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SPIE.

Event: European Conferences on Biomedical Optics, 2019, Munich, Germany

Diagnosis of inflammatory diseases of the paranasal sinuses using diaphanoscopy

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ABSTRACT

Diagnosis of inflammatory diseases of the paranasal sinuses is one of the urgent problems of modern otolaryngology. Presently, radiography, computed tomography, magnetic resonance imaging, rhinoscopy and ultrasound are used to identify these pathologies. However, due to use of carcinogenic roentgen radiation during the study, a high level of false-negative results and painfulness of the diagnostic procedures, application of these methods is limited.

To overcome these shortcomings, the application of the digital diaphanoscopy method seems to be promising. For realization of this approach the experimental setup was designed and assembled. Low-intensity radiation of the visible and near IR ranges and CMOS-camera were used for translucence of the paranasal sinuses and visualizing the pattern of scattering light.

To identify the range of exposure values of the CMOS-camera to obtain maximum sensitivity to identify of pathological changes, experimental studies were conducted on healthy volunteers and patients with inflammatory diseases of paranasal sinuses. During the studies the exposure time of CMOS-camera changed in the range from 0 to 39.7 ms with a step of 1 ms, followed by comparison of the results of digital diaphanoscopy with results of MRI. The results of study 20 volunteers and 15 patients of different genders and ages showed variations in the scattering patterns with the same exposure time. This was explained by such anatomic features as the structure of the skin, the thickness of the skull bone tissue, the size of the sinuses and their asymmetry.

Keywords: optical diagnostics, diaphanoscopy, magnetic resonance imaging, paranasal sinuses, inflammatory diseases.

1. INTRODUCTION

Currently, the pathologies of the paranasal sinuses occupy a leading place among all diseases in otolaryngology[1,2]. According to statistics, the share of these pathologies, as well as the nasal cavity pathologies, accounts for more than 50% of the total number of hospitalized patients with otolaryngological diseases, while their number increases annually[3]. The greatest cases of pathologies of the paranasal sinuses in acute and chronic forms falls on the 18-29 years age and remains constant up to 70 years regardless of gender. Ensuring reliable and painless diagnosis of inflammatory diseases of the paranasal sinuses is one of the urgent problems of modern otorhinolaryngology.

Currently, radiography, computed tomography, magnetic resonance imaging, rhinoscopy and ultrasound are used to identify these pathologies. However, due to use of carcinogenic roentgen radiation during the study, a high level of false-negative results and painfulness of the diagnostic procedures, application of these methods is limited and often impossible in the diagnoses of pregnant women and children[4,5]. To overcome these shortcomings, the application of the digital diaphanoscopy seems to be promising.

The aim of the research is to evaluate the possibility of applying the digital diaphanoscopy method for the study of the paranasal sinuses and the identification of possible disorders.

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Clinical and Preclinical Optical Diagnostics II, edited by J. Quincy Brown, Ton G. van Leeuwen,
Proc. of SPIE-OSA, SPIE Vol. 11073, 110731P · © 2019 SPIE-OSA
CCC code: 1605-7422/19/$21 · doi: 10.1117/12.2526835

2. MATERIAL AND METHODS

For realization this approach the experimental setup were designed and assembled[6]. Low-intensity radiation of the visible (650 nm) and near-infrared (850 nm) ranges and CMOS-camera were used for translucence of the paranasal sinuses and visualizing the scattering pattern of light. The anatomical shape optical applicator was designed to probe of paranasal sinuses.

During diagnostic procedure, the optical applicator was placed in the oral cavity, radiation from the applicator passed through the maxillary sinuses and the surrounding tissues and is fixed by a camera. The scattering patterns were registered sequentially for visible and near-infrared radiation sources, as well as their combination.

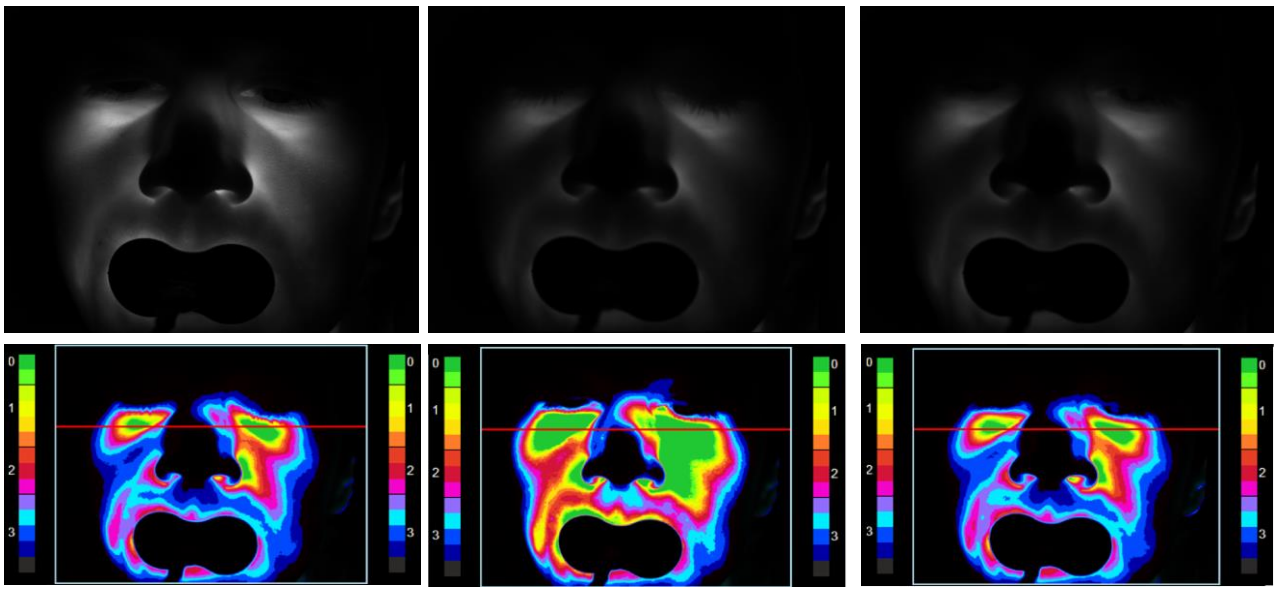
For further analysis of the obtained scattering pattern, the specially developed software was used. This software implements of digital representation algorithm of the diffuse light signals, which display a measure of inflammation (brightness, surface area, shape of right / left symmetry).

Conducted investigation revealed a high impact of external illumination on the visualization result. To minimize the influence of this factor, a protective screen was designed to exclude external illumination. Testing of the protective screen showed a complete elimination of the effect on the result of diagnostics of external lighting.

To identify the range of the exposure time of the CMOS-camera to obtain maximum sensitivity to identify of pathological changes and also to identify features of the study area that may affect the obtained scattering pattern, the experimental studies were conducted on 20 healthy volunteers and 15 patients with inflammatory diseases of paranasal sinuses. The study was approved by the local Committee for Human Biomedical Research Ethics, and all subjects signed an informed consent. In the process of experimental studies, the paranasal sinuses bleaching was performed at the exposure time in the range from 0 to 39.7 ms with a step of 1 ms, followed by comparison of the results of digital diaphanoscopy, which were obtained for patients, with results of MRI.

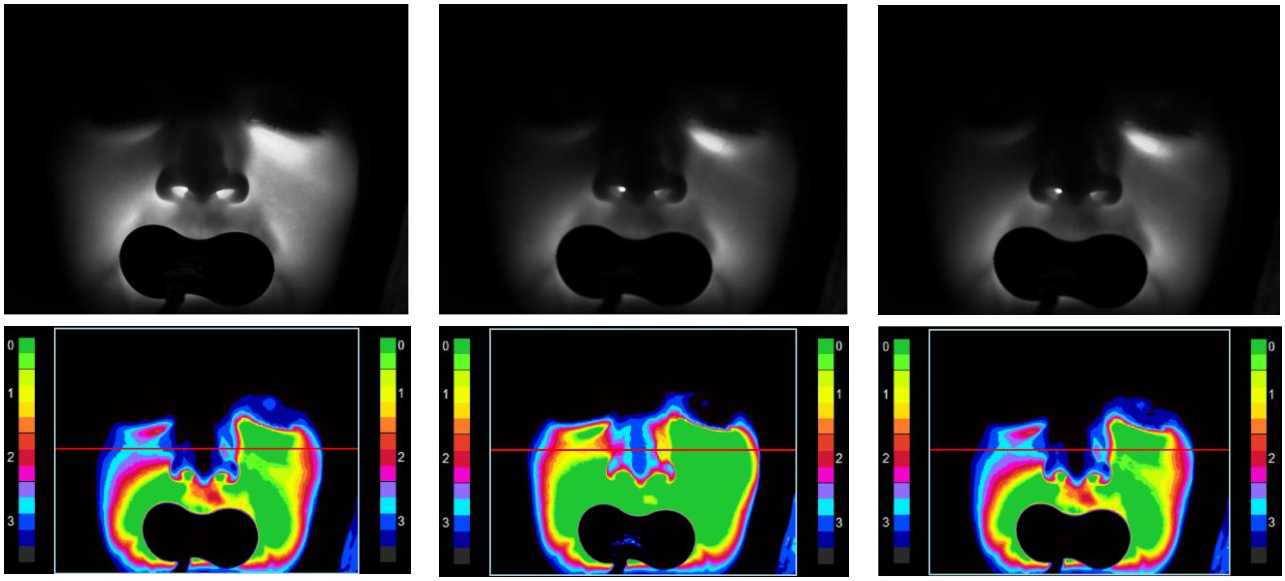
3. EXPERIMENTAL RESULTS AND DISCUSSION

On the figures 1-2 presented the examples of registered and processed images for two volunteers (male and female same age group) at the same exposure time 20.7 ms for visible and near-infrared radiation sources, as well as their combination.



a) b) c)

Figure 1. Examples of registered (top) and processed (bottom) images for volunteer 1 (male) at the exposure time 20.7 ms for visible (a), near-infrared (b) and combination visible and near-infrared (c) radiation sources

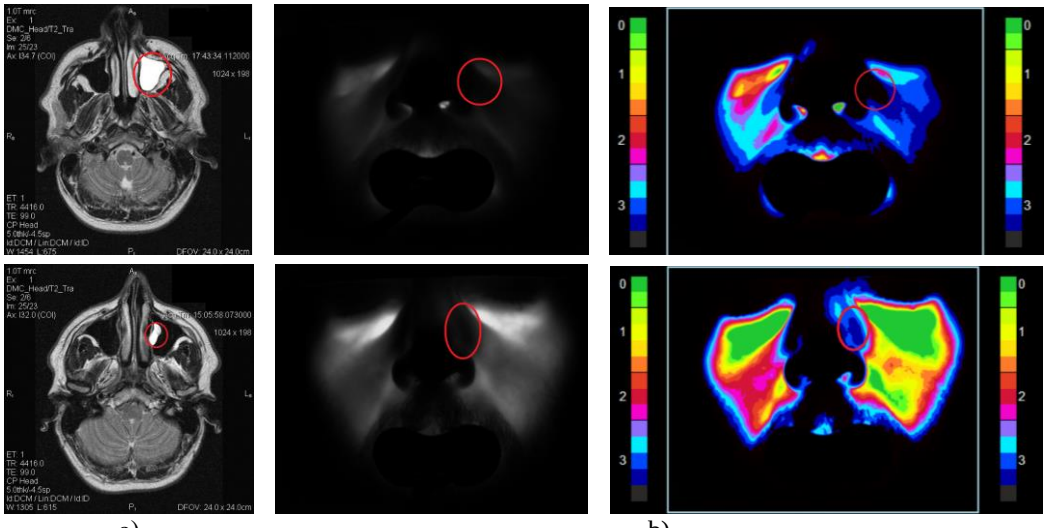


a) b) c)

Figure 2. Examples of registered (top) and processed (bottom) images for volunteer 2 (female) at the exposure time 20.7 ms (a) for visible (a), near-infrared (b) and combination visible and near-infrared (c) radiation sources

The results of the study showed variations in the scattering patterns of light of different volunteers with the same exposure time of CMOS-camera. Using the same exposure time both volunteers' nasal sinuses are well identified, but total scattering patterns of light vary widely. So, volunteer 2 (female) has asymmetry of right and left paranasal sinuses and more intensity in cheek area. The detected asymmetry of the paranasal sinuses of volunteer 2 was associated with inflammation of right sinus, which was confirmed as a result of subsequent studies in the clinic. Besides, the differences were identified in the scattering patterns of light for different wavelengths of radiation sources.

In 4 patients out of 15, cysts were found in the right sinuses with application MRI and diaphanoscopy. The 1T MRI Scanner of the Magnetom series (Siemens) was used for MRI studies. The T2 weighted images by MRI (a) and registered and processed images by diaphanoscopy (b) for two patients (males) presented on the figure 3.



a) b)

Figure 3. The T2 weighted image by MRI (a) and registered and processed images by diaphanoscopy for patient 1 (top) and patient 2 (bottom) for near-infrared (b) radiation source

As can see, the area of cyst has a lower intensity compared to other structures on the results of diaphanoscopy for near-infrared radiation source. This result is related with optical properties of cysts[7], namely, the presence of cystic fluid in the cavity, which has a high absorption in this spectral range[8].

More detail analysis of obtained images for volunteers and patients, as well as their anatomic features allowed to identify the relationship of the registered scattering patterns with the structure of the skin, the thickness of the skull bone tissue[9,10], the size of the sinuses and their asymmetry[11], as well as their optical properties[12–14]. Also, the influence of the parameters of the probing and measuring parts of the device (wavelength, intensity of radiation sources, etc.) on the result obtained was revealed.

4. CONCLUSION

The obtained results using diaphanoscopy and MRI methods let to conclude that the diaphanoscopy has potential to separate normal and pathological conditions of the paranasal sinuses.

In order to identify the totality of all the signs that affect the resulting images of the paranasal sinuses (the presence or absence of pathology, its etiology and morphological features) and parameters of probing and measuring parts of the device, the formation model of the recorded signals will be created using the Monte Carlo method. Using results of modeling the instrumental part of the diaphanoscop will be modernized.

Modernization of device and conducting of studies with participation healthy volunteers and patients with inflammatory diseases of paranasal sinuses, followed by comparison of the results of diaphanoscopy with results of MRI, will allow to form the informative features vector to separate normal and pathological conditions, including detecting the presence of cysts, tumors, inflammation and air-filled cavities, as well as to determine the clear boundaries of inflammations.

The work was supported by the grant of the President of the Russian Federation for state support of young Russian scientists № MK-2634.2019.8.

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