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Digital imaging of the fundus with long-wave illumination

Cyfrowy obraz dna oka w oświetleniu o długiej fali

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Summary: Purpose: To increase the quality, diagnostic value and use of non-invasive fundus examination with transscleral or transpalpebral long-wave (red and near infrared) illumination.
Material and methods: For fundus visualization we used red light diode sources at 660 nm and near infrared light diode sources at 810, 940 nm. Light radiation from diode sources penetrates into the globe through eyelid skin and sclera. Fundus examination was performed without dye injection and local anesthesia. The technique was called «long-wave fundusgraphy» (LFG).
Results: Comparing with fluorescein angiography additional topographical information was received concerning CNV associated with hemorrhage or subretinal fluid, which masked the true borders of the neovascular component. If CNV is completely invisible under a layer of blood or pigment, on fluorescein angiography only a hypofluorescent area is registered. In such cases fluorescein angiography is insufficient for correct diagnosis. Examination of such patients with 940 nm excluded maximum masking property of blood or pigment deposits and permitted visualization of CNV.
Conclusions: Non-invasive, consecutive long-wave imaging may be useful for CNV detecting and may obtain additional information about fundus structures in patients with dye intolerance, retinal hyperpigmentation, haemorrhage or fluid masking subretinal structures, miosis or in the presence of opaque media.
Key words: long-wave fundusgraphy, retina, choroid.
Słowa kluczowe: długofalowa fundusgrafia, siatkówka, naczyniówka.

Currently fluorescein and indocyanine-green angiography (ICG) are standard procedures in the diagnosis of retinal and choroidal diseases that involve intravenous injection of contrast substance. However imaging of the fundus without dye injection is playing an increasingly important role, especially when there is intolerance or risk related to injection of dye.

Photographing of the fundus with various light spectra, including infrared, was first reported by I. Kugelberg (1). However, standard infrared devices and systems of infrared signal reception are unsuitable for fundus visualization. This area of ophthalmology, as a potential source of additional information of eye fundus structures, is presently insufficiently developed and investigated.

Purpose

To increase the quality, diagnostic value and use of non-invasive fundus examination with transscleral or transpalpebral long-wave (red and near infrared) illumination.

Material and methods

This work was carried out together with the Ukrainian Institute of Physics of Metals. The device for fundus imaging consists of generation, focusing and registration of infrared radiation, a power unit and a computer for processing of the received photo or video signal and its demonstration on a monitor. For fundus visualization we used red light diode sources at 660 nm and near infrared light diode sources at 810, 940 nm. Light radiation from diode sources penetrates into the globe through eyelid skin and sclera. Fundus examination was performed without dye injection and local anesthesia. The technique was called «long-wave fundusgraphy» (LFG).

This study was conducted on 210 eyes of 200 patients and 57 eyes of 30 normal subjects. 96 eyes had dry AMD, 114 eyes had exudative AMD with active choroidal neovascularization (CNV). The age range of all persons was 25 to 75 years. Patients were included in the study with different levels of ocular media opacities. LFG was carried out in eyes with small pupils and with dilated pupils in the same patients. All images were acquired by the same operator. We used standard ophthalmologic examination for all patients including ophthalmoscopy, optical coherent tomography (OCT) and fluorescein angiography (FAG).

Results

With 660 nm red illumination images of the retina and retinal vessels were obtained (Fig. 1A).

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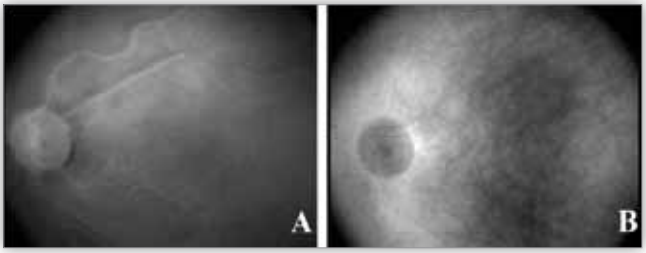

Fig. 1. A – fundus black-white photograph of a 55-year-old woman. Dry AMD manifests as soft drusen. B,C – fundus black-white photograph of the same patient with 660 nm illumination. Borders of large clinically revealed drusen are better estimated in red mode.

Ryc. 1. A – biało-czarna fotografia dna oka u 55-letniej kobiety. Suche AMD w postaci miękkich druz. BC – biało-czarna fotografia tej samej pacjentki w oświetleniu 660 nm. Granice dużych druz stwierdzonych klinicznie są lepiej uwidocznione w podczerwieni.

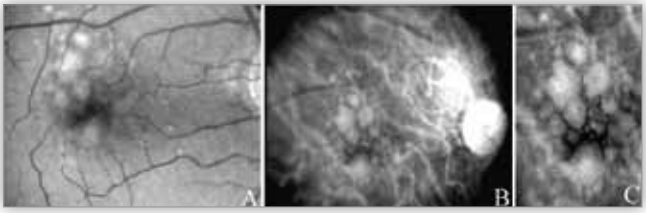

Fig. 2. A – digital photograph with 660 nm a 27-year-old man with a normal fundus. The optic disc looks bright compared with the background. Retinal vessels are well delineated. B – near infrared photograph (wavelength is 940 nm) shows a dark optic disc and choroidal vessels against a bright background.

Ryc. 2. A – cyfrowa fotografia przy użyciu 660nm u 27-letniego mężczyzny z normalnym dnem oka. Tarcza n. II jest jaśniejsza od tła. Naczynia siatkówki mają wyraźne obrysy. B – fotografia w bliskiej podczerwieni (długość fali 940 nm), pokazuje ciemną tarczę n. II i naczynia naczyniówki na jasnym tle.

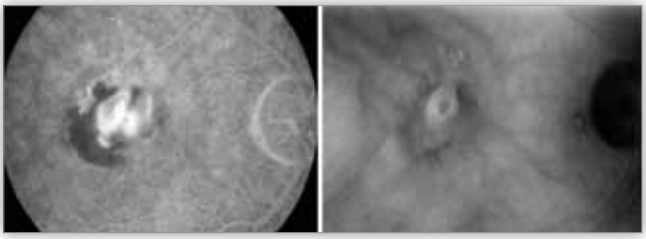

Fig. 3. A – fluorescein angiogram of a 55-year-old woman. Hyperfluorescent area correspond to predominantly classic choroidal neovascularization. B – near infrared photo graph (λ= 940 nm) demonstrates CNV.

Ryc. 3. A – angiografia fluoresceinowa u 55-letniej kobiety. Pola hiperfluorescencji korespondują z klasyczną, dominującą neowaskularyzacją naczyniówki (CNV). B – fotografia w bliskiej podczerwieni (λ= 940 nm) pokazuje CNV.

In near infrared illumination (810, 940 nm) structures of the choroid were more precisely visualized (Fig. 1B). The optic disc was always dark. Retinal vessels were seen against a light bright background. Choroidal vessels were dark and well delineated under the retinal pigment epithelium or thin layer of blood. LFG allows to image structures of the retina and the choroid in red and near infrared spectral areas and also have many advantages over angiography. Examination is possible irrespective of pupil size.

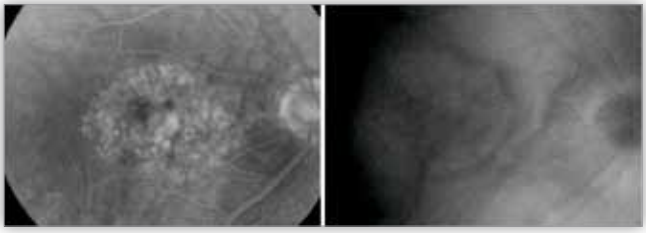

Fig. 4. A – fluorescein angiogram of a 65-year-old woman. Hyperfluorescent area corresponds to occult CNV. B – near infrared photograph (λ=940 nm) demonstrates CNV.

Ryc. 4. A – Angiografia fluoresceinowa u 65-letniej kobiety. Pola hiperfluorescencji korespondują z ukrytą CVN. B – fotografia w bliskiej podczerwieni (λ=940 nm) pokazuje CNV.

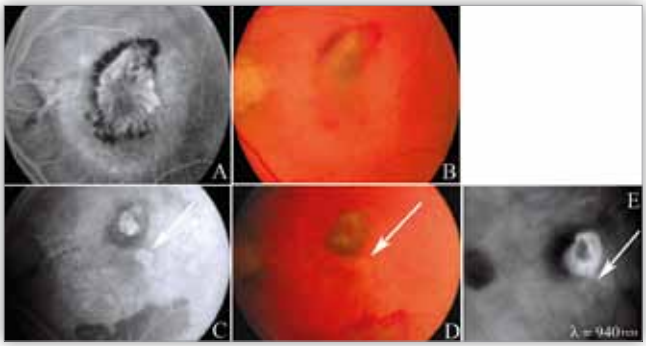

Fig. 5. A – fluorescein angiogram. B – fundus color photograph of 65-year-old man with AMD and the active predominantly classic CNV. C – fluorescein angiogram. D – fundus color photograph and E – near infrared photograph of the same patient with spontaneous CNV contraction 3 months later. Arrow points to hyperfluorescent area corresponded to the retinal pigment epithelium defect after CNV contraction. E – near infrared photograph demonstrates contracted hyperreflective CNV tissue.

Ryc. 5. A – angiografia fluoresceinowa. B – kolorowa fotografia dna oka u 65-letniego mężczyzny z AMD i czynną klasyczną CNV. C – angiografia fluoresceinowa. D – kolorowa fotografia dna oka i E – fotografia w bliskiej podczerwieni u tego samego pacjenta z samorzutną, ściągającą CVN – 3 miesiące później. Strzałki wskazują pola hiperfluorescencji odpowiadające uszkodzeniu nabłonka barwikowego siatkówki po ściągającej CNV. E – fotografia w bliskiej podczerwieni pokazuje ściągniętą hiperrefleksyjną tkankę CVN.

Examination of patients with dry AMD revealed subretinal deposits (soft drusen). In infrared light they appeared as local sites of fading or elevation (for video mode) and were much more numerous compared with ophthalmoscopy and color photography. Part of subretinal deposits corresponded to clinically visible drusen, other were seen only in red light (660 nm). Some subretinal deposits could be detected only in infrared light. We have shown that the borders of clinically visible drusen are more precisely estimated in the red mode of LFG (Fig. 2). However, borders of small subretinal deposits revealed by means of LFG, were not always well visualized because of their small sizes.

Additional information about CNV of various etiologies was obtained (Fig. 3, 4). Red light has smaller significance compared with infrared light in CNV imaging.

We describe one case with spontaneous contraction of CNV tissue under the neuroretina. It concerned 65-year-old man with AMD and the active predominantly classic CNV (Fig. 5).

A three dimensional video image of fundus structures and CNV may be obtained because of the phenomenon of shadowing and motion parallax. We were able to detect CNV in patients with intolerance or risk factors to the injection of fluorescein, when fluorescein angiography was contraindicated.

Discussion

Red and near infrared fundus illumination were used because of greater penetrating ability of long-wave illumination through eyelid skin, sclera and retinal pigment epithelium (2).

Pathohistological findings in excised CNV showed cells of the retinal pigment epithelium, fibrin and fibrous collagen surrounding CNV (3,4,5). Products of blood degradation and melanin are possible sources of high reflectance of near infrared light (6). At 940 nm all CNVs consisted of two components. The first component was represented as a bright (hyper reflective) contour of the membrane, because of accumulation of highly reflective materials. The central part of CNV was dark in near infrared light (hypo reflective), because near infrared light absorbed by water, hemoglobin and its derivatives (Fig. 3).

Contraction of CNV and subsequent perfusion disturbances were not decreased near infrared reflectance of CNV (Fig. 5).

Comparing with fluorescein angiography additional topographical information was received concerning CNV associated with hemorrhage or subretinal fluid, which masked the true borders of the neovascular component (7). If CNV is completely invisible under a layer of blood or pigment, on fluorescein angiography only a hypofluorescent area is registered. In such cases fluorescein angiography is insufficient for correct diagnosis. Examination of such patients with 940 nm excluded maximum masking property of blood or pigment deposits and permitted visualization of CNV.

Conclusion

Non-invasive consecutive long-wave imaging may be useful for CNV detecting and may obtain additional information about fundus structures in patients with dye intolerance, retinal hyperpigmentation, haemorrhage or fluid masking subretinal structures, miosis or in the presence of opaque media.

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