Sinonasal Anatomical Variations: Their Relationship with Chronic Rhinosinusitis and Effect on the Severity of Disease—A Computerized Tomography Assisted Anatomical and Clinical Study

Ahmet Kaygusuz · Mehmet Haksever ·
Davut Akduman · Sündüs Aslan · Zeynep Sayar

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Abstract The anatomy of the sinonasal area has a very wide range of anatomical variations. The significance of these anatomical variations in pathogenesis of rhinosinusitis, which is the commonest disease in the region, is still unclear. The aims of the study were to compare the rate of sinonasal anatomical variations with development and severity of chronic rhinosinusitis patients. CT scan of paranasal sinuses images of 99 individuals were retrospectively reviewed. 65 cases of chronic rhinosinusitis (study group) who had undergone endoscopic sinus surgery were compared with 34 cases without chronic rhinosinusitis (control group). Also in study group Lund-Mackay score of the sinus disease were calculated and compared to the rate of related anatomical variations. There were 74 (74.7 %) males and 25 (25.2 %) females with ages ranging from 13 to 70 years (mean 32.2 years). The anatomical variations recorded were: Septal deviation 47 (72.3) in study and 25 (73.5 %) in control group, concha bullosa 27 (41.5 %) in study and 18 (52.9 %) in control group, overpneumatized ethmoid bulla 17 (26.1 %) in study and 14 (41.1 %) in control group, pneumatized uncinate 3 (4.6 %) in study and 3 (8.8 %) in control group, agger nasi 42 (64.6 %) in study and 19 (55.8 %) in control group, paradoxical middle turbinates 9 (13.8 %) in

study and 4 (11.7 %) in control group, Onodi cell 6 (9.2 %) in study and 2 (5.8 %) in control group, Haller's cells (infraorbital ethmoid cell) 9 (13.8 %) in study and 7 (20.5 %) in control group. None of these results were statistically significant between study and control group ($p > 0.05$). Lund-Mackay score (which was assumed to show the severity of the disease) of the maxillary, ethmoid and frontal sinus were calculated and compared to rate of septal deviation, concha bullosa, agger nasi cells. No significant correlation was conducted ($p > 0.05$). The results of study showed no statistically significant correlation between sinonasal anatomical variations and pathologies of the paranasal sinus. Also these anatomical variations did not increase the severity of pre-existing sinusitis significantly.

Level of Evidence This is a retrospective cohort study (2b).

Keywords Anatomical variations · Chronic rhinosinusitis · Computed tomography · Endoscopic sinus surgery · Paranasal sinuses

Introduction

Sinonasal diseases are common health problems those are frequently seen in rhinologic practice. Although sinusitis is a clinical diagnosis, imaging studies are used to assess the disease and demonstrate the sinonasal anatomy. Currently, computed tomography (CT) especially on coronal plane is the most common method used by surgeons because of its similarity with the surgical orientation. The effects of anatomical variations on sinus diseases have been investigated widely. Despite the presence of many reported studies that focused on whether these anatomical variations play a role in the etiology of chronic rhinosinusitis (CRS), any consensus seems to be remote.

A. Kaygusuz
Department of Otorhinolaryngology Kayseri, Kayseri Develi
State Hospital, Kayseri, Turkey

M. Haksever (✉) · D. Akduman · S. Aslan
Department of Otorhinolaryngology, Bursa Sevkett Yilmaz
Training and Research Hospital, 16800 Yıldırım, Bursa, Turkey
e-mail: drmehmethaksever@gmail.com

Z. Sayar
Department of Otorhinolaryngology, Bilecik State Hospital,
Bilecik, Turkey

The aim of this study is to observe the anatomical variations diagnosed by paranasal sinus CT on coronal plane, in cases, which had gone through endoscopic sinus surgery, and to search whether these variations were actively involved in the etiology of sinusitis. CT images of 99 patients were evaluated. 65 of them had undergone endoscopic sinus surgery for CRS. The control group consisted of 34 patients examined by paranasal CT for headache. All the patients were examined to reveal septal deviation (SD), concha bullosa (CB), agger nasi (AN), Haller's (HC) and Onodi cells (OC), paradoxical middle concha (PMC), pneumatized uncinate bulla (PUB), over-pneumatized ethmoid bulla (OEB), pneumatized crista galli (PCG). The severity of the sinusitis was scored by using CT images of the patients according to Lund-Mackay system. The relation between the rate of variation and sinusitis and also the effect of these variations on the severity of CRS were statistically investigated.

Materials and Methods

This study designed retrospectively by the approval of ethic committee, with the CT scans of 99 patients, who were admitted to our clinic between January 2009 and December 2011. All these patients had symptoms of CRS and/or headache. CT scans were analyzed at the radiology department. CT scans of study group, obtained from patients who had CRS resistant to medical therapy and who had gone through endoscopic sinus surgery (ESS), were evaluated.(n:65). The CT scans obtained from patients who

were admitted to clinic with the complaint of headache, and had no significant clinical and radiological findings of chronic sinusitis other than headache, were evaluated in the control group (n:34). The CT scans of the cases that were ordered for prior sinus surgery, massive nasal polyposis and invasive fungal sinusitis, and other reasons, such as tumoral disease and trauma were excluded. Each side of the patients' sinonasal area (hereafter referred as sides in the article) was evaluated separately. A *Toshiba Asteion CT scanner* (kV (kilo voltage): 120, Mas (milliamperere seconds): 100, scan time: 1 s, FOV (field of view): 250 mm) was used in this study. Images were obtained in the coronal plane using 5 mm slice thickness from the anterior wall of frontal sinus to the posterior wall of sphenoid sinus.

Firstly; paranasal sinus CT scans of sinonasal area in 198 sides of 99 (study group; n:65 and control group; n:34) patients were evaluated. Each side was investigated for the presence of anatomical variations. In radiological detection one of these variations (SD, CB, AN, OEB, PUB, PMC, HC, OC, PCG) at CT scans were regarded as anatomic variation (see Fig. 1). These two groups were compared with each other whether the rate of anatomical variations differs statistically.

Secondly; we tried to find answer of this question? 'Does the presence of anatomical variations increase the severity of sinus disease?' To assess the severity of CRS, the disease was scored according to the criteria of Lund-Mackay in the study group. Full opacification, semi opacification, normal mucosa were scored as 2, 1, 0 respectively. When osteomeatal complex (OMC) is open 0, closed 2 points were counted. Some anatomical variations

Fig. 1 Anatomical variations on paranasal CT scan; Bilateral agger nasi cells (a), Bilateral concha bullosa (b), Left infected concha bullosa (c), Septal deviation and paradoxical middle turbinate (d), Haller's cell (e), Pneumatized uncinate bulla (f)

and their effect on the severity of sinus disease (the sinus that has close relation or neighbor to the analysed anatomical variation) were compared statistically (e.g. rate of concha bullosa and the severity of maxillary sinus disease).

Statistical analyses were made using a dedicated software program. Fisher exact test was used to compare the presence of anatomic variations frequency between CRS and control group. Chi square test was used to compare the sinus scores between cases possessing and not-possessing variations. A *p* value less than 0.05 was considered statistically significant in Chi square and Fisher exact tests.

Results

This study included totally 99 patients with 25 females (25.2 %) and 74 males (74.7 %). The mean age was 32.2 ranging from 13 to 70. Concerning the demographic distribution of patients there were no statistical significance between the groups (Table 1).

The most common anatomic variation in all patients (study group + control group) was detected as SD (72.7 %). AN was noted in 61 (61.6 %) patients. The rates of other anatomical variations were shown in Table 2.

Table 1 Demographic distribution of study and control group

Sex	Study group (n/%)	Control group (n/%)	Total (n/%)	<i>p</i> value
Male	51/78.5	23/67.6	74/74.7	>0.05
Female	14/21.5	11/32.4	25/25.3	
Total	65/100.0	34/100.0	99/100.0	

Table 2 Frequency of anatomic variations in all patients

Anatomic variation	n	%
Septal deviation	72	72.7
Concha bullosa	45	45.4
Right	13	13.1
Left	11	11.1
Bilateral	21	21.2
Pneumatized uncinate	6	6.0
Overpneumatized EB	31	31.3
Agger nasi	61	61.6
Right	8	8.1
Left	3	3.0
Bilateral	50	50.5
Paradoxical MC	13	13.1
Onodi cell	8	8.0
Haller's cell	16	16.1
Pneumatized CG	22	22.2

EB ethmoid bulla, MC middle concha, CG crista galli

Table 3 Distribution of presence of anatomic variations in study and control groups

Anatomic variation	Study group (n/%)	Control group (n/%)	<i>p</i> value
Septum deviation	47/72.3	25/73.5	0.896
Concha bullosa	27/41.5	18/52.9	0.279
Right	6/9.2	7/20.5	0.127
Left	6/9.2	5/14.7	0.504
Bilateral	15/23.0	6/17.6	0.530
Overpneumatized EB	17/26.1	14/41.1	0.125
Pneumatized uncinate	3/4.6	3/8.8	0.410
Agger nasi	42/64.6	19/55.8	0.396
Right	6/9.2	2/5.8	0.711
Left	2/3.0	1/2.9	1.000
Bilateral	34/52.3	16/47.0	0.619
Paradoxical MC	9/13.8	4/11.7	1.000
Onodi cell	6/9.2	2/5.8	0.711
Haller' cell	9/13.8	7/20.5	0.386
Pneumatized CG	13/20.0	9/26.4	0.462

Study group consisted of 65 patients, and control group consisted of 34 patients

EB ethmoid bulla, MC middle concha, CG crista galli

Table 4 Distribution of variation in the study and control groups

	Study group (n/%)	Control group (n/%)	Total (n/%)	<i>p</i> value
Any variation (+)	116/89.2	61/89.7	177/89.4	0.918
Any variation (−)	14/10.8	7/10.3	21/10.6	
Total	130/100.0	68/100.0	198/100.0	

Study group consisted of 130 sides, and control group consisted of 68 sides

The rates of anatomical variations in two groups were calculated separately and compared with each other. There were no significant statistical differences between the groups concerning the rates of all these mentioned variations (Table 3).

Of 198 sides, 177 (89.3 %) were diagnosed as having anatomical variation. 21 sides did not have any variation. In study group, anatomical variations were found in 116 (89.2 %) of 130 sides, and in control group, anatomical variations were found in 61 (89.7 %) of 68 sides (Table 4). By comparing these groups, in terms of the presence of any anatomical variations, there was no statistically significant difference (Table 4).

In our study, we analysed only study group in order to determine the effect of anatomical variations on the severity of CRS. The sinus scores (which were assumed to

Table 5 Comparison of maxillary sinus scores between septum deviation positive and negative cases in the study group

Maxillary sinus score	Septum deviation ^a		Total (n/%)	<i>p</i> value
	+(n/%)	–(n/%)		
0	7/14.8	13/15.7	20/15.3	0.983
1	20/42.6	36/43.3	59/45.3	
2	20/42.6	34/41.0	51/39.4	
Total	47/100.0	83/100.0	130 ^b /100	

^a Since the nasal septal deviation represses to one side of the ostiomeatal complex, the ostiomeatal complex on the other side is interrelated with a non-deviated nasal septum, therefore it was accepted as normal

^b Referred as the number of sides

Table 6 Comparison of Lund-Mackay sinus scores between concha bullosa positive and negative groups, with respect to maxillary, anterior ethmoid, posterior ethmoid sinuses

Lund-Mackay score	Concha bullosa			<i>P</i> value
	+	−	Total	
(n/%)				
Maxillary sinus				
0	7/16.6	13/14.7	20/15.3	0.098
1	24/57.1	35/39.8	59/45.3	
2	11/26.3	40/55.5	51/39.4	
Anterior ethmoid sinus				
0	15/35.7	21/23.8	36/27.7	0.226
1	14/33.3	27/30.6	41/31.5	
2	13/31.0	40/45.6	53/40.8	
Posterior ethmoid sinus				
0	20/47.6	28/31.8	48/36.9	0.072
1	8/19.0	32/36.3	40/30.8	
2	14/33.4	28/31.9	42/32.3	

Of the 130 patients, concha bullosa was present in 42 patients, and absent in 88 patients

Table 7 Comparison of Lund-Mackay sinus scores between groups with or without agger nasi for frontal sinus

Frontal sinus score	Agger nasi			<i>p</i> value
	+(n/%)	–(n/%)	Total (n/%)	
0	47/61.8	40/74.0	87/66.9	0.222
1	14/18.4	9/16.6	23/19.7	
2	15/19.8	5/9.4	20/13.4	
Total	76/100	54	130	

Of the 130 patients, agger nasi was present in 76 patients, and absent in 54 patients

show the severity of sinusitis) were calculated according to the Lund-Mackay classification. A comparison between these sinus scores and rates of anatomical variations is searched.

For maxillary sinus, there was no significant difference between the sinus scores and the rate of SD (Table 5) or CB (Table 6).

For anterior ethmoid and posterior sinuses, there were no significant differences between sinus scores and rate of CB (Table 6). For frontal sinus, there were no significant difference between sinus scores and rate of AN cell (Table 7).

Discussion

The anatomy of paranasal sinuses is very complicated. To evaluate the anatomy and to diagnose the diseases at this area, physical examination and conventional radiographic examinations are not always able to provide sufficient information. Paranasal sinus CT on coronal plan is one of the main methods used to demonstrate the stages of benign inflammatory diseases preoperatively. The advantage of this approach for endoscopic sinus surgery is that; it can provide anatomical and pathological image with the same perspective to the surgeon. Sinonasal region that possess frequently anatomic variations, plays an important role in the pathogenesis of paranasal sinus diseases [1].

Many authors believe that anatomical variations of paranasal sinus structures may predispose patients to recurrent sinusitis [2, 3]. On the other hand, the relative importance of anatomical variations is still a matter of discussion, and a consensus has not been reached [4].

Kim et al. [5], Lerdlum and Vachiranubhap [6], and Stallman et al. [7] demonstrated no specific associations between the anatomical variations and rhinosinusitis, and underlined the local, systemic, environmental factors or intrinsic mucosal disease in the pathogenesis of rhinosinusitis.

In those studies, the presence or absence of sinus mucosal disease was usually specified, but the severity of sinus disease has not mentioned in relation with anatomical variations. In this study, Lund-Mackay scoring system was used. Thought it would be a more accurate comparison with the approach to sinus scoring. In our study, firstly the rates of anatomical variations were compared between the study and control groups. Secondly, any possible relationship between the scores of sinus disease (which was assumed to indicate the severity of disease) and the rates of anatomical variations are investigated in the study group.

The most common anatomical variation in all patients (study + control group), was septal deviation (72.7 %). Mean rate of septum deviation in the literature is about 47.77 % [8]. The rates of other anatomical variations in all patients were summarized in Table 2. Concerning the rates of anatomical variations in the normal population, there are very different numbers in the literature depending on the diagnostic method, case selection and race etc.

The rates of anatomical variations in the study and control groups are summarized separately in Table 3. Surprisingly, we did not detect any significant difference between study and control group concerning the rates of all these anatomical variations.

Many studies in the literature have focused on the effect of SD to the maxillary sinusitis. Luo et al. [9] found that the incidence of sinusitis in narrow side is higher than the wide side. In the study of Jorissen et al. [10] it was reported that most anatomical variations are equally found in control and sinusitis patients. The anatomical variations which are most commonly associated with the sinus pathology are SD, CB. On the other hand, some other studies and also our study showed that there was no significant relationship between the sinusitis and SD [5]. Due to our findings, SD was not the cause of maxillary sinusitis. Another point of view in our study is that; does SD increase the severity of maxillary sinusitis in the study group? We also could not find any significant relation between the severity of maxillary sinusitis and the rate of SD (Table 5).

Lloyd [11], Tonai and Baba [12], Zinreich et al. [13], Bolger et al. [2], and Scribano et al. [14] reported the incidence of CB as 14, 28, 36, 53, and 67 % respectively. In our study, the incidence of CB in the study group and control group were found 41.5 and 52.9 % (statistically insignificant) respectively in accordance with the literature. CB is thought to affect the ostiomeatal unit by narrowing the nasal passage. The presence of CB is associated with increased risk of sinusitis in the studies of Calhoun et al. [15] and Scribano et al. [14]. However, Zienrich et al. [13], Tonai and Baba [12] and Bolger et al. [2], had not reach an evidence of increase in the incidence of CB compared with sinus diseases. Unlu et al. [16] argued that CB does not affect the distribution of disease at paranasal sinuses. In our study we compared the severity of disease in maxillary, anterior ethmoid and posterior ethmoid sinuses to the presence of CB (Table 6). We found no significant statistical evidence between CB and the severity of CRS in that sinuses.

The incidence of AN cells on cadavers and CT images is reported in various rates in different studies (ranging from 10 to 89 % [17]). The rate of AN cells in cadaver was found lower than in the studies performed with paranasal sinus tomography. Bolger and Mawn [18] reported the rate of AN cells in paranasal CT of 202 cases as 98.5 %. Similar results were also reported by other studies, in which all of the cases (100 %) were reported to possess AN cells on CT scan [17]. These differences may be due to the diagnostic method and easy detection of AN cells by CT scan. In our study, the rates of AN cells were 55.8–64.6 % in study and control group respectively, and this was not statistically significant (Table 3).

The effect of AN cells on the drainage way of frontal sinus has been widely discussed in many papers. Brunner

et al. [19] reported that AN cell narrows way out of the frontal sinus that had an effect on the chronic frontal sinusitis, sinus pain. Also similar results reported in a study by Bradley and Kountakis [20]. They concluded that AN cells are a common anatomic feature, present in 93 % of patients. AN air cell disease correlates strongly with frontal sinus disease as assessed by sinus CT scan in the patients undergoing revision FESS. In addition, frontal sinus disease correlates with the severity of overall sinus disease as determined by sinus CT scan [20]. Delgaudio et al. [21] reported there was no relationship between AN cells and the incidence of frontal sinusitis. In the study of Fadda et al. [3] AN cells were detected in 24.3 % of cases, and was associated with frontal sinusitis in multivariate analysis. On the other hand, fewer studies have contrary results. Yanagisawa and Joe [22] reported the rate of AN air cells as 17 %, and there were no significant relationship between AN air cells and frontal sinusitis. There was no statistically significant difference between study and control group concerning the rate of AN cells in our study. We also studied the effect of AN cell on the severity of the frontal sinusitis. In contrast to many of studies no significant correlation was conducted between the rate of AN cells and severity of the frontal sinusitis (Table 7).

If the convexity of the middle concha (MC) is on the lateral side than it is defined as PMC. The rates of PMC are ranging from 15 to 26 % in the literature [2]. The major consequence of these anatomical variation is narrowing of the middle meatus which can lead to obstruction of infundibular drainage. Tonai and Baba [12] reported that rhinosinusitis has higher incidence in patients with large PMC. In contrast, in the series of Azila et al. [23], it was found that rate of PMC was 14/120 cases among the CRS and 27/120 in controls ($p < 0.05$). In our study rate of this variation was 13.8 % among the study group and 11.7 % in controls. These findings showed that presence of paradoxical middle concha could not simply participate in the etiology of chronic rhinosinusitis. But the size and degree of convexity of the MC may be an important factor to cause the obstruction which will lead to rhinosinusitis.

HC (infraorbital ethmoid cell) are the ethmoidal cells that develop into the medial floor of orbit adjacent to and above the maxillary sinus ostium, and which if enlarged can constrict the posterior aspect of the ethmoidal infundibulum and superior medial portion of maxillary sinus ostium. The rate of HC was ranging from 2 to 56.6 % in the literature [2, 23]. In our study, the rates of Haller's cell were found 13.8 % among the cases with CRS, 20.5 % in the control group. Due to our study HC are not involved in the etiology of the CRS. Similar results were demonstrated in the study of Bolger et al. [2]. They found that there was no significant statistical difference between the prevalence of HC and recurrent sinusitis. But in a study by Wanameker

[24] it was reported that Haller's cells may cause recurrent or chronic sinusitis. Many authors thought that HC has implicated as a possible etiologic factor in CRS due to their negative influence on maxillary sinus ventilation by narrowing the infundibulum and ostium depending upon its degree of pneumatization and size [23]. Additionally we calculated maxillary sinus' Lund-Mackay scores of the study group and compared them to the rate of HC. There was no significant difference between the severity of maxillary sinus disease and the rate of HC.

Pneumatization of UP (uncinate bulla) refers to an aeration of air cells into the UP. The UP projects from the ethmoid bone to the ethmoid process of inferior nasal concha. This entity is observed relatively rare, when compared to the other sinonasal anatomical variations. The rate of UP pneumatization in previous studies has been reported to be about 0.4–9 % [3, 13]. Our results, which were 4.6 % in study group and 8.8 % in the control group are compatible with the literature. Authors thought that, pneumatized UP can cause significant functional blockage of the osteomeatal complex. So it was considered as a predisposing factor for the development of sinusitis in the anterior ethmoid and frontal cells, and disrupting the sinus ventilation at the infundibular region. But in our study no statistical significant difference was conducted concerning the rate of pneumatized UB between CRS and control group. Similar to our results, Azila et al. [23] found that 6 (3.3 %) patients with pneumatized UP were equally distributed among the CRS patients and controls. They underlined that the severity of the degree of medialization of uncinate process (causing mucosal contact with middle turbinate or covering up the ostium of maxillary sinus) and the presence of some other anatomical variation such as HC may be an important associated factor that may increase pathogenic effect leading to CRS rather than the presence of this variation alone [23]. Fadda et al. [3] showed that medial deviation of UP was statistically associated with anterior ethmoidal sinusitis.

OC (sphenothmoidal cell) is defined as ethmoid cell pneumatized posterolateral to the sphenoid sinus. The presence of OC during surgery may be a factor increases the risk of injury to the optic nerve and internal carotid artery. Recognition of OC prior to the surgery has particular importance to avoid these unfortunate complications. The rate of OC in previous studies has a very wide range (3.4–51 %) [7]. Those different rates may be due to different criteria for defining OC and difficulty of evaluating the cells on the coronal plane CT. In our study we tried to determine OC on the coronal plane. In our study, the rates of OC in CRS and control groups were 9.2 and 5.8 % respectively. This result was not statistically significant (Table 3).

The rate of any variation in any side of sinonasal area was surprisingly high (89.4 %). Presence of any variation

did not differ significantly between the groups as parallel to our previous findings (Table 4). We think, this high rate of sinonasal anatomical variations must be underlined. It shows the importance of careful assessment of paranasal CT preoperatively to avoid surgical complications.

Conclusion

The results of this retrospective study showed no statistically significant correlation between the rates of sinonasal anatomical variations and CRS. Also these anatomical variations did not increase the severity of the pre-existing sinusitis significantly. This investigation underlined the fact that sinonasal area has very high rate of anatomical variations. Careful assessment of CT in patients with chronic rhinosinusitis is necessary, especially in those undergoing endoscopic surgery.

This study has the limitation of being retrospectively and having a relatively small number of patients as compared to other series. Here it was focused on the rate of variations and their relations with sinusitis. A more scientific study would include, not only the rate of variations but also size, shape and type of specific variations and their interaction with sinus drainage. We should also eliminate the other factors such as job, environmental factors...etc., that may have effects on the development of CRS.

For the elimination of contradictory results in the literature, multicenter studies with the large number of cases are still needed to understand the effect of sinonasal anatomical variations in etiology of CRS.

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