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Generalized Morphometric Characteristics of the Vascular Components of the Mucous Membrane of All the Walls of the Human Frontal Sinus in a Norme

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The purpose of the work was to study the histological structure of the mucous membrane of all the walls of the frontal sinus of a person in order to obtain morphometric data on its structural components: surface blood vessels – arteries and veins, and links of the hemomicrocirculatory bed – arterioles, capillaries and venules in the lamina propria of the mucous membrane of all the walls of the human frontal sinus in a norme.

Materials and methods. The material for the study was the mucous membrane of the frontal sinus of 110 people who died at the age of 22–86 years from causes not related to the pathology of the paranasal sinuses. The collection of material was carried out in the conditions of the Poltava Regional Pathological and Anatomical Bureau of the Department of Health of the Poltava Regional State Administration and in the conditions of the Forensic Morgue of the Bureau of Forensic Examination of the Department of Health of the Poltava Regional State Administration in accordance with the cooperation agreements. In our work, we used age periodization according to G. Craig (2000). After obtaining the mucous membranes of the frontal sinus, their fragments were fixed in a 2.5% solution of glutaraldehyde in a phosphate buffer. Subsequently, sealing was performed in epoxy resin “Epon-812”.

Results. The results of the study showed that the average diameter of the lumen of the resistive and capacitive links of the hemomicrocirculatory bed is the largest in the mucous membrane of the anterior wall of the human frontal sinus (respectively, $11.16 \pm 0.37 \mu\text{m}$ on the left / $11.34 \pm 0.31 \mu\text{m}$ on the right ($p < 0.05$) and $7.63 \pm 0.08 \mu\text{m}$ on the left / $7.57 \pm 0.09 \mu\text{m}$ on the right), the smallest – in the composition of the mucous membrane of the posterior wall (respectively, $6.96 \pm 0.19 \mu\text{m}$ on the left / $6.56 \pm 0.35 \mu\text{m}$ on the right and $8.82 \pm 0.16 \mu\text{m}$ on the left / $9.02 \pm 0.43 \mu\text{m}$ on the right ($p < 0.05$)). Exchangeable hemomicrovessels with the smallest diameter – $3.89 \pm 0.08 \mu\text{m}$ on the left and $4.19 \pm 0.02 \mu\text{m}$ on the right ($p < 0.05$) are found in the certain area. The widest capillaries determined by us in the composition of the mucous membrane of the inferior wall were $4.88 \pm 0.07 \mu\text{m}$ on the left and $4.73 \pm 0.12 \mu\text{m}$ on the right ($p < 0.05$) of the frontal sinus.

Conclusion. The blood supply of the mucous membrane of the human frontal sinus is provided by the vascular hemomicrocirculatory bed, in which we identified 2 main components: surface microvessels (arteries and veins), which provided epithelial trophism and a deep vascular net (arterioles, capillaries and venules), which was localized in the connective tissue of the lamina propria and was represented by arteries and veins.

Keywords: human, frontal sinus, mucous membrane, hemomicrocirculatory bed, surface microvessels, morphometric method.

Introduction. State institution “Center of Medical Statistics of the Ministry of Health of Ukraine” showed that in Ukraine in 2014 such statistics of acute rhinitis, rhinosinusitis and rhinopharyngitis were 489.9 cases per 10,000 population, and the incidence rate was 5–15 cases per 1,000 population depending on season [1].

These patients in relative numbers make up 60–65% of outpatients of ENT doctors, and the diagnosis of acute rhinosinusitis is established in 25% of cases among the twenty diagnoses most often established by otorhinolaryngologists (according to Medical Data Management) [1].

From literary sources, we can see that chronic inflammatory diseases of the upper respiratory tract, such as mucous membranes of the nasal cavity, paranasal sinuses, and nasopharynx, are among the most common pathologies of the respiratory tract [2, 3, 4].

In recent years, we have seen a trend towards an increase in pathological inflammatory conditions of the upper respiratory tract, in particular of paranasal sinusitis, both in relative and absolute numbers in the general structure of ENT-morbidity [2, 3, 4].

Therefore, our study is appropriate and relevant today in the context of modern morphology and clinical medicine, primarily otorhinolaryngology.

The purpose of the work was to study the histological structure of the mucous membrane of all the walls of the human FS in a norme in order to obtain morphometric data on its structural components: surface blood vessels – arteries and veins, and links of

the hemomicrocirculatory bed – arterioles, capillaries and venules in the lamina propria of the mucous membrane of all the walls of the human FS in a norme; to identify the differences in metric data to get an idea of the functional load on each wall of the FS separately.

Materials and methods. The material for the study was the mucous membrane of the FS of 110 people who died at the age of 22–86 years from causes not related to the pathology of the paranasal sinuses.

The collection of material was carried out in the conditions of the Poltava Regional Pathological and Anatomical Bureau of the Department of Health of the Poltava Regional State Administration (DoH of PRSA) and in the conditions of the Forensic Morgue of the Bureau of Forensic Examination of the DoH of PRSA in accordance with the cooperation agreements.

In our work, we used age periodization according to G. Craig (2000) [5].

After obtaining the mucous membranes of the FS, their fragments were fixed in a 2.5% solution of glutaraldehyde in a phosphate buffer. Subsequently, sealing was performed in epoxy resin “Epon-812” [6, 7, 8].

To obtain semi-thin sections, an ultramicrotome of Sumy VO “Selmi” UMTF-7 was used. The evaluation of the quality of the obtained sections was carried out using a stereoscopic microscope. For high-quality attachment of sections to the surface of a glass slide, the latter with the sections were kept for a day in a thermostat at a temperature of 45–50°C. Sections were stained using a 0.1% solution of toluidine blue and 1% methylene blue according to J. A. Lynn, or the polychrome method of staining of histological preparations [9, 10, 11].

The study of the obtained preparations was carried out with the help of a light microscope “Konus”, equipped with a digital microphotography attachment Sigeta DCM-900 9.0MP with the Viorex 3 program (serial number 5604) adapted for these studies.

A MOV-16 eyepiece-micrometer was used to obtain morphometric indicators [12].

The morphometric method was used to determine the metric indicators – the diameters of arteries, veins, capillaries, venules, veins in the lamina propria of the mucous membrane of all the walls of the human FS.

Statistical processing of the obtained results was carried out on a personal computer with the help of Statistica 13 and Microsoft Excel 2010 software packages [13].

The work was carried out in accordance with the requirements of the “Instructions on Conducting a Forensic Examination” (order of the Ministry of Health of Ukraine No. 6 dated January 17, 1995), in accordance with the requirements and norms, standard regulation on ethics of the Ministry of Health of

Ukraine No. 690 dated September 23, 2009, “The Procedure for Extracting Biological Objects from the Dead, whose Bodies are Subject to Forensic Examination and Pathological-Anatomical Research, for Scientific Purposes” (2018).

Results and discussion. We carried out a morphometric analysis for surface blood vessels – arteries and veins, and links of the hemomicrocirculatory bed – arterioles, capillaries, and venules in the lamina propria of the mucous membrane of all the walls of the human FS in a norme.

For the vessels of the anterior wall, the average values of the diameter of the arteries of the surface net were $27.58 \pm 3.07 \mu\text{m}$ on the left and $26.77 \pm 3.17 \mu\text{m}$ on the right (**Table 1**). The average value of the diameter of the veins exceeded that of the arteries and was equal to $33.09 \pm 1.64 \mu\text{m}$ on the left and $32.97 \pm 1.56 \mu\text{m}$ on the right.

For the resistive link of the hemomicrocirculatory bed of the anterior wall, the average diameter values were $11.16 \pm 0.37 \mu\text{m}$ and $11.34 \pm 0.31 \mu\text{m}$ on the left and right, respectively (**Table 1**). Capillaries in the lamina propria of the mucous membrane of the anterior wall of the human FS were of the somatic type, their average diameter was $4.30 \pm 0.06 \mu\text{m}$ on the left and $4.48 \pm 0.10 \mu\text{m}$ on the right.

The average values of the diameter of the venules of the anterior wall were almost twice as high as the indicators for the exchange link of the hemomicrocirculatory bed, but were significantly greater than the similar indicators for arterioles (**Table 1**).

We established that the average values of the diameter of the arteries of the surface net of the inferior wall were $18.55 \pm 1.70 \mu\text{m}$ on the left and $18.62 \pm 1.38 \mu\text{m}$ on the right (**Table 1**). The obtained metric data indicate that the diameter of the studied vessels is almost 30% smaller than the average values for the anterior wall (**Table 1**).

The average diameter of the veins of the inferior wall was $21.72 \pm 1.49 \mu\text{m}$ on the left and $22.03 \pm 1.01 \mu\text{m}$ on the right (**Table 1**). A significant difference between the indicators of both sides has not been determined, but the diameter of the veins of the inferior wall was 30% smaller than the indicators for the anterior wall of the human frontal sinus (**Table 1**), as well as for arteries.

For the resistive link of the inferior wall of the hemomicrocirculatory bed, the average diameter values were $7.60 \pm 0.34 \mu\text{m}$ and $8.01 \pm 0.25 \mu\text{m}$ on the left and right, respectively (**Table 1**), which was also smaller than the value for the anterior wall of the human frontal sinus (**Table 1**).

The average diameter of somatic capillaries in the mucous membrane of the inferior wall of the human frontal sinus was $4.88 \pm 0.07 \mu\text{m}$ on the left and $4.73 \pm 0.12 \mu\text{m}$ on the right (**Table 1**), and was probably greater than the value for the anterior wall (**Table 1**).

Table 1 – The ratio of the morphometric parameters of the diameters of surface blood vessels and links of hemomicrocirculatory bed of all the walls of the human frontal sinus in a norme, μm

Indicator	Anterior wall		Inferior wall		Poterior wall		Septum	
	on the left (n=10)	on the right (n=10)	on the left (n=10)	on the right (n=10)	on the left (n=10)	on the right (n=10)	on the left (n=10)	on the right (n=10)
Diameter of arteries	27.58± ±3.07	26.77± ±3.17	18.55± ±1.70 *	18.62± ±1.38 *	10.72± ±0.35 *, **	11.02± ±0.69 *, **	17.59± ±0.09 *, ***	18.06± ±0.69 *, **
Diameter of arterioles	11.16± ±0.37	11.34± ±0.31	7.60± ±0.34 *	8.01± ±0.25 *	6.96± ±0.19 *, **	6.56± ±0.35 *, **	7.71± ±0.12 *, ***	7.64± ±0.21 *, ***
Diameter of capillaries	4.30± ±0.06	4.48± ±0.10	4.88± ±0.07 *	4.73± ±0.12 *∞	3.89± ±0.08 *, **	4.19± ±0.02 *, **	4.82± ±0.06 *, ***	4.91± ±0.11 *, ***
Diameter of venules	7.63± ±0.08	7.57± ±0.09	8.34± ±0.05 *	8.46± ±0.13 *	8.82± ±0.16 *, **	9.02± ±0.43 *, **	8.62± ±0.21 *	8.76± ±0.32 *
Diameter of veins	33.09± ±1.64	32.97± ±1.56	21.72± ±1.49 *	22.03± ±1.01 *	15.42± ±0.46 *, **	15.84± ±1.27 *, **	23.34± ±0.62 *, ***	23.11± ±0.74 *, ***
Note: hereinafter – ∞ – p < 0.05 compared to the indicators for the opposite side.			Note: * – p < 0.05 compared to the values for the anterior wall.		Note: * – p < 0.05 compared to the values for the anterior wall; ** – p < 0.05 compared to the values for the inferior wall.		Note: * – p < 0.05 compared to the values for the anterior wall; ** – p < 0.05 compared to the values for the inferior wall; *** – p < 0.05 compared to the values for the posterior wall.	

The average values of the diameter of the venules of the inferior wall were equal to $8.34 \pm 0.05 \mu\text{m}$ on the left and $8.46 \pm 0.13 \mu\text{m}$ on the right (**Table 1**). Compared with the indicator for the anterior wall, we have found a probable difference – an excess of 10% (**Table 1**).

The average values of the diameter of the arteries of the surface net of the mucous membrane of the posterior wall of the human FS were $10.72 \pm 0.35 \mu\text{m}$ on the left and $11.02 \pm 0.69 \mu\text{m}$ on the right (**Table 1**).

When compared with the morphometric data given above, it was found that the diameter of the arteries in this area of the mucous membrane of the human frontal sinus was almost three times smaller than the values for the anterior wall (**Table 1**) and twice as much for the same indicator for the inferior wall (**Table 1**).

The average diameter of the posterior wall veins was $15.42 \pm 0.69 \mu\text{m}$ on the left and $15.84 \pm 1.27 \mu\text{m}$ on the right (**Table 1**). No probable difference between the values for the parties was found.

Compared with the metric data for the anterior and inferior wall veins, a negative difference of 50% and 25% was established, respectively (**Table 1**).

The average values of the diameter of the resistive link of the hemomicrocirculatory bed of the poste-

rior wall were $6.96 \pm 0.19 \mu\text{m}$ and $6.56 \pm 0.35 \mu\text{m}$ on the left and right, respectively (**Table 1**). Compared with the indicators of the diameters of the arterioles of the anterior and inferior walls of the human frontal sinus, the values were by 40% and 10% smaller, respectively (**Table 1**).

The average diameter of the capillaries of the mucous membrane of the posterior wall of the human frontal sinus on the left and right did not differ significantly and amounted to $3.89 \pm 0.08 \mu\text{m}$ and $4.19 \pm 0.02 \mu\text{m}$, respectively (**Table 1**). When compared with previously obtained morphometric data of other departments of the mucous membrane, it was probably by 10% and 20% lower than the values for the anterior and inferior wall, respectively (**Table 1**).

Morphometric indicators of the average diameter of venules in the mucous membrane of the posterior wall of the frontal sinus was equal to $8.82 \pm 0.16 \mu\text{m}$ on the left and $9.02 \pm 0.43 \mu\text{m}$ on the right (**Table 1**). Compared with the indicators for the anterior and inferior walls, the values were higher by 20% and 10%, respectively (**Table 1**).

The average values of the diameter of arteries in the lamina propria of the mucous membrane of the human FS septum were $17.59 \pm 0.09 \mu\text{m}$ on the left and $18.06 \pm 0.69 \mu\text{m}$ on the right (**Table 1**). When

compared with the above morphometric data regarding the diameters of the arteries of other walls, it was found that the diameter of the arteries in the mucous membrane of the human FS septum is by 30% significantly smaller than the indicators for the anterior wall (**Table 1**), probably did not differ from the similar indicator of the inferior wall (**Table 1**) and is statistically significantly greater by 70% than the diameter of the arteries of the posterior wall of the human frontal sinus (**Table 1**).

The average diameter of septal veins was $23.34 \pm 0.62 \mu\text{m}$ on the left and $23.11 \pm 0.74 \mu\text{m}$ on the right (**Table 1**). A probable difference between the values for the parties has not been established.

Compared with the metric data for the veins of the anterior wall the established negative difference was 30% (**Table 1**), compared with the indicator of the lower wall the difference is not reliable (**Table 1**), and the average values of the diameter of the veins of the frontal sinus septum exceed the corresponding value of the veins of the posterior wall by 50% (**Table 1**).

The average value of the diameter of arterioles in the lamina propria of the mucous membrane of the frontal sinus septum was $7.71 \pm 0.12 \mu\text{m}$ and $7.64 \pm 0.21 \mu\text{m}$ on the left and right, respectively (**Table 1**).

Compared with the indicators of the average diameter of the arterioles of the anterior and posterior walls of the human frontal sinus, the values were by 30% lower and 10% higher, respectively (**Table 1**). The indicator did not differ statistically significantly

from the values of the diameter of the arterioles on the inferior wall (**Table 1**).

The average diameter of the capillaries of the mucous membrane of the septum of the human frontal sinus on the left and right did not differ significantly and was $4.82 \pm 0.06 \mu\text{m}$ and $4.91 \pm 0.11 \mu\text{m}$, respectively (**Table 1**).

Thus, the severity of frontitis is due to the variability of the structure of the frontal sinuses (FS) and intranasal structures, which can be accompanied by the narrowing of the nasal passages and impaired ventilation of the paranasal sinuses [14], but the peculiarities of the microscopic structure of the mucous membrane of the indicated sinus are also important in this matter [4].

Conclusion. The blood supply of the mucous membrane of the human frontal sinus is provided by the vascular hemomicrocirculatory bed, in which we identified 2 main components: surface microvessels (arteries and veins), which provided epithelial trophism and a deep vascular net (arterioles, capillaries and venules), which was localized in the connective tissue of the lamina propria and was represented by arteries and veins.

Perspectives of further research. To investigate at the microscopic level the relationship between changes in morphometric indicators of surface blood vessels – arteries and veins, and links of the hemomicrocirculatory bed – arterioles, capillaries and venules in acute and chronic frontitis.

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УЗАГАЛЬНЕНА МОРФОМЕТРИЧНА ХАРАКТЕРИСТИКА СУДИННИХ КОМПОНЕНТІВ СЛИЗОВОЇ ОБОЛОНКИ УСІХ СТІНОК ЛОВОВОЇ ПАЗУХИ ЛЮДИНИ У НОРМІ

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Резюме. Метою дослідження було отримання метричних даних – середнього діаметру поверхневих кровоносних судин – артерій і вен, та ланок гемомікроциркуляторного русла – артеріол, капілярів та венул у власній пластинці слизової оболонки усіх стінок лобової пазухи людини у нормі.

Матеріал і методи. Досліджено слизову оболонку лобової пазухи, отриману при патологоанатомічному розтині 110 людей обох статей, віком від 22 до 86 років, які померли від причин не пов'язаних з патологією приносних пазух. Забір матеріала здійснено згідно з міжнародними нормами проведення біологічних досліджень за участю людини. Застосований метод забарвлювання гістологічних препаратів напівтонких зрізів поліхромним барвником, з подальшим статистичним опрацюванням отриманих морфометричних даних.

Результати дослідження показали, що середній діаметр просвіту резистивної і ємнісної ланок гемомікроциркуляторного русла є найбільшим в слизовій оболонці передньої стінки лобової пазухи людини (відповідно 11,16±0,37 зліва / 11,34±0,31 справа мкм (p<0,05) та 7,63±0,08 зліва / 7,57±0,09 справа мкм), найменшим – в складі слизової оболонки задньої стінки (відповідно 6,96±0,19 зліва / 6,56± 0,35 справа мкм та 8,82± 0,16 зліва / 9,02±0,43 справа мкм (p<0,05)). У визначеній ділянці виявляються обмінні гемомікросудини з найменшим діаметром – 3,89±0,08 зліва та 4,19±0,02 справа мкм (p<0,05). Найширші капіляри визначені в складі слизової оболонки нижньої стінки лобової пазухи – 4,88±0,07 зліва та 4,73±0,12 справа мкм (p<0,05).

Висновки. Кровопостачання слизової оболонки лобової пазухи людини забезпечує судинне гемомікроциркуляторне русло, в якому було виділено 2 основні компоненти: поверхневі мікросудини (артерії та вени), що забезпечують трофіку епітелію, та глибоку судинну сітку (артеріоли, капіляри та венули), яка локалізувалася в сполучній тканині lamina propria, і була представлена артеріями та венами.

Ключові слова: людина, лобова пазуха, слизова оболонка, гемомікроциркуляторне русло, поверхневі мікросудини, морфометричний метод.

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