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A new maximum color contrast sensitivity test for detecting early changes of visual function in age-related macular degeneration

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ABSTRACT

Background and objective: To determine the association between age-related macular degeneration (AMD) and color perception established by the Farnsworth–Munsell 100 hue (F–M 100) and maximum color contrast sensitivity (MCCS) tests.
Materials and methods: We performed a case–control study, which comprised of 100 patients with AMD and 100 healthy controls. To test visual acuity (VA), a typical Snellen chart was used. The computerized F–M 100 and MCCS programs were used for color discrimination.
Results: The results of VA, and the F–M 100 and MCCS tests in the healthy controls were statistically significantly better than in the patients with AMD (1.0 vs. 0.82 ± 0.16, $P = 0.005$; 87.39 ± 24.11 vs. 185.39 ± 74.43, $P = 0.005$; 1.33 ± 1.17 vs. 1.96 ± 0.46, $P = 0.005$, respectively). When VA was 1.0 in patients with AMD, the total error scores of the F–M 100 test and MCCS test compared with healthy persons were even worse (166.09 ± 66.57 vs. 87.39 ± 24.11, $P = 0.002$; 1.67 ± 0.92 vs. 1.33 ± 1.17, $P = 0.001$, respectively). Analysis of the results of patients with AMD compared to healthy controls showed the highest error score in the blue color range.
Conclusions: The results of the color contrast sensitivity test decreased by half in patients with AMD compared with ophthalmologically healthy patients when they performed the F–M 100 test and by one and half when they performed a MCCS test in the blue color range.

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1. Introduction

Age-related macular degeneration (AMD) affects the macula and is a leading cause of significant and irreversible loss of central visual acuity in persons aged over 60 in developed countries [1]. In the civilian noninstitutionalized U.S. population aged 40 years and more, the estimated prevalence of any AMD was 6.5%, and the estimated prevalence of late AMD was 0.8% [2].

Epidemiological studies estimate that the prevalence of AMD in Australia, Europe and North America is 0.2% in 55–64-year-old patients and it increases to 13% in the age group of 85 years [3]. According to the Blind Register Centre, about 50% of blind people lose vision due to ADM in Great Britain [4].

It is known that damage to the retina caused by some diseases can result in the loss of color recognition. In fact, the human eye can see at least 7 million colors, interestingly, not all signals reach the brain visual center; about 20% stop at the pituitary gland [5].

Some studies suggest that demographic factors such as age, sex and even ethnicity should also be considered in explaining the communication values of various colors [6,7]. Studies by Guilford et al. have indicated that people prefer colors in the following order: blue, red, green, violet, orange, and yellow but gender differentiation is minor, with men slightly tending to prefer blue to red, and women yellow to orange, although neither preference is sufficient to offset the above order for the general population. Indeed, this order is consistent even across age and national lines [8].

In a variety of central retinal diseases one of the earliest changes in visual processing is the impairment of normal color vision. Therefore, to perform detailed visual examination, various functions, such as cognitive perception, color contrast sensitivity, health of the visual system and the central processing function are tested. Studies have shown that the assessment of the visual acuity testing by the typical Snellen chart using the Landolt rings (C optotypes) alone is insufficient for the visual function testing because it provides limited information about the central vision, thus it is necessary to determine not only the visual acuity, but also the contrast sensitivity [9]. The aim of this study was to assess visual function (visual acuity and color contrast sensitivity) in patients with AMD.

2. Materials and methods

A total number of 200 (395 eyes) patients were enrolled in further analysis according to the subject inclusion and exclusion criteria.

Having obtained permission (No. BE-2-14) from the Kaunas Regional Biomedical Research Ethics Committee, the study was conducted in the Department of Ophthalmology at Kaunas University of Medicine.

The inclusion criteria for patients with AMD were as follows: (1) patients of both genders, diagnosed with early mild or early intermediate AMD who did not have other eye disorders found on detailed ophthalmologic examination; (2) the diagnosis confirmed by color fundus photography; (3) participation consent.

The exclusion criteria for patients with AMD were as follows: (1) related eye disorders (high refractive error, cloudy cornea or lens (nuclear, cortical and posterior subcapsular cataract) except minor opacities, and patients with intraocular lenses, keratitis, acute or chronic uveitis, glaucoma, late age-related macular degeneration, diseases of the optic nerve); (2) systemic illnesses (diabetes mellitus, oncological diseases, systemic tissue disorders, chronic infectious diseases, conditions after organ or tissue transplantation), (3) color fundus photography because of the obscuration in the eye optic system or because of fundus photography quality, (4) congenital color vision deficiencies were excluded by history, (5) patients taking epileptic and sedative drugs.

The inclusion criteria for healthy patients were as follows: (1) no ophthalmological eye disorders were found on detail ophthalmological evaluation; (2) participation consent.

The exclusion criteria for healthy patients were as follows: (1) any eye disorders, (2) patients taking epileptic and sedative drugs.

In this study, visual acuity as well as the transparency of the cornea and lens, and the fundus were investigated in the patients. Biomicroscopy was performed in order to assess the corneal and lenticular transparency. Non-corrected and the best-corrected visual acuity (measured in decimals from 0.1 to 1.0) was evaluated using Landolt's rings (C optotypes) by Snellen test types at a 5 m distance from the chart.

The lens was evaluated by biomicroscopy. The lens was examined using a slit-lamp, positioning the illumination source at a 45° angle and the light beam being set to 2 mm width. Classification and grading of lens opacities was performed according to the Lens Opacities Classification System III.

Refraction testing was performed at each examination to determine the best corrected visual acuity.

Auto Refractometer Accuref-K 9001 Shin Nippon was used for refraction measurement.

Intraocular pressure was measured with Schiotz tonometer. Pupils of the subjects were dilated with tropicamide 1%. After dilation of the pupils, fundoscopy was performed with an ophthalmoscope of the direct monocular type and the slit-lamp, using a double aspheric lens of +78 diopters.

Stereoscopic color fundus photographs of the macula were obtained: centered at 45° and 30° to the fovea for a detailed macula analysis with Visucam NM Digital camera (Carl Zeiss Meditec AG, Germany).

AMD was classified according to the Age-Related Eye Disease Study [10]. Early AMD consists of combination of multiple small drusen, few intermediate drusen (63–124 μm in diameter), or retinal pigment epithelium abnormalities. Intermediate AMD is characterized by extensive intermediate drusen, at least one large (giant) druse (≥125 μm in diameter), or geographic atrophy (GA) not involving the center of the fovea. Advanced AMD: GA involving the fovea and/or or any of the features of neovascular AMD [10]. Diagnosis of early AMD was made if it was confirmed by two ophthalmologists and no other eye disorders were found during a detailed ophthalmological examination.

In the investigation of patients, the following computer tests of color sensitivity were used: the F–M 100 hue test [11] and maximum color contrast sensitivity test [12]. The tests