

RESEARCH

Open Access



A comparative study of paranasal sinus and nasal cavity anatomic variations between the Polish and Turkish Cypriot Population with CBCT

Katarzyna Gruszka¹, Seçil Aksoy^{2*}, Ingrid Różyło-Kalinowska³, Melis Mısırlı Gülbeş⁴, Paweł Kalinowski⁵ and Kaan Orhan^{3,6,7}

Abstract

Background: Genetic and environmental factors especially climatic conditions are thought to influence the shape and size of the paranasal sinuses and anatomic variations may create both a diagnostic and therapeutic challenge. However, no study has been published about the climatic adaptation of the paranasal sinus region in different populations. This study aimed to compare the prevalence of anatomical variants in the paranasal sinus and nasal cavity using Cone-Beam Computed Tomography (CBCT) between Polish and Turkish Cypriot populations.

Methods: The material consisted of volumes acquired utilizing Galileos (Sirona, Germany) as well as Newtom 3G (QR Verona, Newtom, Italy) CBCT units. There were examined 356 Polish and 359 Turkish Cypriot patients in whom paranasal sinuses were included in the field of view. Paranasal sinus anatomic variations were assessed in both populations.

Results: In the Polish population, the most common anatomic variation was septum deviation followed by the Agger nasi cell and concha bullosa with a prevalence of 87.7%, 83.2%, and 54.8% respectively. For the Turkish Cypriot population, the most common anatomic variation was Agger nasi cell followed by concha bullosa and supraorbital ethmoid cells with a prevalence of 81.6%, 68%, and 57.8% respectively. Many anatomic variations were found to show substantial differences among both populations. Incidence rates of hyperpneumatization of the frontal sinus, septum pneumatization, supraorbital ethmoid cells, concha bullosa, uncinata bulla, and internal carotid artery protrusion into the sphenoid sinus were significantly higher in the Turkish Cypriot group, while the incidence of Haller cell, frontal sinus hypoplasia, maxillary sinus hypoplasia, ethmoidmaxillary sinus, sphenomaxillary plate, and septum deviation were significantly higher in Polish population.

Conclusion: According to the Köppen-Geiger world climatic map, the climate is warmer and drier in Turkish Cypriote populations than in the Polish population. These climatic differences influence the paranasal sinus variations between the Turkish Cypriot and Polish populations that must be taken into account by rhinologic surgeons especially when performing frontal and sphenoid sinus surgery.

Keywords: Sinonasal anatomy, Variations, Climate, CBCT

*Correspondence: secil.aksoy@neu.edu.tr

² Faculty of Dentistry, Department of Dentomaxillofacial Radiology, Near East University, 99138 Mersin 10, Turkey
Full list of author information is available at the end of the article

Background

The formation and development of the paranasal sinuses begin with the excavation of the air-filled cavity to the bone in the early weeks of gestation and



© The Author(s) 2022. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

reach their final size until adolescence. During the developmental process of the paranasal sinuses, anatomic variations may occur owing to the intramural and extramural migrations of the ethmoid air cells and overpneumatization of the sinuses as well as bulging of the neurovascular structures to the sinuses [1].

Genetic and environmental factors are thought to influence the occurrence of anatomic variations. The paranasal sinus anatomic variations study in identical and non-identical twins finds out that environmental factors are much more significant than genetic factors [2]. Although some anatomic variations such as nasal septum deviation and supreme nasal concha may exist already in the third trimester of the human fetuses, most of the anatomic variations occur due to trauma and/or chronic infections [3].

Some anatomic variations such as Haller cell, Agger nasi cell, concha bullosa, and nasal septum deviation may induce the obstruction in the drainage pathways of the maxillary and frontal sinuses and predispose the chronic rhinosinusitis. However, the relationship between the anatomic variations and chronic sinusitis remains controversial in the literature [4–9]. Paranasal sinus anatomic variations, even if they do not associate with rhinosinusitis, should also be evaluated to prevent the fatal and major complications secondary to sinus surgery. Moreover, identifying anatomical and morphological relationships is crucial for the surgeon when approaching the skull base to avoid the risk of iatrogenic injuries in these thinnest and most vulnerable structures [10].

Many imaging modalities including plain radiographs [11], computed tomography (CT) [4, 6, 8, 12–14], and cone-beam computed tomography (CBCT) [15–17] are used for the evaluation of the detailed anatomy, pathology, and variations of the paranasal sinuses. Although CT is established as the gold standard for diagnostic imaging of the paranasal sinuses, CBCT has advantages in terms of lower radiation dose, isotropic voxels, lower metallic artifacts, and lower cost than CT [18].

Paranasal sinuses and associated neurovascular structures are very important for otorhinolaryngologists and neurosurgeons however dentists are relatively neglecting this important area. Many studies about the paranasal sinus anatomic variations have been published in specific populations [4, 6, 8, 16] but few studies have focused on the ethnic differences [13, 14]. Previous investigations exploring the climatic and geographic changes of the nasal region have largely concentrated on the nasal morphology, size, and shape of the nasal aperture and internal nasal valve. This study aimed to assess and compare the prevalence of paranasal sinus anatomic variations, and the effect of geography and climate on paranasal

sinus anatomic variety, using CBCT in Turkish Cypriot and Polish populations.

Methods

This retrospective study comprised 356 Polish and 359 Turkish Cypriot patients' CBCT images which included the paranasal sinus region. Patients with evidence of bone disease, relevant drug consumption, skeletal asymmetries or trauma, congenital disorders, anamnesis of surgical procedures, and pathological disorders of the maxilla as well as syndromic patients were excluded from the study.

The study protocol was carried out according to the principles described in the Declaration of Helsinki, including all amendments and revisions. Only the investigators had access to the collected data. The institutional ethical review board of the faculty reviewed and approved informed consent forms and the study (IRB No: YDU/25–147). There was no preference for gender regarding sample choice; however, only high-quality scans were included. Low-quality images, such as those containing scattering or insufficient accuracy of bony borders, were also excluded.

Imaging using CBCT

For the Polish population, all CBCT images were taken by Galileos (Sirona, Germany) unit at 85 kVp and 14 mA with 0.3 mm slice thickness using a large field of view (FOV) (15 cm in diameter) and by Newtom 3G (QR Verona, Newtom, Italy) at 120 kVp and 3–5 mA using a 12 or 9-inch FOV with 0.4 mm slice thickness for Turkish Cypriot population. While the Polish group consisted of 135 males and 221 females with an age range of 6 to 89 years (mean 38.4 years), the Turkish Cypriot group included 170 males and 189 females with an age range of 6 to 89 years (mean 40.2 years). Axial, sagittal, and coronal images were reconstructed and assessed for paranasal sinus variations. All CBCT images were evaluated by two dentomaxillofacial radiologists (SA and KG) for the presence of the paranasal sinus variations listed in Table 1. An additional evaluation was held by the other two observers (IRK and KO) in which no consensus was reached. The results were analyzed through the Statistica for Windows software. Chi² test was used and the level of significance was $p < 0.05$.

Results

The prevalence of the anatomic variations in Polish and Turkish Cypriot Populations is shown in Table 2. In the Polish population, the most common anatomic variation was septum deviation (Fig. 1) followed by the Agger nasi cell (Fig. 2) and concha bullosa (Fig. 3) with a prevalence of 87.7%, 83.2%, and 54.8% respectively. For the Turkish Cypriot population, the most common anatomic

Table 1 Definitions of the paranasal sinus anatomic variations

Variations of the paranasal sinus	Definition
Frontal sinus hyperpneumatization	significant extension to the orbital plate and squamous part of the frontal bone
Frontal sinus hypoplasia	Sinus is devoid of pneumatization more than 6 mm in anteroposterior direction with not much extension to the squamous part of the frontal bone
Interfrontal sinus septa cells	pneumatization of the frontal sinus septum
Agger nasi cells	the most anterior ethmoid cells extramural migration to the frontal process of the maxilla
Supraorbital ethmoid cells	anterior ethmoid cells extending to the roof of the orbit and located behind the posterior wall of the frontal sinus
Crista galli pneumatization	air cavity in crista galli most commonly coming from the frontal sinus
Inferior concha bullosa	air filled cavity in the inferior turbinate
Haller cell	posterior ethmoid cells extramural migration to the floor of the orbit and roof of the maxillary sinus near ostium
Concha bullosa	air filled cavity of the middle turbinate
Uncinate bulla	pneumatization of the uncinat process
Secondary middle turbinate	accessory middle concha
Maxillary sinus hypoplasia	when the maximum horizontal or vertical diameter is less than half of the maximum orbital diameter.
Superior concha bullosa	air filled cavity in the superior turbinate
Secondary superior concha	accessory superior concha
Ethmomaxillary sinus	enlarged posterior ethmoid cells located over the maxillary sinus and draining into the superior meatus
Sphenomaxillary plate	bony plate lying between the maxillary and sphenoid sinus, triangular in shape
Septum deviation	developmental or acquired deviation in nasal septum
Septum pneumatization	pneumatization of the nasal septum
Internal carotid artery (ICA) bulging	projection of the ICA into the sphenoid sinus
Onodi cell	posterior ethmoid cell located in the anterosuperior portion of the sphenoid sinus and closely related to the optic nerve
Anterior clinoid pneumatization	air filled cavity in the anterior clinoid process
Posterior clinoid pneumatization	air filled cavity of the posterior clinoid process
Pterygoid pneumatization	extensive pneumatization of the sphenoid sinus which passes over the line between the foramen rotundum and Vidian canal

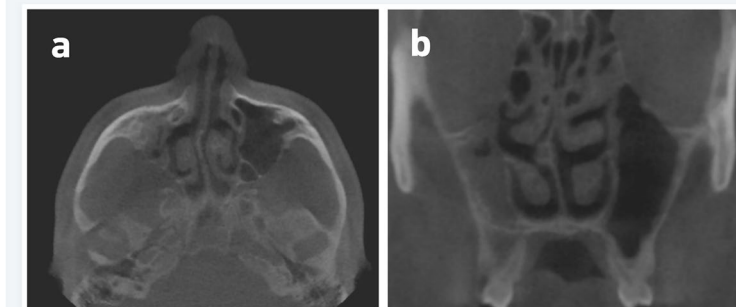


Fig. 1 CBCT images of the nasal cavity and paranasal sinuses. Axial (a) and coronal (b) planes showing right side nasal septum deviation with septal spur (b) and maxillary sinus hypoplasia on the right side

variation was Agger nasi cell followed by concha bullosa and supraorbital ethmoid cells (Fig. 4) with a prevalence of 81.6%, 68%, and 57.8% respectively (Table 2).

Many anatomic variations were found to show substantial differences among both populations. Incidence rates of hyperpneumatization, septum pneumatization, supraorbital ethmoid cells, concha bullosa, uncinat

bulla, and internal carotid artery bulging (Fig. 5) in the sphenoid sinus were significantly higher in the Turkish Cypriot group, while the incidence of Haller cell (Fig. 6), frontal sinus hypoplasia, maxillary sinus hypoplasia (Fig. 1), ethmomaxillary sinus (Fig. 7), sphenomaxillary plate, and septum deviation were significantly higher in Polish population ($p < 0.05$). No statistically significant

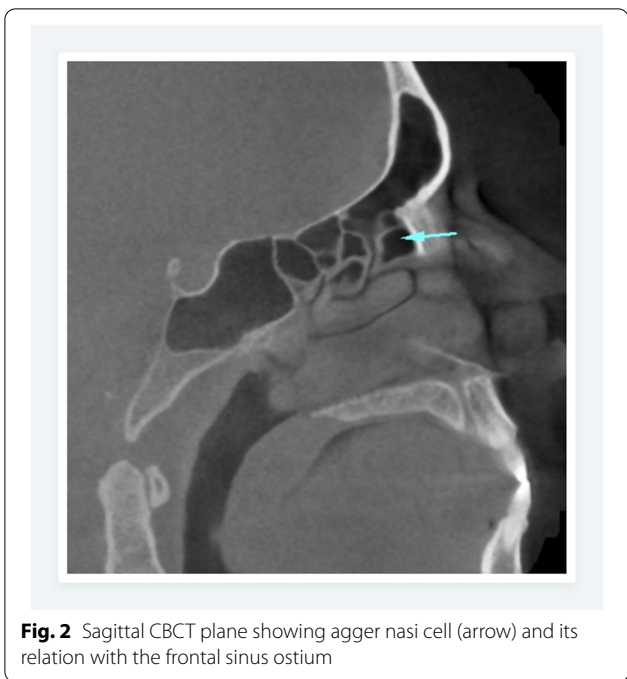


Fig. 2 Sagittal CBCT plane showing agger nasi cell (arrow) and its relation with the frontal sinus ostium



Fig. 4 Coronal CBCT scan of the left supraorbital ethmoid cell

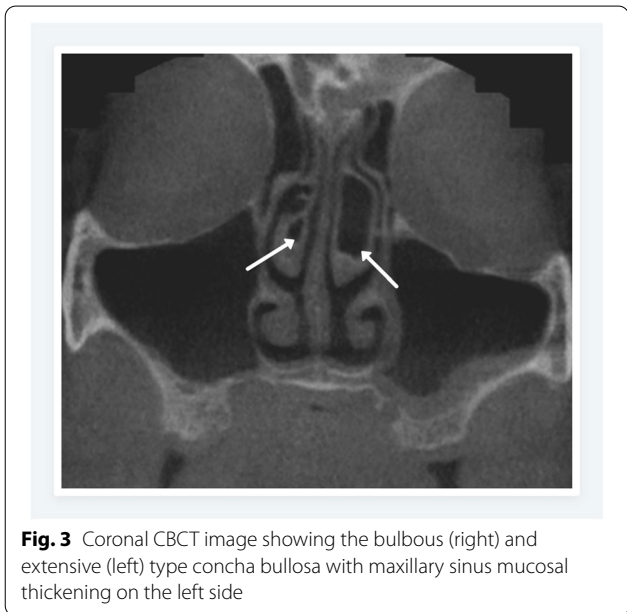


Fig. 3 Coronal CBCT image showing the bulbous (right) and extensive (left) type concha bullosa with maxillary sinus mucosal thickening on the left side

differences were observed for other anatomic variations among the two groups ($p > 0.05$).

Minor changes occurred when the female (Table 3) and male patients (Table 4) were analyzed separately within the groups. While Haller cell and maxillary sinus hypoplasia did not significantly differ among the male patients, nasal septum pneumatization, Haller cell and internal carotid artery bulging into the sphenoid sinus

did not significantly differ between the populations for female patients.

Discussion

Profound knowledge of anatomy, surgical landmarks, and anatomic variations of the paranasal region is the key issue and prerequisite for an effective and successful functional endoscopic sinus surgery (FESS). Determine and describing the precise anatomy, anatomical variations and pathology mostly depend on the advanced imaging methods as well as the experience and skills of the practitioner [12–15]. Previous studies focused on the assessment of anatomic-radiological risk profiles which concluded as the measurements as well as detailed evaluations can help identify those patients who are at high risk for injury [10].

The results of the previous studies indicated that climatic variables such as temperature and humidity predominantly influence the mid-facial anatomy, external nasal morphology, nasal aperture, and turbinate anatomy [19, 20]. However, the influence of climatic variables on paranasal regions was not taken into consideration in these earlier studies.

According to Köppen-Geiger world climatic map, the climate of our research areas is of the Dfb type (no dry season, generally cold winter, warm and humid summer) for the Polish population and Csa type (temperature, dry

Table 2 Comparison of the anatomic variations in Polish and Turkish Cypriot populations

Variations	Polish Population			Turkish Cypriot Population			P value
Frontal sinus hyperpneumatization	4.5%*			22.9%*			< 0,05
Frontal sinus hypoplasia	16.7%*			7.6%*			< 0,05
Interfrontal sinus septa cell	44.1%			41.8%			>0,05
Crista galli pneumatization	4.2%			4%			>0,05
Septum pneumatization	44.1%*			54%*			< 0,05
	Right	Left	Both	Right	Left	Both	
Agger nasi cell	16%	12.1%	55.1%	14.5%	13.1%	54.1%	>0,05
Supraorbital ethmoid cell	3.1%*	3.9%*	25.4%*	7.9%*	12.2%*	37.7%*	< 0,05
Inferior concha bullosa	0.8%	0.8%	1.4%	0.8%	1.4%	-	>0,05
Concha bullosa	11%	12.1%	31.7%*	14.5%	12.8%	40.7%*	< 0,05
Superior concha bullosa	9.6%	8.7%	19.7%	8.8%	13%	18.1%	>0,05
Haller cell	8.4%	8.4%	23.9%*	9.2%	11.2%	15.6%*	< 0,05
Uncinate bulla	3.7%*	2%*	20.5%	11.7%*	7.1%*	23.1%	< 0,05
Secondary middle turbinate	-	-	-	0.9%	-	0.3%	>0,05
Maxillary sinus hypoplasia	4.5%	5.1%*	2.8%	3.9%	0.8%*	2%	< 0,05
Secondary superior concha	-	-	0.6%	0.6%	0.3%	0.6%	>0,05
Ethmomaxillary sinus	13.8%*	6.7%	20.2%*	4.8%*	6.8%	9.1%*	< 0,05
Sphenomaxillary plate	1.4%*	7.3%	27%*	4.5%*	8.2%	8.2%*	< 0,05
Septum deviation	44.4%*	43.3%*	-	20.9%*	26.2*	0.8%	< 0,05
Internal carotid artery bulging	2.3%*	4.8%*	23.9%	7.3%*	7.5%*	28.2%	< 0,05
Onodi cell	18.6%	8.2%	10.4%	12.7%	14.1%	11.9%	>0,05
Anterior clinoid pneumatization	3.4%	4.5%	4.8%	4.2%	3.1%	6.5%	>0,05
Posterior clinoid pneumatization	2.5%	2.3%	4.5%	2.3%	1.7%	5.1%	>0,05
Pterygoid plates pneumatization	6.7%	13.2%	32.6%	9.2%	12%	30.2%	>0,05

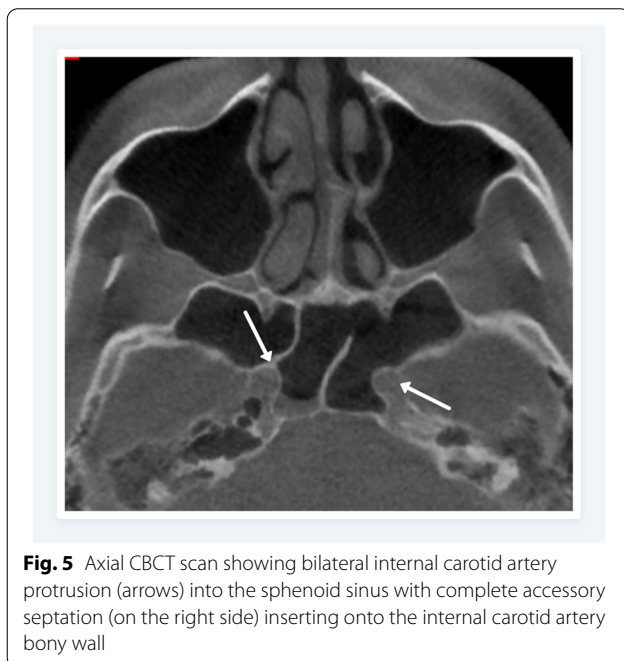


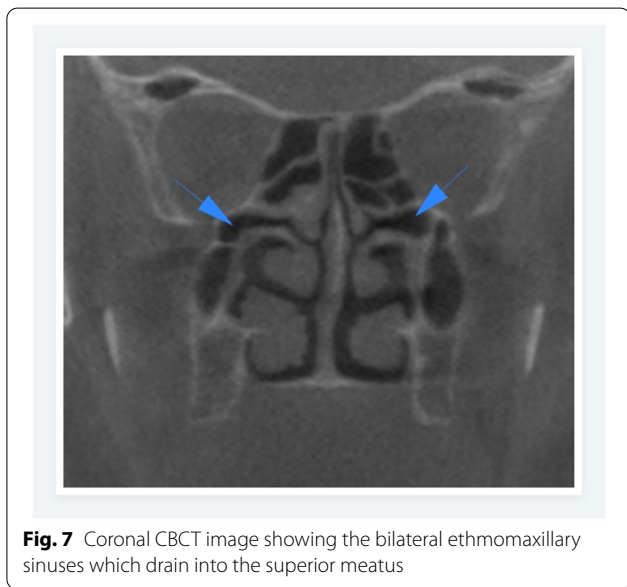
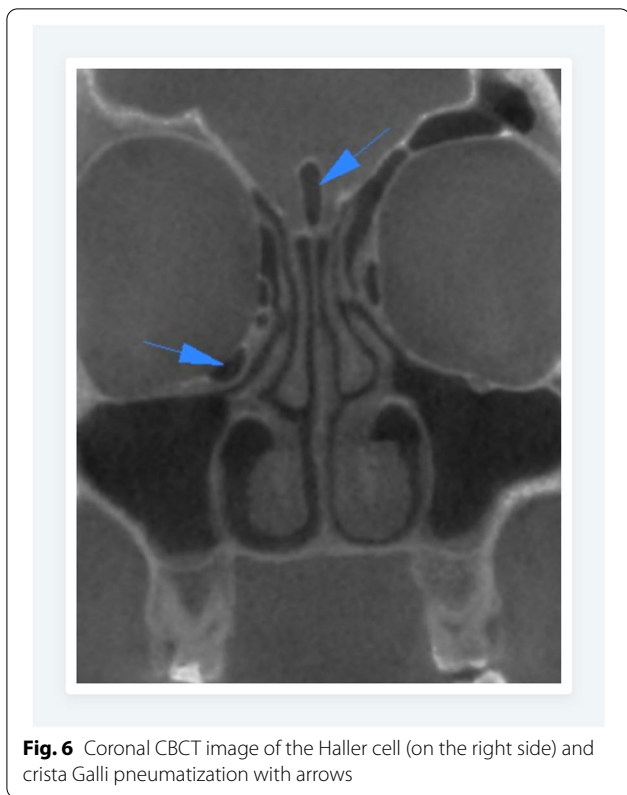
Fig. 5 Axial CBCT scan showing bilateral internal carotid artery protrusion (arrows) into the sphenoid sinus with complete accessory septation (on the right side) inserting onto the internal carotid artery bony wall

and hot summer, cool and rainy winters) for Turkish Cypriot population [21].

Noback et al. [20] found a significant correlation between nasal cavity shape and climatic variables of both temperature and humidity. Variation in nasal cavity shape is correlated with a cline from cold–dry climates to hot–humid climates, with a separate temperature and vapor pressure effect. The bony nasal cavity appears mostly associated with temperature and the nasopharynx with humidity. Similarly in our study, in the Turkish Cypriot population who lives in high temperatures with humidity, the hyperpneumatization, septum pneumatization, and ethmoids variations are more frequent than in the Polish population. This may be due to climate-related variations and a higher surface-to-volume ratio in the nasal cavity.

Hubbe et al. [22] reported significant correlations between nasal cavity measurements and temperature variables and humidity measures. Our findings indicate in line with Huber's study that both nasal cavities together with bone/mucosa interference and sphenoid sinus anatomy might be more strongly responding to climate, possibly vapor pressure.

In this study, it was found a high incidence of Haller cell, frontal sinus hypoplasia, maxillary sinus



hypoplasia, ethmoidmaxillary sinus, and septum deviation in the Polish population. It can be interpreted as the nasal cavity shape which follows climatic trends of the increased difficulty of air-conditioning: from hot-humid to cold-dry. The shape of the paranasal anatomy

might also be related to temperature and humidity which is again in line with Hubbe’s study [22].

It should be stated that based on the results of this study, that dry and cold climates would be the most difficult to condition air, thus nasal cavity shape would follow similar adaptive trends as in the Polish population such as frontal sinus hypoplasia, maxillary sinus hypoplasia, and septum deviation. This results in contracts with Hubbe’s study [22] as in their study multiple regression analysis showed that cold climates are related to higher nasal cavities with high nasal apertures and choanae. This difference can be related to that in our study which we evaluated not just the ethmoid cavity but the frontal and maxillary sinus region as well. It can be also interpreted as nasal cavity morphology might show an increase in air-wall contact with increasing difficulty of air-conditioning in physiologically more demanding environments.

Franciscus et al. [23] found in their study that a narrower superior ethmoidal breadth in supra-Saharan populations compared with sub-Saharan Bantu groups due to temperature changes. In our study, we found hypoplasia both in the Frontal and maxillary sinus which may increase the surface/volume ratio of the circulating air. The shape, however, also increases the surface/volume ratio which is an unexpected feature in climates where air-conditioning is relatively easier. [24].

Previous studies have also concentrated on the prevalence of paranasal sinus variations and their possible influence on chronic sinusitis in specific populations. There was a limited number of studies focused on the temperature and humidity effect on the paranasal sinus area in the literature. Selçuk et al. [25] studied the maxillary, frontal and sphenoid sinus volumes as well as the frontal sinus hypoplasia, nasal septum deviation, and concha bullosa in different climate and altitude conditions, and reported no significant differences which may be attributed to the small number of patients in both groups. On the contrary Asirdizer et al. [26] stated that frontal sinus widths, anteroposterior lengths, and volume were significantly higher in the cold climate group. In another study including fully intact 41 Melanesian crania, Robinson et al. [27] evaluated the paranasal sinus variations and compare their results with the literature. Agger nasi cell was the most commonly observed anatomic variant followed by the concha bullosa and Haller cell with a prevalence of 48.8%, 30%, and 29.3% respectively. Compared with the other researchers, Agger nasi cells were found to be less common in Melanesians than Caucasoids and Mongolian. On the other hand, the carotid artery bulging into the sphenoid sinus was relatively low in Melanesians while Mongoloid have a higher incidence [27].

Table 3 Comparison of the anatomic variations in female patients

Variations	Polish /female			Turkish Cypriot/female			P value
Frontal sinus hyperpneumatization	5.45%			18.37%*			< 0,05
Frontal sinus hypoplasia	16.78%*			9.09%*			< 0,05
Interfrontal sinus septa cell	53.85%			62.16%			>0,05
Crista galli pneumatization	4.09%			4.71%			>0,05
Septum pneumatization	44.8%			53.97%			>0,05
	Right	Left	Both	Right	Left	Both	
Agger nasi cell	15.84%	12.22%	56.56%	16.56%	14.01%	52.23%	>0,05
Supraorbital ethmoid cell	3.18%*	3.64%*	25.45%	9.09%*	11.69%*	32.47%	< 0,05
Inferior concha bullosa	1.36%	0.9%	2.26%	0.53%	1.06%	-	>0,05
Concha bullosa	11.76%	14.48%	32.13%*	13.23%	12.7%	43.92%*	< 0,05
Superior concha bullosa	10.86%	9.05%	22.17%	8.7%	14.13%	16.3%	>0,05
Haller cell	9.5%	7.24%	25.79%	7.94%	9.52%	17.46%	>0,05
Uncinate bulla	3.62%*	1.81%*	18.1%*	13.1%*	7.65%*	25.14%*	< 0,05
Secondary middle turbinate	-	-	-	1.08%	-	0.54%	>0,05
Maxillary sinus hypoplasia	4.52%	5.43%*	1.81%	3.21%	0.53%*	2.14%	< 0,05
Secondary superior concha	-	-	0.45%	1.11%	0.56%	-	>0,05
Ethmomaxillary sinus	16.29%*	5.88%	20.81%*	4.89%*	5.98%	9.78%*	< 0,05
Sphenomaxillary plate	2.26%	8.14%	30.32%*	4.32%	9.19%	12.97%*	< 0,05
Septum deviation	47.06%*	40.27%*	-	19.58%*	24.87%*	1.06%	< 0,05
Internal carotid artery bulging	2.26%	4.98%	20.81%	5.85%	6.91%	23.94%	>0,05
Onodi cell	19.09%	8.64%	10%	13.44%	12.37%	10.22%	>0,05
Anterior clinoid pneumatization	2.27%	5%	3.64%	5.85%	2.66%	3.72%	>0,05
Posterior clinoid pneumatization	2.73%	2.73%	2.27%	1.6%	1.06%	3.72%	>0,05
Pterygoid plates pneumatization	6.33%	14.48%	33.94%	7.45%	11.7%	30.32%	>0,05

Agger nasi cell was frequently encountered anatomic variations in both populations. Agger nasi cells are the most anterior ethmoid cells that locate anterolateral and inferior to the frontal recess. The drainage pathways of the frontal sinus are characterized by the occurrence of these cells [28, 29]. Although it is thought to be a predisposing factor for frontal sinus pathology, previous studies revealed no statistically significant correlation [4, 6, 8]. However, Sivashi et al. [8] reported a negative correlation between the occurrence of Agger nasi cells and maxillary sinusitis and proposed these cells to be a protective barrier for maxillary sinus from descending secretion. The presence of the Agger nasi cell may also adversely affect the FESS outcomes and insufficient removal of these cells is one of the factors predicting the need for revision endoscopic sinus surgery [30, 31].

Nasal septum deviation, which normally divides the nasal cavity into nearly two equal compartments, is defined as the deviation of the bony or cartilaginous parts of the septum to right or/and left sides. The previously reported prevalence of septum deviation vary from 18 to 75.9% [4, 6, 9, 12, 17, 32]. The Polish population presented a statistically significant higher prevalence of septum deviation (87.7%) compared with the Turkish

Cypriots (47.9%). Kucybała et al. [33] in 2017 reported a higher prevalence of nasal septum deviation (79.9%) in the Polish population which is very similar to our study. In another study performed by Teul et al. [34], the incidence of nasal septum deformations has been reported to be 43% in examined Polish children and adolescents. In the literature unilateral hypertrophy/extensive pneumatization of the middle turbinate has been hypothesized to play a significant role in causing contralateral nasal septal deviation [9, 32, 33]. However, studies were opposing this relationship which may be due to some of the pneumatization sizes in the middle concha being too small to cause a septum deviation, especially in the lamellar type [17, 35].

Frontal cells are an object of interest to many researchers. One of the most interesting findings of this study is that supraorbital ethmoid cells have racial differences and Turkish Cypriots have a significantly higher incidence of unilateral and bilateral supraorbital ethmoid cells. Similarly, Cho et al. [14] reported the prevalence of supraorbital ethmoid cells has racial distribution differences and its prevalence was significantly higher in the Caucasians than in the Korean population. In another study, Badia et al. [13] found ethnic differences in the prevalence of

Table 4 Comparison of the anatomic variations in male patients

Variations	Polish /male			Turkish Cypriot/male			P value
Frontal sinus hyperpneumatization	2.96%*			28.33%*			< 0,05
Frontal sinus hypoplasia	16.67%*			5.19%*			< 0,05
Interfrontal sinus septa cell	40.74%			46.67%			>0,05
Crista galli pneumatization	4.44%			3.27%			>0,05
Septum pneumatization	42.96%*			54.12%*			< 0,05
	Right	Left	Both	Right	Left	Both	
Agger nasi cell	16.3%	11.85%	52.59%	11.9%	11.9%	56.35%	>0,05
Supraorbital ethmoid cell	2.96%*	4.44%*	25.19%*	6.4%*	12.8%*	46.4%*	< 0,05
Inferior concha bullosa	-	0.74	-	1.18%	1.76%	-	>0,05
Concha bullosa	9.63%*	8.15%*	31.11%	15.88%*	13.53%*	37.06%	< 0,05
Superior concha bullosa	7.41%	8.15%	15.56%	8.88%	11.83%	20.12%	>0,05
Haller cell	6.67%	10.37%	20.74%	10.65%	13.02%	13.61%	>0,05
Uncinate bulla	3.7%*	2.22%*	24.44%	10.12%*	6.55%*	20.83%	< 0,05
Secondary middle turbinate	-	-	-	0.59%	-	-	>0,05
Maxillary sinus hypoplasia	4.44%	4.44%	4.44%	4.73%	1.18%	1.78%	>0,05
Secondary superior concha	-	-	0.74%	-	-	1.19%	>0,05
Ethmomaxillary sinus	9.63%*	8.15%	19.26%*	4.73%*	7.69%	8.28%*	< 0,05
Sphenomaxillary plate	-*	5.93%	21.48%*	4.73%*	7.1%	2.96%*	< 0,05
Septum deviation	40%*	48.15%*	-	22.35%*	27.65%*	0.59%	< 0,05
Internal carotid artery bulging	2.22%*	4.44%*	28.89%	8.82%*	8.24%*	32.94%	< 0,05
Onodi cell	17.78%	7.41%	11.11%	11.9%	16.07%	13.69%	>0,05
Anterior clinoid pneumatization	5.19%	3.7%	6.67%	2.38%	3.57%	9.52%	>0,05
Posterior clinoid pneumatization	2.22%	1.48%	8.15%	2.96%	2.38%	6.55%	>0,05
Pterygoid plates pneumatization	7.41%	11.11%	30.37%	11.18%	12.35%	30%	>0,05

the paranasal sinus variation between the Caucasian and Chinese populations. While concha bullosa, paradoxical bending of the middle turbinate, Haller cell, and suprabulbar cell were significantly higher in the London population, bent uncinated process and Onodi cell were greater in the Chinese population [13].

Many vital and critical structures surround the sphenoid sinus including the cavernous sinus, carotid arteries, optic nerve, maxillary nerve, and vidian nerve. Depending on the sphenoid sinus pneumatization type the arteries and nerves may protrude into the sinus [36]. One of the most important anatomic variations determined in this study was internal carotid artery (ICA) protrusion into the sphenoid sinus. The prevalence of the ICA protrusion varies between 8 and 41% in the previous studies [7, 12, 16, 37, 38]. The frequency of unilateral ICA protrusion in the sphenoid sinus was significantly higher in male Turkish Cypriotes, whereas there were no significant differences in female patients. Surgical risk is amplified in ICA protrusion, dehiscence of the bony canal surrounding the ICA, and presence of the septum that is inserted to the ICA prominence. Anatomic variations present significant surgical challenges and FESS or transsphenoidal approach to hypophyseal fossa might be

technically difficult to perform in the presence of these variations. Intraoperative injury to ICA, hemorrhage and visual loss are the serious and less common complications of the FESS however some of them may be life-threatening.

The limitation of this study is the radiographic nature of the study that did not include any clinical symptoms and outcomes and did not evaluate the soft tissue. Although the present study was performed on Turkish Cypriote and Polish populations which are classified as Caucasian there could be genetic variations among these populations. Moreover, it would be appropriate to include the results of the similar nasal cavity and maxillary sinus variation studies conducted in different climatic regions including the Turkish and Polish populations. Further studies will be conducted to consider paranasal sinus anatomic variations in the same races with different climatic conditions.

Conclusion

Paranasal sinus variations showed climate differences between the Turkish Cypriot and Polish populations that must be taken into account by rhinologic surgeons

especially when performing frontal and sphenoid sinus surgery.

Acknowledgements

Not applicable.

Authors' contributions

K Gruszka: contributed to data acquisition and interpretation. S Aksoy: contributed to data acquisition, design, interpretation, and writing of the manuscript. I Różyło-Kalinowska: contributed to study design, data acquisition, interpretation, and revision of the manuscript. M Misirli Gulbes: contributed to the writing of the manuscript. P Kalinowski: contributed to statistical analysis of the manuscript. K Orhan: contributed to study design, data acquisition, interpretation, and revision of the manuscript. All authors read and approved the final manuscript.

Funding

None.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The research protocol has the ethical approval from the local Institutional Review Board (with registration no: YDU/25–147).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

¹Private Clinic, Frampol, Poland. ²Faculty of Dentistry, Department of Dentomaxillofacial Radiology, Near East University, 99138 Mersin 10, Turkey. ³Department of Dental and Maxillofacial Radiodiagnosics, Medical University of Lublin, 20-093 Lublin, Poland. ⁴Department of Dentomaxillofacial Radiology, International Final University, 99138 Mersin 10, Turkey. ⁵Department of Hygiene and Epidemiology, Medical University of Lublin, 20-093 Lublin, Poland. ⁶Faculty of Dentistry, Department of Dentomaxillofacial Radiology, Ankara University, 06100 Ankara, Turkey. ⁷Medical Design Application and Research Center (MEDITAM), Ankara University, 06100 Ankara, Turkey.

Received: 26 April 2022 Accepted: 1 November 2022

Published online: 26 November 2022

References

- Zinreich SJ, Albayram S, Benson ML, Oliverio PJ. Sinonasal cavities. In: Som PM, Curtin HD, editors. *Head and neck imaging*. St. Louis: Mosby Elsevier; 2002. pp. 3–175.
- Chaiyasate S, Baron I, Clement P. Analysis of paranasal sinus development and anatomical variations: a CT genetic study in twins. *Clin Otolaryngol*. 2007;32(2):93–7.
- Yilmaz NA, Cicekcibasi AE, Emlik D, Yilmaz MT, Keles B, Salbacak A. Morphometric analyses of the development of nasal cavity in human fetuses: an anatomical and radiological study. *Int J Pediatr Otorhinolaryngol*. 2010;74(7):796–802.
- Al-Qudah M. The relationship between anatomical variations of the sino-nasal region and chronic sinusitis extension in children. *Int J Pediatr Otorhinolaryngol*. 2008;72(6):817–21.
- Haruna S, Sawada K, Nakajima T, Moriyama H. Relationship between pediatric sinusitis and middle turbinate pneumatization—ethmoidal sinus pycocle thought to be caused by middle turbinate pneumatization. *Int J Pediatr Otorhinolaryngol*. 2005;69(3):375–9.
- Kim HJ, Jung Cho M, Lee JW, Tae Kim Y, Kahng H, Sung Kim H, et al. The relationship between anatomic variations of paranasal sinuses and chronic sinusitis in children. *Acta Otolaryngol*. 2006;126(10):1067–72.
- Nitinavakarn B, Thanaviratnanich S, Sangsilp N. Anatomical variations of the lateral nasal wall and paranasal sinuses: A CT study for endoscopic sinus surgery (ESS) in Thai patients. *J Med Assoc Thai*. 2005;88(6):763–8.
- Sivasli E, Sirikçi A, Bayazit YA, Gümüşburun E, Erbagci H, Bayram M, et al. Anatomic variations of the paranasal sinus area in pediatric patients with chronic sinusitis. *Surg Radiol Anat*. 2003;24(6):400–5.
- Stallman JS, Lobo JN, Som PM. The incidence of concha bullosa and its relationship to nasal septal deviation and paranasal sinus disease. *AJNR Am J Neuroradiol*. 2004;25(9):1613–8.
- Fadda GL, Petrelli A, Martino F, Succo G, Castelnuovo P, Bignami M, et al. Anatomic Variations of Ethmoid Roof and Risk of Skull Base Injury in Endoscopic Sinus Surgery: Statistical Correlations. *Am J Rhinol Allergy*. 2021;35(6):871–8.
- Ahmad M, Khurana N, Jaber J, Sampair C, Kuba RK. Prevalence of infra-orbital ethmoid (Haller's) cells on panoramic radiographs. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2006;101(5):658–61.
- Arslan H, Aydinlioğlu A, Bozkurt M, Egeli E. Anatomical variations of the paranasal sinuses: CT examination for endoscopic sinus surgery. *Auris Nasus Larynx*. 1999;26(1):39–48.
- Badia L, Lund VJ, Wei W, Ho WK. Ethnic variation in sinonasal anatomy on CT scanning. *Rhinology*. 2005;43(3):210–4.
- Cho JH, Citardi MJ, Lee WT, Sautter NB, Lee HM, Yoon JH, et al. Comparison of frontal pneumatization patterns between Koreans and Caucasians. *Otolaryngol Head Neck Surg*. 2006;135(5):780–6.
- Orhan K, Aksoy S, Oz U. CBCT imaging of paranasal sinuses and variations. In: Gendeh BS, editor. *Paranasal sinuses*. London: InTech; 2017. pp. 57–77.
- Güldner C, Pistorius SM, Diogo I, Bien S, Sesterhenn A, Werner JA. Analysis of pneumatization and neurovascular structures of the sphenoid sinus using cone-beam tomography (CBT). *Acta Radiol*. 2012;53(2):214–9.
- Smith KD, Edwards PC, Saini TS, Norton NS. The prevalence of concha bullosa and nasal septal deviation and their relationship to maxillary sinusitis by volumetric tomography. *Int J Dent*. 2010;2010:404982. doi:<https://doi.org/10.1155/2010/404982>.
- Hodez C, Griffaton-Taillandier C, Bensimon I. Cone-beam imaging: applications in ENT. *Eur Ann Otorhinolaryngol Head Neck Dis*. 2011;128(2):65–78.
- Evteev A, Cardini AL, Morozova I, O'Higgins P. Extreme climate, rather than population history, explains mid-facial morphology of Northern Asians. *Am J Phys Anthropol*. 2014;153(3):449–62.
- Noback ML, Harvati K, Spoor F. Climate-related variation of the human nasal cavity. *Am J Phys Anthropol*. 2011;145(4):599–614.
- Peel MC, Finlayson BL, McMahon TA. Updated world map of the Köppen-Geiger climate classification. *Hydrol Earth Syst Sci*. 2007;11:1633–44.
- Hubbe M, Hanihara T, Harvati K. Climate signatures in the morphological differentiation of worldwide modern human populations. *Anat Rec (Hoboken)*. 2009;292(11):1720–33.
- Franciscus RG. Comparing internal nasal fossa dimensions and classical measures of the external nasal skeleton in recent humans: inferences for respiratory airflow dynamics and climatic adaptation. *Am J Phys Anthropol*. 2003;36:96–7.
- Churchill SE, Shackelford LL, Georgi JN, Black MT. Morphological variation and airflow dynamics in the human nose. *Am J Hum Biol*. 2004;16(6):625–38.
- Selcuk OT, Erol B, Renda L, Osma U, Eyigor H, Gunsoy B, et al. Do altitude and climate affect paranasal sinus volume? *J Craniomaxillofac Surg*. 2015;43(7):1059–64.
- Asirdizer M, Tatlisumak E, Bora A, Tarhan S, Yilmaz Ovali G, Hekimoglu Y, et al. The Possible Effects of Altitude and Climate on the Development of the Frontal Sinus in Adults. *Int J Morphol*. 2017;35:571–7.
- Robinson M, Donlon D, Harrison H, Houang M, Stammberger H, Wolf G. Variations of the paranasal sinuses in Melanesians as observed by CT. *Rhinology*. 2010;48(1):11–7.
- Daniels DL, Mafee MF, Smith MM, Smith TL, Naidich TP, Brown WD, et al. The frontal sinus drainage pathway and related structures. *AJNR Am J Neuroradiol*. 2003;24(8):1618–27.
- 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.

30. Bradley DT, Kountakis SE. The role of agger nasi air cells in patients requiring revision endoscopic frontal sinus surgery. *Otolaryngol Head Neck Surg.* 2004;131(4):525–7.
31. Khalil HS, Eweiss AZ, Clifton N. Radiological findings in patients undergoing revision endoscopic sinus surgery: a retrospective case series study. *BMC Ear Nose Throat Disord.* 2011;11:4.
32. Aktas D, Kalcioğlu MT, Kutlu R, Özturan O, Oncel S. The relationship between the concha bullosa, nasal septal deviation, and sinusitis. *Rhinology.* 2003;41(2):103–6.
33. Kucybała I, Janik KA, Ciuk S, Storman D, Urbanik A. Nasal Septal Deviation and Concha Bullosa - Do They Have an Impact on Maxillary Sinus Volumes and Prevalence of Maxillary Sinusitis? *Pol J Radiol.* 2017;82:126–33.
34. Teul I, Zbislawski W, Baran S, Czerwinski F. Deformation of the nasal septum in children, adolescents, and adults in Western Pomerania province of Poland. *Eur J Med Res.* 2009;14(4):244–7.
35. Javadrashid R, Naderpour M, Asghari S, Fouladi DF, Ghojzadeh M. Concha bullosa, nasal septal deviation, and paranasal sinusitis; a computed tomographic evaluation. *B-ENT.* 2014;10(4):291–8.
36. Unal B, Bademci G, Bilgili YK, Batay F, Avci E. Risky anatomic variations of sphenoid sinus for surgery. *Surg Radiol Anat.* 2006;28(2):195–201.
37. 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.
38. Kantarci M, Karasen RM, Alper F, Onbas O, Okur A, Karaman A. Remarkable anatomic variations in paranasal sinus region and their clinical importance. *Eur J Radiol.* 2004;50(3):296–302.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Ready to submit your research? Choose BMC and benefit from:

- fast, convenient online submission
- thorough peer review by experienced researchers in your field
- rapid publication on acceptance
- support for research data, including large and complex data types
- gold Open Access which fosters wider collaboration and increased citations
- maximum visibility for your research: over 100M website views per year

At BMC, research is always in progress.

Learn more biomedcentral.com/submissions

