Digital Microscopy Standardization in Ophthalmological Practice

Valery V. Bakutkin, Ilya V. Bakutkin

For citation:
Bakutkin V.V., Bakutkin I.V. Digital Microscopy Standardization in Ophthalmological Practice. *Scientific Research and Innovation. 2020;1(1):3-7*
DOI:10.34986/MAKAO.2020.55.43.001

Authors' credentials:
Valery V. Bakutkin, Doctor of Medicine, Professor, Saratov Rural Hygiene Research Institute Federal Budget Institution of Science, Saratov, RF. (bakutv@bk.ru)

Ilya V. Bakutkin Candidate of Medicine, International Consulting, Audit and Education Academy (MAKAO LLC), Kraevaya, 85a, of. 307, Saratov, RF, 410012. (bakutkiniv@ya.ru)

Acknowledgements:
The work was conducted under Agreement No. 18-29-02008 on Intelligent Laser Eye Surgery System executed with the Russian Foundation for Basic Research.

Received: 11 February 2020
Revised: 1 April 2020
Accepted: 1 April 2020
Published: 15 April 2020

Abstract: Digital methods are intensively introduced into eye diseases diagnostics. An important issue there to is to standardize the procedures for obtaining digital images of eye structures. The research introduces a hardware and software components set designed to obtain digital images of eyes structures using task-specific optical and illumination device. The research studied the possible ways to standardize the eye digital image taking procedure and eliminate image artifacts and glares, as well as how varying the light wavelength can affect the images' information value.

Keywords: eye disease, eye disease diagnostics, telehealth, digital biomicroscopy.

Introduction

The current ophthalmology practice reveals a number of tendencies featuring ever-increasing significance. One of them is the distinctively growing number of eye diseases attributed to the increasing life expectancy and visual workload. The job-related demand to high vision acuity preservation acquires dominating significance. These tendencies highlight the importance of early identification of risks and incipient stages of eye diseases, as well as of the preventive measures and treatment optimization. More attention is given to preventing full or partial loss of sight as these incur permanent disability, employment limitations, lower quality of life and increased medical care expenditures. Another tendency consists in the unequal health care quality level in different regions. In large cities highly qualified treatment and diagnostics is offered by specialized institutions provided with both the trained staff and required equipment. Meanwhile, in small towns and rural areas the medical care quality level often fails to meet the existing standards. Alongside with that the equipment and personnel training expenditures steadily grow. Every new generation of diagnostic and therapeutic equipment is more advanced and feature enhanced diagnostic capability but is also more expensive and can be operated by trained and instructed employees only. Mastering state-of-the-art diagnostic and treatment technologies, methods and equipment is also one of the major consideration in training ophthalmology professionals. At the same time, in their daily work routine ophthalmologists still tend to resort to traditional methods of diagnostics involving biased interpretation of symptoms and dynamics and usage of qualitative estimations when documenting the course and treatment of the disease.

The worldwide correlation between the diseases incurring loss of eyesight and permanent disability is as follows: diabetic retinopathy accounts for around 420 M patients, the number of patients suffering from age-related macular degeneration achieves 200 M and the number of glaucoma patients amounts to 80 M. The growing ophthalmological treatment amount requires introduction of new technologies capable of processing large bulks of information and analyzing medical data. The principal digital healthcare development trends are transition to electronic document control and production of task-specific digital diagnostic devices which can be operated under various conditions including those in remote areas. A significant amount of unbiased data can be yielded by digital biomicroscopy of the eye anterior and posterior segments. This becomes essential in detecting the abnormal change areas which is crucial for disease identification. One of the ways for eye structure disease-related changes to manifest themselves is color. Color perception depends on a large number of a patient's unique features. Color perception can be affected by the eye optical system condition or retina diseases. About 15 per cent of males are subject to different degrees of color blindness, mostly concerning discrimination of red. Currently the images of eye structures are obtained mostly by digital fundus photography. The fundus cameras used for the latter are intended for steady-state operation conditions and can be operated by specially trained personnel which imposes distinctive limitations on its operation range.

Methods and Materials

The purpose and objectives of the research were to optimize the process of making digital images in ophthalmological practice.

This research is dedicated to development of portable diagnostic devices which can be used for out-of-clinic examinations, emergency conditions and in remote areas. The functioning of the hardware and software utilities set is based on digital biomicroscopy of the eye's both anterior and posterior segments. Standardization of lighting becomes one of the most important issues in the situations when digital biomicroscopy is performed with portable diagnostic devices. Under the currently adopted procedures focal or lateral illumination is applied to the eye anterior segment which results in glares occurring when the light is reflected by the cornea. To ensure digital biomicroscopy standardization an optical illumination modifier was developed. It is designed to remove the glares from the images of eye segments.

The designed digital biomicroscopy hardware and software utilities set consists of illumination, photographic registration and control units and supports the eye anterior segment illumination with diffused light. To ensure standardization of the digital image generation the eye of the individual under examination was inspected under uniform background illumination with total isolation from ambient light. This type of illumination was chosen due to its being even, well-balanced and glare-proof. When present, glares can to a significant extent decrease the method's informative value by rendering virtually undistinguishable every structure within the area shielded by the reflected light.

Studies were conducted to investigate how the light-emitting element position affects occurrence of cornea glares. According to the calculations and tests the preferable illumination is provided by a point light source put at the distance of 25–30 mm from the eye anterior surface. Proper choice of the light source position plays an important part in decreasing light reflection. To lower the risk of image fogging and the patients' discomfort it is also required to control the illumination intensity. Figure 1 demonstrates an instance of point light illumination arranged to decrease the cornea glares.

Figure 1. Point-type light source focused on the cornea center, the glare area being the smallest possible

The light source is placed at 15 degrees to the lens axis. The light is focused on the cornea center. The device software has a number of operating modes. A number of testing modes are available to evaluate readiness of the components for operation, the exact mode to be chosen depending on the examination objective. There is also a range of illumination options including both monochrome types and their combinations. The user control of the illumination intensity is software-aided, the eye digital image being displayed in the monitoring window for the eye anterior segment illumination optimization (*Fig. 2*).

Focusing the light on the cornea central area ensures appropriate illumination of the eye anterior segment. The biomicroscopic image features a high degree of detail. Figure 3 demonstrates a biomicroscopic image of an eye anterior segment, obtained with the described illumination type.

The research also studied efficiency of monochromatic light sources for eye digital biomicroscopy. Figure 4 shows the eye anterior segment biomicroscopic image received with the 700–740 nm illumination wavelength. The level of detail is low and the eye anterior segment image becomes blurred.

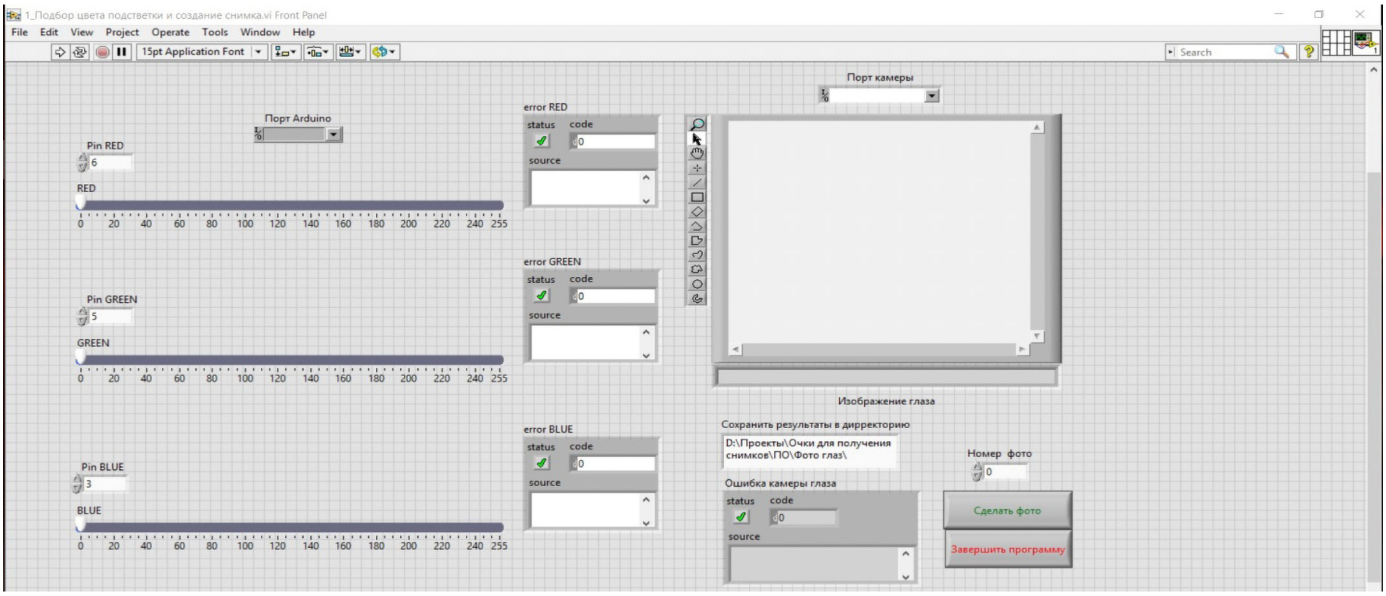

Figure 2. Light source control software interface

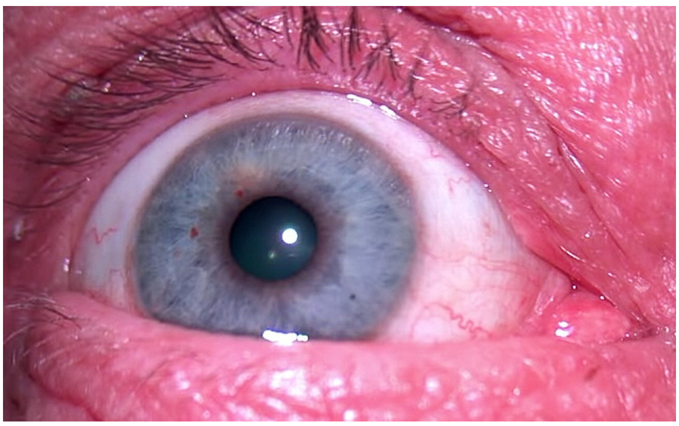

Figure 3. An example of eye anterior segment digital biomicroscopy performed with the proposed set of hardware and software utilities

Figure 4. Eye anterior segment digital image obtained with the 700–780 nm illumination

Application of 450–600 nm wavelength illumination enhances the image quality and increases the biomicroscopic image detail and sharpness (*Figure 5*).

Using the short wavelength band of 360–450 nm results in further increase of image detail.

Monochrome light sources can be used for inspection of individual eye parts. For instance, the best option for examination of the outer segment including eyelids and lacrimal apparatus would be the primary digital biomicroscopy with balanced white light and high image detail in the short wavelength band.

Cornea examination tends to yield more detailed results when performed in short wavelength band.

The eye front chamber structures, namely, those of iris are best visible under balanced white light illumination.

Figure 5. Biomicroscopic image of the eye anterior segment and pupil area illuminated with a 450–600 nm light source

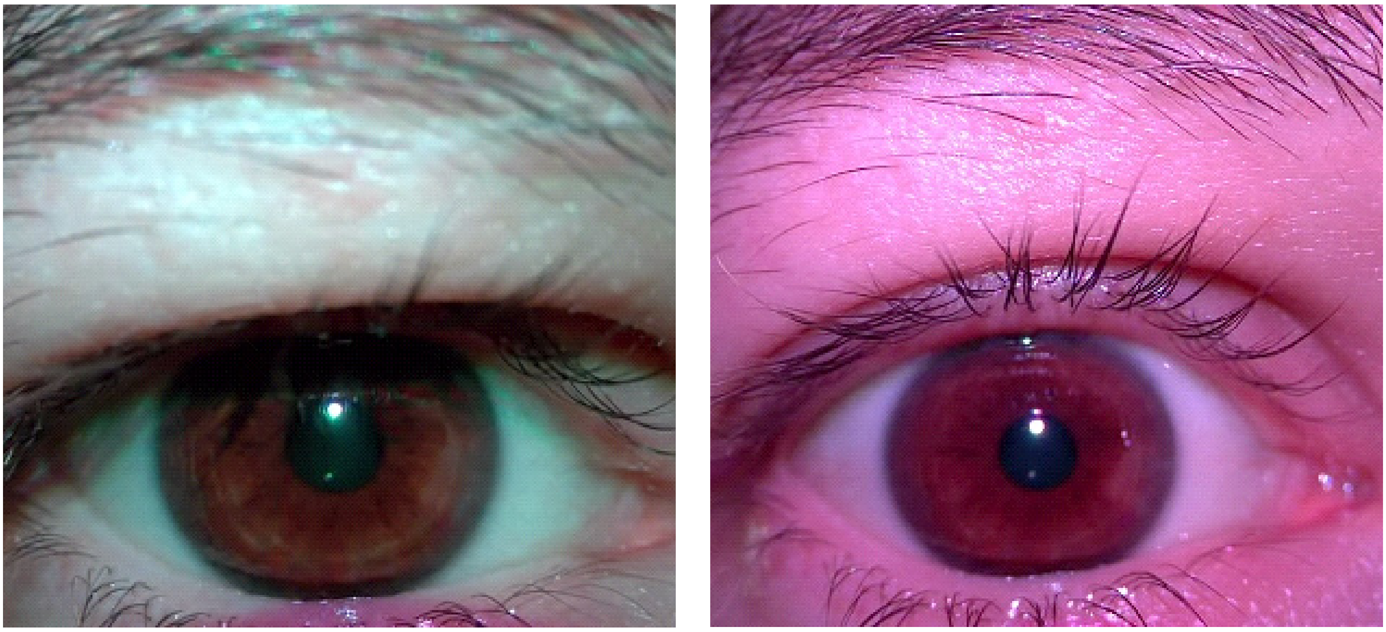

Figure 6. Comparative analysis of illumination impact on the image

Conclusion

Digital methods are intensively introduced in eye disease diagnostics, an important issue thereto being ensuring standardized conditions for making digital images of eye structures. This research suggests addressing this issue with a set of hardware and software utilities designed to obtain digital images of eye structures using task-specific optical and illumination devices. The research investigated the ways to standardize the eye digital image making process and remove artifacts and glares, as well as the impact of different illumination wavelength bands on the information value of the images obtained.

References

1. Bakutkin I.V., Bakutkin V.V. The possibility of chronopo-tentiometry in the assessment of the functional state of the organ of vision. *Russian Journal of Occupational Health and Industrial Ecology*. 2015;(9):30-31. (In Russ.). Avalaible at: http://www.niimt.ru/publishing.html

2. Bakutkin I.V., Bakutkin V.V., Spirin V.F. Light stimulation of the pupillary response of the eye to prevent visual fatigue. *Russian Journal of Occupational Health and Industrial Ecology*. 2015;(9):31-31. (In Russ.) Avalaible at: http://www.niimt.ru/publishing.html

3. Brezhneva A.N., Borisovskii S.A., Tokmakoma R.A., Filist S.A. Neural network models of segmentation angiogram's of an eyeground on the basis analysis RGB codes of pixels. *Sistemnyi analiz i upravlenie v biomeditsinskikh sistemakh=System Analysis and management in Biomedical Systems.* 2010;9(1):72-76 (In Russ.)

4. Dolmatova T.I., Graevskaya N.D., Varchenko N.N., Makurchuk I.E., Lakin V.V., Lapteva K.V. Computer-aided technologies in sports medicine. *Lechebnaya fizkul'tura i sportivnya meditsina.* 2008;(11):23-29. (In Russ.) Avalaible at: http://lfksport.ru/archive200811/

5. Kuzmin A.A., Kuzmina M.N., Jatsun S.F., Naser A.A. The certainty-factor model in medical rule-based systems. *Biomeditsinskaya radioelektronika.* 2012;(4):62-68. (In Russ.).

6. Moskalenko F.M., Chernyakhovskaya M.Yu. Ophthalmology patient monitoring database for medical knowledge bank. *Informatika i sistemy upravleniya*. 2009;(2):40-49. (In.Russ.) Avalaible at: http://ics.khstu.ru/media/2010/N20_07.pdf

7. Brantchevsky S.L., Vasiliev Yu.V., Durasov A.B., Iliasova N.Yu, Ustinov A.V. Method for the distinguishing and quantitative evaluation of the elements of pathological patterns in the retina (pathology of microcirculation). Proceedings SPIE, vol. 2363, pp. 236-242.

8. Gonzalez R., Woods R. Digital Image Processing. 4th Edition. Pearson. 2018. 1163 pp.

9. Moskalenko Ph.M., Chernyakhovskaya M.Yu. An implementation of the computer bank of medical diagnostics for ophthalmology. First Russia and Pacific Conference on Computer Technology and Applications (RPC-2010). Vladivostok, Russia. 2010. pp. 340-343. (In Russ.). Avalaible at: http://iacp-web.dvo.ru/russian/institute/dissertation/referat/Moskalenko_FM.pdf

10. Varun G., Peng L., Coram M., Stumpe M., Wu D., Narayanaswamy A., Venugopalan S., Widner K., Madams T., Jorge C., Ramasamy K., Rajiv R., Philip N., Jessica M., Dale W. Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs. JAMA. 2016;316(22):2402-2410. DOI:10.1001/jama.2016.17216.