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ORIGINAL ARTICLE

Binocular function and stereopsis in neovascular age-related macular degeneration

Nur Demir, Belma Kayhan, Sukru Sevincli, Murat Sonmez

Ophthalmology, Sultan 2. Abdulhamid Han Training and Research Hospital, Istanbul, Türkiye

Abstract

Purpose: A macular lesion preventing the foveal fixation could lead to the fixation from eccentric points in age-related macular degeneration (AMD). There is a lack of knowledge about the binocular function of these patients and the role of preferred retinal locus in binocularity. This study aims to examine binocular fusion and stereopsis in a unique group of patients who have unilateral choroidal neovascular membrane (CNVM) involving the fovea.

Methods: Twenty-five patients with the diagnosis of the CNVM in one eye and type I or type II drusen in the other eye were examined. The Bagolini test was performed to determine binocular fusion. The Stereo Butterfly test was used for stereo acuity determination. CNVM measurements were done with optical coherence tomography.

Results: In the Bagolini test, 12 patients saw two lines with break in one of the lines. Eleven patients saw two lines crossing at higher or lower than the center. Two patients saw only one line. One of 25 patients had gross stereopsis (2500 s of arc). The area of the CNVM was extending to the perifovea in 2 patients suppressing the other eye. In remaining 23 patients, CNVM was located in fovea or extended up to the parafovea.

Conclusion: Binocular fusion is possible if the CNVM lesion size and location allow usage of the fovea-parafovea visual angle. Our study results support that the binocular function of patients with neovascular AMD depends on the corresponding retinal areas and the fusional limit of non-corresponding points.

Keywords: Age-related macular degeneration; binocular function; binocular fusion; nAMD; preferred loci; stereopsis.

Age-related macular degeneration (AMD) is a progressive disease resulting in scar formation in the macular region. It causes central visual loss, relative or absolute scotoma, and a distorted image.[1] AMD increases with aging and patients have a 25% risk of early AMD and 8% risk of late AMD over the age of 75.[2]

The preferred retinal locus (PRL) is a retinal location for alternative, eccentric fixation that could develop in AMD patients. PRL can arise in the relative scotoma area or outside the scotoma.[3,4] Prism glasses specifically designed intraocular lenses or eccentric viewing training are used for visual rehabilitation. The aim of the treatment is the displacement of the retinal image. The success depends on the binocular function. The studies of binocular vision in AMD patients are few in number. The majority of those studies examined binocular contrast summation, binocu-

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Correspondence: Nur Demir, M.D. Sultan 2. Abdulhamid Han Training and Research Hospital, Istanbul, Türkiye
Phone: +90 216 542 20 00 **E-mail:** nurd9920@gmail.com
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lar acuity summation, rivalry, and stereopsis.[3-6] Binocular fixation stability, gaze changes, and reading performance were also studied.[7-9] Déruaz et al.[10] defined the cases that can use multiple PRLs to read a text and alter the PRL according to the text structure. Another study observed that AMD subjects used different PRLs for the fixation of a point stimulus and fixation of a word.[11] Although PRLs have been well-studied monocularly, there is little knowledge about the function of PRLs in binocular viewing.

Our study aimed to examine binocular fusion, the usage of the eccentric fixation in binocular vision, and stereopsis in a unique group of patients who have unilateral choroidal neovascular membrane (CNVM) involving the fovea.

Materials and Methods

This study is a prospective, non-randomized, observational case series. The study was approved by the Ethical Committee (Approval number: E-46418926-050.99—51824) and performed in adherence with the tenets of the Declaration of Helsinki.

We examined the patients in the retina department with the diagnosis of unilateral CNVM. The other eyes of the patients had type I or type II drusen. Patients with strabismus or a history of strabismus and strabismus surgery, significant ocular media opacity, other retinal, choroidal, optic nerve diseases, apparent cognitive pathology, and amblyopia were excluded.

At the visit, the best-corrected visual acuity (BCVA) was recorded. The binocular function was tested with the Bagolini striated glasses. They were set up over patient glasses under normal lighting conditions. The stereo acuity test was measured using the Stereo Butterfly test (2500 second of arc). Patients were tested at 30 cm with the best-corrected near visual acuity under the normal indoor illumination.

Retinal optical coherence tomography (OCT) was performed by the use of spectralis SD-OCT (Version 1.10.4.0, Software_V6.16.2, Heidelberg Engineering, Heidelberg, Germany) without pupil dilation. The scan was conducted on 30×20° of a cube with 25 raster lines separated by 240 µ. The vertical and horizontal distance between the foveola and the healthy border of CNVM was measured. The total area of CNVM was also calculated.

Statistical Analysis

SPSS 20.0 (the Statistical Package for the Social Sciences Inc., Chicago, IL) was used for statistical analysis and interpretation of the data. Continuous variables of descriptive statistical methods were reported as the mean and standard deviation. Categorical variables of descriptive variables were reported as percentage. Parametric t-tests (independent sample t-test) for normal distributed variables were applied for analysis differences for the comparison of the results. $P < 0.05$ was considered as statistically significant.

Results

The study consisted of 25 patients. Single eyes of all patients were diagnosed with CNVM. Sixteen (64%) patients had type I drusen, nine (36%) with type II drusen in their fellow eyes. The mean BCVA of the eyes with CNVM was 0.84 ± 0.47 (LogMAR) and the mean BCVA of the fellow eyes was 0.16 ± 0.15 (LogMAR). The characteristics of the study population have been described in Table 1.

The Bagolini Test Results

Three different answers were received in the Bagolini test. Twelve (48%) patients saw a central break or break in one of the arms of the cross which means that they had suppressed the point corresponding to the lesion in binocular fusion [Figure 1]. Eleven (44%) patients saw the lines crossing at higher or lower than the center with one arm shorter that corresponds to the eye with CNVM [Figure 2]. They could use an extrafoveal fixation point in CNVM eyes in binocular vision. Two (8%) patients saw only one line; they suppressed the other eye [Figure 3].

Seven (58.3%) of 12 patients having scotoma on the Bagolini test had CNVM extending to early treatment diabetic retinopathy study (ETDRS) grid 1 and 3 mm. Five (41.6%) of 12 patients had CNVM involving ETDRS grid 1 mm.

Seven (63.6%) of 11 patients having extrafoveal fixation in one eye in the Bagolini test had CNVM extending to ETDRS grid 1 and 3 mm. Four (36.3%) of 11 patients had CNVM involving ETDRS grid 1 mm.

Table 1. Descriptive data of the study group

Gender (number/percentage)	**Female**	**Male**
	9 (36%)	**16 (64%)**
Age (year)		
mean±SD	71.24±8.97	
BCVA (logMAR) mean±SD	CNVM eye	Fellow eye
	0.84±0.47	0.16±0.15
Fellow eye lesion		
(Number/percentage)	Type I drusen	Type II drusen
	16 (64%)	9 (36%)

BCVA: Best-corrected visual acuity; CNVM: Choroidal neovascular membrane; SD: Standard deviation.

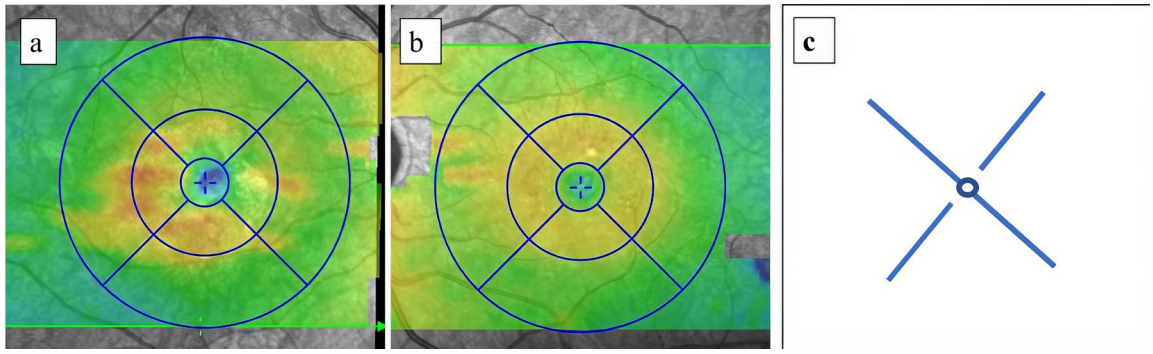

Fig. 1. (a) The right eye with CNVM involving the fovea and parafovea. (b) The left eye with type I drusen. (c) The central suppression of the right eye in the Bagolini test

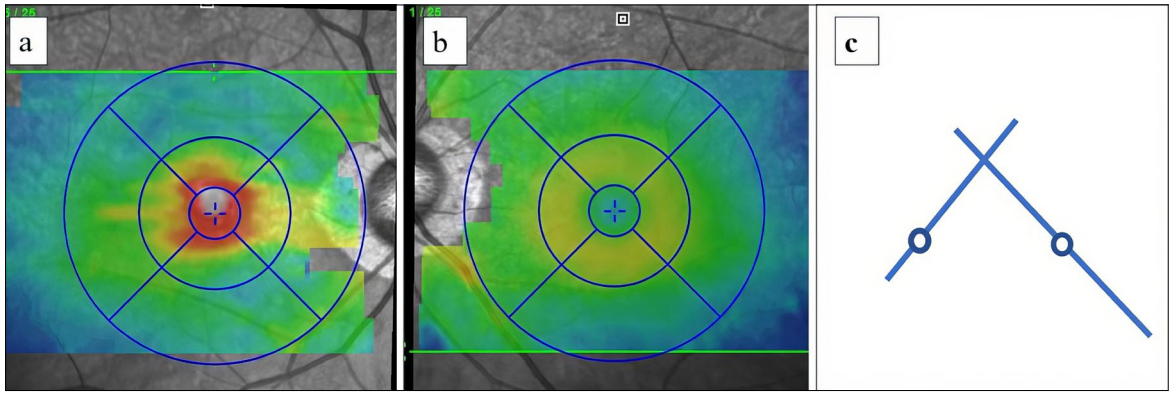

Fig. 2. (a) The right eye with CNVM involving the fovea and parafovea. (b) The left eye with type I drusen. (c) The extrafoveal fixation in the Bagolini test

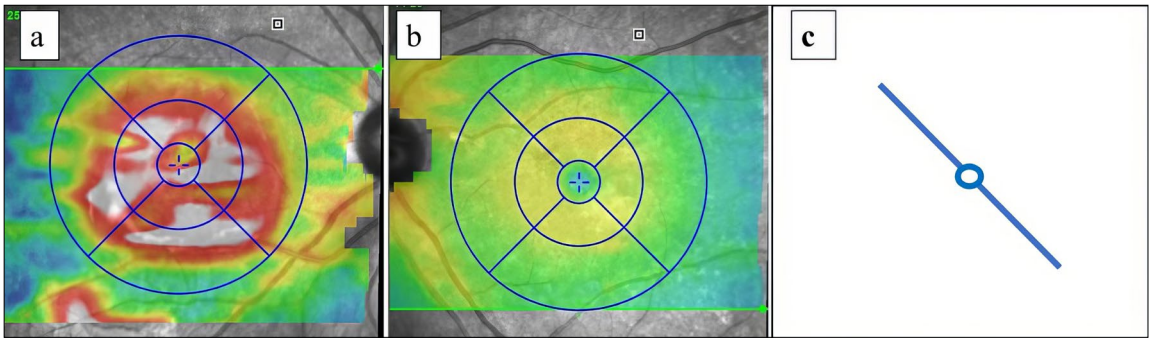

Fig. 3. (a) The right eye with CNVM extending to the perifovea. (b) The left eye with type II drusen. (c) The suppression of the right eye in the Bagolini test

Two patients suppressing the other eye had CNVM extending to ETDRS grid 1, 3, and 6 mm.

Stereopsis

One (4%) of 25 patients had gross stereopsis (2500 second of arc).

Lesion Area

The mean lesion size and extensions showed no difference between the central suppression group and the extrafoveal fixating group. Lesion area extended up to ETDRS grid 3 mm in both groups. Two patients suppressing the other eye had the largest CNVM lesion size extending to ETDRS grid 6 mm (39.61 mm^2 and 42.15 mm^2 lesion size of two patients). The mean lesion size was 14.53 ± 9.56 mm^2 in the central suppression group and 10.01 ± 5.77 mm^2 in the extrafoveal fixating group [Table 2].

Table 2. Comparison of the lesion dimensions of the patients with or without preferred loci

Lesion	Pref. loci (+) n:12		Pref. loci (-) n:13		P*-value
	mean±SD	med (IQR)	mean±SD	med (IQR)	
Area (mm^2)	11.17±6.81	11.41(9.57)	17.87±13.43	13.76 (22.66)	0.277
Superior extension (μm)	1877.58±644.81	1863 (710)	2262.54±1231.23	2145 (2150)	0.415
Inferior extension (μm)	1861.45±745.44	1803 (670)	2347.0±969.84	2638 (1857)	0.192
Temporal extension (μm)	2095.09±823.85	2268 (817)	2394.62±1224.70	2103 (1842)	0.839
Nasal extension (μm)	1992.92±946.08	2252 (1208)	2104.92±909.05	2273 (1715)	0.744

*Mann–Whitney U-test. Mean±SD, mean±standard deviation; med (IQR), median (interquartile range); μm, micrometers; pref. loci, preferred loci.

Discussion

The unique study group in the present study demonstrated that when one eye fixates on the parafovea (ETDRS grid 3 mm) and the other eye uses fovea, binocular fusion with central suppression or from the extrafoveal fixation point is possible. Eyes with AMD lose their central vision and they can use one or more preferred loci in relation to lightning conditions and performance.[12] In a study of 825 patients with low vision, 84.4% of eyes (1130 eyes of 1339) demonstrated an established PRL (1.0–9.0° in diameter) for fixation.[13] The preferred locus is determined with microperimetry or scanning laser ophthalmoscopy with monocular testing.[4,14] Many studies about preferred loci have been published but studies about the binocular usage are very few in AMD patients.[4,14-16]

The present study results were in correlation with some other studies that the eye with better visual acuity drives the fixation. The study done by Sullivan and Walker[17] tested binocular usage of PRLs with an eye tracker and suggested that the better eye PRL dominates in binocular conditions. Binocular reading performance was also in correlation with the reading performance in the better-seeing eye.[7] In another binocular fixation study done with a microperimetry and eye tracker, the better-seeing eye drives the fixation stability of people with AMD with large interocular acuity differences.[14] In a study with a large visual acuity difference between two eyes affected by AMD, PRLs developed on the corresponding retinal area in 51% of cases.[15] The study done by Schuchard[4] correlates with the present study in that non-correspondence of binocular PRLs is a contributing factor to monocular perception.

The lesion size and location of the preferred loci could have an impact on binocularity. Increased differences in relative distance of both eye and direction of fixation points vary with lesion size and location. In this study, any difference in lesion size, vertical, or horizontal elongation of CNVM was not found explaining the preference of the fusion type in the Bagolini test. Patients with CNVM limited to the central 1 mm or elongating to parafoveal area (ETDRS grid 3 mm) could have fusion either with central suppression or an extrafoveal fixation point. Two patients with large CNVM with elongation to the perifoveal area (ETDRS grid 6 mm) had no fusion.

The patient group in this study was unique, in that patients could do only extrafoveal fixation in one eye with CNVM and foveal fixation in the other eye. The eye fixating from fovea was driving the binocular function. The capability of binocular fusion depended on the non-corresponding point of the eye with CNVM to be within fusional limits.

An extremely low stereopsis ratio (4%) in the present study could also be explained with non-correspondence. Stereopsis could be done by not only central but also peripheral retina stimulation. However, non-corresponding points should be within the fusional limit, and a larger stimulus distant from the fovea is necessary.[18] Stereopsis capacity was found in 41.7% of patients with AMD in a study.[6]

Foveal region extends visual angle of 2° and accounts for the highest visual acuity and 6-8 characters. Parafoveal region that extends visual angle of 2–5° accounts up to 15–20 characters.[19] Nikolova et al. discussed the important role of parafoveal pre-processing in binocular vision.[20] This is in accordance with our results that parafovea–fovea could act in binocular vision.

The study group of other studies usually consists of cases with both eyes affected by AMD. In our study, drusen in the control group was not preventing the foveal fixation and this eye was driving fixation. If the CNVM lesion on the other eye allows PRL development and PRL-foveal image fusion, binocularity is possible. We found a lower degree of stereopsis capacity in comparison to other studies. The most probable explanation for that is the existence of a stably foveolar fixating eye and non-corresponding points to be out of fusional limits for stereopsis. In cases of macular pathology, necessitating fixation from extrafoveal PRLs

in both diseased eyes could provide non-corresponding points to be closer in the fusional range.

The limitation of our study is the lack of microperimetry or eye tracker correlation. Another limitation is the subjectivity of the Bagolini glasses test. The test reliability could change with patient's cognitive function and variation of glasses striations.

Conclusion

The present study shows that some patients could use preferred loci in binocular vision if it locates fovea-parafovea visual angle. Our study results support that the binocular function of AMD patients depends on the corresponding retinal area or fusional limit of non-corresponding points.

Ethics Committee Approval: This study was approved by University of Health Sciences Hamidiye Faculty of Medicine Ethics Committee (date: 17.02.2022; number: 2022/4).

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