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Original Article

Computed Tomography Scan Correlation between Anatomic Variations of Paranasal Sinuses and Chronic Rhinosinusitis

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Abstract

Introduction: The aim of this study was to analyze the incidence of anatomic variations of the paranasal sinuses in patients with persistent symptoms of rhinosinusitis and their correlation with paranasal sinus disease.

Materials and Methods: This retroprospective study of 500 patients between the age group 13 and 77 years was performed at Manipal Hospital, Bengaluru, from March 2013 to June 2014 in the Department of Radiodiagnosis.

Results: Multiparametric statistical analysis with Fischer's exact test showed a correlation between left septal deviation and left maxillary sinusitis (MS) ($P < 0.02$). We also found a correlation between bilateral concha bullosa and bilateral MS ($P < 0.002$). In addition, there was a statistically significant difference between left agger nasi cell and homolateral frontal sinusitis ($P < 0.02$).

Conclusion: Computed tomography of the paranasal sinus has improved the visualization of paranasal sinus anatomy and variations and has allowed greater accuracy in evaluating paranasal sinus disease.

Key words: Anatomic variations, Chronic rhinosinusitis, Paranasal sinus

INTRODUCTION

Chronic sinusitis is one of the more prevalent chronic illnesses worldwide, affecting persons of all age groups. The National Institute of Allergy and Infectious Diseases' estimates approximately 134 million Indians to suffer from chronic sinusitis. One in eight Indians suffers from chronic sinusitis.[1] Among Indians, this disease is more widespread than diabetes, asthma or coronary heart disease.

Chronic sinusitis is an inflammatory process that involves the paranasal sinuses and persists for 12 weeks or longer despite adequate medical treatment, the symptoms of which include but are not limited to debilitating headaches, fever and nasal congestion and obstruction. It is almost always accompanied by concurrent nasal airway inflammation and is often preceded by rhinitis symptoms; thus, the term chronic rhinosinusitis has evolved to more accurately describe this condition.[2]

Several authors have assessed the relationship between sinonasal anatomic variants and the incidence of rhinosinusitis.[3] There is now worldwide interest among otolaryngologists in the radiological definition of paranasal regional anatomy. Certain anatomic variations forming the lateral wall of the nose are very important because they can contribute to the blockage of the osteomeatal units, drainage, and ventilation and can thereby increase the risk of sinus mucosal disease. Moreover, anatomic variants with a potential impact on surgical safety occur frequently and need to be specifically sought as part of the pre-operative evaluation. Anatomic variations - such as deviation of the nasal septum, concha bullosa or paradoxical middle turbinate, ethmoidal bulla hypertrophic, agger nasi cell, lateral or medial bending of uncinate process (UP), and Haller cell - are common and emphasized in routine

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evaluation of computed tomography (CT) images. Occasionally, some uncommon anatomic variations, in addition to those mentioned above, can increase the risk of surgical complications, associated with a residual disease or recurrence. Appropriate radiologic imaging and accurate interpretation play an important role in the diagnosis and management of these conditions.[3]

For many years, otorhinolaryngologist and radiologists have to rely on plain radiograph of the paranasal sinuses for assistance in the diagnosis and management of the paranasal sinus diseases. A plain film yields minimal information about delicate bony structures, mucosal changes, and anatomic variations.

The non-invasive cross-sectional imaging techniques of CT provide excellent resolution and good definition of the complete osteomeatal complex (OMC), subtle anatomic variations, soft-tissue abnormalities and to image distal structures such as the posterior ethmoid sinus, relationship of the sinuses to the orbit and the brain that cannot be viewed with direct endoscopy.[4,5]

Recently, the introduction of spiral CT and multidetector CT represents an interesting but incremental change in the way CT is performed. It minimizes patient motion, allows excellent coronal images.[6] The coronal view is best correlated with findings from sinus surgery[7] and allows any desired angle to be created from images made in the axial plane. In addition, this technique provides the advantage of speed and the ability to generate very thin images while producing least radiation dose. Technical advances like cone-beam tomography can further improve dose reduction as well as spatial resolution.[8]

MATERIALS AND METHODS

Study Period

This retroprospective study was performed at Manipal Hospital, Bengaluru, from March 2013 to June 2014 in the Department of Radiodiagnosis on patients who are referred for CT scan of paranasal sinus on clinical grounds of chronic sinusitis. The patients were of age group 13-77 years (average age 45 years). The study group included both urban and rural cases that fulfilled the inclusion criteria.

Inclusion Criteria for Study Group

Adult patients presenting with a history of nasal obstruction, nasal discharge, postnasal discharge and headache, clinically diagnosed to have chronic rhinosinusitis (symptoms for a period of 12-week or more despite adequate medical treatment) and are willing for CT evaluation.

Exclusion Criteria for Study Group

Patients with the previous alteration of the paranasal sinus anatomy due to facial trauma and surgery, patients with tumors, polyposis of the sinonasal cavity, complicated sinusitis, cystic fibrosis, osteomyelitis, and aggressive fungal infections.

Sample Size

This retroperspective study included a sample volume of 500 patients diagnosed to have chronic rhinosinusitis and was willing to undergo CT evaluation.

Technique

Before subjecting the patients for radiographic examinations, informed consent, age, sex, and detailed clinical history will be obtained along with thorough ear, nose and throat examination. Chronic sinus disease is best scanned at 4-6 weeks after medical therapy and not during active infection. The CT examination will be performed with a general electric medical systems, 64-slice multidetector CT LightSpeed VCT. CT techniques include thin-section, axial scanning. The scanning parameters are as follows: Individual detector width 0.625 mm; gantry rotation time 600 ms; tube voltage 120 kVp; tube current, 250 mA; pitch 0.97. Axial images will be reconstructed using the following parameters: 1.25 mm section thickness, high-spatial-frequency reconstruction algorithm (bone preset), and an 18 cm field of view.

Statistical Method

The statistical analysis to assess the relationship between anatomic variations and sinusitis was evaluated using the Fisher's exact test.

RESULTS

A total of 310 of 500 patients showing symptoms of chronic rhinosinusitis who had at least one sign on CT anatomic variation were included in this study during period of 15-month. 202 (65.16%) patients were male and 108 (34.83%) were female (Chart 1) with ages ranging from 13 to 77 years (mean 45.5 years).

Regarding the CT prevalence of sinusal opacities in the group of 310 patients with sinusitis, 256 (82.5%) had maxillary sinusitis (MS), 136 (43.8%) anterior ethmoid sinusitis, 134 (43.2%) posterior ethmoid sinusitis, 89 (28.7%) frontal sinusitis, and 86 (27.7%) had sphenoid sinusitis (Chart 2). Pathology at OMC on CT scan was observed in 91 (29.3%) patients in this series (Table 1).

A detailed analysis of CT scans showed 310 of 500 (62%) patients had common or uncommon anatomic variations, 59.1% of patients were affected by common anatomic

variations, and 9 patients (2.9%) with uncommon variations. CT scans showed that the affected side was right in 83 (26.7%) patients and left in 143 (46.1%). 190 (38%) patients had no signs of disease on CT.

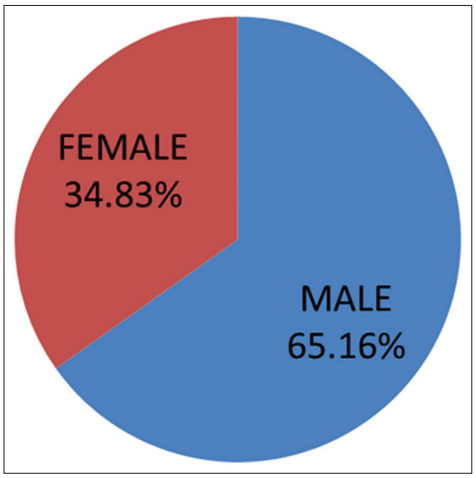

Chart 1: Gender distribution in the study group

The most common anatomic variation observed on CT scans (Chart 3) was a nasal septal deviation, which was presented by 232 patients (74.8%). Concha bullosa of the middle turbinate was the second most common variant, observed in 102 patients (32.9%). A total of 22 patients (9.1%) had hypertrophic ethmoid bulla, whereas agger nasi cell was observed in 11 (3.5%). Considering the UP, its lateral deviation was found in 5 patients (1.6%), whereas its medial deviation was presented by 9 patients (2.9%) and pneumatization UP was observed in 8 patients (2.6%). Haller cell was observed in 56 patients (18%) and onodi cell in 8 patients (2.6%), paradoxical middle turbinate was observed in only 21 patients (6.7%), hypoplastic MS was present in 1 patients (0.32%), and septated MS in 5 patients (1.6%). With respect to the level difference between the ethmoid and cribriform plate, Keros Type I was the most common and seen in 49 patients (15.8%), followed by Type II in 28 (9.03%) and Type III in 7 patients (2.2%); single large sphenoid sinus was seen in 8 patients (2.6%) (Table 2).

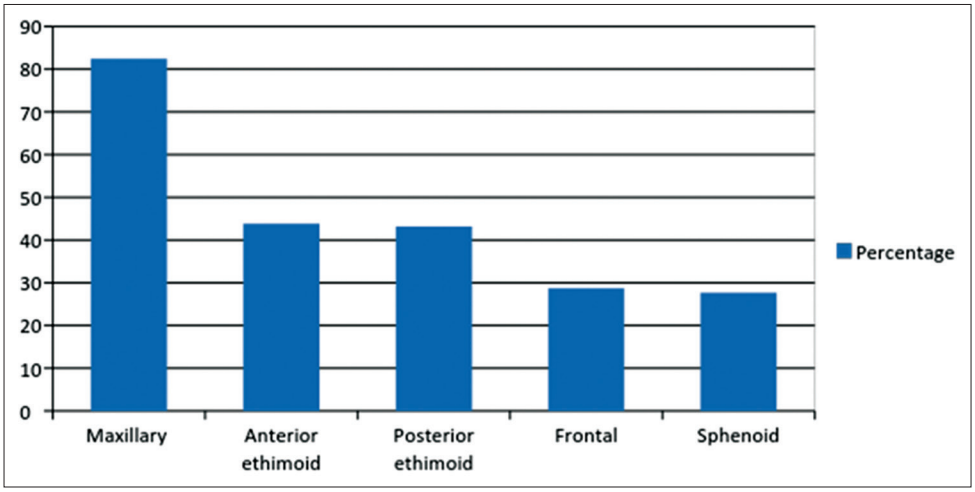

Chart 2: Distribution of sinusitis in the study group

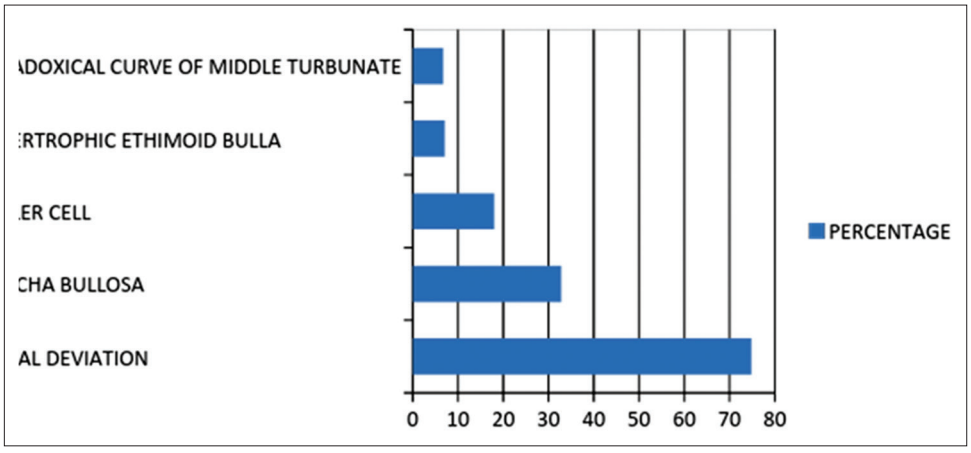

Chart 3: Most common anatomic variations in the study population

A total of 4 uncommon anatomic variations were seen 9 patients (2.9%) in the 310 patients. These included atelectatic of UP in 3 patients (1%), hypoplastic MS in 1 patient (0.32%), pneumatization of crista galli was observed in 3 patients (1%), and pneumatization of the nasal septum in 2 patients (0.64%) (Table 3).

Multiparametric statistical analysis correlations are represented in Table 4. With regard to septal deviation, there was a statistically significant significance between left septal deviation and left MS ($P < 0.02$). We also found a correlation between bilateral concha bullosa and bilateral MS ($P < 0.002$). In addition, there was a statistically significant significance between left agger nasi cell and homolateral frontal sinusitis ($P < 0.02$).

No other statistically significant correlations were demonstrated between any other common and uncommon anatomic variations and ipsilateral, contralateral or bilateral sinusitis (Figures 1 and 2).

Table 1: Prevalence of sinusal opacities of the study population

Sinusitis	*N* (%)				
	Unilateral			Bilateral	Total
	Right	Left	Total		
Maxillary	31 (10)	64 (20.6)	95 (30.6)	161 (51.9)	256 (82.5)
Anterior ethmoid	13 (4.2)	21 (6.7)	34 (10.9)	102 (32.9)	136 (43.8)
Frontal	12 (3.8)	26 (8.3)	38 (12.2)	51 (16.4)	89 (28.7)
Posterior ethmoid	13 (4.2)	15 (4.8)	28 (9)	106 (43.2)	134 (43.2)
Sphenoid	14 (4.5)	17 (5.5)	31 (10)	55 (17.7)	86 (27.7)
Closed OMC	19 (6.1)	14 (4.5)	33 (10.6)	58 (18.7)	91 (29.3)

OMC: Osteomeatal complex

DISCUSSION

Anatomic variations of paranasal sinus structures may predispose patients to recurrent sinusitis and, in selected cases, to a headache. However, the relative importance of anatomic variations is still a matter of discussion, and variable results have been reported. Kim *et al.*, Lerdlum *et al.*,[9] and Stallman *et al.* showed no specific association of anatomic variations in rhinosinusitis, and claimed that local, systemic, environmental factors or intrinsic mucosal disease were more significant in the pathogenesis of rhinosinusitis.[9-11]

The nasal septal deviation is present in 20-31% of the general population, and severe deviation has been noted as a contributing factor for sinusitis.[12] However, some studies have not demonstrated a causal relationship between nasal septal deviation and sinusitis.[13] We found a statistically significant correlation between left septal deviation and left MS ($P < 0.02$) (Table 4).

Normal ethmoid bulla was detected in 288 of 310 patients (92.9%), compared to 17-89% of cases in previous reports.[14,15] Ethmoid bulla hypertrophic - prominent - was present in 7.1% of patients in our study (Table 2). Krzeski *et al.* reported a frequency of 26.75%,[14] while Scribano estimated that it is only 3.5%.[16] In our

Table 2: Common anatomic variations in CT scans

Common anatomic variations	*N* (%)			Bilateral	Total
	Unilateral				
	Right	Left	Total		
Septal deviation	130 (41.9)	102 (32.9)	232 (74.8)	-	232 (74.8)
Hypertrophic ethmoidal bulla	4 (1.3)	3 (1)	7 (2.2)	15 (4.8)	22 (7.1)
Large agger nasi cell	2 (0.64)	3 (1)	5 (1.6)	6 (1.9)	11 (3.5)
Middle turbinate					
Concha bullosa	39 (12.6)	22 (7.1)	61 (19.6)	41 (13.2)	102 (32.9)
Paradoxical	12 (3.8)	4 (1.3)	16 (5.1)	5 (1.6)	21 (6.7)
Uncinate process					
Lateral deviation	1 (0.32)	2 (0.64)	3 (1)	2(0.64)	5 (1.6)
Medial deviation	1 (0.32)	3 (1)	4 (1.3)	5 (1.6)	9 (2.9)
Pneumatization	1 (0.32)	5 (1.6)	6 (2)	2 (0.64)	8 (2.6)
Haller's cell	14 (4.5)	7 (2.2)	21 (6.7)	35 (11.3)	56 (18)
Onodi cell	3 (1)	0	3 (1)	5 (1.6)	8 (2.6)
MS					
Septated	1 (0.32)	2 (0.64)	3 (1)	2 (0.64)	5 (1.6)
Roof of ethmoid					
Type I	49 (15.8)				84 (27.1)
Type II	28 (9.03)				
Type III	7 (2.2)				
Single large sphenoid sinus	-	-	-	-	8 (2.6)

study, there was no significant correlation between hypertrophic ethmoidal bulla and sinusitis of anterior ethmoid.

The term concha bullosa was coined by Zuckerlandl in 1862 to describe pneumatization of the middle turbinate and its incidence was reported to range from 9% to 20% based on initial anatomical dissections. The significance of this most common anatomic variation of the middle turbinate lies in the potential secondary deformity of the turbinate, which increases the probability of obstruction of the middle meatus and lead to recurrent ethmoid sinusitis.

Table 3: Uncommon anatomic variations in CT scans in study population

Uncommon anatomic variations	*N* (%)			
	Right	Left	Bilateral	Total
Pneumatization of crista galli	-	-	-	3 (1)
Pneumatization of nasal septum	-	-	-	2 (0.64)
Atelectatic uncinate process	2 (0.64)	1 (0.32)	0	3 (1)
Hypoplastic MS	1 (0.32)	0	0	1 (0.32)

MS: Maxillary sinus, CT: Computed tomography

Table 4: Correlation between anatomical variations and disease extension of sinusitis (Fisher's exact test)

Anatomic variations (%)	Sinusitis (%)	*P* value
Left septal deviation (32.9)	Left maxillary (64)	0.02
Right septal deviation (41.9)	Right maxillary (31)	0.41
Bilateral concha bullosa (13.2)	Bilateral maxillary (51.9)	0.002
Medial deviation of uncinate process	Anterior ethmoid	
Right (0.32)	Right (4.2)	0.95
Bilateral (0.64)	Bilateral (32.9)	0.52
Haller's cell	Maxillary	
Right (4.5)	Right (31)	0.58
Left (2.2)	Left (64)	0.40
Bilateral (11.3)	Bilateral (51.9)	0.48
Ethmoidal bulla hypertrophic	Anterior ethmoid	
Right (1.3)	Right (4.2)	0.84
Bilateral (2.2)	Bilateral (32.9)	0.58
Agger nasi cell	Frontal	
Right (0.64)	Right (3.8)	0.92
Left (1)	Left (8.3)	0.02

P<0.05 is significant

Bolger *et al*.[17] reported three types of the middle turbinate pneumatization: The vertical lamella was pneumatized in 46.2% of cases ("lamellar cell") in the inferior bulbous portion in 31.2% of patients and in the entire middle turbinate in 15.7% of cases ("true" concha bullosa). Unilateral or bilateral concha bullosa was detected in 32.9% of patients in the present series. According to data from the literature, the incidence of positive CT findings for concha bullosa varies from 14% to 62%.[18] In particular,

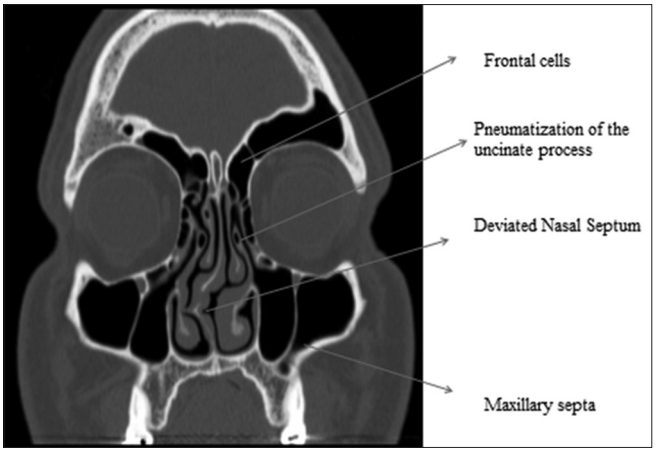

Figure 1: some important anatomic variations: Left Type I frontal cells,pneumatisation of uncinate process,Deviated nasal septum with bony spur to right and bilateral maxillary septa

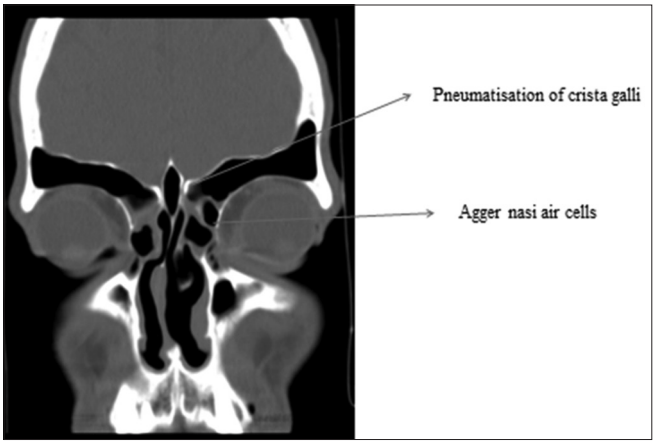

Figure 2: Left Agar Nasi cells and pneumatisation of Crista Galli

Table 5: CT scan findings in anatomic variations in various studies

Anatomic variations	Present study (%)	Peres-Pinas *et al*. (%)	Dua K *et al*. (%)	Zinreich *et al*. (%)	Bolger *et al*. (%)
Year	2013	2005	2000	1993	1991
Number of patients	500	115	55	230	202
Concha bullosa	32.9	24.50	16	36	53.60
Paradoxicalmiddle turbinate	6.7	10	10	15	27
DNS	74.8	58	44	21	96
Haller cells	18	2.70	16	10	45.90
Onadi cells	2.6	10.90	6	8	11
Prominent AG N-cells	3.5	98	40		98.50

CT: Computed tomography

incidences of 37.5%, 44% and 48.1%, respectively, were reported by Krzeski *et al*.,[14] Stallman *et al*.,[3] and Ozcan *et al*.[4] There are different opinions in the literature concerning concomitance with mucosal pathologies. Herein, multivariate analysis showed that bilateral concha bullosa was associated with sinusitis bilateral maxillary ($P < 0.002$) (Table 4) in agreement with previous reports,[4,16] while other studies found no direct relationship.[19] Stallman *et al*. reported a significant relationship between the presence of concha bullosa and deviation of the nasal septal on the contralateral side ($P < 0.0001$).[3]

The paradoxical curvature of the middle turbinate is described as a convexity pointing toward the middle meatus and is reported as a possible cause for closed OMC and mucosal pathologies.[20] In our study, the incidence of middle paradoxical turbinate was 6.7% and was not associated with mucosal pathologies. The rates of this variation in previous publications are highly variable, with incidences ranging from 3% to 40%.[15,17,21] Nouraei *et al*.,[22] in a review of 278 CT scans, found only 2 (0.7%) cases with paradoxical curves.

The UP is another important structure in relation to paranasal sinus drainage, and the incidence of variations in this structure is generally from 15.9% to 44.3%,[14,23,24] in our study, it was 8.1%.

Medial deflection of UP was previously described in 3-19% of cases.[14,25] Herein, it was observed in 2.9% of patients, while lateral deflection of UP was observed in 1.6% of cases. We found that the UP was pneumatized in 2.6% of patients. The rate of UP pneumatization in previous studies has been reported to be from 1% to 9%.[15,17,21]

MS hypoplasia (MSH) is the most important anatomical variation among those involving the MS. MSH typing was done by Bolger *et al*. in 1990.[17] Since MSH is often associated with orbital enlargement, thickening of the bony sinus wall, mucosal pathology, anterior ethmoidal cell variation or frontal sinus hypoplasia, it is important to identify these anatomical variations for proper surgical planning to prevent complications.[26] The incidence of MS septae was found to vary from 20% to 31% in previous reports.[27] In our study, the MS was hypoplastic in 0.32% and septated in 1.6%, less than that previously reported. There was no significant correlation between these anatomical variations and mucosal pathologies; in agreement with literature data.[2]

The OMC is a functional entity of the anterior ethmoid complex that represents the final common pathway for drainage and ventilation of the frontal, maxillary and anterior ethmoid cells. Thus, anatomical variations that redirect nasal airflow or narrow the OMC have been implicated in the development of chronic rhinosinusitis.[28] In this study, the patients with pathologies at OMC (91/310) had involvement of multiple sinuses and were found to have increased symptom severity.

Another common anatomic variant was the presence of infraorbital ethmoid cells, also known as Haller cells. These are found between the MS and the orbit and can increase the risk of orbital injury during ethmoidectomy.[21] Haller cells are a clinically significant anatomic variation because they have been implicated as a possible etiologic factor in recurrent MS due blockage of the OMC.[6] In previous studies, a variable incidence of Haller cells has been noted. In particular, Kennedy and Zinreich[29] and Meloni *et al*.[30] both reported rates of 10%, while Arslan *et al*.[20] reported an incidence of 6% and Bolger *et al*.[31] an incidence of 45.1%. Possible reasons for this discrepancy include differences in interpretation of Haller cells, or in the technique of CT scanning. In our study, the incidence of Haller cells was 18%, and we found no statistically significant relationship with MS, in disagreement with what reported by Van Alyea.[32]

The reported prevalence of the agger nasi cell varies widely among investigators. In anatomic dissection, Messerklinger[33] encountered the agger nasi cell in 10-15% of specimens. Kantarci *et al*.,[7] however, noted this cell in 47% of specimens, while Krzeski *et al*.[14] reported its presence in 52.9% of cases and Van Alyea[32] in 89% of individuals. Kennedy and Zinreich noted the presence of the agger nasi cell in nearly all patients evaluated.[17] Similarly, Bolger *et al*. reported that it was present in 98.5%, of cases.[17] In our study, agger nasi cells were detected in 3.5% of cases, and by multivariate analysis was associated with frontal sinusitis ($P < 0.02$) (Table 5). The incidence rates reported in the literature, from 3% to 100%.[10] may in part be related to the different method of analysis employed by Krzeski *et al*.[14]

Although the sphenoethmoid (onodi) cell is an anatomic variant that is not associated with sinusitis, its presence poses an increased incidence of surgical complications for risk of injury to optic nerves or carotid arteries. In our work, these cells were present in 2.6% of patients. Nouraei *et al*. reported an incidence of 4.7%,[34-36] while Stallman *et al*. reported an incidence of onodi cells from 3.4% to 51%.[3]

According to Keros' classification of the roof of the ethmoid, in our study, there were 15.8% of patients in Group I, 9.03% in Group II, and 2.2% in Group III.[30]

CONCLUSIONS

The results of this retrospective study highlight the statistically significant correlation between some anatomical variations of the paranasal sinuses and chronic rhinosinusitis. Therefore, knowledge of anatomic variations of the paranasal sinuses is important in all cases of chronic rhinosinusitis.

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