Retinal Contraction and Metamorphopsia Scores in Eyes with Idiopathic Epiretinal Membrane

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PURPOSE. Using M-CHARTS (Inami Co., Tokyo, Japan), which were developed by the authors to measure metamorphopsia, and image-analysis software, which was developed to quantify retinal contraction, the authors investigated the relationship between the degree of retinal contraction and the degree of metamorphopsia in eyes with idiopathic epiretinal membrane (ERM).

METHODS. This study was conducted in 29 eyes with ERM (29 patients, 20 women; mean age, 62.1±8.6 years) observed for at least 3 years (mean, 3.55±0.6 years) after diagnosis. Horizontal (MH) and vertical (MV) metamorphopsia scores were obtained with the M-CHARTS. Horizontal and vertical retinal contraction due to ERM was measured by using image-analysis software developed by the authors to calculate horizontal and vertical components of changes in the locations of retinal vessels on sequential fundus images.

RESULTS. There was a significant (P<0.01) positive correlation between the degree of retinal contraction and metamorphopsia score. In addition, there were significant positive correlations between horizontal contraction of the retina and the MV score (P<0.01) and between vertical contraction of the retina and the MH score (P<0.05). No significant correlations were found between change in the metamorphopsia score and change in visual acuity or mean defect.

CONCLUSIONS. Metamorphopsia scores correlate well with measurements of retinal contraction due to idiopathic ERM. Using M-CHARTS is a simple and useful method for quantitatively monitoring metamorphopsia in patients with ERM. (Invest Ophthalmol Vis Sci. 2005;46:2961–2966) DOI:10.1167/iovs.04-1104

Metamorphopsia is a symptom described as perceived distortion of objects. It is frequently observed in macular diseases such as idiopathic epiretinal membrane (ERM), macular hole and age-related macular degeneration. Especially among disturbances in vision reported by patients with ERM, metamorphopsia is one of the most common symptoms. In fact, it has been indicated that metamorphopsia can still be present, even if ERM peeling has been surgically successful and visual acuity has improved.1 In 1999, we developed new visual assessment charts, M-CHARTS (Inami Co., Tokyo, Japan), with which it is possible to quantify the degree of metamorphopsia in patients with disease involving the macula.2,3 It is known that one of the main causes of metamorphopsia in individuals with macula diseases is disarray of the photoreceptors in the sensory retina. Especially in cases of ERM, the photoreceptors and/or the outer segments are dislocated due to the contraction of the proliferating membranes. However, to date there have been no detailed long-term follow-up studies to evaluate the relationship between the progression of retinal contraction and change in metamorphopsia. We therefore decided to conduct this study to investigate the relationship between the severity of retinal contraction and amount of change in metamorphopsia in patients with ERM who were observed over the long-term (at least 3 years) after diagnosis of ERM.

MATERIALS AND METHODS

Subjects

Diagnosis of ERM was based on the results of scanning laser ophtalmoscopy (SLO; Rodenstock, Munich, Germany) with an argon blue laser beam. The inclusion criteria for patients with ERM were as follows: corrected visual acuity of >0.4 (logMAR), a pupil diameter of >3.0 mm, intraocular pressure of <21 mm Hg, clear ocular media, and no systemic diseases that were likely to affect visual functions. Informed consent was obtained from all patients. All experiments were performed in accordance with the Declaration of Helsinki for research involving human subjects.

Twenty-nine patients (20 women; mean age, 62.1±8.6 years) who presented with ERM between 1998 and 2001 met criteria for inclusion in the study and were observed for at least 3 years (mean, 3.55±0.6 years). If ERMs were observed in both eyes, one randomly selected eye was examined. Each subject underwent a complete ophthalmic examination every 6 months, including measurement of best-corrected visual acuity, quantification of metamorphopsia by M-CHARTS, slit lamp biomicroscopy, applanation tonometry, dilated funduscopy, fundus photography, examination by SLO, and central 10° standard automated perimetry (SAP, Octopus 101, program M2; Haag-Streit AG, Koeniz, Switzerland).

Our results after the 3-year follow-up showed that, of 29 eyes with ERM, 15 eyes had a change in metamorphopsia score, with or without a change in retinal contraction; 6 eyes had no change in either metamorphopsia score or retinal contraction; 5 eyes had metamorphopsia score of 2.0 or more; and 3 eyes had spontaneous improvement of ERM.

We therefore focused our study on those 15 eyes as we evaluated the relationship between the severity of retinal contraction and change in metamorphopsia. In addition, 21 fellow eyes were considered normal and served as control eyes to establish normal variations over 3 years in metamorphopsia and of retinal contraction.

Quantification of Metamorphopsia

M-CHARTS were used to monitor metamorphopsia during the follow-up period. In patients with metamorphopsia, a straight line projected onto the retina is recognized as a curved or irregular line. If the straight line is replaced with a dotted line and the dot interval is

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FIGURE 1. Quantification of retinal contraction over 3 years, using fundus photographs. (A) The follow-up fundus image (2003) was superimposed on the baseline image (2000) so that the optic disc and choroidal vessels matched. (B) The change in position of the retinal vessels was evaluated in the 25 areas of the central 20° macular area and the absolute values of horizontal and vertical movements was expressed as a vector. For easier visibility, the vector arrows are shown three times larger than the actual measured vectors. (C) The observed central 15 areas in the vertical direction (the central five areas with the vertical line measured by M-CHARTS plus the five areas to the right and left in the vertical direction). (D) The observed central 15 areas in the horizontal direction (the central five areas with the horizontal line measured by M-CHARTS plus the upper and lower five areas in the horizontal direction).

FIGURE 2. SLO images obtained with an argon blue laser beam and results of M-CHARTS in a patient with ERM in the right eye. (A) Baseline and (B) 3-year follow-up SLO image of the right eye. (C) The results of Amsler charts, M-CHARTS, and Octopus 101 (M2) (Haag-Streit AG, Koenitz, Switzerland) evaluations of metamorphopsia in the right eye at baseline and at the 3-year follow-up visit.
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Quantification of Retinal Contraction

For this study, we developed a new image-analyzing technique to measure contraction of the sensory retina due to proliferation of ERM. The technique is based on the fact that retinal vessels, which are

changed from fine to coarse, the distortion of the line decreases with increasing dot interval until finally the dotted line appears straight. This finding is the basis for development of M-CHARTS to measure metamorphopsia. M-CHARTS consist of 19 dotted lines with dot intervals ranging from 0.2° to 2.0° of visual angle. To measure metamorphopsia, subjects view M-CHARTS at a distance of 30 cm through corrective lenses. When the patient recognizes the dotted line on the chart as being straight, its visual angle is considered to be the metamorphopsia score. In this study, we measured metamorphopsia for horizontal lines and vertical lines to obtain separate scores for horizontal (MH) and vertical (MV) metamorphopsia. Each M-CHART test was repeated three times for each eye at each examination. Amsler charts were also used for qualitative evaluation of metamorphopsia and for comparison. The patient’s fundus information was completely masked from the examiner during the examination.

Results

Case Report

Figure 2 shows the appearance of ERM and the results of evaluating for metamorphopsia in a typical case. ERM was detected in the right eye of this patient by SLO with an argon blue laser beam (Fig. 2A). Best-corrected visual acuity in the affected eye was 0.1 logMAR (logarithm of the minimum angle of resolution). When viewing Amsler charts, the patient reported slightly more severe metamorphopsia in the horizontal than in the vertical direction. The horizontal lines on M-CHARTS also detected the fine metamorphopsia. When a dotted line with an interval of a 0.2° visual angle was used, the severity of metamorphopsia decreased, and it completely disappeared with the interval of a 0.4° visual angle, and thus the patient’s right MH was determined to be 0.4. The right MV was 0.3 obtained by the vertical dotted lines (Fig. 2C).

At the 3-year follow-up visit, the corrected visual acuity of the affected eye remained unchanged at 0.1 logMAR, but progression of the ERM was detected on SLO with an argon blue laser beam (Fig. 2B). The severity of metamorphopsia had also increased after 3 years, both qualitatively using Amsler charts and quantitatively, as shown by M-CHART scores of 1.0 (MH) and 0.5 (MV; Fig. 2C). The average retinal contraction for 25 areas was 0.09 mm in the vertical direction and 0.07 mm in the horizontal direction during the 3 years. The largest vector for retinal contraction (“maximum retinal contraction”) in the 25 components of the sensory retina, move with progression of the ERM. Thus, it is possible to evaluate the degree of retinal contraction by measuring the distances that the retinal vessels have moved between one evaluation time and the next.

We measured retinal contraction in this study using fundus photographs taken at the start of the study (baseline photograph) and after 3 years of follow-up (comparison photograph) using a digital fundus camera (model 60 UVi; Canon, Inc., Tokyo, Japan) and image-analyzing software that we developed (WellSystem Inc., Tokyo, Japan).

First, we enhanced the choroidal vessels in the fundus image with a digital color filter and the two fundus images were then composed by matching the optic discs and choroidal vessels. Next, the distance between the center of the optic disc and the fovea was calibrated to be 15° (4.02 mm) and the central 20° macula area was divided into 25 areas (Fig. 1A). In each of the 25 areas, two overlapping fundus images were flickered back and forth at a speed of 2 Hz, and the retinal vessels were exactly matched manually. The process was repeated three times and the average value was used for each area. The movement of the retinal vessels in each of the 25 areas was displayed as a vector (Fig. 1B) and the values of each vector’s vertical and horizontal components were recorded in millimeters as the index of retinal contraction.

In this study, to assess the correlation between retinal vessel movement and degree of metamorphopsia, we performed the analysis with two approaches: first, the relationships between the amount of change in the average of MV and MH, and both the average and maximum of retinal contraction in all 25 areas; and second, the relationships between all horizontal components of the 25 vectors and changes in MV and MH separately, as well as between all 25 vertical components and changes in MV and MH.

For more directional specific comparison, we further limited our observations to the central 15 areas in the vertical direction (the central five areas with the vertical line measured by M-CHARTS plus the five areas to the right and left in the vertical direction; Fig. 1C) and vice versa for the horizontal direction (Fig. 1D).

As the control, we used values for changes in position of retinal vessels on fundus photographs obtained at baseline and at the 3-year follow-up visit in the 21 normal fellow eyes of the subjects with unilateral ERM.

Figure 3. The correlations between change in metamorphopsia score and the average retinal contraction (A) or maximum retinal contraction (B) in the 25 areas. Spearman rank correlation coefficient (r_s) and slope are shown (P < 0.01 for both).
areas was 0.14 mm in the vertical direction and 0.22 mm in the horizontal direction.

**Group Results**

As we reported previously, metamorphopsia scores was 0 in all normal eyes, and the intraindividual variation of the metamorphopsia score in all ERM subjects was within 1 line (±0.1 score). Therefore, in eyes with ERM in this study, we considered a change in metamorphopsia to be a change in the M-CHART score of ±0.2 or more. The metamorphopsia scores were 0 in 21 control eyes. Analysis for retinal contraction from baseline to the 3-year follow-up visit in the 21 control eyes in this study showed a <0.03-mm variation in any one direction per eye and a mean change ± SD of 0.009 ± 0.006 mm in the vertical direction and of 0.013 ± 0.003 mm in the horizontal direction. Therefore, we considered a change in retinal contraction in eyes with ERM to be a change of 0.05 mm or more.

For the 25-area analysis over 3 years, there was a significant positive correlation (Spearman rank correlation coefficient, \( r_s = 0.74, P < 0.01 \); Fig. 3A) between the severity of average vertical retinal contraction and change in metamorphopsia score (Fig. 3A). There was also a significant positive correlation (\( r_s = 0.66, P < 0.01; y = 1.14x + 0.07 \)) between the maximum value for retinal contraction and change in metamorphopsia score (Fig. 3B). Significant positive correlations were observed between the severity of average horizontal retinal contraction and change in MV (\( r_s = 0.74, P < 0.01 \); Fig. 4A, \( y = 6.44x + 0.02 \)) and also between the severity of average vertical retinal contraction and change in MH (\( r_s = 0.64, P < 0.05; y = 6.11x \); Fig. 4B). However, there was no significant correlation between either the severity of average vertical retinal contraction and change in MV (\( r_s = 0.30, P > 0.05 \); Fig. 4C) or between the severity of average horizontal retinal contraction and change in MH (\( r_s = 0.20, P > 0.05 \); Fig. 4D).

For the vertical 15-area analysis, significant positive correlation was seen between the severity of average horizontal retinal contraction and change in MV (\( r_s = 0.63, P < 0.05; y = 6.24x + 0.02 \); Fig. 5A), but no significant correlation was observed between the severity of average vertical retinal contraction and change in MH (\( r_s = 0.41, P > 0.05 \)). For the horizontal 15-area analysis, significant positive correlation was also seen between the severity of average vertical retinal contraction and the amount of change in MH (\( r_s = 0.67, P < 0.01; y = 6.44x + 0.03 \); Fig. 5B), but not between the severity of average horizontal retinal contraction and change in MH (\( r_s = 0.11, P > 0.05 \)).

According to our small numbers of subjects, there are some outliers in our results. In Figure 3B, even with the (0.42, 0.45) point removed, significant positive correlation (\( r_s = 0.61, P < 0.05; y = 1.66x - 0.01 \)) still existed between the maximum retinal contraction and change in metamorphopsia score. In Figure 4B, with the (0.05, 0.90) point removed, there was still significant positive correlation (\( r_s = 0.61, P < 0.05; y = 5.12x \)) between the severity of average vertical retinal contraction and change in MH. Likewise, with the (0.09, 0.64) point removed, significant positive correlation (\( r_s = 0.57, P < 0.05; y = 5.35x + 0.02 \)) between the severity of average vertical retinal contraction and change in MH. In Figure 5B, showing the 15-area analysis, with the (0.05, 0.90) point removed, significant positive correlation (\( r_s = 0.61, P < 0.05, y = 5.46x + 0.02 \)) remained between the severity of average vertical retinal contraction and change in MH. Likewise, with the (0.10, 0.66) point removed, significant positive correlation (\( r_s = 0.65, P < 0.05 \)) remained.
more severe retinal contraction was associated with increasing metamorphopsia score over time. Specifically, more severe vertical retinal contraction correlated with increasing severity of horizontal metamorphopsia, and more severe horizontal retinal contraction correlated with increasing severity of vertical metamorphopsia.

There have been previous reports of the natural history of ERM, and some of these studies have tried to quantify the progression of ERM. Factors such as the area, the thickness and the contraction of the membranes are considered for the progression of ERM. In an Australian large-population study, the ERM was judged to be progressing if the area of ERM increased by more than 25%, regressing if the area decreased by more than 25%, and stable if the change was less than 25%.

**DISCUSSION**

Using M-CHARTS and the new image-analysis software that we developed, we were able to analyze in detail the relationship between metamorphopsia and retinal contraction during a long-term follow-up study of idiopathic ERM. We found that

![Figure 5](image-url)  
**Figure 5.** The correlations between change in vertical or horizontal metamorphopsia score and the severity of vertical or horizontal retinal contraction in the 15 areas. There was a significant positive correlation between change in (A) MV (P < 0.05) and the severity of average horizontal retinal contraction and in (B) MH (P < 0.01) and the severity of average vertical retinal contraction. Spearman rank correlation coefficients (r_s) and slope are shown.

![Figure 6](image-url)  
**Figure 6.** The correlations between change in visual acuity and the mean defect and the metamorphopsia score. There was no significant relationship between change in (A) visual acuity and change in metamorphopsia score (Spearman rank correlation coefficient, r_s = 0.41, P > 0.05) or in (B) the mean defect area and change in metamorphopsia score (Spearman rank correlation coefficient, r_s = -0.32, P > 0.05).
Regarding quantification of retinal contraction, in 1999, Weinberger et al.\(^8\) reported a method of measuring changes in the position of retinal vessels that used the junctions of major and minor blood vessels at the upper and lower temporal arcades, the disc margin, and vessel junctions temporal to the macula as landmarks.

In this study, we also focused on the retinal contraction caused by the progression of ERM. Retinal contraction caused by ERM usually affects the sensory retina, because the attachment between the sensory retina and the retinal pigment epithelium is relatively weak. During the progression of ERM, the locations of the optic discs and choroidal vessels are usually fixed. Thus, with our image-analysis software, we matched the optic discs and choroidal vessels on the two fundus images and then measured the horizontal and vertical components of the movement of the retinal vessels. This method provided us with a detailed map of the local changes in retinal vessel positions required for the present study.

We demonstrated in a previous study that an increase in metamorphopsia score depends on the stage of ERM\(^3\); and, in the present study, the increase in metamorphopsia score also correlated positively with severity of retinal contraction over 3 years. With these findings, we could conclude that, the degree of metamorphopsia in ERM depends on the severity of retinal contraction due to ERM progression. We also confirmed that MH correlated with the vertical retinal contraction, and MV correlated with the horizontal retinal contraction in both the 25 areas and selected 15 areas with the lines measured by M-CHARTS. There was very little difference between the results in the 15- and 25-area analyses. We suspect there are two reasons for this. One is that ERM causes the contractions that occur in the entire area of the posterior pole and therefore little difference is expected if only comparing the fovea and the periphery. The other is the difficulty to perform a significant analysis because of the small number of vessels around the macula. However, with either approach, we could confirm the significant relationship between the retinal contraction and metamorphopsia score. These results suggested that the direction of metamorphopsia depended on the direction of the retinal contraction due to progression of ERM. We speculated that if the sensory retina contracted in the vertical direction, the photoreceptor and/or its outer segments would also be dislocated in the vertical direction, and eventually would cause an increase of the distortion of the horizontal line (i.e., an increase in MH). The same speculation applies to the horizontal direction.

Our previous results also showed that MH is larger than MV in advanced stages of ERM.\(^5\) In our 3-year follow-up period, we could not detect any predilection for vertical versus horizontal contraction of the retina in eyes with ERM. A possible explanation could be that, in this prospective study, we did not include patients with advanced-stage ERM for whom surgery might be beneficial.

It is known that patients with ERM in the same visual acuity group can have variable metamorphopsia scores.\(^3\) In this study, no significant relationship was found between changes in metamorphopsia score and changes in either visual acuity or mean defect. Visual acuity is the spatial resolving capacity of the visual system. Because our method of quantifying metamorphopsia is to evaluate the ability to detect irregularity in the dotted line other than detecting the resolution, the visual ability required for this task involves Vernier acuity that is a type of hyperacuity.\(^9,10\) The lack of correlation between changes in metamorphopsia score and visual acuity/visual field indicates that metamorphopsia score is a new and different functional parameter in patients with ERM.

In conclusion, the metamorphopsia score obtained using M-CHARTS positively correlated with the severity of retinal contraction in eyes with ERM. Using M-CHARTS is a very simple and useful method of quantitatively monitoring metamorphopsia in patients with ERM. We believe that M-CHARTS will provide us new and additional surgical criteria for patients with ERM.

References