Could there be an association between ethmoid anatomical variations and chronic rhinosinusitis? A clinicoradiological study

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Background

The complicated anatomy of the ethmoid bone is associated with multiple anatomical variations. These anatomical variations may have clinical significance in pathogenesis of rhinosinusitis, which is still unclear, and in the surgical workup to avoid the risk of potential complications.

Aim

The aim of this study was to evaluate the rate of the different ethmoid anatomical variants in the patients with chronic rhinosinusitis (CRS) and to assess if there is any correlation between these variants and CRS.

Patients and methods

This case–control study included 40 patients with CRS (study group) and 20 healthy individuals with no criteria of CRS (control group). Anatomical variations of ethmoid complex were evaluated as either being present or absent in each side in both groups. In the study group, Lund-Mackay scores of the different sinuses were evaluated and compared in relation to the detected ethmoid variants.

Results

No statistically significant difference was found between the rate of different ethmoidal anatomical variations in the study and control groups. There was also no significant difference in the Lund-Mackay scores of the different sinuses in relation to the presence of anatomic variations. The most common ethmoidal anatomical variation in both groups was agger nasi cell.

Conclusion

This study showed that there is no significant association between ethmoidal anatomical variations and CRS, and so, these anatomical variations are not a potential risk factor for chronicity of sinusitis.

Keywords:
chronic rhinosinusitis, ethmoid anatomical variations, ethmoid complex

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Introduction

The ethmoid bone has a significant central location which is related to the different paranasal sinuses. It has a major significance, as it includes the ethmoid air cells, which play a role in olfactory sensation, humidification, ventilation, and phonation. It also may affect the drainage of the maxillary, frontal, and ethmoidal sinuses through the osteomeatal complex [1,2].

The ethmoid bone is a complex structure and has a wide range of anatomical variations. The extent of these variations become more apparent owing to recent advances in computed tomography (CT) scanning and the widespread use of endoscopic sinus surgery. Some anatomic variations including deviated nasal septum, concha bullosa (CB), agger nasi cells, and many others may contribute to the blockage of the osteomeatal unit, and so, it may be associated with the risk of rhinosinusitis [3–5].

Many authors believe that anatomical variations may predispose patients to chronic rhinosinusitis (CRS) [6,7]. On the contrary, the relative importance of these anatomical variations is still unclear [8]. So, this study aimed to assess the incidence of ethmoidal anatomical variations by nasal endoscopy and multislice computed tomography (MSCT) of paranasal sinuses and to evaluate the correlation between these variations and the extent of disease.

Patients and methods

This case–control study was conducted from July 2016 to June 2017 in the Otorhinolaryngology Department of Assiut University Hospital after obtaining approval from the Institutional Ethics Committee.

This study included 60 individuals above 18 years. Of them, 40 patients fulfilled the criteria of CRS after clinical and radiological assessment (study group). They were compared with 20 healthy individuals who had no clinical or radiological criteria of CRS (control group). All patients in the study group had the criteria of diagnosis of CRS according to European Position Paper on Rhinosinusitis and Nasal polyps 2012 (EPOS 2012) guidelines [9].

Patients with invasive fungal rhinosinusitis, sinonasal malignancy, or craniofacial abnormalities were excluded from the study. Patients with previous history of sinonasal surgery or trauma to the sinonasal region or skull base were also excluded from this study.

All individuals in both groups were subjected to full ENT history taking and clinical examination including endoscopic nasal examination for evaluation of the sinonasal pathology and the anatomical variations. MSCT of the nose and paranasal sinuses without intravenous contrast with slice thickness 2–3 mm was obtained from all participants of both groups. In the study group, MSCT had been done after 2 weeks of medical treatment in the form of systemic steroids, decongestant nasal drops, and antibiotic to prevent misinterpretation by the effect of congestion, edema, or discharge. We obtained the axial images of MSCT, and reconstruction of coronal and sagittal images was applied by reformatting the axial images, using a software program (Radiant DICOM Viewer 64-bit version, ; Medixant, Poznan, Poland).

Interpretation of MSCT was done by both radiologist and rhinologist. The severity of mucosal sinus disease and the osteomeatal complex status were scored according to the Lund-Mackay scoring system [10,11] in which a sinus was scored as 0 (no opacification), 1 (partial opacification), or 2 (complete opacification), whereas the osteomeatal complex was scored as either 0 (patent) or 2 (blocked). After that, ethmoid anatomical variations were investigated in MSCT as either being present or absent in each side of both groups.

Ethmoid anatomical variations

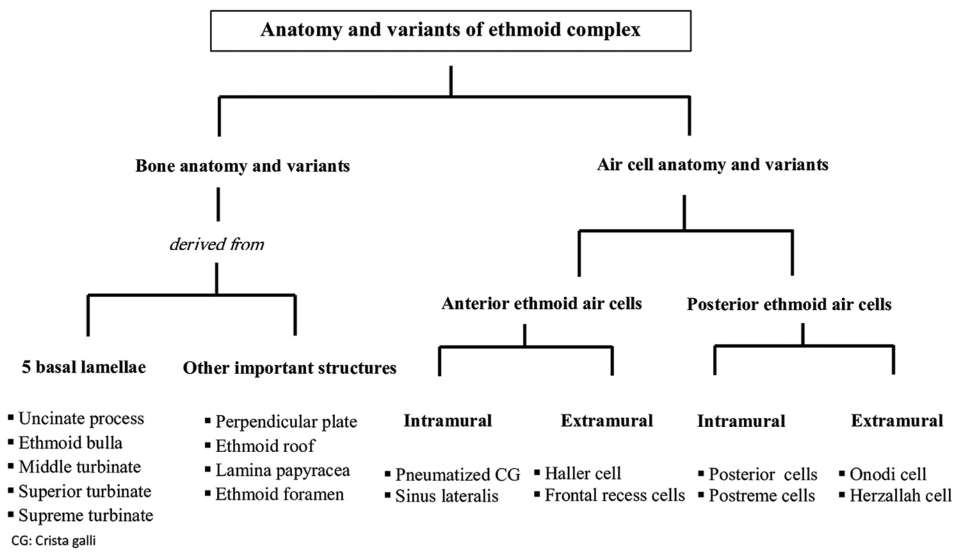
In both groups, the ethmoidal anatomical variations were evaluated in two main types: bone and air cell variants according to the classification of anatomy and variants of ethmoid complex (Fig. 1) [1,2,12,13].

Bone variants

The bone variants which are derived from the five basal lamellae include variants of uncinate process (UP), ethmoid bulla (EB), and middle, superior, and supreme turbinates. The UP was evaluated for pneumatization, hyperplasia, atelectasis, and attachment variants of UP. The superior attachment of the UP was observed in coronal CT scans and classified according to Landsberg and Friedman criteria [14]. The UP may be inserted into the lamina papyracea (type 1), the posterior wall of agger nasi cell (ANC) (type 2), the lamina papyracea and junction of the middle turbinate (MT) with the cribriform plate (type 3), the junction of the MT with the cribriform plate (type 4), the skull base (type 5), or the MT (type 6).

We also investigated the variations of pneumatization of EB which included over-pneumatization, hypoplasia, and absence of EB. The MT was investigated for presence of CB, paradoxical MT, accessory MT, and

Figure 1



Anatomy and variants of ethmoid complex [1,2,12,13].

hypoplasia of MT. Superior turbinate was investigated for pneumatization or associated paradoxical curvature. We also evaluated all individuals for the presence of supreme turbinate, which is usually rudimentary.

Bone variants may be also derived from other important structures including perpendicular plate of ethmoid, ethmoid roof, and lamina papyracea. Perpendicular plate of ethmoid was observed for presence of deviation, spur, or pneumatization. In this study, we investigated ethmoid roof for asymmetry and we also measured the depth of the olfactory fossa in each side, which was classified according to Keros classification as follows [15]: type 1: 1–3 mm, type 2: 4–7 mm, and type 3: 8–16 mm. Moreover, we investigated lamina papyracea for presence of focal dehiscence.

Air cell variants

Air cell variants are classified into anterior and posterior ethmoid air cell variants. Anterior ethmoid air cell variants included in our study were pneumatization of the crista galli, Haller cell, and frontal recess cells. In this study, we evaluated the frontal recess cells according to International Frontal Sinus Anatomy Classification, which classifies the cells related to the frontal recess into anterior, posterior, and medial cells. Anterior cells include ANC, supra agger cell, and supra agger frontal cell. Posterior cells include supra bulla cell, supra bulla frontal cell, and supra orbital ethmoid cell, whereas medial cells include frontal septal cell [13]. On the contrary, posterior ethmoid air cell variants include Onodi cell and Herzallah cell, which represents retromaxillary extension of posterior ethmoid air cell [12].

Statistical analysis

The data were collected and analyzed using a software program SPSS (Statistical Package for the Social Sciences, version 22; IBM, Armonk, New York, USA). Fisher exact test was used to compare the rate of ethmoid anatomic variations between the groups. χ^2 test was used to compare the sinus scores of Lund-Mackay between sides with the variation and those without the same variation. A *P* value was considered statistically significant if less than 0.05.

Results

This study was conducted on two groups. The study group included 40 patients, whereas the control group included 20 individuals. The majority of both groups were males [29 (72.5%) males in the study group and 11 (55%) males in the control group]. The mean age of the study group was 34.43 years, whereas the mean age of the control group was 40.55 years (Table 1), with insignificant differences between the groups.

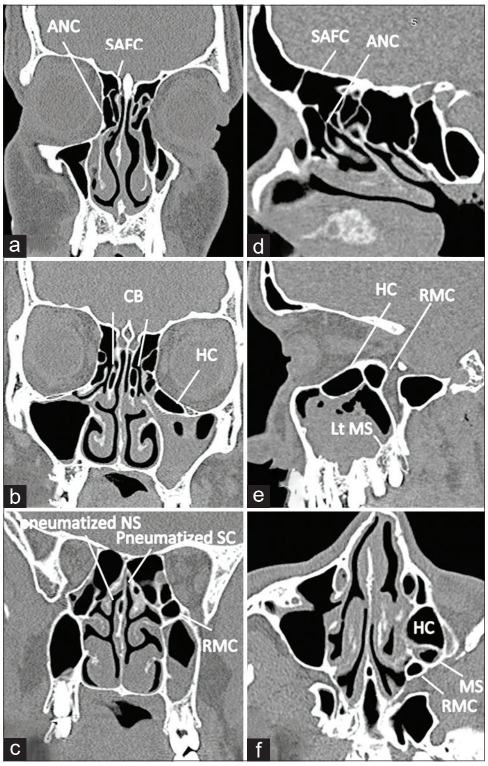
Regarding the rate of anatomical variants, the most common ethmoid anatomic variation in both groups was ANC which was found in 96.3% of study group and 95% of control group. The rates of other anatomical variations are shown in Table 2, with no significant statistical differences found between the groups. Different sinonasal variation CT images were given in a patient with CRS (Fig. 2) and a control (Fig. 3).

Concerning the number of anatomical variants, at least three anatomic variations were present in each side of both groups and the maximum number of the variations was 13 variants per side. The mean number of

Table 1 Demographic distribution of study and control groups

Personal data	Study group (*n*=40) [*n* (%)]	Control group (*n*=20) [*n* (%)]	*P*
Sex			
Male	29 (72.5)	11 (55.0)	0.175
Female	11 (27.5)	9 (45.0)	
Age (years)			
Mean±SD	34.43±10.25	40.55±13.87	0.058
Range	18.0-55.0	18.0-60.0	

Figure 2



Coronal reformatted (a–c), sagittal reformatted (d and e) and axial plane (f) CT images show different variations in a 19-year-old male patient. ANC, agger nasi cell; CT, computed tomography; SAFC, supra agger frontal cell. CB, concha bullosa; HC, haller cell; NS, nasal septum; SC, superior concha; RMC, retromaxillary cell; Lt MS, left maxillary sinus.

Table 2 Distribution of ethmoid anatomic variations in study group vs control group

Anatomic variations of ethmoid complex					Patient group (*n*=80 sides) [*n* (%)]	Control group (*n*=40 sides) [*n* (%)]	*P*
Bone variants	5 basal lamellae	Uncinate process	Attachment	Type 1	51 (63.8)	18 (45.0)	0.246
				Type 2	6 (7.5)	3 (7.5)	
				Type 3	4 (5.0)	4 (10.0)	
				Type 4	5 (6.3)	6 (15.0)	
				Type 5	3 (3.8)	4 (10.0)	
				Type 6	11 (13.8)	5 (12.5)	
			Pneumatization		3 (3.8)	1 (2.5)	0.719
			Hyperplastic UP		1 (1.3)	0	0.478
		Ethmoid bulla	Absent EB		2 (2.5)	0	0.313
			Hypoplastic EB		3 (3.8)	1 (2.5)	0.719
			Over-pneumatized EB		8 (10.0)	2 (5.0)	0.350
		Middle concha	Concha bullosa		31 (38.8)	19 (47.5)	0.359
			Paradoxical MC		4 (5.0)	0	0.150
			Secondary MC		1 (1.3)	0	0.478
			MC hypoplasia		6 (7.5)	0	0.076
		SC	Pneumatized SC		8 (10.0)	2 (5.0)	0.350
	Other important structures	Nasal septum	Septal deviation		30 (37.5)	12 (30.0)	0.417
			Spur		12 (15.0)	3 (7.5)	0.242
			Pneumatization		18 (22.5)	8 (20.0)	0.754
			Asymmetry of ER		14 (17.5)	4 (10.0)	0.278
		Ethmoid roof	Keros type	Type I	45 (56.3)	15 (37.5)	0.053
				Type II	35 (43.8)	25 (62.5)	
		Pneumatized CG			2 (2.5)	2 (5.0)	0.472
Air cell variants		Haller cell			7 (8.8)	0	0.054
		Frontal recess cell		ANC	77 (96.3)	38 (95.0)	0.747
				SAC	27 (33.8)	15 (37.5)	0.685
				SAFC	19 (23.8)	8 (20.0)	0.643
				SBC	54 (67.5)	32 (80.0)	0.152
				SBFC	6 (7.5)	0	0.076
				SOEC	15 (18.8)	3 (7.5)	0.104
				FSC	38 (47.5)	12 (30.0)	0.067
		Onodi cell			17 (21.3)	3 (7.5)	0.057
		Herzallah cell			19 (23.8)	7 (17.5)	0.433

ANC, agger nasi cell; EB, Ethmoid bulla; ER, Ethmoid roof; FSC, frontal septal cell; MC, Middle concha; SAC, supra agger cell; SAFC, supra agger frontal cell; SBC, supra bulla cell; SBFC, supra bulla frontal cell; SC=superior concha; SOEC, supra orbital ethmoid cell; UP, Uncinate process.

Table 3 Number of variations per side in study group vs control group

No. of anatomical variations per side	Study group (*n*=40)	Control group (*n*=20)	*P*
Mean±SD	7.28±2.19	6.30±1.42	1.000
Range	3-13	4-9	

the variations per side in the study and control groups was 7.28 and 6.30, respectively, showing no statistical significance between the groups (Table 3).

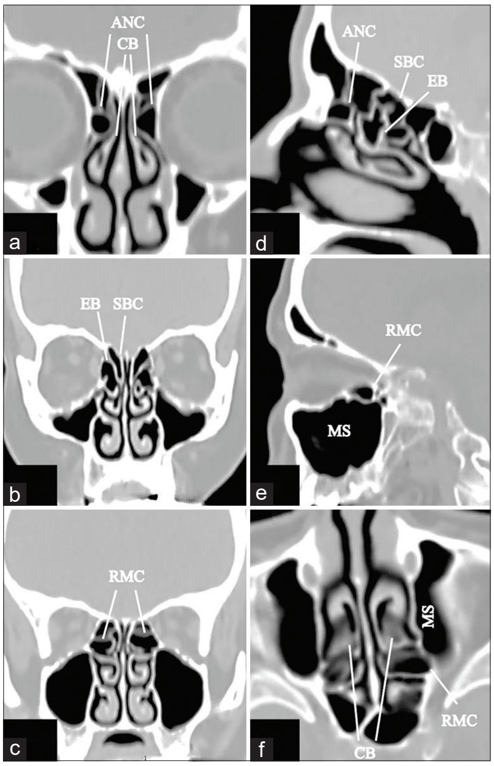
Regarding the type of anatomical variants, at least three air cell variants were present in each side of both groups. The mean number of air cell variants per side in patient group and control group was 3.76 and 3.30, respectively, whereas the mean number of bone variants per side in study group and control group was 3.51 and 3, respectively, with insignificant difference between both groups (Table 4).

With reference to the site of anatomical variants, in the study group, Lund-Mackay scoring of the different sinuses (frontal, maxillary, anterior ethmoid, posterior ethmoid, and sphenoid sinuses) was compared in correlation with ethmoid anatomical variations, showing no significant statistical difference (Tables 5–9).

Discussion

Although there are a lot of studies about the etiology of CRS, the role of anatomical variants is still under debate. Some anatomic variations are thought to be risk factor for sinus diseases. For this reason, it becomes essential for the surgeon to be aware of these variants, especially if the patient will be prepared for endoscopic sinus surgery [16]. So, researching these variations can help us to understand their role in the pathogenesis of sinusitis. Thus, it is essential for the rhinologist to

Figure 3



Coronal reformatted (a–c), sagittal reformatted (d and e), and axial plane (f) CT images show different variations in a 44-year-old female control. ANC, agger nasi cell; CB, concha bullosa; CT, computed tomography; EB, ethmoid bulla; SBC, supra bulla cell; RMC, retromaxillary cell; MS, maxillary sinus.

be aware of these variants, especially if the patient is a candidate for endoscopic sinus surgery [16]. So, researching these variations can provide information on their possible role in the pathogenesis of sinusitis.

In the current study, we did not find any significant difference between both groups regarding the rates of the ethmoidal variations. Many studies reported that sinonasal anatomical variations may predispose patients to sinusitis [7,17]. We agree with other studies that showed no specific correlation between these anatomic variations and rhinosinusitis, which supposed that systemic, environmental factors, and mucociliary disease had a more significant role in the pathogenesis of rhinosinusitis [18–20].

Regarding bone ethmoidal variants, variations of the MT and nasal septum were among the common variations. Many anatomical variations of MT have been described in various studies. Among these, CB was found to be the most common variation. CB was seen in 38.8% patient group and 47.5% control group. CB is one of the common anatomical variations of sinonasal structures, with a reported prevalence range of 14–67% in the literature [21–23]. Many studies reported that the presence of CB may be associated with sinusitis [23,24]. However,

Table 4 Distribution of bone and air cell variants in the study group vs control group

No. of anatomical variations per side	Study group (*n*=80 sides)	Control group (*n*=40 sides)	*P*
Bone variants			
Mean±SD	3.76±1.52	3.30±0.91	1.000
Range	2-8	2-6	
Air cell variants			
Mean±SD	3.51±1.31	3.00±1.06	1.000
Range	1-8	1-5	

Table 5 Correlation between Lund-Mackay frontal sinuses score and related anatomic variations

Anatomic variation	Lund-Mackay frontal sinus score [*n* (%)]			*P*
	0 (*n*=35)	1 (*n*=20)	2 (*n*=25)	
ANC				
Positive	34 (97.1)	19 (95.0)	24 (96.0)	
Negative	1 (2.9)	1 (5.0)	1 (4.0)	0.919
SAFC				
Positive	7 (20.0)	3 (15.0)	9 (36.0)	0.203
Negative	28 (80.0)	17 (85.0)	16 (64.0)	
SBFC				
Positive	3 (8.6)	0	3 (12.0)	0.300
Negative	32 (91.4)	20 (100.0)	22 (88.0)	
SOEC				
Positive	5 (14.3)	4 (20.0)	6 (24.0)	
Negative	30 (85.7)	16 (80.0)	19 (76.0)	0.628

ANC, agger nasi cell; SAFC, supra agger frontal cell; SBFC, supra bulla frontal cell; SOEC, supra orbital ethmoid cell.

Table 6 Correlation between Lund-Mackay maxillary sinuses score and related anatomic variations

Anatomic variation	Lund-Mackay maxillary sinus score [*n* (%)]			*P*
	0 (*n*=11)	1 (*n*=54)	2 (*n*=15)	
Septal deviation				
Positive	5 (45.5)	22 (40.7)	3 (20.0)	0.287
Negative	6 (54.5)	32 (59.3)	12 (80.0)	
Concha bullosa				
Positive	8 (72.7)	22 (40.7)	1 (6.7)	0.075
Negative	3 (27.3)	32 (59.3)	14 (93.3)	
Paradoxical MC				
Positive	0	4 (7.4)	0	0.363
Negative	11 (100.0)	50 (92.6)	15 (100.0)	
Haller cell				
Positive	1 (9.1)	6 (11.1)	0	0.403
Negative	10 (90.9)	48 (88.9)	15 (100.0)	
Over-pneumatized EB				
Positive	1 (9.1)	5 (9.3)	2 (13.3)	0.892
Negative	10 (90.9)	49 (90.7)	13 (86.7)	

EB, Ethmoid bulla; MC, Middle concha.

other studies had not found any evidence of increase in the prevalence of CB in patients with sinusitis, which is in agreement with our study [20,22]. In our study, the most common anatomical variation of the nasal septum was septal deviation among patients (37.5%) and controls (30%). Septal deviation is present in 20–31% of the general population, and

Table 7 Correlation between Lund-Mackay anterior ethmoidal sinuses score and related anatomic variations

Anatomic variation	Lund-Mackay anterior ethmoid sinus score [*n* (%)]			*P*
	0 (*n*=6)	1 (*n*=43)	2 (*n*=31)	
Septal deviation				
Positive	4 (66.7)	17 (39.5)	9 (29.0)	0.202
Negative	2 (33.3)	26 (60.5)	22 (71.0)	
Concha bullosa				
Positive	4 (66.7)	23 (53.5)	4 (12.9)	0.061
Negative	2 (33.3)	20 (46.5)	27 (87.1)	
Paradoxical MC				
Positive	0	4 (9.3)	0	0.163
Negative	6 (100.0)	39 (90.7)	31 (100.0)	
Over-pneumatized EB				
Positive	0	3 (7.0)	5 (16.1)	0.302
Negative	6 (100.0)	40 (93.0)	26 (83.9)	

EB, Ethmoid bulla; MC, Middle concha.

Table 8 Correlation between Lund-Mackay posterior ethmoid sinuses score and related anatomic variations

Anatomic variation	Lund-Mackay posterior ethmoid sinus score [*n* (%)]			*P*
	0 (*n*=17)	1 (*n*=35)	2 (*n*=28)	
Septal deviation				
Positive	9 (52.9)	14 (40.0)	7 (25.0)	0.158
Negative	8 (47.1)	21 (60.0)	21 (75.0)	
Onodi cell				
Positive	2 (11.8)	8 (22.9)	7 (25.0)	0.548
Negative	15 (88.2)	27 (77.1)	21 (75.0)	
RMC				
Positive	4 (23.5)	7 (20.0)	8 (28.6)	0.729
Negative	13 (76.5)	28 (80.0)	20 (71.4)	

RMC, retromaxillary cell.

Table 9 Correlation between Lund-Mackay sphenoidal sinuses score and related anatomic variations

Anatomic variation	Lund-Mackay sphenoid sinus score [*n* (%)]			*P*
	0 (*n*=39)	1 (*n*=23)	2 (*n*=18)	
Septal deviation				
Positive	17 (43.6)	7 (30.4)	6 (33.3)	0.538
Negative	22 (56.4)	16 (69.6)	12 (66.7)	
Pneumatized SC				
Positive	7 (17.9)	0	1 (5.6)	0.058
Negative	32 (82.1)	23 (100.0)	17 (94.4)	
Onodi cell				
Positive	7 (17.9)	3 (13.0)	7 (38.9)	0.104
Negative	32 (82.1)	20 (87.0)	11 (61.1)	

SC, superior concha.

severe deviation has been found to be associated with sinusitis [25]. It was found that the incidence of sinusitis is higher in the narrow side than the wide side [26]. On the contrary, other studies showed that there was no significant relationship between the sinusitis and septal deviation, which is in agreement with our study [19,20].

With reference to air cell variants, the common variants among both groups were ANC followed by supra bulla cell. Furthermore, ANC was the most common of all variations (bone + air cell variants) in both group, which is consistent with the study done by Karki *et al.* [27]. ANC was seen in 96.3% of the patient group and 95% of the control group. The incidence of ANC is reported in various rates among different studies, ranging from 10 to 100%, depending on the method of evaluation [28,29]. In the study of Fadda *et al.* [7], ANC was detected in 24.3% of cases and was associated with frontal sinusitis in multivariate analysis. On the contrary, many studies reported that there was no relationship between ANC and the incidence of sinusitis [20,30]. This is in consistency with our study as there was no statistically significant difference between the patient and control group concerning the rate of ANC.

Regarding the number of anatomical variations, at least three ethmoid anatomic variations were observed on each side in both groups. So, all the sides in both groups have ethmoidal anatomic variations. More anatomical variations were noticed in the study group than the control group, with no significant difference. So, this means an increase in the number of anatomical variations had no correlation with CRS. The study conducted by Peter *et al.* [31] reported that an increase in the number of anatomical variations was associated with CRS (as indirectly revealed by the presence of accessory maxillary ostia in the cadavers as they arise following persistent blockage of the natural maxillary ostium), and this is not in agreement with our findings. However, the study of Peter *et al.* [31] showed some limitations as it was applied on cadavers and CRS was indirectly supposed by the presence of accessory maxillary ostia. In the current study, we have also noticed that the prevalence of multiple ethmoid anatomical variations was more in comparison with single anatomical variation in both groups, which is in agreement with the study done by Aramani *et al.* [8].

Additionally, we studied the type of ethmoid anatomical variants and its possible relation with rhinosinusitis. At least three air cell variants were present in each side of both groups. Moreover, three bone variants were present at least in each side of the study group and control group. Hence, no significant relationship was found between the type of ethmoid variations and rhinosinusitis. In the literature, we have not found any study focused on the type of variations and its relation with sinusitis.

Among the study group, we have found no significant difference in Lund-Mackay scoring of the different sinuses (frontal, maxillary, anterior ethmoid, posterior ethmoid, and sphenoid sinuses) in relation to the variations. Thus, there was no correlation between the site of ethmoid anatomic variations and RS. This study also noticed that the presence of anatomical variations was not associated with increased Lund-Mackay scoring of related sinuses. This indicated that the presence of these variants did not increase the severity of CRS, which is consistent with Kaygusuz *et al.* [20].

Many studies in the literature have focused on the effect of septal deviation to the maxillary sinusitis. The study conducted by Luo *et al.* [26] showed that the incidence of maxillary sinusitis is higher in the narrow side than the wide side. On the contrary, other studies showed that there was no significant relationship between the maxillary sinusitis and septal deviation, which is in agreement with our findings [20,32]. Moreover, we could not find any significant relation between the severity of maxillary, anterior ethmoid, and sphenoid sinusitis and the rate of septal deviation. Fadda *et al.* [7] have focused on the ANC and its relation to frontal sinusitis, and they found a significant association between ANC and frontal sinusitis. On the contrary, many studies reported that there was no relationship between ANC and the incidence of frontal sinusitis [20,30], which is consistent with our study. Furthermore, we did not find a significant correlation between the rate of ANC and the severity of the frontal sinusitis.

To conclude, many studies reported that the ethmoid anatomical variations have been suggested as potential risk factors for developing CRS by many authors. Other studies showed that, not all, but some anatomical variations such as septal deviation, CB, haller cell, and ANC may predispose to recurrent or chronic rhinosinusitis. However, many other studies showed that there is no specific association between anatomical variation and CRS, which is in consistency with our study. These studies supposed that pathogenesis of CRS is multifactorial, including systemic, environmental factors, and mucociliary disease.

Conclusion

This study evaluated the correlation between ethmoid anatomical variations and CRS. The study revealed that the prevalence of multiple ethmoid anatomical variations is more common than a single variant. Among these all variations, ANC is the most commonly detected anatomical variation in both groups. There was no statistical significant difference between patient and control groups regarding the incidence of the different ethmoidal anatomical variations. As well, the increase in the number of these variations, their sites, and types are not associated with increased incidence of CRS. In addition, these variants do not potentiate the severity of CRS. Thus, in conclusion, the different ethmoidal anatomical variations are not a potential risk factor for chronicity of sinusitis which is mostly multifactorial (e.g., systemic, environmental, and intrinsic mucosal factors).

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Conflicts of interest

There are no conflicts of interest.

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