Visualization of retinal breaks on ultra-widefield fundus imaging using a digital green filter

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Abstract

Purpose We compare the ability of resident physicians to identify retinal breaks on ultra-widefield color fundus photos using the traditional image compared to an image with a green filter overlay.

Methods Residents were shown fundus photos of 10 eyes with either a retinal tear or hole. Participants were shown each photo twice—once with traditional color settings and once with a green filter overlay. Participants were scored on whether the break was correctly identified and timed on how long it took to identify the pathology.

Results Residents were able to correctly identify more retinal breaks on fundus photos with a green filter overlay compared to photos with traditional settings (P = 0.02). Residents were also able to identify breaks on fundus photos more quickly on images with a green filter overlay compared to the traditional images (P < 0.001).

Conclusions The application of a green filter overlay may help in identifying retinal breaks.

Keywords Imaging · Medical education · Retina · Telemedicine

Introduction

Advances in retinal imaging have revolutionized the ability of ophthalmologists to better visualize and document retinal pathologies. First made available in the year 2000, Optos confocal scanning laser ophthalmoscopy (cSLO; Optos PLC, Dunfermline, Scotland) was the first ultra-widefield (UWF) fundus camera that allowed for 200-degree fundus photography in a single shot [1]. By using an ellipsoid mirror, cSLO was able to capture a broader area in a single shot. Further technological developments in UWF fundus cameras have enabled eye professionals to capture the entirety of the retina with only a few images, allowing for easier documentation and better detection of peripheral pathologies.

Subsequent advances in Optos technology have allowed for the creation of pseudocolor photos by combining red (633 nm) and green (532 nm) laser sources that scan simultaneously [2]. Due to the difference in wavelengths, the green laser scans from the sensory retina to the pigment epithelial layers and the red laser scans from the retinal pigment epithelium (RPE) to the choroid (Fig. 1) [2]. Accordingly,
the application of a green filter laser may be helpful in the assessment of the integrity of the retina. In clinical practice, our group has previously noted that the application of a green filter to fundus photos allowed for ease of both visualization and identification of retinal breaks.

The incidence of retinal breaks in adults greater than 20 years old is estimated to be 2–9% in clinical studies and autopsy studies [3–6]. A significant proportion of approximately 35% of symptomatic retinal breaks results in a retinal detachment, making it crucial to identify retinal breaks in a timely manner to appropriately triage and manage these patients to prevent vision-threatening complications [7]. In this digital era with the rise of telemedicine where more visits rely on fundus images in lieu of indirect ophthalmoscopy, it is critical to identify strategies for better detection of retinal breaks [8]. Our study examined if using a green filter overlay could facilitate the diagnosis of retinal breaks in ophthalmology residents.

We present a prospective cross-sectional study to compare the utilization of a green filter versus the traditional filter settings on Optos UWF fundus photos. The goal of this study is to compare the ability of resident physicians who are training in ophthalmology at a single institution to identify retinal breaks in fundus photos using the traditional filter compared to a green filter overlay.

**Materials and methods**

**Study design**

This prospective cross-sectional study was performed in accordance with the Health Insurance Portability and Accountability Act of 1996 and the Declaration of Helsinki. Both the Institutional Review Board of Mass General Brigham and the Office of Educational Development's Research Review Committee at Harvard Medical School approved the study protocol.

**Image acquisition**

Patients with a confirmed retinal tear or retinal hole by clinical exam were imaged with a UWF fundus camera (Optos P200DTx icg, Optos, Marlborough, MA, USA). To establish the ground truth for the images, two expert ophthalmologists independently graded the images for identification of the retinal break and confirmed an agreement with a documented clinical exam. The green filter was applied over the fundus photo using the OptosAdvance software [9]. The green filter setting was set between 55 and 60%, depending on the exposure of the initial photo, to best highlight the edges of the retinal break. A slide deck consisting of original fundus photos as well as the same fundus photos with a green filter overlay was created. Each eye appeared twice in the slide deck (once as the original fundus photo and once with a green filter overlay), and all images were randomly scrambled. Either the traditional fundus color photo or the photo with a green filter overlay could be shown first. No two consecutive fundus photos were of the same eye.

**Study subjects**

Survey participants consisted of ophthalmology residents at a single institution. Participants were presented with fundus photos on the Optos system with either a single retinal tear or hole. Again, participants were shown each fundus photo twice in a randomized order, once with traditional color settings and once with the addition of a green filter overlay. Residents were shown one image at a time. All testing was performed on a single monitor with consistent resolution and brightness settings. Residents were told that all images contained a retinal break and given up to thirty seconds to identify the retinal tear or retinal hole (Fig. 2). The goal of the study was not initially revealed to the participants. Participants were scored on whether the break was correctly identified and timed on how long it took to identify the pathology. If participants were unable to identify a break within thirty seconds, they were assumed to have incorrectly graded the photo. Participants were not allowed to modify their responses.

Participants were next asked to participate in a post-test survey. During the post-test survey, residents were informed that the goal of the study was to assess whether a green filter overlay over fundus photos was helpful in identifying retinal breaks. Participants were allowed to review images again but were unable to modify their responses. Participants were asked (1) whether a green filter overlay made it easier to identify retinal breaks and (2) whether a green filter overlay would be a useful tool in ophthalmology clinics or telemedicine applications.
Statistical analysis

Analyses were performed using R version 3.6.3 (R Foundation for Statistical Computing) [10]. The distribution of continuous numerical data was checked both graphically and with the Shapiro–Wilk normality test. Data that was not normally distributed was presented as the median and the interquartile range (IQR). Data that was not normally distributed, including the number of retinal breaks that participants correctly identified with each filter setting and the response time, was analyzed using the Mann–Whitney U test. McNemar’s exact test was used to compare each individual participant’s scores using the traditional filter and the green filter overlay. The statistical significance level was set as < 0.05.

Results

A total of 20 paired fundus images—10 with the traditional filter and 10 with a green filter overlay—were collected from 10 eyes of 10 patients. The slide deck consisted of 10 traditional images and 10 images with a green filter overlay completely scrambled. Participants were shown the fundus photos in a randomized order, and either the traditional photo or the green filter overlay could appear first. A total of nineteen ophthalmology residents at a single institution participated in the survey, including seven post-graduate years (PGY)-2 residents, six PGY-3 residents, and six PGY-4 residents.

Overall, participants correctly identified a median of 2 (IQR: 1–3) more retinal breaks on photos with a green filter overlay compared to photos with the traditional filter ($P = 0.02$). The median number of correctly identified retinal breaks was 9 (IQR: 8–9) out of 10 images with the green filter overlay and 7 (IQR: 6–7) out of 10 images with the traditional filter setting. For images in which participants correctly identified the retinal break, participants spent 1.9 (IQR: 0.4–4.2) seconds less on images with a green filter overlay compared to on images with the traditional filter ($P < 0.001$). The median time spent on each image was 6.4 (IQR: 5.7–7.7) seconds on images with a green filter overlay and 8.3 (IQR: 8.1–9.8) seconds on images with the traditional filter setting.

Looking at each individual resident’s responses, twelve of nineteen residents identified more breaks on images with the green filter overlay relative to the traditional image (Table 1). For the seven residents who did not perform better, there was
no statistically significant difference between their performance on images with the green filter overlay compared to their performance on images with the traditional filter settings. No resident performed better on the images with the traditional filter compared to images with the green filter overlay. Looking at differences by the number of years in training, four PGY-2 residents, five PGY-3 residents, and three PGY-4 residents, for a total of twelve residents, performed better on images using the green filter overlay. Three PGY-2 residents, one PGY-3 resident, and three PGY-4 residents did not perform better on either filter setting.

In a post-test survey, 17 (89.5%) participants responded that they felt that the green filter made it easier to identify retinal breaks; 2 (10.5%) residents responded that they could not tell the difference. Additionally, 17 (89.5%) participants responded that they thought a green filter would be a useful function in the clinic.

**Discussion**

We present a prospective cross-sectional study that suggests that physicians at earlier stages of their training were better able to identify breaks on fundus photos with a green filter overlay compared to fundus photos with traditional settings. Additionally, for images in which participants did identify breaks correctly, participants were able to identify breaks more efficiently on the images with a green filter overlay compared to images with the traditional filter. The potential clinical utility of a green filter overlay was also supported by the participants’ responses in the post-test survey, as the majority of the residents expressed that the green filter made it easier to identify breaks and would be a useful implementation in clinical settings. We hypothesize that the improved identification of retinal tears on fundus imaging with a green filter overlay is from improved visualization of the edges of the retinal break on the digital monitor. The green laser penetrates more superficially relative to the red laser due to its shorter wavelength (with green laser scanning from the sensory retina to RPE and red laser scanning from RPE to the choroid, Fig. 1) and thus may better highlight and contrast the edges of the retinal break. At the same time, it is important to note that a clinical exam with indirect ophthalmoscopy with or without indentation remains the gold standard for the detection of a retinal break. The addition of fundus imaging, including the application of a digital green filter overlay, should be used as a complement to the clinical exam or in settings where expertise or proper instruments are not available.

**Table 1** % Correct by participant

| ID | PGY year | Green and traditional correct (%) | Green-only (%) | Traditional-only (%) | Neither (%) | Exact McNemar’s test (P-value) |
|----|----------|-----------------------------------|---------------|---------------------|-------------|-----------------------------|
| R1 | PGY3     | 50                                | 40            | 0                   | 10          | <.001                       |
| R2 | PGY2     | 60                                | 30            | 10                  | 0           | .002                        |
| R3 | PGY2     | 50                                | 30            | 10                  | 10          | .002                        |
| R4 | PGY3     | 60                                | 30            | 0                   | 10          | <.001                       |
| R5 | PGY2     | 60                                | 30            | 10                  | 0           | .002                        |
| R6 | PGY3     | 60                                | 30            | 10                  | 0           | .002                        |
| R7 | PGY2     | 70                                | 20            | 10                  | 0           | .10                         |
| R8 | PGY4     | 50                                | 30            | 20                  | 0           | .20                         |
| R9 | PGY4     | 80                                | 20            | 0                   | 0           | <.001                       |
| R10| PGY4     | 60                                | 30            | 10                  | 0           | .002                        |
| R11| PGY3     | 70                                | 20            | 10                  | 0           | .10                         |
| R12| PGY2     | 50                                | 30            | 20                  | 0           | .20                         |
| R13| PGY2     | 40                                | 20            | 20                  | 20          | 1.00                        |
| R14| PGY4     | 40                                | 30            | 20                  | 10          | .20                         |
| R15| PGY3     | 50                                | 40            | 10                  | 0           | <.001                       |
| R16| PGY2     | 50                                | 40            | 10                  | 0           | <.001                       |
| R17| PGY3     | 80                                | 20            | 0                   | 0           | <.001                       |
| R18| PGY4     | 60                                | 30            | 10                  | 0           | .002                        |
| R19| PGY4     | 60                                | 20            | 10                  | 10          | .10                         |

Performance by the individual resident. The proportion of retinal breaks each participant answered correctly on both filters, green filter only, traditional filter only, and on neither filter. Exact McNemar’s test was performed in order to assess any statistically significant asymmetry between the participant’s ability to detect retinal breaks in different settings. Statistically significant P-value is bolded.
Nonetheless, over the years, retinal imaging has become an essential part of ophthalmic clinical care, including in improving diagnostic accuracy and guiding clinical management. While many studies have explored the use of imaging to detect retinal pathologies, the application of simple colored filters to improve and aid in the detection of retinal breaks has not yet been previously studied. The potential application of a green filter overlay on fundus photos would be a relatively easy and inexpensive technique to develop and implement within the clinical setting that could improve the overall detection of retinal breaks, especially within the realm of telemedicine.

Catalyzed by the recent coronavirus disease-2019 (COVID-19) pandemic, there has been a surge in telemedicine throughout the healthcare field [11]. In retina clinics, many have adopted store-and-forward asynchronous models [12, 13]. In these models, nursing staff or technicians at primary care clinics or imaging stations obtain retinal imaging such as fundus photographs. These photographs are then forwarded to a reading center, where an eye care professional evaluates and makes recommendations for follow-up and further evaluation [8]. Retinal breaks tend to present acutely and require immediate attention, and prior studies have suggested a sensitivity and specificity for the detection of retinal breaks using UWF fundus photos to be 76% and 85%, respectively [14]. These values were deemed to be too low for imaging to replace indirect ophthalmoscopy, but future studies that assess the sensitivity and specificity with the application of color filter settings could potentially allow for ultra-widefield fundus photos to be used as a screening tool for patients with new floaters and flashes, especially in settings where access to specialized eye care is limited.

Coupled with tele-ophthalmology, in more recent years, there has been a growing interest in applying artificial intelligence (AI) and deep learning algorithms to retinal imaging for the management and prognosis of eye diseases [15, 16]. Prior research shows that there is increased success in developing these deep learning models on tasks that humans can complete intuitively, compared to models on tasks that require conscious thought [17]. Therefore, optimizing fundus photos to allow for easier detection by the human eye could contribute to the development of a deep learning algorithm that identifies retinal pathologies with high sensitivity and specificity, which would complement well with the potential applications of telemedicine.

However, there are limitations to the current study. To keep the survey brief, only ten fundus images with a retinal break were used, and nineteen training ophthalmologists at a single institution were tested. A larger study including more eyes with a larger variety of participants such as optometrists or expert ophthalmologists could strengthen the findings of this study and further assess the generalizability of our findings. Furthermore, for better direct comparison, each image was used twice (once with the traditional filter and once with the green filter overlay), meaning the participants may have recognized the photo when it was presented the second time. While the images were presented in a randomized order to minimize this potential confounder, it is possible that this may have influenced the participant’s response. It is also important to recognize that the Optos camera has inherent boundaries superiorly and inferiorly that would limit peripheral exams in the vertical meridians. Without an imaging protocol that specifically searches out these superior or inferior blocked areas, a retinal break in these areas could be missed even with an enhanced green filter overlay. Furthermore, all images in this study contained a retinal break. Future studies that include eyes with and without a retinal break could further establish the sensitivity and specificity of detecting retinal breaks using a digital green filter. Despite these limitations, we demonstrate an improved performance in resident ophthalmologists using the green filter overlay compared to the traditional settings in the detection of retinal breaks. Implementing an option in the image system viewer for a green filter overlay on fundus imaging is a relatively simple technique that may improve the detection of retinal breaks. The application of green overlay in ultra-widefield imaging has the potential for clinical use, especially in telemedicine, to screen, diagnose, and monitor major eye diseases for patients in primary care and community settings.

**Declarations**

**Ethics approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of Mass General Brigham and with the 1964 Helsinki declaration and its later amendments or comparable standards.

**Consent to participate** Verbal informed consent was obtained from all individual participants included in the study.

**Consent for publication** The work from this manuscript has been accepted for paper presentation at The Association for Research in Vision and Ophthalmology (ARVO) Meeting, May 1–7, 2021 and Retina Society Meeting, September 29–October 2, 2021.

**Conflict of interest** Please note that author J.B.M is a consultant for Alcon, Allergan, Topcon, Carl Zeiss, Sunovion, and Genentech. All other authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers’ bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge, or beliefs) in the subject matter or materials discussed in this manuscript.
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