# **ANATOMICAL PREREQUISITES FOR THE DEVELOPMENT OF RHINOSINUSITIS**

## **Anatomické predpoklady pre rozvoj rinosínusitídy**

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**SUMMARY**

**Introduction:** The size of the middle nasal concha, uncinate process and natural anastomosis is an important parameter in the structure of OMC. The aim of our study was to improve the assessment of the morphological structure of OMC com- ponents according to SCT and to identify features of the ana- tomical structure, potentially associated with the development of complications of chronic inflammatory processes in this area.

**Materials and methods:** The study involved evaluation of a total of 226 spiral computer tomograms (SCTs) of 25 – 60-year-old males and females (115 males and 111 fe- males), divided into groups according to the severity of abnor- mal changes in PNSs. The length of the uncinate process, the width of the middle nasal concha and the dimensions of the natural anastomosis were determined.

**Results:** The study showed a significant (p = 0.04) reduction of bone density in the uncinate process with chronic inflam- matory process in the maxillary sinus accompanied by hyper- plasia of the mucous membrane to 5 mm. Haller cell was determined in 7 (3.097 %) patients. Its presence was accom- panied by mucosal hyperplasia in all cases. The average vol- ume of Haller cell was 7.42 ± 2.6 mm3 in the average anasto- mosis size in patients with Haller cell of 3.32 ± 0.82 mm.

**Conclusions:** SCT is an intravital, non-invasive and informative method for determination of the features of the OMC struc- ture. Features of the anatomical structure of OMC can be associated with hypoventilation of the maxillary sinus and the development of chronic inflammatory process.

**Key words:** osteomeatal comlex, computed tomography, un- cinate process, natural anastomosis, Haller cell.

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**SÚHRN**

**Úvod:** Veľkosť strednej nosovej mušle, háčikového výbežku a prírodnej anastomózy je dôležitým parametrom štruktúry ostiomeatálneho komplexu (OMK). Účelom našho výskumu bolo zlepšiť hodnotenie morfologickej štruktúry komponentov OMK pomocou výsledkov špirálovej počítačovej tomografie a zistiť vlastnosti anatomickej štruktúry, ktoré sú potenciálne nebezpečné pre vývoj komplikácií chronických zápalových procesov v tejto oblasti.

**Materiál a metódy:** Výskum zahŕňal 226 špirálových počítačových tomografov (ŠPT) 25- až 60-ročných mužov a žien (115 mužov a 111 žien), ktoré boli rozdelené do skupín so závažnosťou patologických zmien v paranazálnych dutinách. Bola zístená dĺžka háčikového výbežku, šírka strednej nosovej mušle a veľkosť prírodnej anastomózy.

**Výsledky:** Výskum preukázal významné (p = 0,04) zníženie hustoty kostného tkaniva v háčikovom výbežku pri hyperplázii sliznice na 5 mm. Hallerova bunka bola identifikovaná u 7 (3,097 %) pacientov. Jej prítomnosť bola sprevádzaná hyperpláziou sliznice vo všetkých prípadoch. Priemerný objem Hallerovej bunky bol 7,42 ± 2,6 mm3 s priemernou veľkosťou anastomózy u pacientov s Hallerovou bunkou 3,32 ± 0,82 mm.

**Závery:** ŠPT – je životná, neinvazívna a informačná metóda určovania charakteristík OMK. Zvláštnosti anatomickej štruktúry OMK môžu viesť k hypoventilácii hornej čeľustnej dutiny a rozvoju chronického zápalového procesu.

**Kľúčové slová:** osteomeatálny komplex, počítačová tomografia, háčikový výbežok, prírodná anastomóza, Hallerova bunka.

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### Introduction

The anatomical structure of human osteomeatal complex (OMC) components is of exceptional impor- tance in otorhinolaryngology (7). The size of its com-

ponents, such as the middle nasal concha, uncinate process and natural anastomosis, is an important para- meter in the structure of OMC osseous tissue. These structures determine the conditions for the physiological

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ventilation of the paranasal sinuses. A decrease in OMC osseous tissue density is one of the signs of chronic acute rhinosinusitis.

These parameters of OMC structure acquire es- sential importance due to the high incidence of dis- eases of the upper respiratory tract in general and the paranasal sinuses in particular. In addition, there is a tendency towards an increase in the number of chronic cases of rhinosinusitis and development of complications of chronic inflammatory processes in paranasal sinuses. However, the study of the anatom- ical structure and physiological function of OMC components presents difficulties to this day. Currently, there is a method of intraoperative determination of air flow velocity via OMC, but this procedure is inva- sive and is performed directly during surgery, present- ing inconvenience for a physician who is unable to determine the extent of surgery prior to operation (19). Invasiveness of the process is a disadvantage for patients.

Recently, rapid development of computed tomogra- phy (CT) has induced a new trend in the study of this anatomical area. This method of research is used to determine particular characteristics of the structure of the paranasal sinuses and OMC area at the pre-opera- tive stage and to identify the factors potentially danger- ous for the development of complications and to cor- rect them during surgery.

In view of all the above, the aim of our study was to improve the assessment of the morphological struc- ture of OMC components according to SCT and to identify features of the anatomical structure, potentially dangerous for the development of complications of chronic inflammatory processes in this area.

### Material and methods

A retrospective research was performed using a total of 226 spiral computer tomograms (SCTs) of 25 – 60-year-old males and females (115 males and 111 females) for 2 years (2018 – 2019). All the patients were consulted at the Department of Otorhinolaryngology of Kharkiv Regional Hospital. All the patients were divided into groups. Group 1 con- sisted of subjects who underwent a SCT study per- formed for reasons unrelated to ENT diseases (suspect- ed stroke, etc.) (Tab. 1).

Group 2 comprised patients with hyperplasia of the mucous membrane of the maxillary sinus up to 5 mm according to SCT, as the main marker of its hy- poventilation (6). Presence of any other abnormalities as defined by SCT served as exclusion criteria. The fol- lowing parameters of OMC structure were determined in all the study groups: the length of the uncinate pro- cess, the width of the middle nasal concha, the dimen- sions of the natural anastomosis (Tab. 2), and the min- imum density of the uncinate process. Significant attention was paid to the minimum density indicator, potentially dangerous for the development of compli- cations.

**Figure 1. Osteomeatal complex components in the physiological state of the paranasal sinuses.** Coronary reconstruction (1 – unci- nate process, 2 – middle nasal concha, 3 – natural anastomosis). In addition, attention was paid to anatomical formations associated with the narrowing of the natural anastomosis, particularly to Haller cell. **Obrázok 1. Komponenty osteomeatálneho komplexu vo fyziologickom stave paranazálnych dutín** (PD)**.** Koronárna sekcia (1

– háčikový výbežok, 2 – stredná nosová mušľa, 3 – prírodné spojenie).



**Figure 2. SCT.** Coronary reconstruction. Osteomeatal complex (yellow indicates Haller cell, red indicates natural anastomosis).

**Obrázok 2. CKT.** Koronárna sekcia. Osteomeatálny komplex (šípka hore označuje Hallerovu bunku, šípka dole prirodzené spojenie).

SCT study was performed using Toshiba Aquilion-4 multisection CT scanner, Japan. RadiANT DICOM Viewer 4.6.9. (64bit) was used to determine our mea- surements as a simple, fast DICOM viewer for medical images. Osseous tissue density was calculated using the Hunsfield scale, considering that according to Hofer, the air density was 1000 Hu and the water density was 0 Hu.

Findings were processed using the methods of vari- ation statistics. Correspondence of distribution to nor- mal one was determined by Shapiro–Wilk`s test. The statistical data are presented in M ±  format, where M is the arithmetic mean, and  is the standard devia- tion. Correlation analysis was performed using Spearman

rank correlation coefficient. The statistical difference be- tween the studied values was considered significant at p < 0.05.

The volume of Haller cell was identified by deter- mining the sum of the area of the shapes that it formed on each slice multiplied by the slice thickness.

The study complies with Helsinki Declaration re- quirements. All the patients were informed of their par- ticipation in the study, having obtained written informed consent to participation. The study was approved by the Bioethics Committee of Kharkiv National Medical University.

**Table 1. Distribution of patients by age and sex. Tabuľka 1. Rozdelenie pacientov podľa veku a pohlavia.**

the average natural anastomosis size in patients with Haller cell of 3.32 ± 0.82 mm (Tab. 3).

**Figure 3. Means with confidence intervals.**

**Obrázok 3. Graf priemerných intervalov s intervalmi spoľahlivosti.**

**Diagram with confidence interval**

6

5

4

3

2

1

0

### Results of the study

20

0

|  |  |  |
| --- | --- | --- |
| **Age groups** | **Men** | **Women** |
| Subjects with- out determined abnormalities | Hyperplasia of mucous membrane | Subjects without deter- mined abnor- malities | Hyperplasia of mucous membrane |
| 25 – 44 | 24 | 29 | 29 | 21 |
| 44 – 60 | 25 | 37 | 27 | 34 |
| **Total** | **115** | **111** |

-20

-40

-60

-80

-100

-120

-140

**Diagram with confidence interval**

Results of the calculation of the studied parameters are shown in Table 2.

**Table 2. Dimensions of the middle nasal concha, uncinate process and natural anastomosis.**

**Tabuľka 2. Veľkosť strednej nosovej mušle, háčikového výbežku a prírodného spojenia.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter under study** | **Width of the middle nasal concha** | **Length of the uncinate process** | **Dimensions of the natu- ral anasto- mosis** | **Minimum density of the unci- nate pro- cess** |
| Subjects without determined abnormali- ties | M, mm | 3.22 | 1.3 | 5.2 | –69.5 |
|  | 1.2 | 0.7 | 1.004 | 97 |
| Hyperplasia of mucous membrane | M, mm | 6.77 | 3.3 | 3.91 | 93.5 |
|  | 3.3 | 1.04 | 0.92 | 114 |

Calculation showed that patients with thickening of the mucous membrane of the maxillary sinus as defined by SCT had a significant increase in the size of the middle nasal concha (p = 0.0016) (Fig. 3).

The study identified a significant (p = 0.04) reduc-

tion of bone density of the uncinate process with

A. Thickness of the middle nasal concha. B. Density of the uncinate process

**Table 3. Indicators of Haller cell volume and size of natural anasto- mosis.**

**Tabuľka 3. Ukazovatele hodnoty objemu Hallerovej bunky a veľkosti prirodzeného spojenia.**

|  |  |  |
| --- | --- | --- |
| **Indicators** | **M** |  |
| Haller cell volume | 7.42 | 2.6 |
| Anastomosis width | 3.32 | 0.82 |

The study showed a significant (p = 0.01) strong negative correlation between Haller cell volume and anastomosis size (Fig. 4).

**Figure 4. Correlation between the size of Haller cell and natural anastomosis.**

**Obrázok 4. Ukazovatele hodnoty objemu Hallerovej bunky a veľkosti prirodzeného spojenia.**

5

y = -0,3161x + 5,6684

4,5

4

**Haller cell volume, mm2**

3,5

3

2,5

chronic inflammatory process in the maxillary sinus accompanied by hyperplasia of the mucous membrane to 5 mm.

In addition, Haller cell was determined in 7 (3.097 %) patients. The presence of Haller cell in all cases was accompanied by mucosal hyperplasia. The average volume of Haller cell was 7.42 ± 2.6 mm3 in

2

1,5

1

0,5

0

0 5 10 15

**Natural anastom osis,m m**

### Discussion

Morphological structure of the bone tissue is impor- tant parameter for physiological state of PNSs and OMC (19).

Noninvasive detection of internal intravital peculiar- ities is extremely important for human organism mor- phology and function (11) with nonobligatory linear- feedback connection (10). Adherence to the principle of non-invasive investigation is so important that the study of processes in the human body is often replaced by modeling or experiments (3, 9, 15, 18). Spiral com- puted tomography is one of the “gold standard” meth- ods used to provide a detailed, intravital and informa- tive study of the anatomical structure and anthropometric peculiarities (5).

The study identified the parameters of the structure that can affect the functional state of the osteomeatal complex components. Calculation of the average di- mensions of the uncinate process, middle nasal concha and natural anastomosis showed a significant increase in the transverse dimensions of the middle nasal concha in patients with mucosal hyperplasia up to 5 mm, sug- gesting that this parameter could play a significant role in sinus ventilation among all OMC components. Therefore, otorhinolaryngologists may find it more ap- propriate to pay attention to the structure of the middle nasal concha and combine surgical treatment with par- tial resection of the area to improve sinus ventilation. Calculation of the size of the middle nasal concha also suggested that an increase in its transverse size by

* 1. % could result in the narrowing of the natural anastomosis between the maxillary sinuses and, as a consequence, be associated with a decrease in ven- tilation. The findings also suggest that a 24.8 % de- crease in the natural anastomosis size could result in sinus hypoventilation with catarrhal changes in this area. In 56 patients (24.58 %) the size of the natural anastomosis was less than 4 mm, which made endo- scopic access impossible due to the parameters of the endoscope structure. In these cases, it might be more appropriate to give preference to another type of surgi- cal access (if possible through a hole in the tooth or

even via microscopic maxillary sinusotomy).

In the course of the study in catarrhal maxillary sinusitis, a significant decrease in the density of the un- cinate process was also compared with the physiologi- cal condition, which can serve as a marker of a patho- logical process in the paranasal sinuses. This fact is also confirmed by some other studies (17), in particular when calculating the density of the uncinate process in acute recurrent rhinosinusitis. In contrast to this study, the abovementioned research involved calculation of the density of the uncinate process in chronic maxillary rhinosinusitis, which was not noted by the authors.

As is known, according to Dong et al., inflamma- tory processes in PNSs occur not only in pathomorpho- logical changes in its mucous membrane, but also affect the osseous tissue of its walls, inevitably entailing such significant changes as bone alteration, manifested by

demineralization, disappearance of trabeculae, focal sclerosis and cortical destruction (8, 2, 16). It can be assumed that the severity of these changes correlates with the severity of the pathological process in the sinus and oral cavity (4, 12, 1).

In our study, attention was paid to calculating the minimum density, which is especially dangerous for the development of complications. However, in the previ- ous studies, we calculated this parameter using uncer- tainty calculation (13, 14). It should also be noted that the density index is quite variable and may vary de- pending on age and gender, presents of dental disor- ders (20).

We detected Haller cell in 3.97 % cases and deter- mined its volume. Interestingly, its presence was accom- panied by pathological changes in the sinus in all cases. Therefore, it can be assumed that this additional ana- tomical formation promotes hypoventilation of the sinus and creates optimal conditions for pathological changes in the maxillary sinus. Moreover, a strong significant negative correlation (r = –0.97) was found between the size of the natural anastomosis and the volume of Haller cell.

This study is of great practical importance for doc- tors of various specialties. In all cases SCT study should become the gold standard for diagnosing almost all forms of rhinosinusitis, especially when it comes to chronic forms. Knowing the structural features, the rela- tive positions of the structures of the ostiomeatal com- plex, the presence or absence of additional formations in the anastomosis region, it is possible to predict the possibility of the development and course of rhinosinus- itis. Thus, a family doctor examining a patient with a narrowing of the natural connection between the nasal cavity and paranasal sinuses, revealed by SCT find- ings, can promptly refer this patient to the otolaryngol- ogist, where the necessary volume of treatment will be quickly and efficiently performed, which can improve the prognosis for the course of the disease and prevent the development of complications.

Dentists should also be cautious. We can assume that it is more expedient to treat odontogenic maxillary sinusitis in patients with narrowing of the natural anas- tomosis together with an otolaryngologist.

Of course, this study is of particular value to otolar- yngologists. Since the anatomical structure of the osteo- meatal complex is a key zone for predicting the occur- rence, further development, and course of inflammatory diseases in the paranasal sinuses. Knowledge of the structure of this area also makes it possible to predict the risks of complications and choose the most effec- tive treatment. As can be seen from our study, in some cases the dimensions of the natural anastomosis are less than 4 mm, which makes it impossible to conduct en- doscopic access in the treatment of chronic or acute inflammatory processes in paranasal sinuses. In these cases, it may be preferable to give another access (mi- croscopic maxillary sinusotomy or access through the alveolar socket in odontogenic maxillary sinusitis). A sig-

nificant decrease in the density of the uncinated pro- cess can become a marker of the development of the chronic inflammatory process in the paranasal sinuses and one of the indicators for the differential diagnosis between the acute and chronic form. Therefore, know- ing the density of the uncinated process, we can sus- pect the chronicity of rhinosinusitis.

The sizes of the elements of the osteomeatal com- plex can help solve the question of the advisability of expanding the anastomosis by partial resection or plas- tic surgery of its components. Visualization of the Haller cell almost always leads to a narrowing of the anasto- mosis, proportional to the size of the specified cell. Thus, when imaging large Haller cells, the physiological functioning of the anastomosis will be reduced, result- ing in hypoventilation of the sinuses with the develop- ment of rhinosinusitis. Such patients constitute a special cohort of patients in terms of the risk of rhinosinusitis.

### Conclusions

SCT is an intravital, non-invasive and informative method for determination of the features of the OMC structure. Features of the anatomical structure of OMC can be associated with hypoventilation of the maxillary sinus and the development of chronic inflammatory process in this area.\*

**\*Compliance with Ethics Requirements:** The authors declare no conflict of interest regarding this article. The authors declare, that all the procedures and experiments of this research respect the ethical standards in the Helsinki Declaration of 1975, as revised in 2008 (5), as well as the national law.

**Conflict of interest**: The authors declare no conflict of interest.

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