

PRACA POGLĄDOWA  
REVIEW ARTICLE

## CURRENT VIEW ON THE STRUCTURE AND FUNCTION OF THE FRONTAL SINUS: LITERATURE REVIEW

### AKTUALNY STAN WIEDZY NA TEMAT BUDOWY I FUNKCJI ZATOKI CZOŁOWEJ: PRZEGLĄD LITERATURY

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#### ABSTRACT

**Introduction:** Chronic inflammatory diseases of the mucous membranes of the nose, paranasal sinuses, and pharynx are the most common pathology of the upper airways. Pathological processes develop more often in the maxillary and ethmoidal sinuses than in the frontal ones; however, the clinical course of frontitis is more severe. Fundamental understanding of the specific structure of frontal sinuses is crucial in the awareness of the precursors of the onset and development of its pathology, the choice of methods of diagnostics and treatment.

**The aim:** The paper was aimed at the analysis of the publications on current data related to the structure and functions of the human frontal sinus and its structural components.

**Materials and methods:** The bibliosemantic method has been used during the study. Findings of the current research works on the study of the human frontal sinus have been analyzed.

**Review:** The resulting analysis shows that despite the significant amount of research works devoted to the study of the structure and functions of the frontal sinus, the morphofunctional features of its mucosa and the state of local immune protection remained unknown for a long time.

**Conclusions:** The resulting literature review showed that the study of the morphofunctional properties of the frontal sinus is relevant to date that is reflected in the number of research works, elucidating its topographoanatomical, histological, physiological and immunohistochemical features.

**KEY WORDS:** frontal sinuses, mucous membrane, morphology, immunohistochemistry

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#### INTRODUCTION

Chronic inflammatory diseases of the mucous membranes of the nose, paranasal sinuses, and pharynx are the most common pathology of the upper airways. Currently, a substantial increase of this pathology in both absolute figures and its incidence is noted in the structure of general ENT-morbidity [1].

Air pollution, increased incidence of the respiratory viral infections and allergens contribute to the growth of the diseases of the mucous membrane of the nose, paranasal sinuses and pharynx [2].

Notably, the paranasal sinusitis account for about a third of ENT-pathology. Pathological processes develop more often in the maxillary and ethmoidal sinuses; frontal sinuses are affected relatively rarely, but the clinical course of frontitis is more severe and quite often (from 0.8 to 3%) is accompanied by the severe intraorbital or intracranial complications. The severity of frontitis is resulted from the variability of the structure of the frontal sinuses and intranasal structures, which can be accompanied by narrowing of the nasal passages and impaired ventilation of the paranasal sinuses [3-5].

Individual anatomical features of the structure of the frontal sinuses, variable symptoms of their pathological

processes, the difficulty of the examination and treatment require the improvement of the current and developing of the novel methods of diagnostics [5].

#### THE AIM

The paper was aimed at the analysis of the publications on current data related to the structure and functions of the human frontal sinus and its structural components.

#### MATERIALS AND METHODS

The bibliosemantic method has been used during the study. Findings of the current research works on the study of the human frontal sinus have been analyzed.

#### REVIEW AND DISCUSSION

Nowadays, the arsenal of the powerful research methods, including spiral computed tomography, computer craniometry, magnetic resonance tomography, laser spectroscopy, 3D technology, etc. is currently used to study the structure and functions of the frontal sinus and diagnosis of pathological

processes [6-12]. However, classical methods of morphological study are still relevant in the study of topographo-anatomical features of the human frontal sinus. In this way, craniometric study, conducted at the Department of Clinical Anatomy and Operative Surgery of the Ukrainian Medical Stomatological Academy, showed that human frontal sinuses have a considerable range of individual differences in the shape and size. More often these sinuses are located closer to the median line, have different length in the saggital direction, sometimes continuing in the intramural portion of the frontal bone. Generally, the left frontal sinuses are larger than the right ones. Superiorly, the frontal sinuses insignificantly came over the supraorbital ridges; laterally, they reached the supraorbital foramen and posteriorly, occupied approximately the anterior one third of the upper wall of the orbit. In several cases the frontal sinuses significantly extended in the lateral direction, had extra inlets or septa. Morphometric studies have revealed a wide range of individual variability of the linear dimensions of the frontal sinuses, which were larger in men in contrast to women, though had no statistically significant difference ( $p > 0.05$ ). In men the biggest saggital size of the right and left frontal sinuses was 23.4 mm and 22.68 mm, respectively, and their smallest saggital size was 8.62 mm and 8.589 mm, respectively. In men the height of the right and left frontal sinuses ranged from 35.56 to 12.02 mm, and from 34.08 to 12 mm, respectively. The transverse size varied, too: 32.54-20.22 mm for the right frontal sinus, and 32.58 – 20.44 mm for the left sinus. In women the biggest saggital size of the right and left frontal sinuses was 22.22 mm and 23.24 mm, respectively, and their smallest saggital size was 8.44 mm and 7.94 mm, respectively. In women the height of the right and left frontal sinuses ranged from 34.36 to 9.22 mm, and from 32.79 to 12.22 mm, respectively. The transverse size varied, too: 32.43 – 19.8 mm for the right frontal sinus, and 32.08-19.76 mm for the left sinus [13].

Inferiorly, the intersinus septum, which separates the right and left frontal sinuses, is located medially more often, and, superiorly, can be deviated aside. Near the septum on the lower wall of the frontal sinus there is the opening of the frontonasal duct that more often opens into the anterior part of the crescent-shaped fissure of the medial nasal passage. In some cases, the frontal sinus opens into the nasal cavity with the opening, but not with a duct [14, 15].

A thorough study of the morphology of mucous membrane of the frontal sinus is extremely relevant to date. Currently, for example, it is known that in 87% of cases very common cysts of the maxillary sinuses are considered to be "unreal"; the reason for their occurrence is the degenerative changes in the mucous membrane. Speaking about the cysts of the frontal sinuses, too little information has been found to date in the medical scientific publications; the clinicians describe a similar pathology more often as the cases of muco- or pyocèle or dermoid cysts. At the same time very rarely this pathology has been confirmed by the findings of morphological studies, which is a significant drawback, since the analysis of the morphological features of cysts of the frontal sinuses permits to develop the maximum sparing surgical techniques for their removal [16, 17].

The comparative morphometric analysis of the thickness of the epithelium of mucous membrane of the posterior wall and septum of the human frontal sinus confirmed the absence of significant differences between the values of the left and right frontal sinuses. Its mean thickness on the septum was  $36.01 \pm 1.23 \mu\text{m}$  on the left and  $35.21 \pm 1.31 \mu\text{m}$  on the right and was insignificantly bigger than on the posterior walls of the frontal sinuses. The mean thickness of the proper lamina of the mucous membrane of the septum was also slightly bigger as compared to the posterior wall ( $26.56 \pm 1.54 \mu\text{m}$  on the left and  $27.06 \pm 1.36 \mu\text{m}$  on the right), but the difference was insignificant. The thickness of the submucous layer was 10% bigger on the septum ( $127.17 \pm 8.48 \mu\text{m}$  on the left and  $124.93 \pm 7.89 \mu\text{m}$  on the right) which differed insignificantly from the similar value on the posterior wall ( $111.17 \pm 9.77 \mu\text{m}$  on the left and  $115.47 \pm 6.48 \mu\text{m}$  on the right). The outer diameter of the acini was significantly smaller by 15 % on the septum ( $25.42 \pm 1.68 \mu\text{m}$  on the left and  $25.89 \pm 1.38 \mu\text{m}$  on the right), as compared to the posterior wall ( $29.77 \pm 2.07 \mu\text{m}$  on the left and  $30.17 \pm 2.25 \mu\text{m}$  on the right). The mean values of the diameters of the lumens of vessels of the mucous membrane of the posterior wall and septum of the frontal sinus, except for the venules, were significantly different and were bigger on the septum; in this way the mean diameter of the veins and arteries of the posterior wall was 35 % and 70 %, respectively, smaller [18].

The glands, regional peculiarities of which are the various nature of secretion and histofunctional differences of the acinar and ductal epithelial cells and tinctorial properties of the content of ducts, have been detected in the mucous membrane of all walls of the human frontal sinus [19]. Compound branched glands, containing the acini and excretory ducts, are located in the submucous layer of the frontal sinuses mucosa. Submucous layer is formed by the loose fibrous connective tissue with dense network of blood microvessels, surrounding the glands. The acines are formed by the cuboidal cells, the cytoplasm of which contains numerous secretory granules, consisting mainly of proteins. The nuclei of these cells, mainly orbicular and sometimes with minor invaginations contain chromatin and mainly one eccentric nucleolus. In the acini among cuboidal cells the sporadic cambial cells with dark homogenous cytoplasm and small orbicular nucleus have been found. The sporadic lymphocytes in the basal parts ensure a barrier function of the glands of the frontal sinuses mucosa. The fibroblasts form the gentle capsule around the acini. The excretory duct is formed by 2-4 acini and lined with 1-2 layers of cuboidal epithelial cells, nuclei of which are located in the center of the cell, containing one eccentric nucleolus. The excretory ducts carry the secretion from the acini to the surface of the frontal sinuses mucosa. The external layer of these ducts consists of myoepithelial cells, surrounded by a loose connective tissue, which contains mainly fibrillar component and sporadic fibroblasts [20].

The morphometry has shown that in the mucous membrane of the anterior wall of the human frontal sinus the mean value of the outer diameter of acines of the serous glands of the anterior wall of human frontal sinus was  $(26.81 \pm 2.06) \mu\text{m}$ ; the mean value of the diameter of the lumen was  $(5.56 \pm 0.16) \mu\text{m}$ ; the mean value of the height of the epithelial cells was

( $9.74 \pm 1.02$ )  $\mu\text{m}$ . The mean value of the outer diameter of the excretory ducts on the anterior wall was ( $33.94 \pm 2.41$ )  $\mu\text{m}$ ; the mean value of the diameter of the lumen was ( $15.95 \pm 0.98$ )  $\mu\text{m}$ ; the mean value of the height of the epithelial cells was ( $8.99 \pm 0.76$ )  $\mu\text{m}$  [21].

Histological studies have revealed that in the submucous layer of the inferior wall of the human frontal sinus the acini of the serous glands are formed by the prismatic cells, cytoplasm of which contains numerous secretory granules. The nuclei of these cells are orbicular and contain mainly decondensed chromatin. The mean value of the outer diameter of the acini of the serous glands of the inferior wall of the human frontal sinus is ( $34.17 \pm 2.39$ )  $\mu\text{m}$ , which is significantly greater than the value on the anterior wall ( $p < 0,05$ ). The mean value of the height of the epithelial cells is ( $12.24 \pm 0.98$ )  $\mu\text{m}$ , and the mean value of the diameter of the lumen is ( $11.67 \pm 0.84$ )  $\mu\text{m}$  that is significantly greater than the similar values on the anterior wall of the human frontal sinus ( $p < 0,05$ ). The mean value of the outer diameter of the excretory ducts of the serous glands of the human frontal sinus inferior wall is ( $42.90 \pm 3.12$ )  $\mu\text{m}$  and is significantly greater than the value on the anterior wall ( $p < 0,05$ ). The value of the diameter of the lumen is ( $17.16 \pm 0.86$ )  $\mu\text{m}$  and differs insignificantly from the value on the anterior wall. The mean value of the height of the epithelial cells is ( $12.87 \pm 1.31$ )  $\mu\text{m}$  that is also greater than the similar value on the anterior wall ( $p < 0,05$ ) [21, 22, 23].

Serous glands in the mucous membrane of the posterior wall of the human frontal sinus are compound, branched and consist of acini and excretory ducts. The mean value of the outer diameter of the acini of the serous glands of the human frontal sinus posterior wall is ( $30.49 \pm 1.97$ )  $\mu\text{m}$ . The value of the diameter of their lumens is ( $7.93 \pm 0.22$ )  $\mu\text{m}$  ( $p < 0,05$ ). The mean value of the height of the epithelial cells is ( $13.28 \pm 1.04$ )  $\mu\text{m}$  that is greater than the similar value on the anterior wall ( $p < 0,05$ ), but differs insignificantly from the similar value on the inferior wall of the human frontal sinus. The mean value of the outer diameter of the excretory ducts of the serous glands of the human frontal sinus posterior wall is ( $37.53 \pm 2.67$ )  $\mu\text{m}$ , that is significantly greater than the value on the anterior wall but significantly lower than on the inferior wall ( $p < 0,05$ ). The mean value of the height of the epithelial cells is ( $4.88 \pm 0.32$ )  $\mu\text{m}$ , that is almost twice lower than the similar value on the anterior wall and 2,6 times lower than the value on the inferior wall of the frontal sinus ( $p < 0,05$ ). The value of the diameter of the lumen is ( $27.77 \pm 1.12$ )  $\mu\text{m}$ , that is considerably higher than the values on the anterior and inferior walls ( $p < 0,05$ ) [21, 23].

In the mucous membrane of the septum of the human frontal sinus the value of the mean outer diameter of the acini of the serous glands is ( $24.90 \pm 1.08$ )  $\mu\text{m}$ , the diameter of their lumens is ( $5.02 \pm 0.01$ )  $\mu\text{m}$ , the mean height of the epithelial cells is ( $8.67 \pm 0.06$ )  $\mu\text{m}$ , that are the least values among all walls. The mean metric values of the serous gland ducts of the human frontal sinus septum are ( $32.28 \pm 1.18$ )  $\mu\text{m}$  for the outer diameter; ( $13.56 \pm 0.06$ )  $\mu\text{m}$  for the diameter of the lumen; ( $8.37 \pm 0.03$ )  $\mu\text{m}$  for the height of the epithelial cells [21].

Immunohistochemical studies are crucial in the study of the state of the local immune system of the mucous membranes and their glandular apparatus [24].

Immunohistochemical studies, carried out by the researchers from the Ukrainian Medical Stomatological Academy, have found the presence of cells, expressing the CD 3 polypeptide membrane complex, in the connective tissue of the proper lamina and submucous layer of all walls and septum of the human frontal sinus. The greatest number of the periacinar CD 3-positive cells is in the mucous membrane of the septum, and periductal CD 3-positive cells have been found in the mucosa of the inferior wall.

Scarce CD 20-positive cells have been found in the periacinar connective tissue in the mucous membrane of all walls of the frontal sinus. Numerous B- lymphocytes have been found in the periductal stroma of all walls and the biggest amount is in the mucous membrane of the anterior wall of the human frontal sinus.

Numerous plasmocytes have been found in the periacinar stroma of both serous and mucous glands of the mucous membrane of the human frontal sinus (the biggest amount is in the inferior wall). They form the chains of 10-12 cells along the basal membrane. The number of CD 138 positive cells in the periductal connective tissue is smaller than in the periacinar one; however, in the mucous membrane of the posterior wall the number of periductal plasmocytes is considerable [25, 26].

The catheterization of the human frontal sinus mucosa with the CD 68 transmembrane glycoprotein has revealed a very strong level of the marker expression by the free macrophages, which were localized diffusely in the connective tissue, surrounding the acini and ducts. Persistent CD 68 expression in the cytoplasm of the serous cells of the acini (on all walls of the frontal sinus with the decrease from 3 to 1 point on the inferior and posterior walls, respectively, and the septum) was unexpected [27].

## CONCLUSIONS

The profound study of the frontal sinus is relevant to date for both theoretical medicine and clinical practice. The specific topography of the sinus can contribute to the progress of the pyoinflammatory processes into the nasal and cranial cavities, eye socket, as well as can cause the certain difficulties during surgeries. Therefore, a number of current scientific works are devoted to the study of morphofunctional characteristics of the frontal sinus, elucidating its topographoanatomical, histological, physiological and pathophysiological features. Morphofunctional peculiarities of the mucous membrane of the frontal sinuses and their structural elements are not fully studied to date and, consequently, this issue has become a great concern for the researchers from the Ukrainian Medical Stomatological Academy, who devoted a number of researches on this issue. Particularly, the immunohistochemical studies have been carried out, which are the great potential for the analysis of the local immune system of the mucous membranes and their glandular apparatus, since the analysis of the state of the immunological protection of the frontal sinuses is crucial for a deep understanding of the causes of their inflammation, choice of the methods of diagnostics and treatment.

REFERENCES

1. Kazakovtsev VP, Kulikova OM, Anohina YaYu. Razrabotka rekomendatsiy po snizheniyu zabolevaemosti naseleniya g. omska hronicheskimi boleznyami slizistoy obolochki nosa, okolonosovyih pazuh i glotki. *Fundamentalnye issledovaniya*. 2013; (7–1): 96-100.
2. Kazakovtsev VP. Gigienicheskaya otsenka vliyaniya sotsialno-ekonomicheskikh faktorov na formirovanie hronicheskoy patologii verhnih dyihatelnyih putey naseleniya promyshlennogo tsentra / V.P. Kazakovtsev, V.A. Lyapin // *Fundamentalnye issledovaniya*. 2012; (12–2): 274–76.
3. Bezshapochnyi SB, Meshcheriakov VN, Kovalev EV, Loburets VV. Clinico-morphologic and biomicroscopic parallels in the management of patients with various forms of purulent paranasal sinusitis and methods of correcting microcirculatory disorders. *Vestn Otorinolaringol*. 1991 Sep-Oct;(5):25-31.
4. Langille M, Walters E, Dziegielewski PT, Kotylak T, Wright ED. Frontal sinus cells: identification, prevalence, and association with frontal sinus mucosal thickening. *Am J Rhinol Allergy*. 2012 May-Jun; 26 (3): 107-10.
5. Kuchmin VN. Hirurgicheskie osobennosti lobnoy pazuhi v sisteme cherepa. *Byulleten meditsinskih internet-konferentsiy*. 2014; 4 (5): 668.
6. Minenkov GO. Rol kompyuternoy tomografii v diagnostike razlichnykh form i opredelenii rasprostranennosti porazheniya chelyustno-litsevoy oblasti pri fibroznoy osteodisplazii. *Meditsinskaya vizualizatsiya*. 2011; (1): 56-60.
7. Piskunov IS, Emelyanova AN. Varianty anatomicheskogo stroeniya lobnykh pazuh po dannym rentgenovskoy kompyuternoy tomografii. *Vestn Otorinolaringol*. 2011; (1): 16-21.
8. Sahlstrand-Johnson P, Jannert M, Strombeck A, Abul-Kasim K. Computed tomography measurements of different dimensions of maxillary and frontal sinuses. *BMC Med Imaging*. 2011 Apr 5;11:8.
9. Lewander M, Lindberg S, Svensson T, Siemund R, Svanberg K, Svanberg S. Non-invasive diagnostics of the maxillary and frontal sinuses based on diode laser gas spectroscopy. *Rhinology*. 2012 Mar;50(1):26-32.
10. Sun Y, Meng F, Jiang S, Zhang N. Computed tomography analysis of anatomic structure related to endoscopic axilla approach for surgery of frontal sinus. *Lin Chung Er Bi Yan Hou Tou Jing Wai Ke Za Zhi*. 2013 Jan;27(2):70-2.
11. Tian Y, Cui B. Three-dimensional reconstruction and visualization of the fronto-ethmoidal cells based on CT images. *Lin Chung Er Bi Yan Hou Tou Jing Wai Ke Za Zhi*. 2014; 28(20): 1573-76.
12. Beaini TL, Duailibi-Neto EF, Chilvarquer I, Melani RF. Human identification through frontal sinus 3D superimposition: Pilot study with Cone Beam Computer Tomography. *J Forensic Leg Med*. 2015 Nov;36:63-9.
13. Dovbnia YuM. Kraniometrychne doslidzhennia lobovoi pazukhy liudyny. *Visnyk problem biolohii i medytsyny*. 2017; 136(2): 286-89.
14. Palchun VT, Kryukov AI. *Otorinolaringologiya*. Kursk: KGMU, Moskva: Litera; 1997. 512 s.
15. Angélico Jr FV, Rapoport PB. Analysis of the Agger nasi cell and frontal sinus ostium sizes using computed tomography of the paranasal sinuses. *Braz J Otorhinolaryngol*. 2013; 79(3): 285-92.
16. Capra GG, Carbone PN, Mullin DP. Paranasal sinus mucocele. *Head Neck Pathol*. 2012; 6 (3): 369-72.
17. Volkov AH, Pyskunov SZ, Pyskunov YS, Gyusan AO, Zakharova NA. Kisty lobnykh pazukh. *Rossyiskaya rinologiya*. 2013; (3): 24-8.
18. Pronina OM, Serbin SI, Pyroh-Zakaznikova AV, Polovok OYu, Rozhnov VH. Porivnialna morfometrychna kharakterystyka strukturnykh elementiv slizovoi obolonky peretyny ta zadnoi stinky lobovoi pazukhy liudyny v normi. *Visnyk problem biolohii i medytsyny*. 2014; 108 (2-2): 98-101.
19. Pronina OM, Serbin SI, Yeroshenko HA, Ryabushko MM. Rehionalni osoblyvosti zaloz slizovoi obolonky lobovoi pazukhy liudyny. *Visnyk problem biolohii i medytsyny*. 2012; (2-2): 212-15.
20. Serbin SI. Histo-topohrafichni ta morfometrychni osoblyvosti zaloz slizovoi obolonky perednoi ta zadnoi stynok lobovoi pazukhy liudyny u normi. *Svit medytsyny ta biolohii*. 2012; (4): 93-96.
21. Dovbnia YuM, Pronina OM. Morfometrychna kharakterystyka seroznykh zaloz slizovoi obolonky lobovoi pazukhy liudyny. *Aktualni problemy suchasnoi medytsyny: Visnyk Ukrainskoi medychnoi stomatolohichnoi akademii*. 2015; 15 (4-52): 227-9.
22. Pronina Ye, Dovbnia Yu, Yeroshenko G. Morphological and functional features of human frontal sinus anterior wall glands. *Cambridge Journal of Education and Science*. 2016; 15 (1): 89-92.
23. Dovbnia Yu.M. Histotopohrafichni osoblyvosti zaloz slizovoi obolonky perednoi i zadnoi stynok lobovoi pazukhy liudyny. *Visnyk problem biolohii i medytsyny*. 2017; 138 (3-2): 51-4.
24. Bezshapochnyi SB, Gasiuk IuA, Loburets VV, Vakhnina AB. The mechanisms of local protection of the mucous membrane of the nasal cavity and paranasal sinuses. *Vestn Otorinolaringol*. 2013;(4):44-7.
25. Dovbnia YuM, Pronina OM, Yeroshenko HA. Imunohistokhimichna kharakterystyka slizovoi obolonky lobovoi pazukhy liudyny. *Visnyk problem biolohii i medytsyny*. 2017; 135 (1): 284-286.
26. Dovbnia YuM. Rozpodil imunotsytiv v slizovii obolonci perednoi stinky lobovoi pazukhy liudyny. *Visnyk problem biolohii i medytsyny*. 2016; 129 (2-2): 97-9.
27. Dovbnia YuM, Pronina OM, Yeroshenko HA. Osoblyvosti ekspresii retseptoriv CD 68 v seroznykh zalozakh slizovoi obolonky lobovoi pazukhy liudyny. *Svit medytsyny ta biolohii*. 2016; (3): 111-113.

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*The Authors declare no conflict of interest.*

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