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SPIE.

Event: XXV Annual Conference Saratov Fall Meeting 2021; and IX Symposium on Optics and Biophotonics, 2021, Saratov, Russian Federation

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ABSTRACT

The paper presents the results of a study of conditionally healthy volunteers and patients with various maxillary sinuses diseases by digital diaphanoscopy with a comparison of the results obtained with CT studies. The results of the classification of pathological changes based on a quantitative assessment of the registered scattering patterns of light are also presented.

Keywords: optical diagnostics, digital diaphanoscopy, maxillary sinuses, inflammatory diseases, purulent sinusitis, cyst, chronic rhinosinusitis with nasal polyps, computed tomography.

1. INTRODUCTION

Nowadays, timely and safe diagnosis of patients with various maxillary sinuses diseases remains an urgent task of otolaryngology, which is primarily due to the annual increase in the incidence of the population[1–4] and the development of complications caused, among other things, by the COVID-19 disease[5], as well as the development of resistance to therapy. Currently, in the practice of an ENT doctor, there is no toolkit that allows quickly, accurately, painlessly and safely diagnose.

The digital diaphanoscopy is one of the methods of optical imaging[6–9]. This method is based on probing the maxillary sinuses by safe and painless optical radiation of the LED applicator at different wavelengths (650 and 850 nm), followed by registration of scattering patterns of light by a CMOS camera and its digital processing. The LED applicator brightness controller was developed for the diagnosis of males and females[7,10], allowing the adjustment of the power emitted by the LED applicator for different patients, depending on their gender and anatomical features[8,11–13].

For further analysis of the recorded scattering patterns of light, a literature review was conducted in the field of medical image processing, in particular, an analysis of algorithms for classifying maxillary sinus pathologies in digital diaphanoscopy[8,14]. Thus, an algorithm for analyzing the registered scattering patterns of light was formed, based on the calculation of some coefficients that allow differentiating various pathologies based on their magnitude.

The aim of this work was to determine the ranges of calculated coefficients for pathological changes of various types and quantitative assessment of maxillary sinus pathologies.

2. MATERIAL AND METHODS

The study group was formed considering differences in age, gender and anatomical features. Studies were carried out in 33 conditionally healthy volunteers, including 21 women and 12 men. At the same time, the study group consisted of persons aged 18 to 27 years with a body mass index value within the normal range, pre-obesity and obesity of the 1st degree.

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Optical Technologies for Biology and Medicine, edited by Elina A. Genina, Valery V. Tuchin,
Proc. of SPIE Vol. 12192, 121920A · © 2022 SPIE · 1605-7422 · doi: 10.1117/12.2625796

The group of patients with various maxillary sinus pathologies was also examined: 5 patients with cyst, 3 patients with deviated nasal septum, 2 patients with chronic rhinosinusitis with nasal polyps (CRSwNP), 5 patients with left-sided/right-sided sinusitis, 3 patients with odontogenic sinusitis. The age of the patients ranged from 14 to 68 years. At the same time, the results of the patients' studies were compared with the reference method of computed tomography (CT).

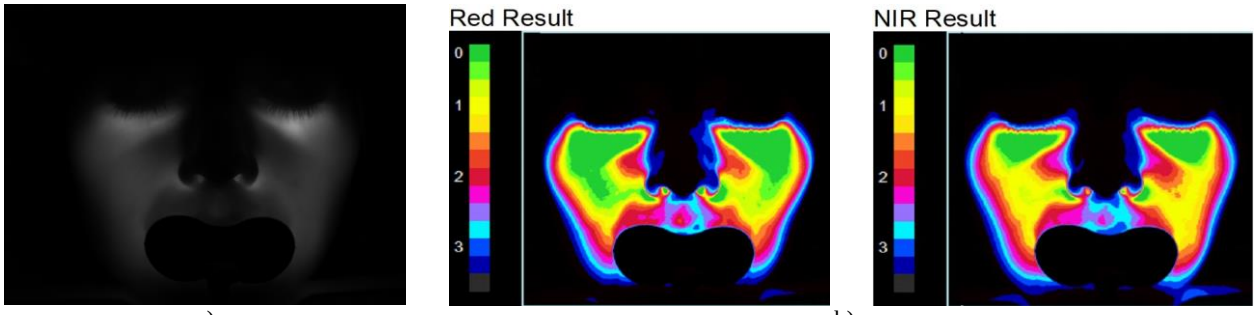
The developed classification algorithm consisted of 2 stages. For the primary division of the group of subjects into two classes (healthy, with pathology), the intensity parameter (in % ratio) was used as a decisive feature, characterizing the amount of radiation that reached the camera detector after absorption by biological layers and various pathologies.

The second stage of the analysis consisted of calculating the coefficient K, whose value will allow classifying patients into two groups depending on the presence of a pathological change. The following formula will be used to calculate the coefficient K: $K = (I_{eye}/I_{sinus})*100$ % (where I_{eye} – intensity in the eye socket area, I_{sinus} – intensity in the maxillary sinus area). The intensity values were obtained using an open source ImageJ program for image analysis and processing.

3. EXPERIMENTAL RESULTS AND DISCUSSION

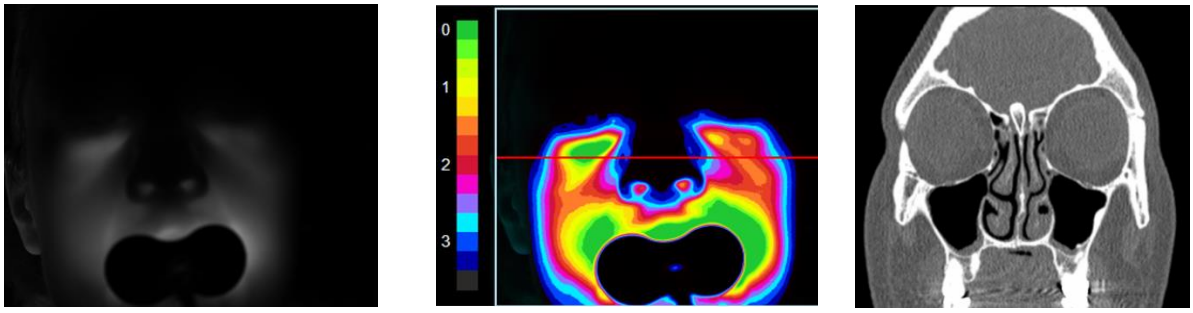
Figure 1 shows an example of registration of scattering patterns of light (a) and digital processing of obtained images (b) for a conditionally healthy volunteer (female). Figure 2 shows an example of a study for a patient with deviated nasal septum. Figure 3 shows an example of a study for patients with left/right-sided sinusitis, respectively, as well as the CT diagnosis results.

On the basis of the obtained results, it can be concluded that the revealed pathologies of the maxillary sinuses by digital diaphanoscopy are confirmed by the CT results.



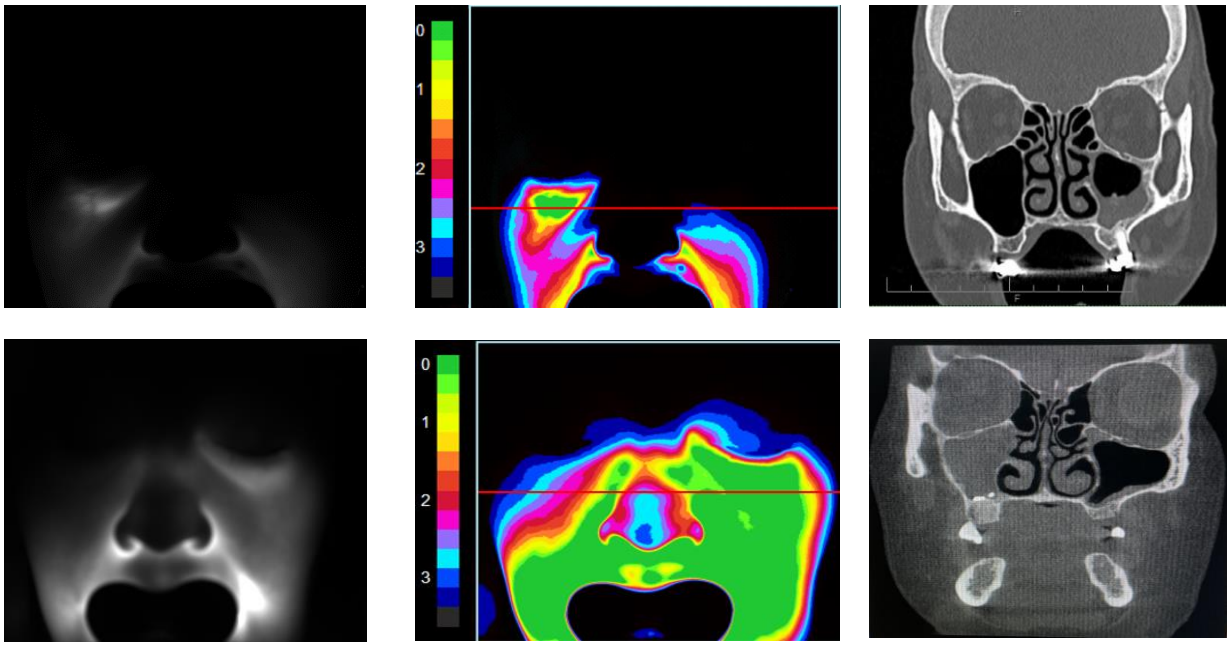
a) b)

Figure 1. Example of a registered scattering pattern of light (a) and the result of digital image processing (b) for a female. The value of the optical radiation power is 35 mW for 650 nm and 25 mW for 850 nm, the camera exposure time is 40 ms.



a) b) c)

Figure 2. Example of a registered scattering pattern of light (a), the result of digital image processing (b) and the result of CT examination (c) for a patient with deviated nasal septum (female). The value of the optical radiation power 25 mW for 850 nm, the camera exposure time is 40 ms.



a) b) c)

Figure 3. Examples of registered scattering patterns of light (a), the results of digital image processing (b) and the results of CT examination (c): for a female patient with left-sided sinusitis (top), for a female patient with right-sided sinusitis (bottom). The value of the optical radiation power is 25 mW for 850 nm, the camera exposure time is 40 ms.

Table 1 shows the values of the intensity parameter and the calculated coefficients K for the studied volunteers and patients with maxillary sinuses pathologies. Differences in parameters in the patient group and in the healthy group were tested for significance using the Mann-Whitney test.

Table 1. Summary table of statistical data processing results

	Healthy volunteers	Pathologies
Number of subjects studied (N)	33	18
Mean of the intensity parameter, %	98.53±3.27	45.39±26.07*
Mean of the coefficient K, %	1.35±0.74	15.78±13.91*

* – The significance of the difference between the values was confirmed with $p < 0.05$ according to the Mann-Whitney test

This table shows the average results of the calculated coefficients for all groups of subjects – healthy, patients with pathology. On the basis of the obtained results, the boundary between a healthy sinus and a sinus with pathology is clearly traced. A further set of experimental data will allow to refine the calculated parameters separately for each disease of the maxillary sinus.

4. CONCLUSION

The proposed method of digital diaphanoscopy is promising for detecting pathological changes in the maxillary sinuses. This is confirmed by the experimental data obtained. First of all, the registered scattering patterns of light clearly demonstrate a violation of the symmetry of the maxillary sinuses, which was accepted as a diagnostic sign. Furthermore, the developed classification algorithm based on a quantitative assessment of registered light scattering patterns will allow classification of pathological changes. This will form the basis of the classification model and will allow identifying diagnostic criteria. Thus, together with otolaryngologists, methodological recommendations will be developed for the diagnosis of pathological changes in the maxillary sinuses by digital diaphanoscopy.

ACKNOWLEDGMENT

The reported study was funded by RFBR according to the research project № 20-32-90147.

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