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Associations between subjective and objective visual function in patients with unilateral macular holes ☆,☆☆,☆☆☆

E. Mönestam *, M. Andersson, S. Åström

Department of Clinical Sciences/Ophthalmology, Umeå University, S-90185 Umeå, Sweden

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Abstract

Forty-six patients with uniocular macular holes and unaffected, fellow eyes were studied to evaluate inter- and intraocular associations between various objective tests of visual function and perceived visual ability. The affected eye had significant associations between visual acuity (VA) and the fovea threshold test, but for the fellow eye only VA and low-contrast VA 10% were associated. The reduction in visual acuity under low-contrast conditions relative to high-contrast did not differ between the affected eye and the healthy eye. Subjective visual ability seems to depend more on the visual acuity of the affected eye than the healthy eye.

Keywords: Visual acuity; Low-contrast visual acuity; Macular hole; Visual function

1. Introduction

Idiophatic macular hole is a rather common macular disease affecting older people, and is more prevalent among women and men (La Cour & Friis, 2002). The prevalence in the general population has been estimated to be 3.3 per 1000 people 55 and older (Luckie & Heriot, 1995). The major complaints of those affected are metamorphopsia, and loss of central vision.

Previous research regarding visual function in eyes with macular holes are most commonly based on high-contrast visual acuity (VA) pre- and postoperatively (Casuso, Scott, & Flynn, 2001; Leonard, Smiddy, Flynn, & Feuer, 1997; Scott, Moraczewski, Smiddy, Flynn, & Feuer, 2003; Wittich, Overbury, Kapusta, & Watanabe, 2006). The VA-level represents only one aspect of impaired visual function resulting from macular hole development. Other aspects are low-contrast acuity, and visual field sensitivity or size of the scotoma, which are increasingly recognized as important variables in explaining perceived visual ability in various patient groups, (Burstedt, Mönestam, & Sandgren, 2005; Gardiner, Armstrong, Dunne, & Murray, 2002; Hazel, Latham Petre, Armstrong, Benson, & Frost, 2000; Szlyk et al., 1997; Tranos, Ghazi-Nouri, Rubin, Adams, & Charteris, 2004). The body of knowledge regarding macular function will increase if the associations between various tests of visual function in healthy eyes and eyes with different types of macular disease is better understood (Villate, Lee, Venkatraman, & Smiddy, 2005; Wittich et al., 2006).

The patients' own perception of their visual performance is also important. A questionnaire on self-assessed visual function allows an estimation of the patients' subjective visual ability, and thus captures the full extent of the disability suffered by the patient in the real world. A number of vision-targeted quality of life questionnaires exist, such as the visual function questionnaire (VF-14) (Steinberg et al., 1994) and NEI-VFQ-25 (Mangione et al., 2001).

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* Corresponding author. Fax: +46 90 145997.
E-mail address: eva.monestam@vll.se (E. Mönestam).

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The objective of this study was to associate various clinical visual function tests, for the affected eye and the fellow eye, intra- and interocularly, and with the patients' self-assessed visual ability, recorded with a visual function questionnaire (VF-14), in patients with a unilateral macular hole before surgery. We hypothesize that the results from the affected eye differ from the fellow eye. We specifically investigate the relation in visual acuity under low contrast conditions relative to high-contrast between the affected eye and the healthy eye and how the patient's self-assessed visual ability relates to the visual function of the affected eye and the unaffected eye, respectively. The patients had different stages of macular hole and it was also investigated whether the vision measures were related to the stage (Gass, 1995).

To the authors' knowledge there are no previous research investigating these relations in patients with a macular hole in one eye.

2. Patients and methods

Forty-six patients with a full-thickness idiopathic macular hole were recruited. All patients had been admitted the posterior segment unit of the Eye clinic of Norrlands University Hospital, Umeå, Sweden.

The inclusion criteria were; corrected VA of 20/25 (log MAR 0.1) or better in the fellow eye, clear ocular media without any significant cataract, and absence of any other clinically diagnosed ocular condition, past or present. Patients were excluded if they were unable to understand the tests. Informed consent was obtained from all patients, and no patient invited, declined to participate. The patients underwent all tests and examinations mentioned below on the same day. Three years after the study it was confirmed by telephone interview that no fellow eye had developed symptoms of a macular hole. Forty-six patients were included in the study; 14 eyes were graded as having a stage 2 hole, 27 eyes a stage 3 hole, and 2 eyes had a stage 4 hole. For 3 eyes, data regarding the stage of the hole was missing. The study followed the tenets of the Declaration of Helsinki and was approved by the local ethics committee.

2.1. Self-reported visual function questionnaire

Perceived visual ability was assessed using the VF-14 questionnaire, which is a measure of self-assessed disability regarding activities of daily living affected by vision. This questionnaire was primarily developed for cataract patients, and consists of 14 questions regarding vision-demanding activities. Five questions are related to near-acuity activities such as reading, writing cheques, sewing, four questions are related to activities of intermediate distance such as recognizing people, seeing stairs, and five questions are related to distance-acuity activities such as TV-viewing, reading signs and car-driving. The VF-14 score was calculated as previously described (Steinberg et al., 1994). The range of the VF-14 score is 0–100. A score of 0 denotes a very low visual function whereas 100 points stands for unrestricted/unaffected subjective ability to perform the vision-dependent activities as a result of visual impairment.

The VF-14 questionnaire has been found to be valid and reproducible also for patients with retinal diseases (Linder et al., 1999). All patients completed the VF-14 by themselves.

The 25-item NEI VFQ-25 questionnaire is more commonly used in retinal research, (Mangione et al., 2001; Tranos et al., 2004), compared with the VF-14 questionnaire, which was primarily developed for cataract patients. We used the VF-14 questionnaire because it focuses on perceived visual ability and has no subscales such as General Vision, Ocular pain, Vision-Specific Role limitations, Dependency, Social Functioning and Mental Health.

2.2. Tests of visual function

All tests were carried out in the same room, and in the same order, by one examiner masked to the questionnaire results. All patients were tested using their best-corrected refractive correction, which in most cases was equal to their habitual correction.

The order of the visual function tests was as follows:

(1) Monocular and binocular high-contrast VA (VA right eye/left eye/binocularly). VA was measured with Early Treatment Diabetic Retinopathy Study (ETDRS) charts, positioned at a distance of 4 meters (m). Participants who failed to read the largest letters with their affected eye were tested at 2 or 1 m. Lighting conditions were standardized, using an ETDRS chart illuminator cabinet No. 2425 (Precision Vision, La Salle, IL). VA was scored as the total number of letters read correctly and transformed to the logarithm of the minimum angle of resolution (log MAR) units.

(2) Monocular low-contrast VA for each eye (LCVA 10% and 2.5%). Low-contrast VA (LCVA) was tested using ETDRS logarithmic contrast charts (10% and 2.5%) at a distance of 4 m. Participants who failed to read the largest letters at 4 m were tested at 2 or 1 m. LCVA was scored as VA, i.e., the total number of letters read correctly, and transformed to the logarithm of the minimum angle of resolution (log MAR) units. Log MAR = 3 was used for patients unable to read any letter on the low-contrast chart at a distance of 1 m, ($n = 2$).

(3) Fovea threshold test (Humphrey visual field analyzer (HFA; Zeiss Humphrey Systems, Dublin CA)). Both eyes were tested with threshold-measuring computerized perimetry using the Central 10-2 program of the Humphrey Field Analyzer. Measurement of the fovea threshold was included. The fellow eye was in all cases tested first to familiarize the patients with the perimeter.The reliability of the tests was checked with fixation losses of <20% and false-negative or false-positive responses of <15%.

2.3. Ophthalmological examination

After the tests of visual function were completed, the pupils were dilated and an ophthalmological examination was performed. The macular hole was diagnosed and graded by biomicroscopy, according to the classification by Gass (1995). Data collected also included age, gender, duration of symptoms, lens status, and general history of the patients.

2.4. Statistical methods

Two-sided independent samples t-tests were used to analyze gender-related differences regarding age, high- and low-contrast VA data, and fovea sensitivity results. VF-14 scores were skewed and therefore non-parametric Kruskal–Wallis tests were used. The associations between the assessed stage of the macular hole and the visual functional tests were analyzed by Spearman's correlation statistics and one-way ANOVAs. P-values less than .05 were considered significant for these tests.

The associations between the objective visual function results (VA, LCVA 10% and 2.5%, and fovea threshold test), and the VF-14 questionnaire total score were first examined using Spearman's correlation analyses.

There are generally high levels of statistically significant correlations between most of the variables studied for the same eye. Therefore, partial correlation coefficients (r_P) were used to control for the influence of multicollinearity. These correlation statistics were also adjusted for age and gender. To avoid type I errors the p-value for significance was set as low as <.005 to correct for the multiple comparisons (Table 2).

Data were analyzed by SPSS software 12.0.

3. Results

3.1. Characteristics of the patients and visual functional data

Forty-six patients were included in the study, 36 females (78%) and 10 males (22%). Mean age was 67 years ($SD = 6.3$; median 66; min–max 50–81). The women were significantly younger than the males (65.6 vs 70.5 years, respectively, $p = .03$).

Table 1 shows data regarding high- and low-contrast VA for the affected eye and the healthy eye, respectively. The women had overall worse visual function compared with males, but the differences were not statistically significant also after adjustment for age, data not shown.

Median VF-14 score was 91.3 (min 57–max −100, with six patients scoring 100).

3.2. Visual function and the association with the stage of the macular hole

Fourteen eyes were graded as having a stage 2 hole, 27 eyes a stage 3 hole, and 2 eyes had a stage 4 hole. For 3 eyes, data regarding the stage of the hole was missing. The mean duration of the macular hole symptoms was 8.3 months (min 2–max 20 months), which means how long the patient had experienced symptoms before they were examined at the university clinic.

There were statistically significant associations between the stage of the macular hole regarding high-contrast VA and the fovea threshold test ($p = .026$ and $p = .035$, respectively (ANOVA)), meaning that an eye with a higher stage of the hole have worse visual function. Regarding low-contrast acuity 10% and 2.5%, no significant associations were found.

The reduction in VA under low-contrast relative to high-contrast did not differ between the affected and the fellow eyes (Table 1). In other words, the difference in logMAR acuity between for instance LCVA 10% and high-contrast VA or LCVA 10% and 2.5% was approximately the same irrespective if the eye had a macular hole or not.

There was also no significant difference between the stage of the macular hole and the relation between for instance LCVA 10% and high-contrast VA, meaning that the also these relations were unchanged regardless of the stage of the macular hole (data not shown).

Table 1
Visual acuity data (high-contrast and low-contrast 10%, 2.5%) for all patients analyzed

Variable	Affected eye	Fellow eye
Mean VA (logMAR) (*SD*)	0.76 (0.15)	0.02 (0.09)
Mean low-contrast VA (10%) (logMAR) (*SD*)	0.95 (0.37)	0.28 (0.12)
Mean low-contrast VA (2.5%) (logMAR) (*SD*)	1.34 (0.45)	0.59 (0.19)
Fovea sensitivity (dB) HFA	17.4 (10.0)	34.8 (1.6)

3.3. Correlation analyses

Partial correlations for the visual functional data are shown in Table 2. The results did not change if binocular VA data were used instead of data from the fellow eye. The results also did not change if a summary score of the 5 questionnaire near-acuity items was used instead of the VF-14 total score.

The eye affected with a macular hole had statistically significant associations between high-contrast VA vs fovea threshold test and VF-14 total score, after controlling for the influence of multicollinearity. On the other hand, regarding the healthy fellow eye, the only statistically significant association was between high-contrast and low-contrast VA 10% ($r_P = .55$; $p = .001$; Table 2).

There was a strong significant partial correlation between LCVA 2.5% and 10% for the affected eye ($r_P = .70$; $p = .000$), which was not detected when analyzing the same variables of the fellow eye.

Surprisingly, we found a statistically significant correlation, after controlling for age and gender, between LCVA 2.5% for the fellow eye and VA in the affected eye ($r_P = .49$, $p = .003$).

Table 2
Partial correlation-coefficient matrix between visual functional data (VA, LCVA 10% and 2.5%, and fovea threshold test) and questionnaire total score (VF-14) for the eye affected with a macular hole and the fellow healthy eye, respectively

	Visual acuity (logMAR)	Low-contrast VA (10%)	Low-contrast VA (2.5%)	Fovea threshold
Affected eye				
Low-contrast VA (10%)	$r = -.20$ $p = .28$			
Low-contrast VA (2.5%)	$r = .19$ $p = .30$	**$r = .70$** **$p = .000$**		
Fovea threshold	**$r = -.66$** **$p = .000$**	$r = -.43$ $p = .014$	$r = -.20$ $p = .28$	
VF-14	**$r = -.44$** **$p = .003$**	$r = -.24$ $p = .18$	$r = -.03$ $p = .86$	$r = .32$ $p = .037$
Fellow eye				
Low-contrast VA (10%)	**$r = .55$** **$p = .001$**			
Low-contrast VA (2.5%)	$r = .24$ $p = .18$	$r = .24$ $p = .19$		
Fovea threshold	$r = .21$ $p = .25$	$r = .27$ $p = .13$	$r = -.39$ $p = .027$	
VF-14	$r = -.18$ $p = .31$	$r = -.36$ $p = .036$	$r = -.31$ $p = .07$	$r = -.14$ $p = .44$

To control for the influence of multicollinearity each variable, except the VF-14 score, was controlled for the other variables, age and sex. The VF-14 variable was controlled for age and sex. Correlation coefficients in boldface are statistically significant ($p < .005$).

4. Discussion

Most macular holes are believed to begin as an occult central neurosensory retinal dehiscence followed by centrifugal retraction and concentration of photoreceptors. The foveal cones are dislocated to the edge of the hole, and there are no cones in the center (Ezra, 2001; Green, 2006; Smiddy & Flynn, 2004). The contraction and condensation probably involve a broad area of the posterior vitreoretinal interface, which is focally intense in the region of the foveolar and perifoveolar area (Gass, 1995).

High-contrast VA has been estimated to be approximately 20/100 (log MAR 0.7) at an eccentricity of 10 degrees from the fovea, (Seiple, Holopigian, Szlyk, & Wu, 2004). The diameter of most macular holes is less than 5 degrees. This discrepancy that VA from an anatomic view should be better than it is in eyes with a macular hole, can probably be attributed to the above mentioned anatomic changes in the foveolar area. An inversely proportional association between best corrected Snellen VA and the diameter of the macular hole, with smaller holes having better VA has also been shown (Chew et al., 1999). Low-contrast acuity of various percentages of contrast and their relation to distance from fovea has been studied and contrast sensitivity has been shown to demonstrate a deeper fall-off with eccentricity than acuity (Melmoth & Rovamo, 2003; Seiple et al., 2004).

The present study shows that although the eyes tested, which were affected with macular holes of stages II–IV, have worse visual function for all tests performed, the reduction in VA under low-contrast did not differ between the affected and fellow eyes. The relations of high-contrast VA and LCVA 10% and 2.5% were also unchanged regardless of the stage II–IV of the macular hole. The influence of the functional depression, caused by the dislocation of foveal cones, on LCVA can be deduced from high-contrast VA. There is no additional burden on LCVA caused by the dislocation of the cones.

The affected eye had significant associations between visual acuity (VA) and the fovea threshold test, but for the fellow eye only VA and Low contrast VA 10% were associated. We used the Bonferroni correction, setting the p-value for significance as low as $p < .005$ as well as using partial correlations and for each variable control for the other variables (except VF-14 total score) and age and sex. This approach aims to give a low probability of erroneous significant differences. The drawback is that several truly significant associations might be insignificant especially as the number of patients was 46. Data based on the perception of patients are also subject to greater variability than data recorded without any cooperation of the patients. These mechanisms might explain why these results seem somewhat random.

A surprising finding is that LCVA 2.5% and foveal threshold test for the fellow eye was associated with VA of the affected eye. This finding might be an indication of subclinical vitreous traction of the macula of the fellow eye as described in recent research using ocular coherence tomography (OCT) (Chan, Duker, Schuman, & Fujimoto, 2004). One might speculate that pathological changes in the vitreoretinal interface in the fellow, presumed healthy eyes might cause deterioration of other tests of visual function, not found by testing only high-contrast VA. None of the 46 study patients had developed symptoms of a macular hole in the fellow eye 3 years after the present study, which should rule out an impending development of a macular hole in the fellow eye at the time of the study (Niwa, Terasaki, Ito, & Miyake, 2005). On the other hand, recent research analyzing localized visual acuity and mfERG did not find any significant difference between unaffected fellow eyes and control eyes (Szlyk et al., 2005). There is a growing body of research combining psychophysical data such as acuity and contrast sensitivity with local electrophysiological responses and to Humphrey visual field thresholds from the same subjects (Seiple et al., 2004). Further research, by combining OCT-findings and mfERG data with results from various visual function tests, are clearly warranted to clarify this subject.

There was no correlation between high-contrast VA of the unaffected better- seeing eye, and the VF-14 score. This finding differs from what has been found in previous research regarding cataract patients. Most studies in cataract patients have found that self-assessed visual function as measured by a questionnaire is to a larger extent more depending on the VA of the better eye than the worse eye (Steinberg et al., 1994). This disparity between cataract patients and patients with a unilateral macular hole might be explained by the fact that cataract is almost always a disease affecting both eyes more or less. The better eye in a cataract patient generally is probably not as free from ocular comorbidity, as the fellow eye in the carefully selected patients from the present study. The self-assessed trouble with vision experienced by patients with a uniocular macular hole and a healthy eye, seem to depend more on the VA of the affected eye, than the VA of the better eye.

It seems that in eye conditions affecting both eyes, such as cataract, RP and AMD, the better eye determines the visual function, and in cases with one healthy eye the degree of visual deficit of the affected eye determines the subjective visual function. Further research regarding the nature of these subjective scores is clearly warranted as the questions in the VF-14 questionnaire do not include depth perception or diplopia. The rationale for having surgery in uniocular cases is supported by these findings.

The characteristics of the cohort in this study were consistent with other studies of macular holes (Polk, Smiddy, & Flynn, 1996). There was a predominance of females and mean VA of the affected eyes was approximately 20/165 (log MAR 0.9). The women had overall worse visual function and were younger compared with the males, but the differences in visual function after adjusting for age were not statistically significant.

The relatively low number of patients ($n = 46$) might be considered a limitation of the study, as the statistical power is reduced. However, in order to minimize the effects of confounding variables it was considered essential that the patients selected had to be clinically free of any other eye disease past or present. Coexisting conditions such as cataract and age-related macular degeneration of the affected or the fellow eye may directly influence the VA, especially the low-contrast measurements. The selection of patients was therefore very careful in order to reduce bias of this type.

Another limitation of the study is the absence of anatomical data regarding size and structure of the macular hole, and the structure of the vitreoretinal interface of the fellow eyes. OCT was not available when most of the patient data were collected. Further research is clearly warranted regarding the various visual functional variables examined, and their relations after successful surgery. Further studies are also required to understand the relationship between visual function and the morphologic changes in the cross-sectional images in eyes with a macular hole.

In conclusion, the anatomic changes in the foveolar area caused by a macular hole did not cause any additional reduction in visual acuity under low-contrast conditions relative to high-contrast compared with the healthy eye.

In eye conditions affecting both eyes, such as cataract, RP and AMD, the better eye determines the visual function, and in cases with one healthy eye the degree of visual deficit of the affected eye determines the subjective visual function. The rationale for having surgery in uniocular cases is supported by these findings.

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