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RESEARCH ARTICLE

Sphenoethmoid Cell: The Battle for Places Inside of the Nose Between a Posterior Ethmoid Cell and Sphenoid Sinus: 3D-Volumetric Quantification

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Abstract: ***Background*:** Sphenoethmoid cells may be above the sphenoid sinus with/ or without contact to optical nerve. Although sphenoethmoid cells are theoretically considered to possibly influence the sphenoid sinus volume, we could not find any study in the literature on this issue.

***Aims*:** The aim of our study was to detect sphenoethmoid cells and measure the sphenoid sinus volume using multiplanar computerized tomography and also investigate the correlation between the presence of sphenoethmoid cells and the sphenoid sinus volume.

***Methods*:** Retrospectively 141 patients who had available paranasal computerized tomography images were included in this study. The sphenoid sinus volumes of each patient were calculated individually for each side, and the relationship between the presence of sphenoethmoid cell and sphenoid sinus volume was investigated.

***Results*:** Sphenoethmoid cells were detected at 106 (37.5%) of the total 282 sides in 141 patients. No gender difference was observed. The total sphenoid sinus volume was significantly lower in the group of patients who had bilateral sphenoethmoid cells than in the sphenoethmoid cell negative group. In patients with a unilateral sphenoethmoid cell, a significant decrease in the sphenoid sinus volume was observed only for the side where the sphenoethmoid cell was located.

***Conclusion*:** It was observed that the sphenoethmoid cells caused a significant reduction in the sphenoid sinus volume on the side where they were located. In the case of low sphenoid sinus aeration, the sphenoethmoid cell should be kept in mind. Further studies with an extended patient series are required to explore this issue.

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1. INTRODUCTION

The sphenoethmoid air cells (SEC) (formerly known as "Onodi cells") are located in a superior and lateral position to the sphenoid sinus (SS) [1]. The prevalence of sphenoethmoid cells is reported as 8-65.3% [2-4]. The SEC are also closely associated with the SS, the optic nerve (ON), and the internal carotid artery (ICA) [2, 5, 6].

The SS, which is deeply seated in the skull and surrounded by vital structures such as the ICA and the ON, is considered the most inaccessible paranasal sinus [7]. To prevent serious complications, such as injuries to these vital structures during transsphenoidal and endoscopic sinus surgery, a comprehensive knowledge of the variable anatomy of the SS is necessary [8, 9].

The paranasal sinuses begin their development from very early stage in utero and show very different features in shape and size [10]. While ethmoid sinuses originate from invagination of the lateral nasal wall, the SS originates from the posterior invagination of the nasal capsule. The posterior ethmoid cells and SS are pneumatized synchronously, and they exhibit major volumetric growth during the same period of life. It is natural to expect the SS and the SEC to have distinct pneumatization characteristics because these two structures have separate embryological origins. Possible inter-individual volumetric discrepancies and factors that determine the pneumatization patterns in the SS, posterior ethmoid cells, and particularly the SEC are yet to be discovered. Nomura *et al.* [11] stated that the SEC displaces the SS downward and reduces its volume. In general, the SEC is accepted to be an obstacle especially during the endoscopic transsphenoidal sellar surgery and must be opened for safety of the surgery and accessibility to the sellar region [6, 12].

Initial knowledge of human paranasal sinus pneumatization was obtained by anatomical measurements, injecting various materials into cadavers or performing plain radiography. Currently, computerized tomography (CT) and magnetic resonance imaging (MRI) provide more precise information and allow a more accurate assessment of the region. Computerized tomography is a gold standard tool for analyzing the sphenoid sinus and its surrounding structures [13]. It should be noted that during CT evaluation, all three dimen-

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sions (axial, coronal and sagittal) should be examined for proper identification of the SEC [5].

Several studies have evaluated the paranasal sinus volume using CT scans [14-16]. However, to the best of our knowledge, the correlation between the presence of SEC and the quantitative measurement of SS volume has not been reported. In this study, we aimed to detect the SEC and to measure SS volumes quantitatively using a high resolution multiplanar (axial, coronal and sagittal) CT scan and to analyze the correlations between the presence of the SEC and the SS volume.

2. MATERIALS AND METHODS

Following the Ethics Committee approval, retrospective data of 141 patients (80 males and 61 females) aged 18 years or older who underwent paranasal CT scans due to chronic sinusitis between March 2014 and March 2015, were screened and included in this study. Patients with traumatic signs or histories, malignancy, congenital malformation, or a history of endoscopic sinus surgery were excluded. The presence of SEC was evaluated in each CT scan, and patients were categorized into four groups: Group I: SEC negative (Control group); Group II: Bilateral SEC positive, Group III: Right SEC positive, Group IV: Left SEC positive. The relationship between the SEC and the SS volume was investigated according to the SS volume of each patient calculated individually for each side.

2.1. Image Acquisition

Routine paranasal CT scans were performed using a 128-slice multi-detector CT scanner (Ingenuity CT, Philips Healthcare, Andover, MA, USA). The exposure settings were 120 kV and 160 mA with a rotation time of 0.5 SECc and a collimation of 64 x 0.625. Axial images with 0.6 mm thickness were obtained, and coronal and sagittal CT scan images were 0.9 mm thick. All the images were sent to workstation (Syngo. *via* Work Station, Erlangen, Germany). The sphenoid sinus borders were drawn by the radiologist in each section of the sphenoid sinus area of interest. This process was done separately for each side. When all the sections of the sphenoid sinus area of interest were finished, the computer converted all of the obtained sections to volume measurement and obtained a sphenoid sinus volume using the volume programme of Syngo. *via* work station.

2.2. Statistical Analyses

The Shapiro-Wilk test was used to test normality, and the Levene test was used to test homogeneity of variance. An independent T test and one-way ANOVA (Robust Test: Brown- Forsythe) were used for the comparisons of two independent groups and multiple groups. Post-hoc analyses were performed with Fisher's least significant difference (LSD) test. Quantitative variables are presented as the means ±SD (standard deviation), whereas numbers (n) and frequencies (%) are used to present categorical variables. A confidence level of 95% was adopted for the analyses, and a p value less than 0.05, indicated statistical significance. Statistical analyses were performed using SPSS 22.0 (IBM Corporation, Armonk, New York, USA).

3. RESULTS

The mean (±SD) age of the study population was 35.5 (±13.2) years, and the age of the patients ranged from 18 to 68 years. Eighty of 141 patients were female. The frequency of female patients was higher (56.7%); however, no significant difference was observed between the patient groups in terms of age (p=0.143) or gender (p=1.000).

Sphenoethmoid cells were detected at 106 (37.5%) of the total 282 sides in 141 patients (Table **1**). Among the SEC positive patients, the frequencies of bilateral, right side and left side SEC positive patients were 47.2%, 25.0% and 27.8%, respectively. The presence of bilateral SEC was more common (~47%) than unilateral existence in both genders. The existence of unilateral SEC was distributed similarly (25% *vs*. 28%) for each side in both genders (Table **2**).

Table 1. Location and prevalence of sphenoethmoid cells.

-	Right Side	Left Side	Total Number of Sides
Unilateral SEC	18	20	38
Bilateral SECs	34	34	68
Total Number of SECs	52/141(36.8%)	54/141(38.2%)	106/282 (37.5%)

Table 2. Location of sphenoethmoid cells by gender.

Location of Sphenoethmoid Cell	Total		Females		Males	
	n	(%)	n	(%)	n	(%)
Bilateral	34	47.2	15	46.9	19	47.5
Right Side	18	25.0	8	25.0	10	25.0
Left Side	20	27.8	9	28.1	11	27.5
Total	72	100.0	32	100.0	40	100.0

In the absence of an SEC (Group I, Control), the mean total SS volume of the patients was 15.1 cm^3, and the mean volume of each side was comparable (7.8 cm^3 for the right side and 7.3 cm^3 for the left side). The total SS volume was significantly lower in the group of patients who had bilateral SEC (Group II) than in the SEC-negative group (Group I, Control). However, in cases where SECs were present unilaterally (Group III and IV), a significant decrease in the SS volume was observed only for the side in which the SEC was present (Fig. **1**, Table **3**). The volumes of each sides of the SEC-negative group in our study were compared with the previous studies (Table **4**). In addition, previous studies of authors, study modality, number of subjects and/or performed technique, sphenoethmoid cell prevalence were presented at Table **5**.

4. DISCUSSION

Endonasal endoscopic sinus surgery may be required for indicated paranasal sinus diseases. In addition, transsphenoidal endonasal endoscopic surgery is preferred for the management of pituitary lesions [17]. Because the SS is near

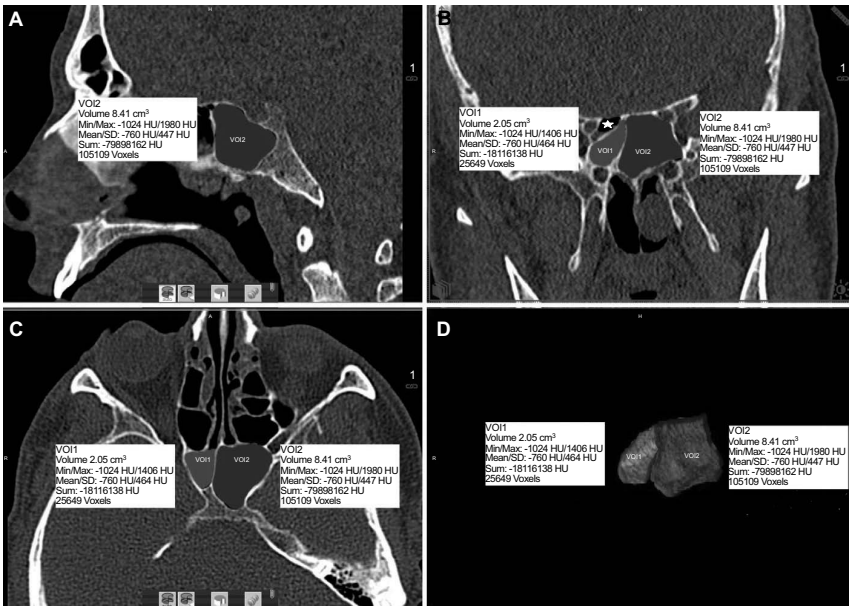

Fig. (1). Volumetric measuement of right (green color) and left (purple color) sphenoid sinuses in coexistence with right SEC (asterisk) with three-dimensional CT volume rendering technique (**A, B, C**). While the right sphenoid sinus volume is 2.05 cm^3 in coexistence with right-sided SEC, left sphenoid sinus volume is 8.41 cm^3 in the absence of SEC (**D**). *(The color version of the figure is available in the electronic copy of the article).*

Table 3. Distribution of sphenoethmoid cells and sphenoid sinus volumes.

Presence of Spheoethmoid Cell	n (%)	Mean (±SD) Volume of Right SS (mL)	Mean (±SD) Volume of Left SS (mL)	Mean (±SD) Total Volume of SS (mL)
Negative (Group I, Control)	69 (48.9)	7.82 (±3.55)	7.25 (±2.65)	15.07 (±5.37)
Bilateral (Group II)	34 (24.1)	4.92 (±2.94)	4.08 (±2.57)	9.00 (±4.37)
Right Side (Group III)	18 (12.8)	4.70 (±2.81)	7.85 (±3.47)	12.55 (±4.89)
Left Side (Group IV)	20 (14.2)	8.28 (±2.97)	4.41 (±2.49)	12.69 (±4.60)
Total	141 (100)	6.79 (±3.55)	6.16 (±3.12)	12.95 (±5.51)
p value	-	<0.001	<0.001	<0.001
Post Hoc Tests	I→II	<0.001	<0.001	<0.001
p value	II→III	0.817	<0.001	0.016
	II→IV	<0.001	0.676	0.010
	III→IV	0.001	<0.001	0.932
	II→IV	<0.001	0.676	0.010

SS: Sphenoid Sinus.

Table 4. Comparative data of our and previous studies about the volume of sphenoid sinus.

Authors [Reference Number]	Country	Number of Cases	Average Sphenoid Sinus Volume (mL)	Right Sphenoid Sinus Volume (mL)	Left Sphenoid Sinus Volume (mL)	Total Sphenoid Sinus Volume (mL)
Kawarai *et al*. [15]	Japan	20	N/A	N/A	N/A	15.4±6.9
Kim *et al*. [30]	Korea	60	N/A	N/A	N/A	13,766
Oliveira *et al*. [31]	Brazil	47	N/A	6.157±3.5	7.26±3.6	N/A
Selcuk *et al*. [32]	Turkey	115	7.81 and 6.35	N/A	N/A	N/A
Our Study	Turkey	141	N/A	7.82±3.55	7.25±2.65	15.07±5.37

N/A: Not avaliable. ¶: Detected volumes in two different regions in a country.

Table 5. Various studies on study modality, number of subjects, performed technique and prevalence of sphenoethmoid cell.

Author	Study Modality	Number of Subjects and/or Performed Technique, Including Criteria	Sphenoethmoid Cell Prevalence
Hwang *et al*. [5]	Computed Tomography	100 patients, retrospective image analysing	32%
Nomura *et al*. [11]	Computed Tomography	200 patients, septal or chronic sinonasal symptoms	34.3%
Chmielik *et al*. [20]	Computed Tomography	196 patients, retrospective image analysing	39.8%
Al-Abri *et al*. [21]	Computed Tomography	435 patients, chronic sinonasal symptoms	8%
Leunig *et al*. [22]	Computed Tomography	641 patients, chronic sinus conditions	8.4%
Pérez-Piñas *et al*. [23]	Computed Tomography	110 patients, inflammatory sinus pathology	10.9%
Kasemsiri *et al*. [24]	Computed Tomography	187 patients, retrospective image analysing	49.5%
Wada *et al*. [25]	Computed Tomography	261 patients, chronic rhinosinusitis	50.8%
Tomovic *et al*. [4]	Computed Tomography	170 patients, retrospective image analysing	65.3%
Thanaviratananich *et al*. [2]	Cadaveric Half-head	65 specimen, endoscopic ethmoidectomy	60%
Yeoh *et al*. [27]	Cadaveric Head	102 specimen, endoscopic sphenoethmoidectomy	50.98%
Kainz and Stammberger [28]	Cadaveric Half-head	52 specimen, endoscopic sphenoethmoidectomy	42%
Jones *et al*. [26]	Computed Tomography	100 patients with rhinosinusitis and 100 controls with intraorbital disease	7% in patients, 9% in controls
Our Study	Computed Tomography	141 patients, chronic sinusitis	37.5%

several vital structures; *i.e*. the ON, CA, and vidian nerve, complications in the interventions performed on this sinus may be more dangerous than those in other sinuses. Therefore, preoperative in-depth assessment of anatomical variations of the SS is extremely vital to prevent damage to these important and close structures.

Some anatomical cell variations may be present near the paranasal sinuses. The SEC is one of the cell variations around the sphenoid sinus and is known as a sphenoethmoidal cell. Săndulescu *et al.* [18] stated that important variations may be present at the sphenoethmoidal junction, and most of these are associated with the presence of an SEC and intrasinusal bulgings of the ON. Ozturan *et al.* [19] stated that the SEC aeration may achieve and enclose the ON in various extensions. The most posterior ethmoid cell is thought to be an obstacle for the endoscopic endonasal transsphenoidal sellar surgery and should be opened for exact view of the surgery and accessibility to the sellar region [6, 12].

Radiological techniques such as CT and MRI are widely used to improve diagnosis and preoperative assessments in the sphenoethmoidal region. The results suggested that three planes (axial, coronal and sagittal) for CT examinations should always be used in sinus CT examinations for proper detection and definition of the SEC [6].

Various prevalence rates have been reported for the SEC ranging from 8% to 65.3% [2-4]. With the evolution of radiological techniques, new CT studies have also been emerged. Technically, the inspection of all three dimensions (axial, coronal and sagittal) of CT scans has also been possible to detect the SEC. In this study, the prevalence of

SEC was found to be 37.5%. The prevalence of SEC in this study is comparable with the previous reported prevalence rates of CT study by Hwang *et al*. [5], Nomura *et al.* [11], and Chmielik *et al.* [20]. The results of this study revealed higher prevalence of SEC than the CT studies of Al-Abri *et al.* [21], Leunig *et al.* [22] and Pérez-Piñas *et al.* [23], and our results were also lower than the CT reports of Kasemsiri *et al.* [24], Wada *et al.* [25] and Tomovic *et al.* [4]. In addition, in a CT study involving the patients with both rhinosinusitis and healthy volunteers, the SEC prevalence was found to be 9% in healthy volunteers and 7% in the patients with rhinosinusitis [26]. Data from healthy volunteers were not obtained in this study. In addition, Thanaviratananich *et al.* [2], Yeoh *et al.* [27] and Kainz and Stammberger [28] studied the prevalence of sphenoethmoid cells in cadavers and found 60%, 50.98%, and 42%, respectively. For comparing various studies on study modality, number of subjects, performed technique, including criteria and the prevalence of sphenoethmoid cell are presented in Table **5**. In the light of the above data, regarding the inclusion criteria, studies on SEC prevalence have been performed either on chronic sinus disease as this study or on randomly paranasal sinus CTs or cadaveric specimens. The prevalence of SEC in our study was performed on chronic sinus disease and our results were compared with the CT studies of Nomura *et al.* [11] and Wada *et al.* [25]. This study's results were also higher than healthy individuals in the CT study (Table **5**). This may be caused by the inclusion criteria kept higher than the prevalence values obtained from healthy volunteers. Interestingly, studies performed on cadavers were also found to be higher than the prevalence of CT studies' values on healthy volunteers. Here again, these prevalence discrepancies may be due to in racial and regional differences as well as the different techniques performed.

Aeration of the sphenoid bone starts after birth, and expansion of the SS is age-related. In general, the volume of the SS increases until the third decade of life [29]. In our study, which included patients aged between 18 and 68 years, the mean age was 35 years, and no statistically significant difference was observed in terms of patient's age ($p=0.143$).

In the literature, several studies have measured the SS volume using CT scanning [14-16]. In general, the results of the sphenoid sinus volumes were comparable with the results of the other contries' studies in the aspects of racial or regional differences (Table **4**). However, the correlation between the presence of an SEC and the sphenoidal sinus volume has not been studied. In this study, using a multiplanar CT-volume rendering technique, it was revealed that the unilateral presence of the SEC reduced the SS volume of the side on which it was located. For example, when a left-sided SEC was present, a statistically significant reduction was observed in the left-sided SS volume compared to the right side. However, bilateral SECs had a more statistically significant reductive effect on the total SS volume by reducing both the left and right sphenoid volumes.

Although it has been suggested that the SEC must be opened during the transsphenoidal endoscopic sellar surgery and the presence of the SEC caused a reduction in the SS volume, we could not find any volumetric study on this issue in the literature. While planning our study, it was decided to investigate the relationship between the SS and the SECs in the following manner. It was determined whether two cells competed to fill a certain volume or whether they showed increased pneumatization together with the action of similar stimulating factors. Based on the results of this study, it was concluded that the SECs compete with the SS to fill a certain volume, resulting in a reduction in the volume of the SS.

From the surgeon's perspective, in patients with a small SS volume coexisting with SEC, surgery and instrumentation of the affected SS may be more difficult under pathological conditions, and thus the skull base, pituitary gland, and carotid artery may be entered incorrectly, resulting in a greater risk of injury without opening the SEC. On the other hand, with the surgical opening of the SEC, it may become possible to contribute to cleaning of the pathology of the affected SS to improve patients' clinical condition.

CONCLUSION

According to our study, sphenoethmoid cells significantly reduce the sphenoid sinus volume of the side on which they are located. In the case of low sphenoid sinus aeration, the most posterior ethmoid cell should be kept in mind. With this study, the ideas that the most posterior ethmoid cell that is an obstacle to the sphenoid sinus surgery and the opening of this cell will increase the volume of the sphenoid sinus, were made clearly with the quantitative data. Further studies with an extended patient series are required to explore this issue.

LIST OF ABBREVIATIONS

ON	=	Optic Nerve
ICA	=	Internal Carotid Artery
CT	=	Computerized Tomography
MRI	=	Magnetic Resonance Imaging

AUTHORS' CONTRIBUTIONS

MS drafted and wrote the manuscript. IG and IT managed and measured the major part of the radiological parameters. IA collated the data and contributed to statistical analysis. EUS, RO, BA, NA and MK helped to collect data draft and edit the manuscript. All the authors read and confirmed the script.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Necmettin Erbakan University, Medical Faculty, Ethical Commity, #2015/239.

HUMAN AND ANIMAL RIGHTS

All research procedures followed were in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1975, as revised in 2008.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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REFERENCES

[1] Onodi A. The optic nerve and accessory sinuses of the nose. New York: William Wood & Co 1910.

[2] Thanaviratananich S, Chaisiwamongkol K, Kraitrakul S, Tangsawad W. The prevalence of a posterior ethmoid cell in adult Thai cadavers. Ear Nose Throat J 2003; 82(3): 200-4.

[3] Yoon KC, Park YG, Kim HD, Lim SC. Optic neuropathy caused by a mucocele in an posterior ethmoid cell. Jpn J Ophthalmol 2006; 50(3): 296-8.

[4] Tomovic S, Esmaeli A, Chan NJ, *et al.* High-resolution computed tomography analysis of the prevalence of onodi cells. Laryngoscope 2012; 122(7): 1470-3.

[5] Hwang SH, Joo YH, Seo JH, Cho JH, Kang JM. Analysis of sphenoid sinus in the operative plane of endoscopic transsphenoidal surgery using computed tomography. Eur Arch Otorhinolaryngol 2014; 271(8): 2219-25.

[6] Shin JH, Kim SW, Hong YK, *et al.* The onodi cell: An obstacle to sellar lesions with a transsphenoidal approach. Otolaryngol Head Neck Surg 2011; 145(6): 1040-2.

[7] Hewaidi G, Omami G. Anatomic variation of sphenoid sinus and related structures in Libyan population: CT scan study. Libyan J Med 2008; 3(3): 128-33.

[8] Wu HB, Zhu L, Yuan Hs, Hou C. Surgical measurement to sphenoid sinus for the Chinese in Asia based on CT using sagittal reconstruction images. Eur Arch Otorhinolaryngol 2011; 268(2): 241-6.

[9] Fukushima T, Maroon JC. Repair of carotid artery perforations during transsphenoidal surgery. Surg Neurol 1998; 50(2): 174-7.

[10] Weiglein A, Anderhuber W, Wolf G. Radiologic anatomy of the paranasal sinuses in the child. Surg Radiol Anat 1992; 14(4): 335-9.

[11] Nomura K, Nakayama T, Asaka D, *et al.* Laterally attached superior turbinate is associated with opacification of the sphenoid sinus. Auris Nasus Larynx 2013; 40(2): 194-8.

[12] Imre A, Pınar E, Yuceer N, Songu M, Olgun Y, Aladag I. Does posterior ethmoid cell limit the exposure of sella during transsphenoidal pituitary surgery? Kulak Burun Bogaz Ihtis Derg 2015; 25(2): 82-6.

[13] Cherla DV, Tomovic S, Liu JK, Eloy JA. The central posterior ethmoid cell: A previously unreported anatomic variation. Allergy Rhinol (Providence) 2013; 4: e49-51.

[14] Ariji Y, Kuroki T, Moriguchi S, Ariji E, Kanda S. Age changes in the volume of the human maxillary sinus: A study using computed tomography. Dentomaxillofac Radiol 1994; 23(3): 163-8.

[15] Kawarai Y, Fukushima K, Ogawa T, *et al.* Volume quantification of healthy paranasal cavity by three-dimensional CT imaging. Acta Otolaryngol Suppl 1999; 540: 45-9.

[16] Fernández JMS, Anta Escuredo JA, Sánchez Del Rey A, Montoya FS. Morphometric study of the paranasal sinuses in normal and pathological conditions. Acta Otolaryngol 2000; 120(2): 273-8.

[17] Wormald PJ. The agger nasi cell: The key to understanding the anatomy of the frontal recess. Otolaryngol Head Neck Surg 2003; 129(5): 497-507.

[18] Săndulescu M, Rusu MC, Ciobanu IC, Ilie A, Jianu AM. More actors, different play: Sphenoethmoid cell intimately related to the maxillary nerve canal and cavernous sinus apex. Rom J Morphol Embryol 2011; 52(3): 931-5.

[19] Ozturan O, Yenigun A, Degirmenci N, Aksoy F, Veyseller B. Co-existence of the posterior ethmoid cell with the variation of perisphenoidal structures. Eur Arch Otorhinolaryngol 2013; 270(7): 2057-63.

[20] Chmielik A, Chmielik L, Boguslawska-Walecka R. The prevalence and CT detection of onodi cell types. The European Congress of Radiology; 2014 March 6-10; Vienna, Austria. pp. 1-15.

[21] Al-Abri R, Bhargava D, Al-Bassam W, Al-Badaai Y, Sawhney S. Clinically significant anatomical variants of the paranasal sinuses. Oman Med J 2014; 29(2): 110-3.

[22] Leunig A, Betz CS, Sommer B, Sommer F. Anatomic variations of the sinuses; multiplanar CT analysis in 641 patients. Laryngorhinootologie 2008; 87(7): 482-9.

[23] Pérez-Piñas I, Sabaté J, Carmona A, Catalina-Herrera CJ, Jiménes-Castellanos J. Anatomical variations of the paranasal sinus region studied by CT. J Anat 2000; 197(Pt 2): 221-7.

[24] Kasemsiri P, Thanaviratananich S, Puttharak W. The prevalence and pattern of pneumatization of onodi cell in Thai patients. J Med Assoc Thai 2011; 94(9): 1122-6.

[25] Wada K, Moriyama H, Edamatsu H, *et al.* Identification of onodi cell and new classification of sphenoid sinus for endoscopic sinus surgery. Int Forum Allergy Rhinol 2015; 5(11): 1068-76.

[26] Jones NS, Strobl A, Holland I. A study of the CT findings in 100 patients with rhinosinusitis and 100 controls. Clin Otolaryngol 1997; 22(1): 47-51.

[27] Yeoh KH, Tan KK. The optic nerve in the posterior ethmoid in Asians. Acta Otolaryngol 1994; 114(3): 329-36.

[28] Kainz J, Stammberger H. Danger areas of posterior rhinobasis. An endoscopic and anatomical-surgical study. Acta Otolaryngol 1992; 112(5): 852-61.

[29] Yonetsu K, Watanabe M, Nakamura T. Age-related expansion and reduction in aeration of the sphenoid sinus: Volume assessment by helical CT scanning. AJNR Am J Neuroradiol 2000; 21(1): 179-182.

[30] Kim J, Song SW, Cho JH, Chang KH, Jun BC. Comparative study of the pneumatization of the mastoid air cells and paranasal sinuses using three-dimensional reconstruction of computed tomography scans. Surg Radiol Anat 2010; 32(6): 593-9.

[31] Oliveira JM, Alonso MB, de Sousa E, *et al*. Volumetric study of sphenoid sinuses: Anatomical analysis in helical computed tomography. Surg Radiol Anat 2017; 39(4): 367-74.

[32] Selcuk OT, Erol B, Renda L, *et al.* Do altitude and climate affect paranasal sinus volume? J Craniomaxillofac Surg 2015; 43(7): 1059-64.