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Evaluation of mucociliary clearance in the postoperative period after a maxillary sinus surgery

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Abstract

Aim – evaluation of the local function of the mucociliary clearance (MCC) in the postoperative period in patients with foreign bodies in the maxillary sinuses, who have undergone various surgical treatment.

Material and methods. Using an original analysis technique for high-speed digital video recording of a microscopic picture of a specimen, obtained by brush biopsy from specific regions of the nasal cavity and paranasal sinus under endoscopic control, the MCC of the nasal mucosa was evaluated in the control group (n=60) and in the group of patients, who received various surgery (n=60) of maxillary sinuses.

Results. We obtained the data on persistent and apparent local MCC disorders in the field of the surgical intervention in the postoperative period.

Conclusion. Surgical interventions with access not in the area of the natural ostium of the maxillary sinus are more gentle, since they do not injure the mucociliary clearance in the key region – the ostium.

Keywords: mucociliary clearance, maxillary sinus, foreign bodies in maxillary sinus, endoscopic antrostomy, endoscopic transmaxillar antrostomy.

Conflict of interest: nothing to disclose.

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Исследование мукоцилиарного клиренса в послеоперационном периоде при различных вмешательствах на верхнечелюстной пазухе

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Аннотация

Цель – оценка локальной функции МЦК в послеоперационном периоде у больных с инородными телами верхнечелюстных пазух при различных способах проведения хирургического вмешательства на верхнечелюстной пазухе.

Материал и методы. С помощью оригинальной методики анализа высокоскоростной цифровой видеозаписи микроскопической картины препарата, полученного путем браш-биопсии из интересующих зон полости носа и околоносовых пазух под эндоскопическим контролем, проведена оценка МЦК слизистой полости носа в контрольной группе (n=60) и в группе больных после хирургических вмешательств (n=60) по поводу инородных тел верхнечелюстных пазух.

Результаты. Получены данные, свидетельствующие о развитии стойких и выраженных локальных нарушений МЦК в области оперативного вмешательства в послеоперационном периоде.

Выводы. Хирургические вмешательства с доступом не в области естественного соустья верхнечелюстной пазухи являются более щадящими, так как не изменяют мукоцилиарный клиренс в ключевой зоне – в области соустья.

Ключевые слова: мукоцилиарный клиренс, верхнечелюстная пазуха, инородные тела верхнечелюстных пазух, эндоскопическая антростомия, эндоскопическая трансмаксиллярная гайморотомия.

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МЦК – мукоцилиарный клиренс; FESS – Functional Endoscopic Sinus Surgery.

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INTRODUCTION

Mucociliary clearance (MCC) represents a non-specific mechanism that provides local protection to the respiratory mucosa from external influences, including infection. The main protective function of the nose and paranasal sinuses is implemented by the mucous membrane, which is covered with pseudostratified epithelium consisting of ciliated, goblet, as well as short and long intercalary epitheliocytes. MCC is damaged in various processes, both acute and chronic [1, 2, 3]. In addition, there are known diseases that are characterized by congenital defects of the human epithelium ciliated system. Furthermore, various drugs also affect the MCC (for example, intranasal decongestants increase by several folds the time of mucociliary transport).

The development of chronic processes in the nasal cavity and paranasal sinuses is primarily associated with the defects in the MCC system of the mucous membrane in the nasal cavity and paranasal sinuses. Impairment of the evacuation of discharge from the sinuses, as well as dysfunction of the anastomoses, represents a scientifically proven basis for the development of endonasal sparing rhinosurgical techniques, in particular, the so-called Functional Endoscopic Sinus Surgery technique, which has been widely implemented worldwide in recent decades [3, 4, 7].

However, it is quite challenging to monitor the MCC in vivo. Few studies have investigated the MCC, especially in the area of the paranasal sinuses and nose. The available Russian fundamental study [1] describes methods of studying the MCC at the micro level and provides data on MCC changes in various pathologies, but there is no data about MCC studies during rhinological surgeries and in the postoperative period. Concurrently, most rhinologists are well aware of such problems as excessive formation of crusts and the specific local accumulations of mucus on the nasal mucosa are detected locally during endoscopic examination in certain areas in a number of patients after interventions on the nasal cavity and paranasal sinuses. The issues on MCC formation during the postoperative period in the nasal cavity have not been sufficiently studied [7].

One of the most important studies in this area was presented by Finnish scientists. In 2006, J. Myller et al. published the results of their study [7], which measured MCC parameters in 27 patients with chronic and acute recurrent rhinosinusitis. The patients underwent surgery, and in some cases, the removal of the uncinate process and antrostomy were performed, while in other cases, only antrostomy was performed. The MCC study was conducted using sterile human albumin labeled with technetium-99, and the shooting was performed with a gamma camera for 40 minutes. The labeled material was injected into the maxillary sinus by puncture in the lower nasal passage (total radiation dose 40 μCi for bilateral examination). The authors showed that, on average, MCC activity reaches 87.2% of the normal during surgery with the removal of the uncinate process and 94.2% with antrostomy. Three cases were recorded when the MCC activity was less than 50% of the norm, two cases during the intervention with the removal of the uncinate process, and one case with antrostomy. It is interesting to note that similar results were achieved during examination nine months after surgery. In the study immediately after it, in approximately half of the cases (51.9% in each of the 14 cases, respectively), MCC was not only below the normal, but also showed no movement of the labeled substance as a whole during the entire 40 minutes. The authors concluded that the endoscopic intervention had a significant effect on the restoration of the functional state of the mucous membrane in the paranasal sinuses. They also reported that there was a comparatively low significance, whether the surgery was performed with the uncinate process resection or without it. In addition, in the conclusion, they noted that the restoration of the MCC almost never occurs to the average normative values according to the used method of measuring MCC and never exceeds them.

According to the data of Elwany S and Hisham M [8] obtained using the saccharin test, in the group of patients with chronic rhinosinusitis, the MCC time was 37.0 ± 15.7 min, while it approached on average to normal values and amounted to 20.3 ± 7.5 min after surgery.

A.J. Bizaki, et al. [9] performed a large-scale comparison of MCC in patients who underwent an endoscopic intervention in the maxillary sinuses, as well as balloon dilatation of the ostium of the maxillary sinuses. A gamma camera and human albumin labeled with technetium-99 were used to study MCC, as well as a saccharin test and an endoscopic technique with the use of methylene blue. Subjectively, the results of the surgical interventions were assessed using the SNOT-22 questionnaire. The authors noted statistically significant differences in these groups in assessing the subjective state (not in favor of endoscopic interventions); MCC studies have shown no significant difference between the different approaches. It was also noted that the saccharin test does not completely reproduce the data obtained using the labeled agent or endoscopic examination with methylene blue, and these differences were statistically significant.

Thus, in the contemporary literature, the issue of the state of the mucous membrane and MCC in the postoperative period is not widely covered; moreover, the available data is contradictory. The conventional assessment of MCC using the saccharin test is seldom applicable in this case, since this refers to its local changes in certain sites of the nasal cavity, which cannot be evaluated using this method.

AIM

The study aimed to assess the local MCC function in the postoperative period among patients with foreign bodies of the maxillary sinuses using various methods of surgical intervention in the maxillary sinus.

MATERIAL AND METHODS

We have developed a modern method for assessing MCC using a contemporary high-speed digital video recording of the microscopic presentation of the preparation with its subsequent mathematical processing.

Image registration was performed in transmitted light using a Zeiss microscope and a Zeiss 100/1.25 field lens with a numerical aperture and oil immersion. The light source is a 1 W green light-emitting diode installed in an illuminator with a plastic collector lens. The illuminator is placed under the stage of the microscope in such a way that the image of the light-emitting diode is projected using the collector lens into the plane of the iris aperture diaphragm of the microscope's achromatic condenser. The maximum numerical aperture of the condenser (at fully open diaphragm) is 0.65. A photograph of the apparatus is presented in **Figure 1**.

The image of ciliated epithelial cells was recorded using a digital complementary metal oxide semiconductor camera acA 1920–155um (Basler, Germany) with a maximum image resolution of 1920 × 1200 pixels at a frame rate of 164 frames per second. The size of one pixel corresponds to 5.86 × 5.86 microns in the object plane of the microscope. The camera was controlled using a software developed in the LabVIEW environment. To measure the ciliary action frequency, the image size was reduced to 200 × 200 pixels. Also, the frame rate was increased to 400 frames per second.

A series of 4000 frames with the duration of 10 seconds was used for measurements. This enables ciliary action measurements of up to 200 Hz with a frequency resolution of 0.1 Hz. The recorded series of images was processed using a specially developed program. The processing algorithm includes the following operations.

1. Loading a series of 4000 images into the computer memory.
2. Selection by the operator of the site of interest, namely the image area within which the ciliary action frequency is measured.
3. Construction of sequences of the changes in the brightness of each pixel in time (for example, for a site of 10 × 10 pixels, 100 rows of 4000 points in each are plotted).
4. Calculation of modified periodograms with a Hanning window for each series using the fast Fourier transform algorithm.
5. Construction of an estimate of the power spectrum of the pixel brightness fluctuations within the region of interest as an average of the modified periodograms.
6. Detection of peaks in the power spectrum.
7. Isolation of the peak corresponding to the fundamental frequency of the cilia oscillations (first harmonic).

A general view of our software is presented in **Figure 2**.

Рисунок 1. *Общий вид установки для исследования МЦК.*
Figure 1. *General view of the facility for MCC analysis.*

A series of video images of cilia are presented in Figure 3.

A separate area for researching video recording frames marked in the software is presented in Figure 4.

The study included 60 patients with foreign bodies of the maxillary sinus. The study group included patients aged 18–50 years old, and their foreign bodies in the maxillary sinuses were exclusively due to previous endodontic interventions on the teeth of the upper jaw.

The study excluded patients with a history of chronic diseases of the paranasal sinuses, as well as with burdened allergic anamnesis. The disease duration was from 1 month to 3 years. The patients were divided into two equal groups of 30 people, each of which underwent surgical treatment. In group I, patients underwent surgery using the endoscopic endonasal approach to

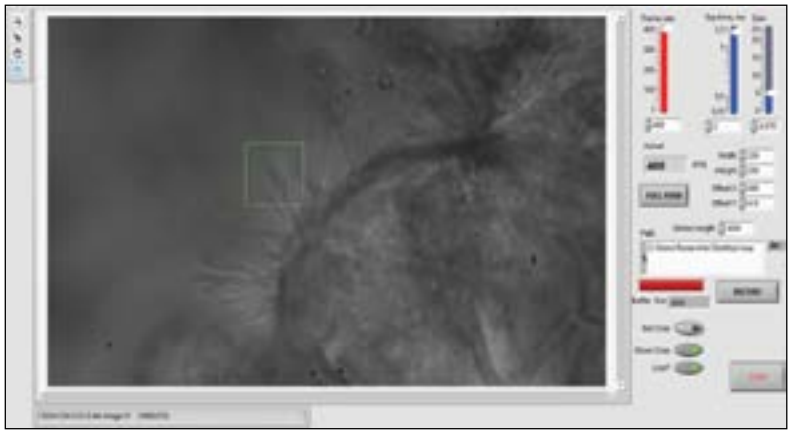

Рисунок 2. *Вид ПО для исследования МЦК, разработанного нами.*
Figure 2. *Software for MCC analysis, developed by the authors.*

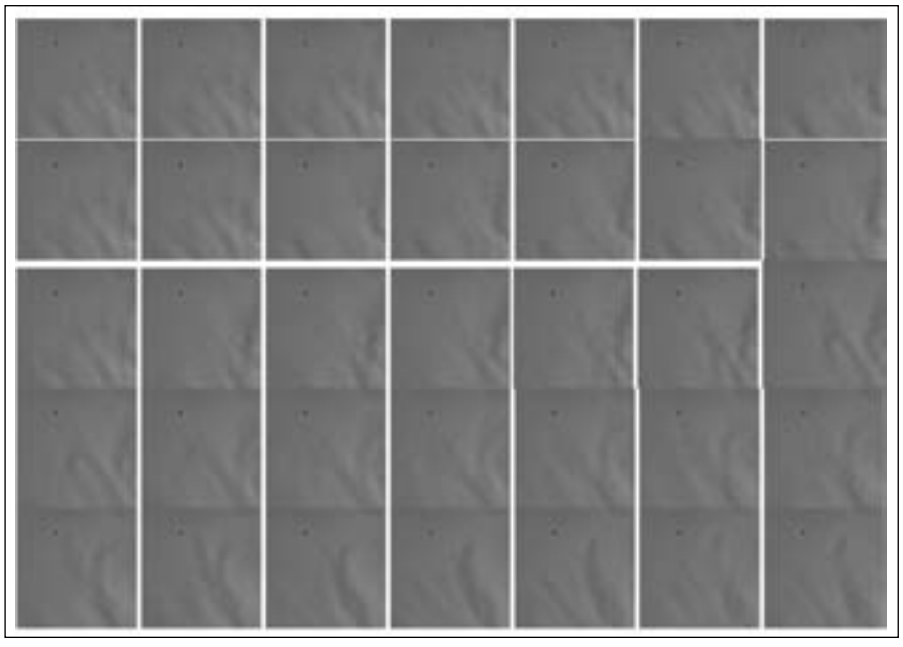

Рисунок 3. *Серия кадров микроскопической цифровой записи цилиарного эпителия.*
Figure 3. *A series of shots of microscopic digital recording of the ciliary epithelium.*

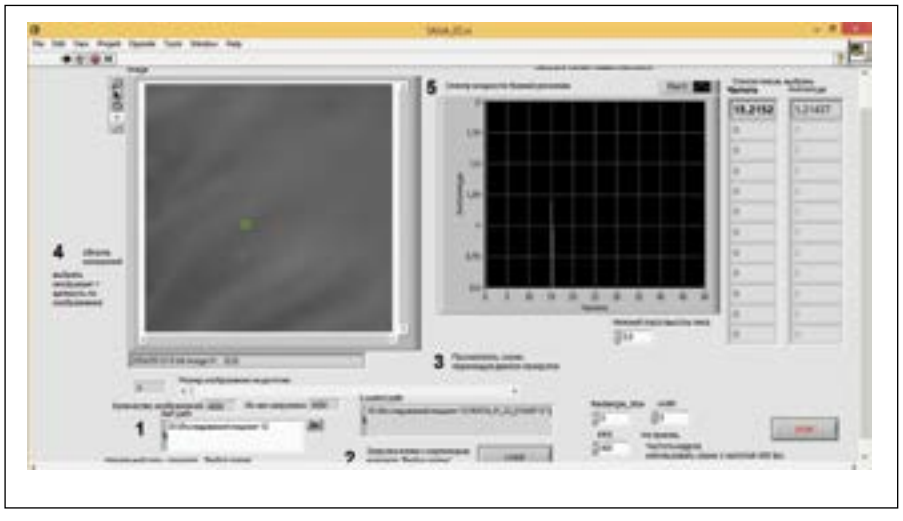

Рисунок 4. *Выделенная для обработки область кадра с изображением цилиарного эпителия.*
Figure 4. *The area of the shot with the image of the ciliary epithelium, selected for processing.*

the maxillary sinus (endoscopic antrostomy). In group II, access to the maxillary sinus was performed using endoscopic transmaxillar antrostomy (using the Storz trocar or VS Kozlov–VN Krasnozhen funnel).

The control group consisted of 60 healthy individuals without any pathology of the nasal cavity and paranasal sinuses. The control group included individuals based on voluntary informed consent, after an endoscopic examination of the nasal cavity, which revealed the absence of obstacles to taking a brush biopsy from the middle meatus.

Brush biopsy sample was taken under endoscopic guidance from the nasal mucosa of the area of the natural ostium. Straight and curved Storz brushes, as well as Olympus, Bioline, etc. were used. The intake of vasoactive drugs and smoking were forbidden during several hours prior to the study.

RESULTS AND DISCUSSION

The results of the study are presented in **table 1** (data are presented one month after the surgery in groups I and II) and in **table 2** (data four months after the surgery in groups I and II).

According to our data, a significant decrease was noted in MCC indicators in the early postoperative period (after 1 month) in patients operated on by endoscopic antrostomy (group I). The revealed difference in MCC value between the control group and group I was statistically significant (t_{noted} = 2.02, p = 0.46 with the number of degrees of freedom f = 88; t_{table} = 1.99 with a significance level of p = 0.05). There were also statistically significant differences between groups II and I (t_{noted} = 2.09, p = 0.41 with the number of degrees of freedom f = 58; t_{table} = 2.00 with a significance level of p = 0.05).

In the group II patients who underwent surgery by transmaxillar endoscopic antrostomy using a trocar or funnel, no statistically significant changes in MCC indices relative to the control group were registered (tnoted = 0.26, p = 0.79 with the number of degrees of freedom f = 88; ttable = 1.99 with a significance level of p = 0.05).

A decrease in these indicators was also noted in the patients of group I and four months after surgery with a

Group of patients examined	Number of examined patients	Frequency of the first harmonic of the spectrum F, Hz	Mean deviation ± m
Control group	60	11.76	±2.56
Patients after endoscopic antrostomy	30	5.17	±2.46
Patients after transmaxillar antrostomy	30	10.94	±1.89

Таблица 1.*Результаты исследования активности МЦК в послеоперационном периоде у ринологических больных в сравнении с контрольной группой через 1 месяц после оперативного вмешательства*

Table 1. *MCC fucnction study results in the 1 months of postoperative period, in rhinological patients, in comparison with the control group*

Group of examined patients	Number of examined patients	Frequency of the first harmonic of the spectrum F, Hz	Mean deviation ± m
Control group	60	11.76	±2.56
Patients after endoscopic antrostomy	30	6.05	±1.34
Patients after transmaxillar antrostomy	30	11.23	±2.16

Таблица 2. *Результаты исследования активности МЦК в послеоперационном периоде у ринологических больных в сравнении с контрольной группой через 4 месяца после оперативного вмешательства*

Table 2. *MCC fucnction study results in the 4 months of postoperative period, in rhinological patients, in comparison with the control group*

certain tendency to their improvement (**table 2**). In this case, no statistically significant differences were noted between the results of assessing the MCC of groups I and II, although there was quite a large variability in the results of group II.

Thus, we can conclude on the significant influence of surgical interventions on the MCC in the area where the intervention occurred. Local surgical trauma to the mucosa leads to a decrease in the frequency of the ciliary action of the epithelium, an increase in the time of mucus transport in this area, and mucostasis, which contributes to the formation of thicker mucus, followed by the formation of crusts in this area.

Interestingly, the indices of the local MCC improve only partially over time in the postoperative period. These phenomena, when they develop in the key area of the sinus anastomoses, can also contribute to the mild impairment of the evacuation of secretions from the paranasal sinuses. Similar results were obtained by international authors in the study of the restoration of the ciliary epithelium and its functional organization after rhinosurgical interventions [8], as well as in the study of the role of removal of the uncinate process [9].

CONCLUSIONS

Surgical intervention for sinusitis caused by foreign bodies, which represent secondary changes in response to an inflammatory reaction and irritation of the mucous membrane, with no access to the area of the natural sinus ostium, taking into account local changes in the MCC, is in this case more sparing, since it does not impair the transport function of the mucosa in the area of the sinus ostium.

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

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