Original Article

Scanning laser ‘en face’ retinal imaging of epiretinal membranes

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Abstract

Purpose: Comparison of scanning laser ophthalmoscopy (SLO) based ‘en face’ imaging techniques of patients with epiretinal membranes (ERM) and evaluation of the accuracy of preoperative diagnostic imaging.

Methods: A consecutive, prospective series of 53 study eyes of 46 patients with clinically diagnosed and in optical coherence tomography (OCT) confirmed symptomatic ERMs were included in this study. Spectral domain (SD-) OCT volume scans (20° × 20° with 49 horizontal sections, ART 15) including SLO en face and fundus autofluorescence (FAF) images of the macula were obtained with HRA2 (Heidelberg Retina Angiograph-Optical Coherence Tomography, Heidelberg Engineering, Heidelberg, Germany). In addition, wide-field SLO color and FAF images (Optomap 200Tx, Optos PLC, Dunfermline, UK) were performed also covering the macular area. En face images of both devices were graded for each included study eye based on SD-OCT cross sectional scans.

Results: Grading of SD-OCT (HRA2) based SLO en face green–blue enhanced multi-color, green reflectance, blue reflectance and standard multi-color visualization revealed a better detectability of ERM than SD-OCT-based en face infrared or FAF images or wide-field SLO (Optomap) based pseudo-color, red laser separation, green laser separation, or FAF images. Both FAF visualizations, HRA2 and Optomap based, achieved low mean scores. SD-OCT based en face thickness map visualization revealed good visualization but poor demarcation of epiretinal membranes.

Conclusions: In summary, en face regular or enhanced multicolor SLO images acquired with HRA2 allow a better visualization of epiretinal membranes for preoperative evaluation compared to SD-OCT based en face thickness map or pseudo-color images acquired with Optomap while infrared or FAF images are least suitable to depict epiretinal membranes.

Keywords: Epiretinal membrane (ERM), Retinal imaging, Optical coherence tomography (OCT), En face, Fundus autofluorescence

Introduction

Epiretinal membranes (ERMs) are fibrocellular avascular proliferations on the surface of the internal limiting membrane (ILM) and cause symptoms such as reduced visual acuity and metamorphopsia due to tractional retinal changes and retinal wrinkling with moderate or even severe distortion.¹ ² The gold standard treatment option is removal of the ERM, often resulting in an improvement of visual acuity and metamorphopsia.³ Various operation techniques with or without peeling of the internal limiting membrane have proven to restore the retinal architecture including the restoration of the visual function in a significant number of patients.⁴ ⁵ However, in some of these patients, at least a part of the symptoms described may still be present even after successful surgery.⁶

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Preoperative correct visualization of the ERM is of high importance to the retinal surgeon and is being enabled through constantly improving imaging devices. Optical coherence tomography (OCT) has revolutionized the diagnostic visualization of the ERM in cross-sectional scans. Alternative en face imaging techniques such as fundus autofluorescence (FAF) or the recently improving en face OCT technology has also been reported to visualize ERM in diagnostic and post-operative follow up visits and even predict certain outcomes.

The goal of this study was to compare various en face imaging techniques (OCT, scanning laser ophthalmoscopy (SLO), FAF) of patients with ERM and evaluate their value in the accuracy of preoperative diagnostic imaging.

### Patients and methods

#### Patients

A consecutive, prospective series of 53 study eyes of 46 patients, mean age 70 years (range: 55–85 years), with clinically diagnosed and in OCT confirmed symptomatic epiretinal membranes (ERM) were included in this study, 23 women and 23 men, 23 right and 30 left eyes. Exclusion criteria were macular diseases other than ERM and significant media opacities.

After informed consent, pupils were dilated and a full retinal examination was performed by a retina specialist. A spectral domain (SD-) OCT volume scan (20° × 20° with 49 horizontal sections, ART 15) including en face images and a fundus autofluorescence (FAF) image obtained with HRA2 (Heidelberg Retina Angiograph-Optical Coherence Tomography, Heidelberg Engineering, Heidelberg, Germany) of the macula was performed in mydriasis for each study eye. In addition, wide-field SLO color and FAF images (Optos PLC, Dunfermline, UK) of each included study eye were performed covering the macular area.

Wavelengths of HRA2 SD-OCT are 870 nm for SD-OCT. Acquisition speed for SD-OCT is 40,000 A-scans per second with a scan depth of 1.9 mm. Optical resolution for SD-OCT is approximately 3.8 μm axial and 6 μm lateral in high resolution mode. Wavelengths of HRA2 for SLO and FAF imaging are 488 nm and 518 nm for “green laser” SLO images. Wavelengths of HRA2 for infrared images are 815 nm. For wide-field SLO imaging, the acquisition speed for one image is approximately 0.25 s scanning with two laser wavelengths scanning at 532 nm (“green laser separation”) and 633 nm (“red laser separation”). The pixel resolution is 3,900–3,072 pixels per image (up to 200°), resulting in approximately 17–20 pixels per degree. Additional wide-field fundus autofluorescence (FAF) images were obtained with an excitation wave length of 532 nm and a broad band detector.

### Table 1. Grading of ERM for each en face visualization.

<table>
<thead>
<tr>
<th>Score</th>
<th>Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No ERM detectable</td>
</tr>
<tr>
<td>1</td>
<td>ERM indirectly through wrinkled retinal vessels detectable</td>
</tr>
<tr>
<td>2</td>
<td>ERM detectable but borders not definable</td>
</tr>
<tr>
<td>3</td>
<td>ERM detectable, borders definable but in disagreement with cross sectional OCT scans</td>
</tr>
<tr>
<td>4</td>
<td>ERM detectable and borders definable in accordance with cross sectional OCT scans</td>
</tr>
</tbody>
</table>

Preoperative correct visualization of the ERM is of high importance to the retinal surgeon and is being enabled through constantly improving imaging devices. Optical coherence tomography (OCT) has revolutionized the diagnostic visualization of the ERM in cross-sectional scans. Alternative en face imaging techniques such as fundus autofluorescence (FAF) or the recently improving en face OCT technology has also been reported to visualize ERM in diagnostic and post-operative follow up visits and even predict certain outcomes.

The goal of this study was to compare various en face imaging techniques (OCT, scanning laser ophthalmoscopy (SLO), FAF) of patients with ERM and evaluate their value in the accuracy of preoperative diagnostic imaging.
at 540 to 800 nm as described in previously published works.\textsuperscript{11,12}

All research was conducted in accordance with institutional guidelines and board approval and conformed to the tenets of the World Medical Association Declaration of Helsinki.

Evaluation and quantification of cross sectional OCT scans

En face images of both devices (HRA2 and Optomap) were graded for each included study eye by one retina expert (SD), in case of doubt, a second retina expert (LR) was consulted. The following en face visualizations were graded: standard multi-color OCT (1), green–blue enhanced multi-color OCT (2), en face infrared (3), green reflectance (4), blue reflectance (5), FAF (6) and retinal thickness map (7) for SD-OCT and pseudo-color (8), red laser separation (9), green laser separation and (10) visualization and SLO based FAF (11) for wide-field SLO imaging. The grading scheme for each study eye evaluated visibility and demarcation of the imaged ERM based on a comparison with the SD-OCT cross sectional images and can be seen in Table 1. Mean scores were calculated for each visualization 1–11 (Fig. 1).

Statistical analysis

Data were collected and analyzed using SPSS Version 19.0 (SPSS Inc, Chicago, IL, USA). A p-value of <0.05 was considered as statistically significant. All graded visualizations were tested for normal distribution. Non-parametric analyses for ordinal variables (Wilcoxon Signed Rank Test) were applied.

Results

Grading of HRA2 based en face green–blue enhanced multi-color (2), green reflectance (4), blue reflectance (5) and standard multi-color (1) visualization revealed a better detectability of ERM than HRA2 based en face infrared (3) or FAF (6) images or wide-field SLO (Optomap) based pseudo-color (8), red laser separation (9), green laser separation (10) or FAF and (11) images, see Table 2 and Fig. 2. Overall, with the exception of infrared images, HRA2 based en face visualizations – especially the various multi-color en face visualizations – performed better than Optomap-based SLO images regarding detection and accurate marking of ERM.

The SD-OCT based thickness map (7) revealed a good visualization of epiretinal membranes (mean grading score 3.235 ± 0.55094, see Table 2) but showed in the majority of graded study eyes (29 out of 53 study eyes) a larger or smaller extension of the ERM borders when being compared to SD-OCT cross sectional images (Fig. 3).

Both FAF visualizations, HRA2 and Optomap based, achieved low mean scores. Comparing en face HRA2 based FAF to Optomap based FAF images, HRA2 based FAF had a significantly higher score than FAF images obtained with Optomap (0.435 ± 0.5644 vs. 0 ± 0).

Discussion

In this study, epiretinal membranes were best visualized in HRA2 based green–blue enhanced multicolor en face SLO images, followed by other en face HRA2 based multicolor images and SLO en face visualizations obtained with Optomap. IR and FAF images did not validly depict ERMs. While Spectralis OCT excitation wavelengths are 488 nm for the “blue” and 518 nm for the “green” laser, Optomap SLO excites with 532 nm (“green” laser) and 633 nm (“red” laser) resulting in en face images showing rather deeper than superficial retinal layers.\textsuperscript{13,14} This might be an explanation for a better detection of epiretinal structures such as ERM in HRA2 compared to Optomap SLO en face images.

The SD-OCT based thickness map of the macula is currently being used to evaluate ERMs of examined patients and, due to its follow up mode, offers the possibility of a valid comparison over the course of time. In patients with ERM or

![Table 2](image)

Mean grading score with standard deviation of all graded en face visualizations 1–11.

<table>
<thead>
<tr>
<th>Imaging device</th>
<th>Visualization mode</th>
<th>Nr.</th>
<th>Mean grading score</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRA2</td>
<td>Standard multi-color</td>
<td>1</td>
<td>2.8208</td>
<td>0.68003</td>
</tr>
<tr>
<td></td>
<td>Green–blue enhanced multi-color</td>
<td>2</td>
<td>3.5660</td>
<td>0.51922</td>
</tr>
<tr>
<td></td>
<td>Infrared</td>
<td>3</td>
<td>1.4906</td>
<td>0.84632</td>
</tr>
<tr>
<td></td>
<td>Green reflectance</td>
<td>4</td>
<td>3.3208</td>
<td>0.84406</td>
</tr>
<tr>
<td></td>
<td>Blue reflectance</td>
<td>5</td>
<td>3.0755</td>
<td>1.03029</td>
</tr>
<tr>
<td></td>
<td>HRA2 FAF</td>
<td>6</td>
<td>0.4375</td>
<td>0.5644</td>
</tr>
<tr>
<td></td>
<td>OCT thickness map</td>
<td>7</td>
<td>3.2353</td>
<td>0.55094</td>
</tr>
<tr>
<td>Optomap</td>
<td>Pseudo-color</td>
<td>7</td>
<td>2.1373</td>
<td>0.99035</td>
</tr>
<tr>
<td></td>
<td>Red laser separation</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Green laser separation</td>
<td>9</td>
<td>2.1569</td>
<td>0.98737</td>
</tr>
<tr>
<td></td>
<td>SLO based FAF</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
macular pucker, color coded SD-OCT thickness maps reflect focal or semi-focal thickening of the retina and thus provide useful information of retinal pathologies in the z-axis. In our study however, we were able to show that enhanced en face SLO multicolor images obtained with HRA2 are very suitable to not only depict ERMs, but also reveal a precise demarcation of ERM borders, which may be helpful for retinal surgeons or even for postoperative follow up visits. Thus, HRA2 en face images can complement the commonly used SD-OCT thickness map visualizations.

Enhanced HRA2 en face images of the retina can be obtained with devices of the latest OCT generations and are therefore not commonly available and do not yet belong to standard OCT examinations in a routine clinical setting. Another limitation of this study is its strictly cross sectional character which does not allow for any assumptions regarding the visualization during the development or worsening of this disease. Further studies are needed to better evaluate the visualization of the early development of ERMs and the practical use of those imaging techniques after surgery in a routine clinical setting.

In summary, HRA2 based en face enhanced or regular multicolor images can visualize ERMs for a better and more precise preoperative evaluation additionally to the commonly used color coded SD-OCT thickness maps while IR or FAF images are not suitable to depict epiretinal membranes.

**Conflict of interest**

The authors declared that there is no conflict of interest.

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