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The study of local mucociliary clearance of the middle nasal meatus in clinically healthy individuals and patients with foreign body in the maxillary sinus

© Oleg V. Mareev¹, Gleb O. Mareev¹, Igor Yu. Ermakov², Ivan V. Fedosov³

¹Saratov State Medical University named after V.I. Razumovsky (Saratov, Russia)

²SPb Clinical Hospital No.40 (Saint Petersburg, Russia)

³Saratov State University named after N.G. Chernyshevsky (Saratov, Russia)

Abstract

Aim – to obtain the values of local mucociliary clearance (MCC) of the middle nasal meatus in normal conditions and in patients with foreign body in the maxillary sinuses.

Material and methods. To assess the local MCC, we used the original method of modern high-speed digital video recording of the microscopic picture of the specimen, followed by its mathematical processing. The study included a group of rhinologically healthy individuals (60 people) and a group of patients with foreign body in the maxillary sinus (90 people).

Results. We obtained the standard values of MCC in rhinologically healthy individuals (11.76 ± 3.01 Hz). In patients with foreign body in the maxillary sinuses, there was a correlation of the local MCC index with the severity of morphological changes, registered by computed tomography (CT), of the paranasal sinuses in the area of the middle nasal meatus and adjacent sinuses. Depending on the results of CT scanning, we identified 3 groups among the patients with foreign bodies in the maxillary sinuses – no morphological changes (CT1), changes outside the ostium (CT2) and pronounced morphological changes in the middle nasal meatus and surrounding paranasal sinuses (CT3). In the CT1 group the average values of the local MCC of the middle nasal meatus were 13.53 ± 2.46 Hz; in group CT2 – 11.71 ± 2.02 Hz; in the CT3 group – 6.84 ± 3.48 Hz. The differences in indicators in groups were statistically significant according to the Mann – Whitney test. The average value of the local MCC of the middle nasal meatus in patients without maxillary sinus mycetoma was 13.30 ± 2.91 Hz,

in patients having maxillary sinus mycetoma – 10.74 ± 3.69 Hz; this difference was also statistically significant.

Keywords: mucociliary clearance, foreign body in maxillary sinus, rhinology, computed tomography.

Conflict of interest: nothing to disclose.

Citation

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Information about authors

Oleg V. Mareev – PhD, Professor, the Head of the Department of otorhinolaryngology. ORCID: 0000-0002-7240-5651

E-mail: ovmareev@mail.ru

Gleb O. Mareev – PhD, Professor of the Department of otorhinolaryngology.

ORCID: 0000-0002-5906-8080

E-mail: dr-mareev@mail.ru

Igor Yu. Ermakov – otorhinolaryngologist.

E-mail: ermakov1988@inbox.ru

Ivan V. Fedosov – PhD, Associate professor, Department

of Optics and biophotonics. ORCID: 0000-0002-3619-245X

E-mail: fedosov-optics@mail.ru

Corresponding Author

Gleb O. Mareev

Address: Saratov State Medical University, 112 B. Kazachiya st., Saratov, Russia, 410012.

E-mail: dr-mareev@mail.ru

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Исследование показателей локального мукоцилиарного клиренса среднего носового хода у клинически здоровых лиц и больных с инородными телами верхнечелюстной пазухи

© О.В. Мареев¹, Г.О. Мареев¹, И.Ю. Ермаков², И.В. Федосов³

¹ФГБОУ ВО «Саратовский государственный медицинский университет имени В.И. Разумовского» Минздрава России (Саратов, Россия)

²СПб ГБУЗ «Городская больница №40» (Санкт-Петербург, Россия)

³ФГБОУ ВО «Саратовский национальный исследовательский государственный университет имени Н.Г. Чернышевского» Минобрнауки России (Саратов, Россия)

Аннотация

Цель — исследование значений локального мукоцилиарного клиренса (МЦК) среднего носового хода в норме и у больных с инородными телами верхнечелюстных пазух.

Материал и методы. Для оценки локального МЦК использован оригинальный метод современной высокоскоростной цифровой видеозаписи микроскопической картины препарата с последующей ее математической обработкой. В исследование вошли группа ринологически здоровых лиц (60 человек) и группа больных с инородными телами верхнечелюстной пазухи (90 человек).

Результаты. Получены нормативные значения МЦК у ринологически здоровых лиц ($11,76 \pm 3,01$ Гц). У больных с инородными телами верхнечелюстных пазух наблюдалась зависимость показателя локального МЦК от выраженности морфологических изменений на компьютерной томографии (КТ) околоносовых пазух в области среднего носового хода и прилежащих пазух. В зависимости от изменений на КТ были выделены 3 группы среди больных с инородными телами верхнечелюстных пазух — с отсутствием изменений (КТ1), изменениями вне области соустья (КТ2) и выраженными морфологическими изменениями в области среднего носового хода и окружающих околоносовых пазух (КТ3). Для группы с изменениями КТ1 средние значения локального МЦК среднего носового хода составили $13,53 \pm 2,46$ Гц; для группы КТ2 — $11,71 \pm 2,02$ Гц; для группы КТ3 — $6,84 \pm 3,48$ Гц. Различия показателей в группах по данным КТ-исследования статистически значимы по критерию Манна — Уитни. Средние значения локального МЦК среднего носового хода у больных без мицетомы верхнечелюстной пазухи составили $13,30 \pm 2,91$ Гц, с мицетомой верхнечелюстной пазухи

— $10,74 \pm 3,69$ Гц; эти отличия также статистически достоверны.

Ключевые слова: мукоцилиарный клиренс, инородные тела верхнечелюстных пазух, ринология, компьютерная томография.

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Сведения об авторах

Мареев О.В. — д-р мед. наук, профессор, заведующий кафедрой оториноларингологии. ORCID: 0000-0002-7240-5651
E-mail: ovmareew@mail.ru

Мареев Г.О. — д-р мед. наук, профессор кафедры оториноларингологии. ORCID: 0000-0002-5906-8080
E-mail: dr-mareev@mail.ru

Ермаков И.Ю. — врач-оториноларинголог.
E-mail: ermakov1988@inbox.ru

Федосов И.В. — канд. физ.-мат. наук, доцент кафедры оптики и биофотоники. ORCID: 0000-0002-3619-245X
E-mail: fedosov-optics@mail.ru

Автор для переписки

Мареев Глеб Олегович

Адрес: Саратовский государственный медицинский университет, ул. Б. Казачья, 112, г. Саратов, Россия, 410012.
E-mail: dr-mareev@mail.ru

МЦК — мукоцилиарный клиренс;
КТ — компьютерная томография.

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■ BACKGROUND

Mucociliary clearance (MCC) is a nonspecific mechanism that provides local protection of the respiratory mucosa from external influences, including infections [1]. The mucous membrane plays a major protective role in the nose and paranasal sinuses, and it is covered with pseudostratified epithelium consisting of ciliated, goblet, and short and long intercalary epitheliocytes. Mucociliary clearance is damaged in various processes, both acute and chronic [2]. Certain diseases are accompanied by congenital defects in the human ciliary epithelial system. Mucociliary clearance is also affected by various drugs (intranasal decongestants increase the time of mucociliary transport several times) [3, 4].

Impaired evacuation of secretions from the sinuses in the presence of impaired anastomosis is a scientifically substantiated basis for the development of endonasal sparing rhinosurgical techniques, the so-called functional endoscopic sinus surgery, which has been widely introduced worldwide in recent decades.

However, the ability to monitor MCC in vivo is very limited. Not so many studies have focused on the study of MCC, particularly in the area of the paranasal sinuses and nose. A Russian fundamental study [6] described methods for studying MCC at the micro level and provided data on changes in MCC in various pathologies; however, no studies of MCC have provided information during rhinological surgeries and in the postoperative period. Simultaneously, most rhinologists are well aware of problems such as excessive formation of crusts and peculiar local

accumulations of mucus on the nasal mucosa, which are detected locally during endoscopic examination in certain areas in some patients after interventions on the nasal cavity and paranasal sinuses [7]. The issues of MCC formation in the nasal cavity during the postoperative period have not been sufficiently examined [8, 9].

Thus, the study of mucociliary clearance using modern techniques in postoperative rhinological patients appears to be a very relevant and a pressing issue in otorhinolaryngology [10, 11]. Considering the variety of rhinological pathologies, the study theme is the state of MCC of the nasal cavity (middle meatus) under normal conditions and in the presence of foreign bodies in the maxillary sinuses, as well as after various surgical approaches to the maxillary sinus for foreign bodies [12]. The solution to this exact issue is of particular interest in modern otorhinolaryngology because of the constantly increasing incidence of this pathology and its clearly artificial, secondary nature (i.e., occurs in the presence of the deliberate absence of any pathological changes in the MCC). In the discussion about various options for surgical access to the maxillary sinus and their priority, no full-fledged practical answer is justified from the standpoint of mucociliary clearance and its changes.

■ AIM

This study aimed to study the local MCC values of the middle nasal meatus under normal conditions and in patients with foreign bodies in the maxillary sinuses.

MATERIAL AND METHODS

In this study, we assessed the MCC using modern high-speed digital video recording of the microscopic pattern of the specimen with subsequent mathematical processing [13]. The result of the spectral analysis obtained during the processing of a digital video signal is the first harmonic F , whose frequency is expressed in Hz and is a characteristic of the ciliary beating frequency (local MCC). To study the local function of MCC, a brush biopsy was collected from the area of natural anastomosis under endoscopic control. Straight and curved brushes from Storz, Olympus, Bioline, etc., were used. Similar methods for studying local MCC have been described in the modern literature [14, 15]. The intake of vasoactive drugs and smoking was prohibited several hours before the study.

We used high-resolution computed tomography (CT) images obtained using cone-beam tomography. The analysis of the tomograms and their measurements were performed in the freely distributed program Sante DICOM Viewer. Based on the CT results, all patients were divided into three subgroups.

- Group 1 showed a virtual absence of changes in the sinuses or minor changes in the form of local thickening of the mucosa on the walls of the sinus without changes in the area of the anastomosis and middle nasal meatus, and anterior cells of the ethmoidal labyrinth (CT1).

- Group 2 had significant thickening of the walls of the sinuses without changes in the anastomosis area and the absence of a significant reaction from the middle nasal meatus and the anterior cells of the ethmoidal labyrinth (CT2).

- Group 3 had a pronounced productive–proliferative process, obstruction of the sinus anastomosis, concomitant lesions of the cells of the ethmoidal labyrinth or frontal sinus, and the presence of polypous changes in the mucous membrane in the middle meatus (CT3).

This work was performed at the N.P. Simanovsky Otorhinolaryngology Clinic of S.R. Mirotvortsev Clinical Hospital No. 1 of V.I. Razumovsky, Saratov State Medical University. The study was approved by the ethics committee of V.I. Razumovsky Saratov State Medical University, Protocol No. 3 dated November 5, 2019, based on the informed consent for participation in the study, signed by the participant.

Sixty clinically healthy individuals with no pathology of the nasal cavity and paranasal sinuses participated in the study of normal MCC values. All participants underwent CT using modern high-resolution computed tomography images, which confirmed the absence of pathology of the nasal cavity and paranasal sinuses.

The study enrolled 90 patients with foreign bodies in the maxillary sinus. The study group included patients aged 18–50 years whose foreign bodies in the maxillary sinuses were exclusively the result of previous endodontic interventions on the maxillary

teeth. All patients were diagnosed based on high-resolution cone-beam CT data. Patients who had a previous history of chronic diseases of the paranasal sinuses, burdened allergy history, signs of allergic or vasomotor rhinitis in the anamnesis, or hereditary diseases accompanied by defects in mucociliary clearance were excluded from the study. The case history was from 1 month to 9 years.

The results were statistically processed using Microsoft Excel, Statistica software packages, and online statistical calculators. Statistical calculations were performed at a significance level of $\alpha = 0.05$.

RESULTS

The analysis of the normative values of MCC in a group of clinically healthy individuals revealed a normative average MCC value (frequency of the first harmonic of the spectrum) of 11.76 ± 3.01 Hz ($\pm \sigma$, mean square deviation). The specified distribution in the sample was a normal binomial distribution, and the mean and median values were approximately equal. The MCC values are normally highly variable parameters with a range (variation interval) in the sample of 10.18, the minimum MCC value was 6.72 Hz, and the maximum value was 16.90 Hz. The sample was actually symmetrical around the mean value.

The study of MCC value dependence on age is of particular interest. However, when calculating the linear correlation coefficient between age and MCC values, no relationship was found between these parameters (-0.05). Regression analysis in the group also did not find a relationship between age and the MCC value (R -square = 0.002; coefficient at $X_1 = -0.013$).

In patients with foreign bodies in the maxillary sinuses, the normative average local MCC (frequency of the first harmonic of the spectrum) was 10.84 ± 3.80 Hz ($\pm \sigma$, mean square deviation). The specified distribution in the sample is a normal binomial distribution, and the values of the mean and median are approximately equal. Moreover, the MCC values represent normally a highly variable parameter with a range (change interval) in the sample of 17.00; the minimum MCC value was 1.64 Hz, whereas the maximum value was 18.64 Hz. The sample was actually symmetrical around the mean.

If the entire sample of initial values of local MCC of the middle meatus in patients with foreign bodies in the maxillary sinuses was compared with a similar indicator measured in the control group, the differences were statistically insignificant ($t_{\text{case}} = 0.19$, $df = 148$, $t_{\text{table}} = 1.98$, with a significance level α of 0.05). That is, in the general population, the measured index of the initial MCC of the middle nasal meatus in patients with foreign bodies does not differ statistically significantly from that in individuals with no pathology of the paranasal sinuses and is close to the normative values, although it exhibits the highest variability (the range of changes in the index is 1.7 times greater than its average value).

Study group	Average values of local MCC (Hz)	Mean square deviation, G
Control group	11,62	3,01
Patients with a foreign body in the maxillary sinus		
CT1	13,53	2,46
CT2	11,71	2,02
CT3	6,84	3,48

Table 1. Average values of the local MCC of the middle nasal meatus in different study groups

Таблица 1. Средние значения локального МЦК среднего носового хода в различных группах исследования

Thus, this indicator must be compared between the main study groups and divided into appropriate subgroups according to the stages of changes detected on CT of the paranasal sinuses. This will enable us to identify the main factors influencing the initial MCC of the middle nasal meatus.

CT revealed the following changes in the maxillary sinus. In 24 (30.0%) patients, changes in the sinuses were minimal, such as insignificant infiltration of the sinus mucosa adjacent to the location of the foreign body (CT1). In 39 (26.7%) patients, changes were noted in the sinuses, such as significant thickening of the mucous membrane both at the location of the foreign body and at other walls of the maxillary sinus (CT2). In 37 (43.3%) patients, significant changes in the maxillary sinus were registered with pronounced polyposis, infiltration, and thickening of the mucous membrane up to the complete obliteration of the maxillary sinus lumen. Changes were also noted in the area of the ethmoidal labyrinth, frontal sinus, and middle meatus (CT3). Mycetoma in the maxillary sinus (layered structures of variable density filling its lumen entirely or partially) was registered in 67 cases (74.4%) and was discovered during surgery.

The initial values of local MCC when distributed into groups depending on the process stage, recorded according to CT data, are presented in **Table 1**. With such a grouping, the data on local MCC of the middle nasal meatus are significantly different. A graphical representation of the distribution by the level of the initial value of the local MCC by group is presented in **Fig. 1**.

This data presentation clearly demonstrates the difference in the initial values of the local MCC of the middle nasal meatus in patients with foreign bodies and its dependence on changes recorded on CT.

The significance of differences in the obtained data in the initial level of local MCC of the middle nasal meatus depending on the CT stage of the process was analyzed using the Mann–Whitney U test (**Table 2**).

In most cases, the differences between the control and study groups of patients with foreign bodies in the maxillary sinuses, depending on the CT stage of the process, are statistically significantly different. The greatest differences were noted in all groups with the CT3 subgroup.

	Control group	CT1	CT2
CT1	0,01442* $p(x \leq Z) = 0.007208$		
CT2	0.7679 $p(x \leq Z) = 0.616$	0.003097* $p(x \leq Z) = 0.9985$	
CT3	0,0000038* $p(x \leq Z) = 1$	0.0000069* $p(x \leq Z) = 1$	0.000076* $p(x \leq Z) = 1$

Table 2. The statistically significant differences between the main study groups according to the Mann – Whitney criterion (values of p and p_{crit}), significant values marked with *

Таблица 2. Статистическая значимость различий между основными группами исследования по критерию Манна – Уитни (значения p и $p_{крит}$), значимые отмечены *

The dependence of the initial level of local MCC of the middle nasal meatus on the presence of mycetoma in the maxillary sinus, recorded according to CT data, is presented in **Figure 2**.

The average values of local MCC of the middle meatus in patients without mycetoma of the maxillary sinus were 13.30 ± 2.91 and 10.74 ± 3.69 Hz, respectively. According to the Mann–Whitney test ($p = 0.00004113$), differences in the level of local MCC of the middle nasal meatus in the presence of mycetoma in the maxillary sinus were significantly different from the MCC values in its absence ($p(x \leq Z) = 0.00002057$).

When considering the dependence of the initial values of the local MCC of the middle nasal meatus on age in the control group, the linear correlation coefficient was 0.12, indicating the absence of a relationship between age and the local MCC of the middle nasal meatus. A univariate regression analysis in the group also showed the absence of a relationship between age and MCC value ($R\text{-square} = 0.015$; coefficient at $X1 = -0.396$).

The average values for the distribution of initial values of local MCC of the middle nasal meatus by age group in patients with foreign bodies in the maxillary sinus are presented in **Table 3**.

Graphically, the level of the average value of the initial MCC of the middle nasal meatus in patients is presented in **Fig. 3**.

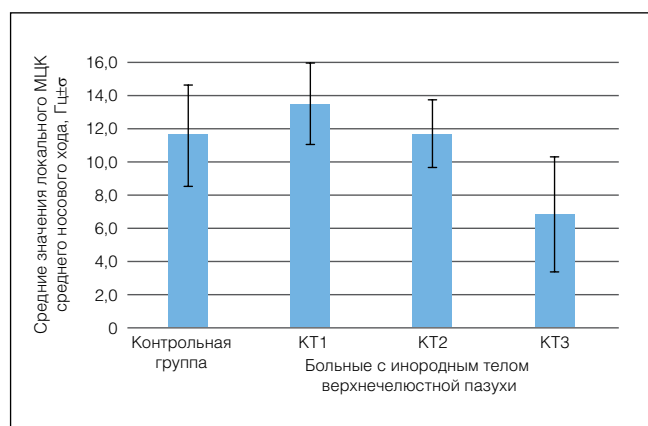


Figure 1. The average level of local MCC of the middle nasal meatus in the main study groups ($M \pm G$, Hz).

Рисунок 1. Средний уровень локального МЦК среднего носового хода в основных группах исследования ($M \pm G$, Гц).

Age groups	< 30	30–39	40–49	50–59	60 >
Number of patients examined	19	19	25	21	5
Frequency of the fundamental harmonics of the spectrum (Hz)	11,43	11,10	10,26	11,12	9,28
$\pm \sigma$	3,25	3,85	4,08	4,15	3,16

Table 3. Mean initial values of local MCC in the distribution of patients with foreign bodies in the maxillary sinuses by age
Таблица 3. Средние исходные значения локального МЦК при распределении больных с инородными телами верхнечелюстных пазух по возрастным группам

DISCUSSION

The normative average local MCC (frequency of the first harmonic of the spectrum F) in our study was 11.76 ± 3.01 Hz ($\pm \sigma$, mean square deviation). The values of local MCC are normally highly variable parameters with a range (variation interval) in the sample of 10.18; the minimum and maximum MCC values were 6.72 and 16.90 Hz, respectively. According to the literature [4, 5, 7, 9, 13, 14, 15], the ciliary beat frequency has a normal range of 7–12 Hz. Although some authors consider MCC age-dependent, no relationship was found between the normative indicators of MCC and age in clinically healthy individuals.

Based on the literature data, which noted a statistically significant decrease in MCC in smokers, smokers were excluded from the normative group of the study.

Given the diversity of information in the literature regarding MCC impairment in certain diseases [7, 10, 11], patients with foreign bodies in the maxillary sinuses were selected for this study. These patients initially did not have the prerequisites for MCC dysfunction; all the disorders that developed in them occurred due to the inflammatory process in the maxillary sinus because of the entry of a foreign body into it during manipulations on the maxillary teeth. In such patients, the dynamics of changes in the local MCC can be observed, including other phenomena associated exclusively with maxillary sinusitis, surgical intervention, and surgical trauma during the formation of access to the maxillary sinus.

The study groups included approximately equal numbers of patients with different stages of morphological changes in the middle meatus and paranasal sinuses according to CT data. From this viewpoint, the groups formed for the clinical study are quite homogeneous and representative.

Grouping the data in the main study groups revealed that the greatest influence on the initial level of local MCC was caused by inflammatory changes in the area of the middle nasal meatus and the anterior group of the paranasal sinuses. They usually occur with the long-term persistence of a foreign body and are accompanied by the emergence of clear and stable morphological changes in the mucous membrane of this area (significant thickening and inflammatory polypous growths), as recorded on a CT image. These differences in the values of the initial local MCC when grouped according to CT data are statistically significant. Moreover, the presence of a factor such as mycetoma in the maxillary sinus negatively affects the initial level of local MCC of the middle nasal meatus.

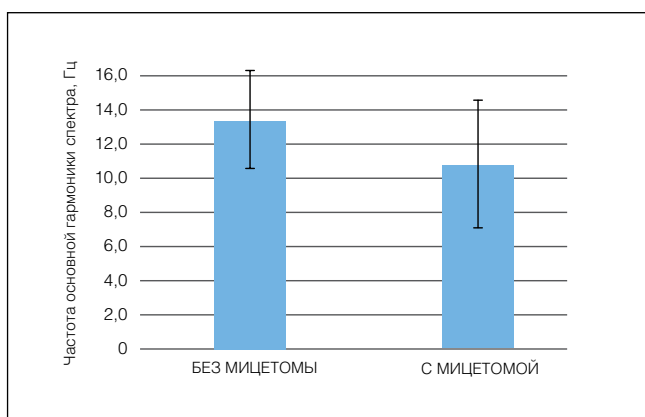


Figure 2. Mean initial values of local MCC in the distribution of patients with foreign bodies in the maxillary sinuses into groups, depending on the presence of mycetoma in the maxillary sinus according to CT ($M \pm \sigma$, Hz).

Рисунок 2. Средние исходные значения локального МЦК при распределении больных с инородными телами верхнечелюстных пазух по группам в зависимости от наличия в верхнечелюстной пазухе мицетомы по данным КТ ($M \pm \sigma$, Гц).

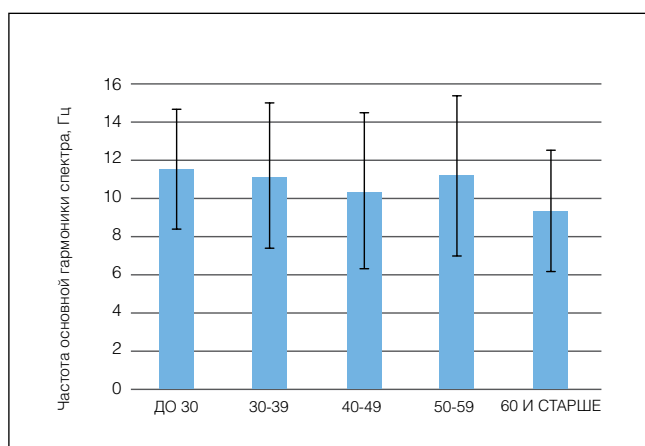


Figure 3. Mean initial values of local MCC in the distribution of patients with foreign bodies in the maxillary sinuses by age ($M \pm \sigma$, Hz).

Рисунок 3. Средние исходные значения локального МЦК при распределении больных с инородными телами верхнечелюстных пазух по возрастным группам ($M \pm \sigma$, Гц).

CONCLUSION

Inflammatory changes in the middle nasal meatus and the anterior group of paranasal sinuses demonstrated the greatest influence on the initial level of local MCC, which usually occurs with long-term persistence of a foreign body. The changes were accompanied by the appearance of clear, stable morphological changes in the mucous membrane of this area (significant thickening and inflammatory polypous growths), as recorded on a CT image. The presence of mycetoma in the maxillary sinus also negatively affects the initial level of local MCC of the middle nasal meatus.

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

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