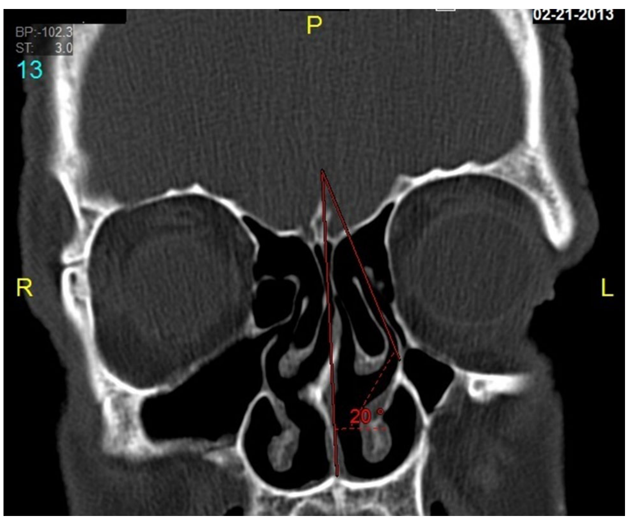

Fig. 3 The figure shows the method used to measure a narrow-angled uncinate process with bilateral extensive type concha bullosa

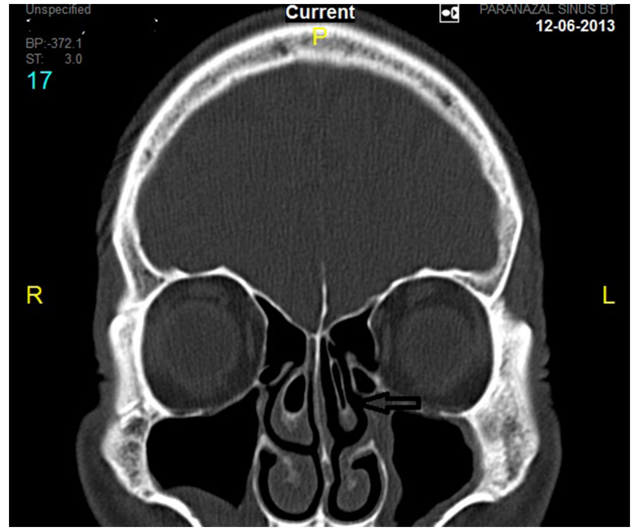

Fig. 4 The figure shows a lamellar type of concha bullosa at left side (with *black arrow*) in a patient with mucosal thickening and chronic sinusitis

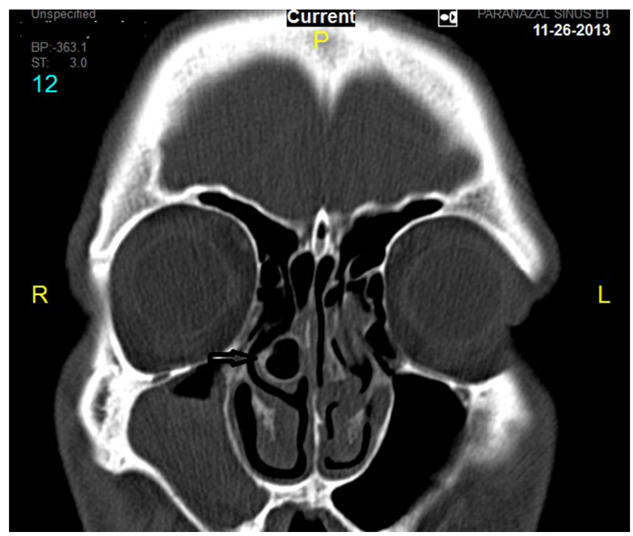

Fig. 5 The figure shows a bulbous type of concha bullosa at *right* side (with *black arrow*) in a patient with chronic sinusitis and *left* nasal polyps

used to compare continuous variables and Pearson Chi-square and Fisher Freeman Halton tests were used for categorical variables. Dependent group comparisons for continuous variables were done with paired samples *t* test and for categorical variables with Mc Nemar Bowker test. Correlations between variables were analyzed with Spearman's rank correlation coefficient. $p < 0.05$ was set at statistical significance.

Results

The study group consisted of 82 male and 87 female patients. Among 338 middle turbinates, 194 conchae (57 %) were normal and lamellar, bulbous and extensive (true) type conchae were found in 72, 53 and 19 sides, respectively. The mean right and left maxillary sinus volumes in all patients were 15.21 ± 0.47 and 15.51 ± 0.48 mm^3. Mean CT scores at right and left sides were 0.63 ± 0.08 and 0.62 ± 0.07, respectively. Uncinate angles were found $30.57 \pm 0.62°$ at right side and $30.20 \pm 0.68°$ at left side. There was no difference between male and female patients in regard to age and sinus volume at left side. However, right sinus volume and uncinate angles in both sides showed statistical significance. Male patients had significantly lower uncinate angle (Table 1). There was no

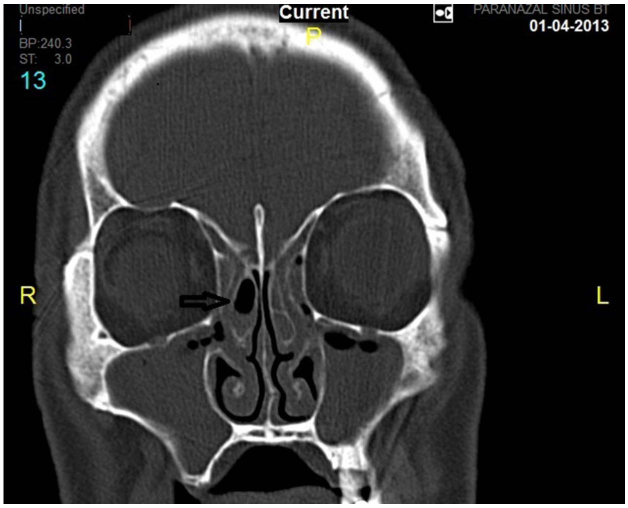

Fig. 6 The figure shows an extensive type of concha bullosa at *right* side (with *black arrow*) in a patient with pansinusitis

Table 2 The table shows the difference between right and left nasal cavity in regard to uncinate angle and maxillary sinus volume

	Right side	Left side	*p* value
Males			
MMSV	16.32 ± 0.74	16.46 ± 0.78	0.742
Uncinate angle	29.32 ± 0.8	28.56 ± 0.89	0.444
Females			
MMSV	14.17 ± 0.58	14.61 ± 0.58	0.157
Uncinate angle	31.76 ± 0.92	31.74 ± 1	0.981

Sinus volume was given in mm^3 ± SD and uncinate angle in degree ± SD

MMSV mean maxillary sinus volume, *CT* computed tomography

difference between right and left nasal cavity regarding uncinate angles in both genders. In addition, we found no difference between right and left maxillary sinus volumes in male and female patient groups ($p = 0.742$ and $p = 0.157$, respectively) (Table 2).

We compared the maxillary sinus volumes in patients with a concha bullosa subtype or without concha bullosa. There was no significance between any of these groups in both sides. In addition, comparison of uncinate angles between patients with or without concha bullosa revealed no difference (Table 3). The existence of concha bullosa did not differ inbetween two genders for both sides ($p = 0.626$ and $p = 0.075$). Concha bullosa incidence was similar for both right and left sides.

We performed further analysis to find out any association between degree of uncinate angle and maxillary sinus volume. Maxillary sinus volume and degree of uncinate angle also did not show any significant correlation in both right and left sides; $r = -0.124$, $p = 0.107$ and $r = -0.136$, $p = 0.078$, respectively.

Discussion

The morphological studies of lateral nasal wall in utero showed that although the first buds of turbinates are visible in the seventh week, the maxillary sinus appears later, between 10th and 15th weeks of gestation [3, 23]. The uncinate process appears during the pneumatization of maxillary sinus and it is influenced by maxillary sinus formation during craniofacial bone development [4]. After birth there is a sustained increment at maxillary sinus volume until it reaches to maximum pneumatization at 2nd to 3rd decades [14]. Maxillary sinus volumes at two sides show significant correlation in normal population [2, 9, 11, 16]. However, some pathological conditions have negative impacts on growth of paranasal sinus such as congenital syndromes [22], chronic rhinosinusitis [9, 18], osteopetrosis [32], radiotherapy [12] or severe septal deviation [15]. Growth restriction and thickening of bony walls due to chronic inflammation were the proposed theories which explain the volume decrease in longstanding chronic rhinosinusitis [10, 17, 18]. On the contrary, Cho et al. [9] pointed out that although maxillary sinus volume was smaller and sinus walls were thicker in patients with chronic rhinosinusitis compared to controls, there was no

Table 1 The table shows the difference between males and females in regard to age, maxillary sinus volume and uncinate angle

	Males ($n = 82$)	Females ($n = 87$)	*p* value	All patients ($n = 169$)
Age	42 ± 1.66	42.72 ± 1.53	0.749	42.37 ± 1.12
RMSV	16.32 ± 0.74	14.17 ± 0.58	**0.025**	15.21 ± 0.47
LMSV	16.46 ± 0.78	14.61 ± 0.58	0.059	15.51 ± 0.48
RUA	29.32 ± 0.8	31.76 ± 0.92	**0.050**	30.57 ± 0.62
LUA	28.56 ± 0.89	31.74 ± 1	**0.020**	30.20 ± 0.68

Sinus volume was given as mm^3 ± SD and uncinate angle in degree ± SD

p values in bold indicate significance

RMSV right maxillary sinus volume, *LMSV* left maxillary sinus volume, *RUA* right uncinate angle, *LUA* left uncinate angle

Table 3 The table shows ipsilateral and contralateral maxillary sinus volume and uncinate angle in both nasal cavities in regard to existence of concha bullosa subtypes

	Concha bullosa (−)	Type I CB	Type II CB	Type III CB	*p* value
Right side					
İp. MMSV	14.69 ± 0.66	15.32 ± 0.95	16.62 ± 1.02	15.82 ± 2.06	0.51
Cont. MMSV	14.71 ± 0.63	15.97 ± 1.2	17.69 ± 1.14	15.55 ± 1.75	0.16
Uncinate angle	30.95 ± 0.85	30.16 ± 1.5	30.52 ± 1.35	28.55 ± 1.93	0.60
Left side					
İp. MMSV	15.09 ± 0.62	15.51 ± 0.92	14.54 ± 1.3	17.13 ± 3.13	0.76
Cont. MMSV	15.45 ± 0.68	15.39 ± 0.88	15.83 ± 1.26	15.88 ± 2.42	0.99
Uncinate angle	30.78 ± 0.87	28.44 ± 1.31	31 ± 2.16	29.75 ± 3.74	0.23

ip. ipsilateral, *cont.* contralateral, *MMSV* mean maxillary sinus volume, *CB* concha bullosa

relation between volume and wall thickness. Some authors reported that maxillary sinus volume may also decrease due to iatrogenic causes like radiation exposure inhibiting growth centers [12] and osteoneogenesis and fibrosis after Caldwell-luc surgery [22]. In another study, contralateral maxillary sinus volume with severe septal deviation was significantly larger compared to ipsilateral side [15]. There is a chicken–egg causality dilemma that whether the chronic sinusitis and osteitic inflammation causes volume loss or small sinus volume influences sinusitis. This association is still a debated issue among otolaryngologists.

Concha bullosa, a pneumatized middle turbinate is among the most common anatomic variations of the nasal cavity. It may completely fill the space between the septum and lateral nasal wall if large enough [25]. We suggested that since the turbinates are the first structures developed in lateral nasal wall, they may affect the development of consecutive neighbor structures like uncinate process, osteomeatal complex and maxillary sinus. Furthermore, a pneumatized middle concha may eventually impair maxillary sinus growth. There are many contradictory results in previous studies which evaluated the association between concha bullosa and mucosal disease at paranasal sinus. Some authors reported that concha bullosa may predispose to maxillary sinusitis by obstructing osteomeatal complex and blocking maxillary sinus drainage [7, 8] but some did not [21, 25, 31, 32]. In addition, the type of concha bullosa (extensive and bulbous) was considered as an important determinant of osteomeatal disease and sinusitis in few studies [25, 33], however Hatipoglu et al. [13] indicated contradictory results.

Uncinate process is an important component of osteomeatal complex that contributes to normal sinus physiology. It is a curved lamina that originates from medial wall of maxillary sinus articulating with inferior concha. The length of uncinate process was reported to show significant difference between patients with or without chronic sinusitis [30]. Uncinate process is in close proximity with middle turbinate at osteomeatal region. Thus, we proposed that a pneumatized concha may effect uncinate process deflection and cause narrow-angled osteomeatal opening. We know that the paranasal sinuses require proper amount of ventilation through their openings to maintain normal physiology [24]. Therefore, any obstructive pathology at osteomeatal complex can alter sinus physiology adversely. To the best of our knowledge, there is no other study in the literature which evaluated the possible effect of concha bullosa on the maxillary sinus volume and angle of uncinate process. However, we failed to show a significant causal relationship between concha bullosa and maxillary sinus volume or uncinate angle. This insignificance may be related to homogenous characteristics of study group which included only patients who referred to CT with positive clinical findings and a presumed sinonasal disease. The absence of asymptomatic normal population and relatively small number of cases may be the shortcomings of the presented study. We believe that further comprehensive studies with large sample sizes are required to elucidate the association between concha bullosa and maxillary sinus volume in general population.

Concha bullosa resection, alone or combined with endoscopic sinus surgery was advocated to improve surgical outcomes like sinonasal symptoms and mucosal disease in few studies [5, 29], however, the actual association between concha bullosa and sinusitis has not been proved in most of the previous studies objectively [1, 19, 21, 25, 31–33]. We suggested that to perform concha bullosa resection in sinus surgery may be reserved only for patients with extensive type concha bullosa to relieve airway obstruction or to improve surgical field exposure. We believe that it is unnecessary to excise pneumatized concha in each patient undergoing endoscopic sinus surgery routinely.

In conclusion, concha bullosa is a common anatomical variation at nasal cavity. The existence of concha bullosa does not have any association with the volume of maxillary sinus and angle of uncinate process.

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Conflict of interest None.

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