Original article

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Assessment of the prevalence of sphenoethmoidal cells in the Serbian population using computed tomography

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Sphenoethmoidal cells (SEC) are posteriorly located ethmoidal cells that surround the sphenoid sinus (SS) and are in close contact with adjacent neurovascular structures. They represent normal anatomical variations that can affect the course of transsphenoidal and endoscopic paranasal sinus surgery. Three types of SECs have been described in the literature: the Onodi cell (OC), the inferior sphenoethmoidal cell (ISEC), and the whole lateral SEC. The aim of this study was to examine the prevalence of SECs in the Serbian population and their association with SS pneumatization type. Our investigation randomly included a sample of 200 subjects. These were the patients who underwent computed tomography (CT) at the Radiology Centre of the University Clinical Centre Niš during 2021. The most prevalent SEC was OC, observed in 56 (28%) subjects on at least one side. Although no statistically significant association was found between OC and SS pneumatization, a higher frequency of OC cells was observed in more pronounced pneumatization types. Whole lateral SECs and ISECs are less frequent, with only one whole lateral and three ISECs recorded. In this work, we have shown the representation of SEC in the Serbian population, which does not differ significantly from that reported in other European studies.

Recognising SECs on CT images may help surgeons, before and during surgery, to reduce the percentage of complications these cells can contribute to.

Key words: sphenoid sinus, anatomic variation, computed tomography

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Procena prevalencije sfenoetmoidalnih ćelija u srpskoj populaciji primenom kompjuterizovane tomografije

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Sfenoetmoidalne ćelije (*enlg*. *sphenoethmoidal cells* - SEC) su posteriorno lokalizovane etmoidne ćelije koje okružuju sfenoidni sinus (SS) i nalaze se u neposrednom kontaktu sa susednim neurovaskularnim strukturama. Predstavljaju normalne anatomske varijacije koje mogu uticati na tok transsfenoidalnih i endoskopskih operacija paranazalnih sinusa. U literaturi su opisana tri tipa SEC: Onodi ćelija (OC), inferiorna sfenoetmoidalna ćelija (engl. *inferior sphenoethmoidal cell* - ISEC) i lateralna sfenoetmoidalna ćelija koja u potpunosti zahvata lateralni zid sfenoidnog sinusa. Cilj ove studije bio je da se ispita prevalencija SEC u srpskoj populaciji, kao i njihovu povezanost sa tipom pneumatizacije SS. Istraživanje je obuhvatilo slučajni uzorak od 200 ispitanika koji su tokom 2021. godine bili podvrgnuti kompjuterizovanoj tomografiji (engl. *computed tomography* - CT) u Centru za radiologiju Univerzitetskog kliničkog centra Niš. Najčešće prisutna SEC bila je OC, koja je registrovana kod 56 ispitanika (28%) bar sa jedne strane. Iako nije utvrđena statistički značajna povezanost između prisustva OC i tipa pneumatizacije SS, učestalost OC bila je veća kod izraženijih tipova pneumatizacije. Sfenoetmoidalna ćelija koja u potpunosti zahvata lateralni zid SS I ISEC bile su znatno ređe, pri čemu je zabeležen samo jedan

slučaj sfenoetmoidalne ćelije koja u potpunosti zahvata lateralni zid SS i tri slučaja ISEC. U ovom radu prikazana je zastupljenost SEC u srpskoj populaciji, koja se ne razlikuje značajno od podataka objavljenih u drugim evropskim studijama. Prepoznavanje SEC na CT snimcima može pomoći hirurzima, pre i tokom operacije, u smanjenju učestalosti komplikacija koje su povezane sa njihovim prisustvom.

Ključne reči: sfenoidni sinus, anatomska varijacija, kompjuterizovana tomografija

Introduction

During growth, the posterior ethmoidal cells may expand backwards into the sphenoid sinus (SS). Such cells are called sphenoethmoidal cells (SEC) (1). The sphenoid sinus may also extend anteriorly among the ethmoidal cells, creating the anterior recess (2). Sphenoethmoidal cells are a variation of posterior ethmoidal cells, with their frequency differing among ethnic and population groups (3–5).

During surgical procedures, such as functional endoscopic paranasal sinus surgery (FESS) or transsphenoidal approach to the pituitary gland and middle cranial fossa, the presence of SEC may contribute to the development of iatrogenic damage (1). Their size can exceed the SS itself, potentially leading to disorientation for the surgeon during surgery (1,2).

Due to inadequate drainage pathways, the sphenoethmoidal cells are prone to inflammatory processes (2). Their anatomical proximity to important neurovascular structures gives these changes special clinical significance (1,6).

For a long time, OC was described as the most significant representative of the SEC (3). The Onodi cell is a type of SEC that extends superolaterally to the SS and involves the bony canals of the optic nerve (ON) and their lumens. When OC occurs bilaterally and involves both optic nerve channels, it is called a Central OC (2). Other types of SEC have also been identified. Inferior sphenoethmoidal cell (ISEC), known also as Jingfeng cells, extend inferolaterally and cover the foramen rotundum with their volume (5). While the whole lateral SEC extends both superolaterally and inferolaterally, involving the optic nerve and foramen rotundum (4).

Most of the earlier research on SEC and the SS was based on anatomical, cadaveric studies. Today, thanks to the widespread use of computed tomography (CT), these structures can be analysed in detail in vivo. The advantage of CT is its precise representation of bony anatomy, while multiplanar reconstructions (MPR) significantly facilitate visualisation of the relationship between the SS and the SEC (1,2,7).

Significant variability in the representation of SEC is reported in the literature, which may depend on the characteristics of the studied population. Data on this anatomical variation in the Serbian population are limited.

Aim

The aim of this study was to examine the prevalence of sphenoethmoidal cells in the population

of southeastern Serbia and to analyse their association with the type of sphenoid sinus pneumatization.

Material and methods

In this retrospective study, 200 subjects who underwent CT at the Radiology Centre of the University Clinical Centre in Nis in 2021 were included. Subjects were randomly selected from the CT database. Inclusion criteria included subjects aged 18 or older who were referred for a CT examination due to various clinical indications. Exclusion criteria included previous surgical interventions in the region of the paranasal sinuses, the presence of inflammatory or neoplastic processes in the paranasal region, as well as a history of viscerocranial trauma.

All CT data included in this study were obtained at the Radiology Centre of the University Clinical Centre Niš using a 64 - multislice CT system (SOMATOM Definition AS, Siemens Healthineers, Erlangen, Germany). All examinations followed routine head CT protocols with a tube voltage of 120 kV. Image acquisition was performed in a helical mode, and datasets were reconstructed with a slice thickness of 1.0 mm. The reconstruction field of view ranged from 16 to 32 cm. Subsequent image evaluation was carried out on the syngo.via platform (Siemens Healthineers, Erlangen, Germany), employing a bone reconstruction algorithm and multiplanar reconstructions in the axial, coronal, and sagittal planes.

All images analysed in this study were anonymised in accordance with ethical standards. Ethical approval was obtained from the Ethics Committee of the University Clinical Centre Niš (Approval No. 4665/7).

Morphometric analysis

Morphometric analysis included a detailed evaluation of the presence and type of SEC, according to criteria described in previous CT-based studies. Sphenoethmoidal cells were defined as posterior ethmoidal cells pneumatized in relation to the SS.

The following types of SEC have been identified (Figure 1):

Onodi cell – SEC that extends superolaterally in relation to the SS and has a close relationship with the bony channel of the optic nerve (7). All OC were then classified based on their course of extension into OC with superior, lateral, or superolateral extension (Figure 2)

Central Onodi cell - bilateral expansion of the SEC with involvement of both optic canals (2)

Inferior sphenoethmoidal cell – SEC that extends inferolaterally in relation to the SS, with involvement of the foramen rotundum (5).

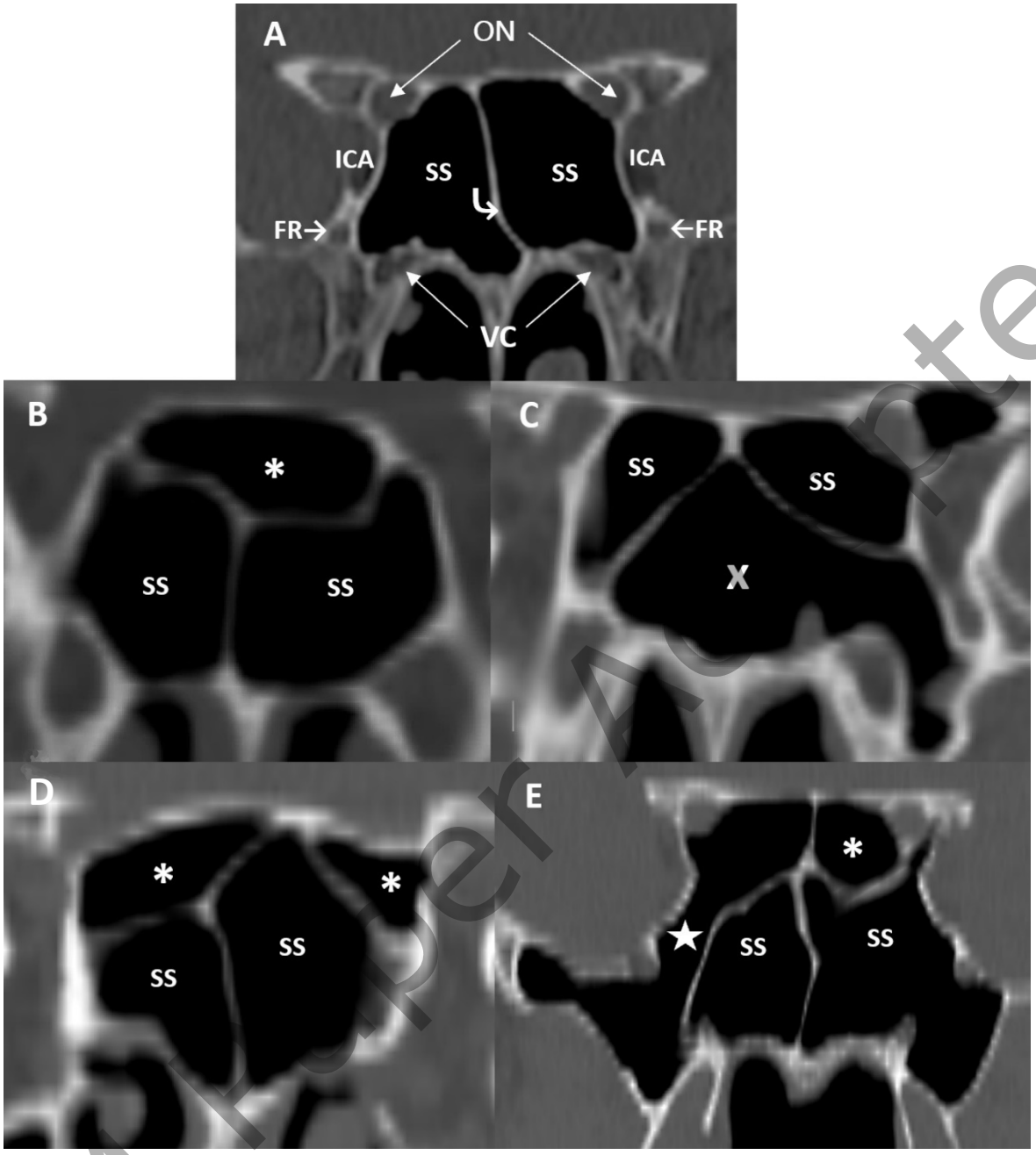

Figure 1. Types of sphenoethmoidal cells, evaluation on coronal CT images. A) Normal sphenoid sinus anatomy with symmetrically annotated right and left structures: SS – sphenoid sinus; ON – optic nerve; ICA – internal carotid artery; FR – foramen rotundum; VC – Vidian canal; ↳ – sphenoid sinus septa. B) Central Onodi cell with bilateral involvement of the optic canals. C) Inferior sphenoethmoidal cell on the left side (x). D) Bilateral Onodi cells (*). E) Whole lateral sphenoethmoidal cell (★) on the right side and an Onodi cell (*) on the left side.

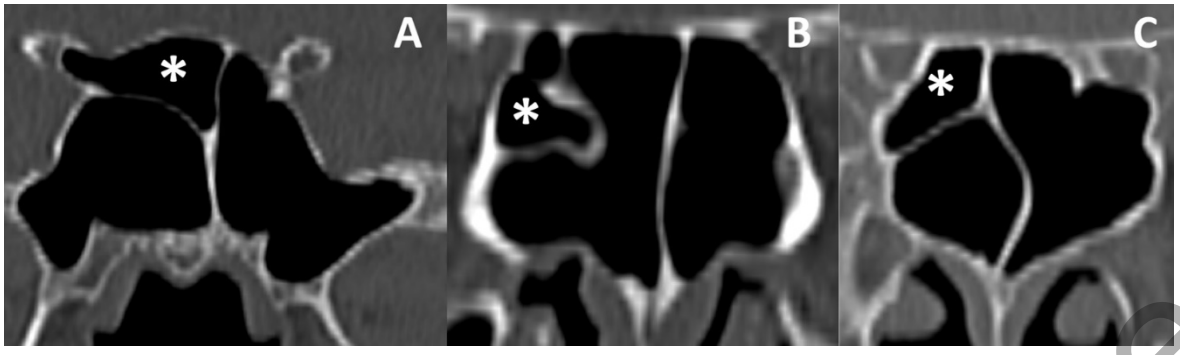

Figure 2. Direction of Onodi cell (*) extension in relation to the sphenoid sinus. A) Superior extension. B) Lateral extension. C) Superolateral extension.

Whole lateral sphenoethmoidal cell – a type of SEC that extends both superolaterally and inferolaterally in relation to the SS, involving the optic nerve and the foramen rotundum (4)

Then the type of SS was analysed, based on the relationship of pneumatization to the sella turcica (Figure 3) (8):

Conchal - characterised by minimal pneumatization, where the sinus cavity is more than 10 mm away from the front edge of the sella turcica, and there is a massive bony barrier between the sinus and the sella.

Presellar type - pneumatization of the SS that extends to the front edge of the sella turcica, where the posterior edge of the pneumatization is at a distance of less than 10 mm from the front edge of the sella turcica.

Sellar - pneumatization of the SS that extends below the sella turcica, where the posterior border of the sinus crosses the front edge of the sella and occupies the space below the pituitary fossa.

Postsellar type - represents the most pronounced form of pneumatization, in which the SS extends beyond the posterior edge of the sella turcica, often towards the dorsum sellae and the clivus.

All variables were analysed separately for the left and right sides of the SS to identify possible asymmetries.

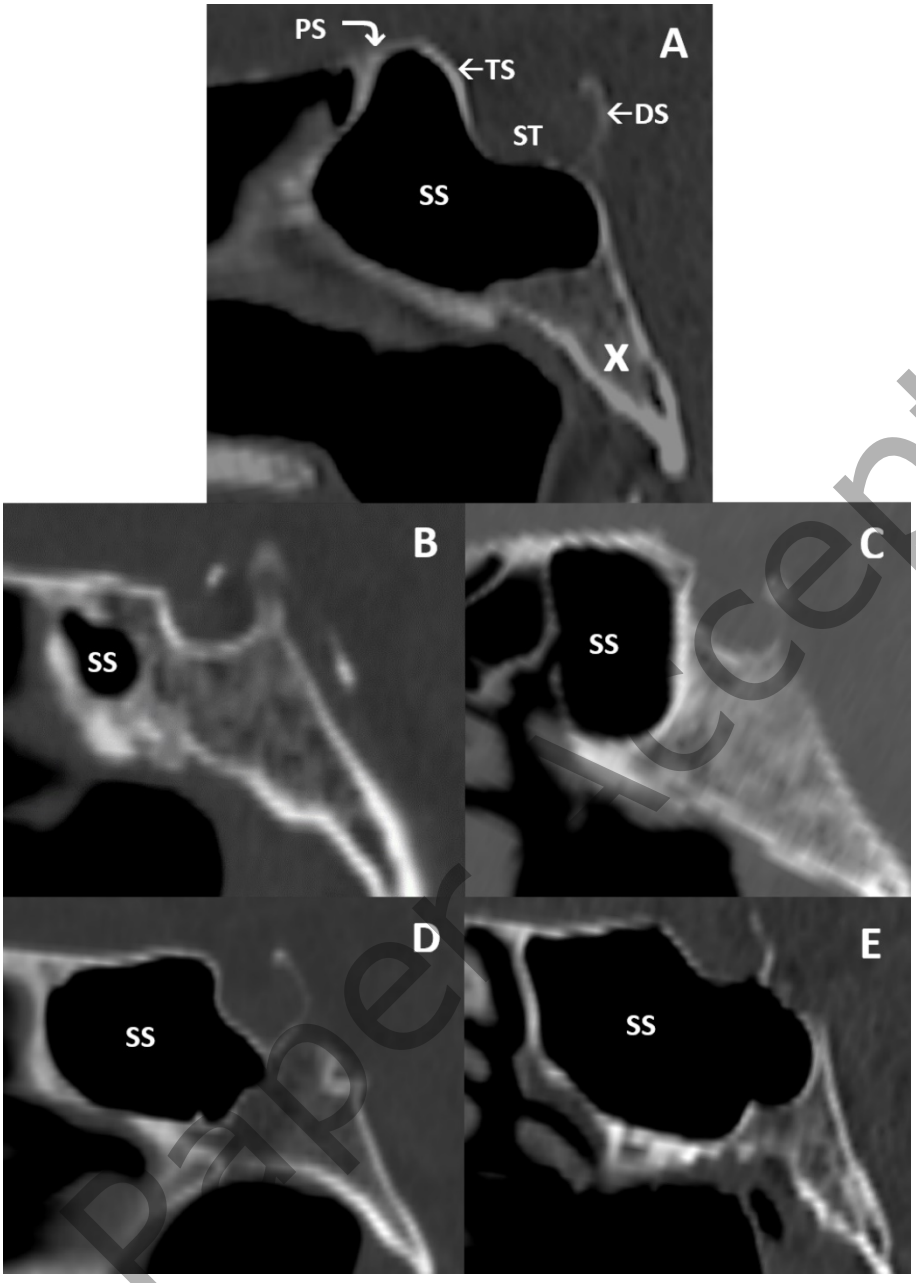

Figure 3. Types of sphenoid sinus pneumatization evaluated on sagittal CT images. A) Annotated normal sphenoid sinus anatomy: SS – sphenoid sinus; PS – planum sphenoidale; TS – tuberculum sellae; ST – sella turcica; DS – dorsum sellae; x – clivus. B) Conchal type. C) Presellar type. D) Sellar type. E) Postsellar type.

Statistical analysis

Data are presented as mean ± standard deviation and as absolute and relative frequencies. The χ^2 test was used to examine the association between OC and SS pneumatization. A linear-by-linear association test assessed the existence of a linear trend. McNemar's test analysed the

distribution of OCs between the left and right sides. The χ^2 test also evaluated the association between Onodi cells and sex. The Shapiro–Wilk test was used to check the normality of the age distribution. Due to deviation from normality in one group, the Mann–Whitney U test was used to compare age differences between subjects with and without OC. Statistical significance was set at $p < 0.05$.

Results

A total of 200 subjects were included in the retrospective study. Inferior sphenoethmoidal cells were identified in three subjects (1.5%), all exclusively on the left side, while the whole lateral type was registered in one subject (0.5%) on the right side. Due to the small number of cases, these variants were analysed descriptively (Table 1). The OC was present in 56 subjects (28.0%) on at least one side; bilaterally in 21 subjects, only on the left in 17 subjects, and only on the right in 18 subjects. McNemar's test did not reveal a statistically significant difference in the presence of OC between the left and right sides ($p = 1.000$) (Table 1).

Analysis of the association between the presence of OC and the type of SS pneumatization did not show a statistically significant difference in the distribution of individual pneumatization types ($\chi^2 = 5.73$; $p = 0.125$; Table 2). However, a statistically significant linear trend was observed, whereby the presence of OC was more frequent in more pronounced types of SS pneumatization ($p = 0.017$). The analysis carried out separately for the left side showed that the presence of OC was not statistically significantly related to the type of pneumatization of the left SS ($\chi^2 = 5.89$; $p = 0.117$; Table 2), but a statistically significant linear trend was registered with a higher frequency of OC in more pronounced types of pneumatization ($p = 0.018$). On the right side, there was also no statistically significant association between the presence of the OC and the type of pneumatization of the SS ($\chi^2 = 4.05$; $p = 0.399$; Table 2), but a statistically significant linear trend was noted, where the presence of the OC was more frequent in the postsellar type of pneumatization ($p = 0.046$).

Table 1. Prevalence of sphenoethmoidal cells according to side.

SEC		Present OC n = 200	Absent OC n =	p
OC	Right	38	162	1.000
	Left	39	161	
ISEC	Right	0	200	-
	Left	3	197	
Whole lateral	Right	1	199	-
	Left	0	200	

The p value refers to McNemar's test comparing the presence of Onodi cells between the right and left sides. Due to the small number of inferior and whole lateral sphenoethmoidal cells, these variants were analysed descriptively only.

Table 2. Presence of Onodi cells in relation to the type of sphenoid sinus pneumatization.

Pneumatization type	Present OC on 1 ≥ side		Present OC on the right		Present OC on the left	
	n (%)	p	n (%)	p	n (%)	p
Conhal	0 (0)	0.125	0 (0)	0.399	0 (0)	0.117
Presellar	3 (13)		2 (8.7)		2 (8.7)	
Sellar	20 (27.8)		10 (13.9)		10 (13.9)	
Postsellar	33 (32)		26 (25.5)		26 (25.2)	

Onodi cells were analysed as present on at least one side (Onodi ≥1 side), as well as separately by side. Central Onodi cells were included in the analysis of both sides.

Regarding the direction of Onodi cell expansion, the superior extension was the most common pattern on both sides of the sphenoid sinus, whereas lateral and superolateral extensions were less frequently observed (Figure 4).

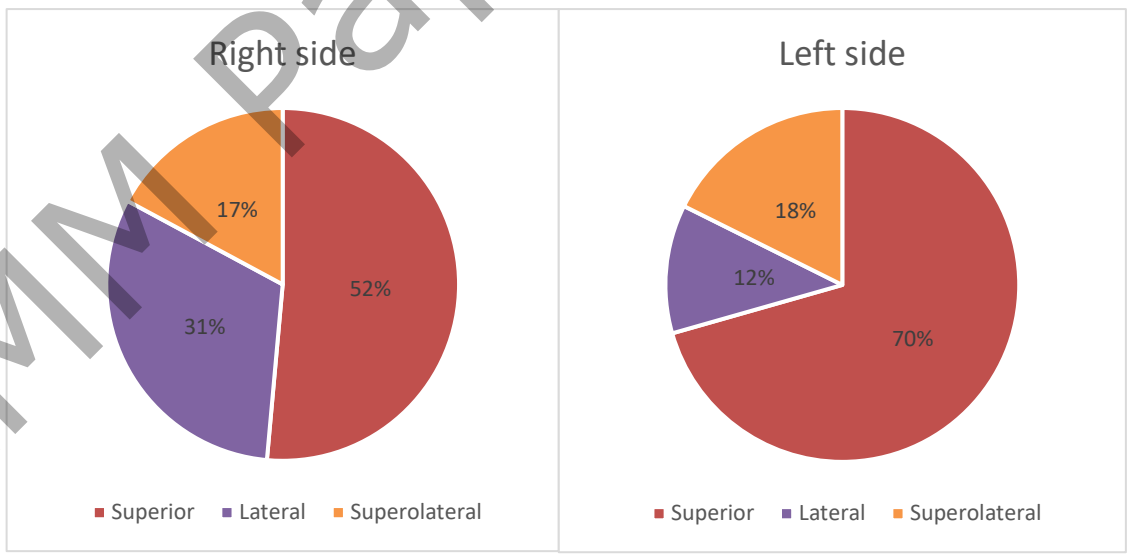

Figure 4. Distribution of different directions of Onodi cell extension relative to the sphenoid sinus on both sides.

No statistically significant difference was found in the prevalence of OC in relation to the sex of the subjects ($\chi^2 = 1.26$; $p = 0.262$). No statistically significant difference in age was found between subjects with and without OC ($p = 0.405$).

Discussion

Our data show that the most prevalent type of SEC was the OC, which was present in 28% of cases at least on one side. Inferior sphenoethmoidal and whole lateral cells are significantly less frequent. These results are in accordance with data from the literature, where the percentage of presence detected by CT examination ranges from 21% to 33% (1,2,5). These data are consistent across different countries in Europe (2,7), Asia (1,5). According to our knowledge, no studies have examined populations from other regions of Serbia. However, according to the work of Tomović et al (9), the frequency in the American population, across different ethnic groups, is quite high and ranges from 1 to 83.3%. In addition to population characteristics, the approach of SS analysis, using all three planes, as recommended by Chmielik et al (7), instead of two as in some studies, may influence the representation of OC. There are described differences in the prevalence of OC between different methods (cadaveric, endoscopic), which is why we relied only on CT studies.

The prevalence of ISEC and whole lateral cells in our population is very low. This is consistent with Liu et al (4), in whose work, the representation of these cells was 1.3% in 335 subjects. There are very few papers that use the terms ISEC and whole lateral SEC, especially since a large number of papers synonymously discuss SEC as OC (1).

Although no statistically significant association was found between the presence of OC and individual types of SS pneumatization, a significant linear trend was observed, both in the analysis of both sides and in the analyses conducted separately for the left and right sides. These results indicate that OC is more common in more pronounced forms of SS pneumatization, especially the postsellar type. This corresponds to the concept that greater pneumatization of the SS allows for posterior and lateral expansion of the ethmoidal cells. Our results are in accordance with the work of Fadda et al (10), who also observed a higher prevalence of OC in sellar and postsellar types of pneumatization. Senturk et al (1) also examined this association, but examined pneumatization via SS volume and found that the presence of SEC reduces SS volume. Perhaps the presence of the SEC affects the type of pneumatization and the volume of SS differently. The type of

pneumatization may reflect the pattern of expansion of air-filled cavities within the paranasal region, whereas the presence of sphenoethmoidal cells (SEC) may compromise the volume of the sphenoid sinus (SS), making it smaller and thus more difficult to access. Although previous studies have reported a correlation between the type of pneumatization and SS volume—indicating larger volumes in sellar and postsellar types—this relationship should be interpreted with caution during preoperative planning. Specifically, the postsellar type is associated with a larger volume and more space for endoscopic manipulation only in the absence of OC.

In our sample, OC expansion most frequently occurred in the superior direction relative to the SS. The importance of this is somewhat reflected in the work of Fadda et al (2), where the superolateral form of OC extension was the most prevalent, which was also found to be most often associated with sphenoiditis. In their second paper, Fadda et al (10), also point to the importance of the proximity of the SEC to neurovascular elements. The very criterion for defining SEC implied their close contact with OC, i.e., FR. Due to limited drainage capacity, inflammation of the SEC may involve adjacent neural structures, resulting in symptomatology. In cases of preserved bony walls, such complications are rare; however, protrusion and dehiscence of the bony walls increase the risk of infection spread. Therefore, clinicians must be aware of the likelihood of multiple anatomical variations coexisting to avoid iatrogenic damage to these neurovascular elements (10).

Conclusion

Sphenoethmoidal cells, especially the Onodi cell, represent a relatively common anatomical variation in the population of southeastern Serbia. Other types of sphenoethmoidal cells are considerably less common. Their presence shows a clear trend of more frequent occurrence in more pronounced types of pneumatization of the sphenoid sinus, such as sellar and postsellar types. As a result, these cells may increase the risk of intraoperative complications, such as injury to the optic nerve or carotid artery, during endoscopic and transsphenoidal procedures. Therefore, careful preoperative evaluation of computed tomography images is essential for identifying sphenoethmoidal cells and preventing potential surgical complications.

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