• Clinical Research •

Feasibility of telemedicine program using a hand-held nonmydriatic retinal camera in Panama

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Abstract

● **AIM:** To evaluate the image quality of a telemedicine screening program for retinal disease using a nonmydriatic camera among rural island communities in Bocas del Toro, Panama.

● **METHODS:** In June 2018, a group of three medical students volunteered at clinics operated by the Floating Doctors in the province of Bocas del Toro, Panama. Non-mydriatic images of the retina were obtained using the Pictor Plus (Volk Optical, Mentor OH), randomized, and sent to two board-certified ophthalmologists at the University of California, Irvine for analysis using a modified version of the FOTO-ED scale. Inter-rater reliability was calculated using the kappa statistic.

● **RESULTS:** Seventy patients provided a total of 127 images. Average image quality was 3.31, and most frequent image quality was 4/5 on the FOTO-ED scale. Thirty patients had at least one eye image with ideal quality (42.86%), while only one patient had no adequate photos taken (1.43%). However, high quality images were obtained in both eyes in only 12 patients (17.14%). The inter-rater reliability between the two ophthalmologists was 0.614.

● **CONCLUSION:** Further improvements are necessary to acquire higher quality images more reliably. This may include further training and experience or mydriasis.

● **KEYWORDS:** telemedicine; retina; nonmydriatic camera; fundus; screening; feasibility; low-resource setting
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INTRODUCTION

Visual impairment causes a significant global economic burden, resulting in an estimated 30.2% relative reduction in employment and 0.3% GDP loss[1]. Of the 300 million visually impaired individuals worldwide, 90% live in developing countries[2]. Furthermore, up to 75% of blindness is considered to be avoidable[2]. While the majority of the global burden of ocular disease is a result of untreated cataracts, other major contributors include posterior segment conditions such as glaucoma, age-related macular degeneration (AMD), and diabetic retinopathy (DR)[3]. Retinal pathology may represent an underappreciated contributor to the global burden of eye disease. For instance, the global prevalence of DR is estimated at 35.4%, and as the global incidence of diabetes rises, the burden of visual disease from DR is expected to increase[4]. In addition, AMD is the leading cause of blindness in people older than 65y worldwide[4]. Retinal pathology is becoming a larger issue as the global population ages and the prevalence of diabetes increases each year[5]. Further complicating the picture, screening for retinal pathology is considerably more difficult than anterior ocular conditions; multiple studies have demonstrated that the accuracy of DR screening by non-ophthalmic health care providers is lower than rates achieved by ophthalmologists and retinal specialists[5-6].

Rural populations with limited access to medical care are frequently targets of medical aid organizations[7-8]. In particular, Bocas del Toro is a remote archipelago in western Panama where inhabitants lack access to reliable health care[9]. The primary healthcare provider for the greater than 25 isolated island communities in this region is a non-profit organization stationed in Bocas del Toro (entitled "The Floating Doctors"). This organization is primarily run by volunteer family medicine, emergency medicine, or internal medicine physicians from the United States and Europe, as well as those from Central and South America. However, only very rarely do they have an on-

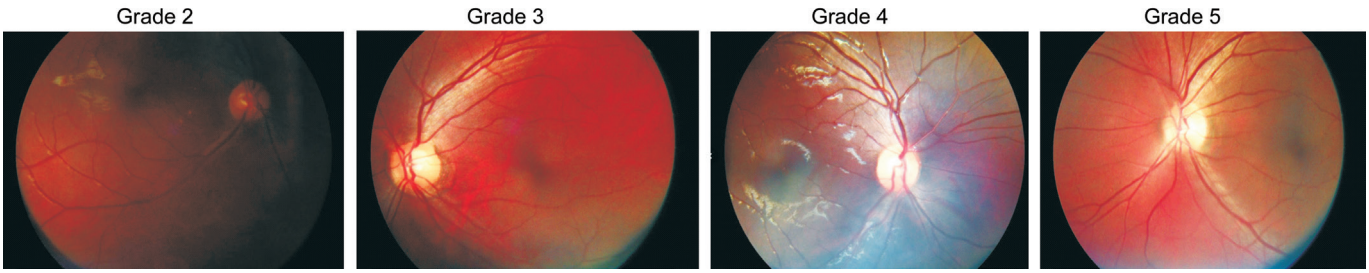

Figure 1 Modified FOTO-ED scale[25].

site ophthalmologist, which creates a gap in access to care in the realm of retinal disease.

One possible solution to this care gap may come in the form of telemedicine. Telemedicine screening programs using digital fundus photography have shown promising results in the remote diagnosis of DR[4-5,10-14]. Both hand-held and tabletop retinal cameras have been used to acquire clinically useful images of the retina[15-16]. Furthermore, compared to direct ophthalmoscopy, hand-held retinal cameras provide a wider field of view, and have demonstrated improved diagnostic accuracy of DR and optic disc edema by non-ophthalmologic providers to levels comparable with ophthalmologists[17-18]. Although non-ophthalmic health care providers typically report lower levels of confidence with direct fundoscopy and demonstrate lower DR screening accuracy compared to trained ophthalmologists[5-6], the wider field of view may help alleviate this concern[17]. Telemedicine screening for DR is the most well-validated of the ocular telemedicine programs[19-20], but there is evidence to support telemedicine screening and handheld portable fundus camera use for AMD, suspicious optic nerve, retinopathy of prematurity, and papilledema, as well[10,21-23].

As medical students frequently volunteer to provide medical care abroad[24], there may be utility in utilizing medical students in ophthalmologic telemedicine screening programs. If medical students can quickly obtain high quality images of the retina with minimal interruption to clinic workflow, patients with retinal disease might be triaged efficiently when these communities do receive ophthalmologic care. Such a program might also improve monitoring of chronic retinal pathology, such as DR, and improve long-term patient outcomes.

The Pictor Plus (Volk Optical, Mentor OH) is a relatively inexpensive, hand-held fundus camera with a 45° field of view (nine times that of a standard direct ophthalmoscope)[17]. The aim of this study is to retrospectively review an ophthalmologic telemedicine program between University of California, Irvine and the Floating Doctors to determine if minimally trained medical students can improve ophthalmic care in Bocas del Toro by obtaining retinal images of sufficient quality to remotely diagnose retinal pathology using a hand-held, nonmydriatic fundus camera.

SUBJECTS AND METHODS

Ethical Approval This study received Institutional Review Board (IRB) approval from the University of California, Irvine (IRB #2019-5579), and was conducted in accordance with the Declaration of Helsinki. Formal informed consent was waived by the IRB given the retrospective nature of the study (expedited, category 5).

In June 2018, a group of three medical students volunteered at clinics operated by the Floating Doctors in the province of Bocas del Toro, Panama. Non-mydriatic images of the retina were obtained using the Pictor Plus in adult (18+ years of age) patients at the request of a Floating Doctors provider once it was determined such photos may have diagnostic value. After discussion with Floating Doctors providers, it was agreed that obtaining retinal images would be diagnostically useful in all patients presenting with an ocular complaint, or with a history of diabetes previously diagnosed by the Floating Doctors. The medical students trained with the Pictor Plus for approximately 20h prior to their first day at the Floating Doctors clinic.

All images were sent to two board-certified ophthalmologists at the University of California, Irvine for remote diagnosis. The photos were randomized so that the left and right eye of the same patient would not appear in sequence. Images were analyzed using a modified version of the FOTO-ED scale developed by Bruce *et al*[25] (Figure 1). This is a validated scale used to grade images based on diagnostic utility and ability to visualize individual components of the retina, optic nerve, vessels, and periphery. The reviewers were able to enlarge images and adjust brightness.

In keeping with the FOTO-ED Scale, grade 5 images were considered highest quality, while grade 1 was considered unusable. Grade 4 images were considered not ideal, but sufficiently useful to identify subtle findings that may appear mildly defocused or shadowed. Inter-rater reliability was calculated using the kappa statistic. Sufficient or insufficient quality for each specific aspect of the retina was determined based on a subjective judgement indicated by the image graders based on whether they could, with certainty, determine if the specified area was normal or abnormal.

RESULTS

Seventy patients provided a total of 127 images. Image quality

Table 1 FOTO-ED scores *n* (%)

Parameters	Grader 1	Grader 2	Combined
Ideal quality (5)	8 (6.30)	23 (17.97)	31 (12.20)
Not ideal but still able to exclude subtle findings (4)	54 (42.52)	41 (32.28)	95 (37.40)
Only able to exclude emergent findings (3)	41 (32.28)	26 (20.31)	67 (26.38)
Unable to exclude all emergent findings (2)	16 (12.6)	27 (21.26)	43 (16.93)
Inadequate for any diagnostic purpose (1)	8 (6.30)	10 (7.81)	18 (7.09)

graded by two ophthalmologists using the modified FOTO-ED scale is displayed in Table 1. Average image quality was consistent across graders at 3.30±0.99 [all data are presented as mean±standard deviation (SD), unless otherwise specified] for grader 1 and 3.31±1.22 in grader 2. Modal image quality was 4/5 on the FOTO-ED scale (37.40% of images). Of the 127 images, 62 and 64 images were rated at 4 or higher by grader 1 and grader 2, respectively (48.82% and 50.39%). Thirty patients had at least one eye image with ideal quality (42.86%), while only one patient had no adequate photos taken (1.43%). High quality images (grades 4 or 5) were obtained in both eyes in 12 patients (17.14%). The inter-rater reliability between the two ophthalmologists was 0.614.

Image quality stratified by the individual component of the posterior segment is shown in Table 2. The vitreous was most reliably imaged (91.76% images able to grade), followed by the optic nerve rim (91.05% images able to grade). High quality images of the fovea were obtained least reliably (69.00% images able to grade). The most common retinal findings included tortuous vessels (20 patients), cotton wool spots (8 patients), drusen (6 patients), optic nerve pallor (7 patients), enlarged cup-to-disc ratio (22 patients), and peripapillary atrophy (22 patients). Image quality in patients with suspected cataracts is shown in Table 3. Image quality was 1.02 points lower in patients with suspected cataracts than those without.

Table 2 Image quality of individual components *n* (%)

Parameters	Sufficient quality to determine if area is normal	Insufficient quality to determine if area is normal
Vitreous	117 (91.8)	10 (8.25)
Vessels	113 (89.0)	14 (11.05)
Fovea	88 (69.0)	39 (31.0)
Optic nerve rim	117 (91.1)	10 (8.95)
Optic nerve cup	109 (85.0)	18 (15)

N and percentages averaged across the two graders.

Table 3 Image quality in patients with suspected cataracts

Parameters	*n* (%)	Average image quality
Cataract suspected	32 (25.4)	2.53
Cataract not suspected	94 (74.6)	3.55

DISCUSSION

The burden of ocular disease in Panama is significant, with up to 3.0% of the population blind, and 16.1% with moderate visual impairment[26]. Although unoperated cataracts are the leading cause of blindness in Panama (66.4%), glaucoma (10.2%), AMD (5.1%), pterygium (2.2%), and DR (1.5%) contribute significantly to the burden of eye disease[26]. Medical students obtaining retinal images using the Pictor Plus in the remote setting of Bocas del Toro, Panama were able to obtain reasonably high-quality images of the retina, optic nerve, optic vessels and vitreous humor. Image quality by the non-ophthalmologists using a tabletop non-mydriatic fundus camera were grades 4 or 5 in 37%-44% of all images obtained in the FOTO-ED study[27]. These are comparable to the results presented herein, where 49.61% of images were grade 4 or 5. Another more recent study using a hand-held camera demonstrated 63% excellent quality images (on a four-tiered scale that included grades inadequate, fair, good, and excellent) but these were obtained by ophthalmologic providers in a darkened room, increasing mydriasis and likely improving imaging reliability[5]. Despite our study demonstrating image quality consistent with the FOTO-ED study, the more recent study implies that more reliable quality may be achieved. Furthermore, we found there were fewer patients with high quality images taken of both eyes (17.1%). Often, confounding factors in older patients (difficulty keeping one eye open, unilateral cataract), may have impaired our ability to capture high quality images in both eyes.

Average image quality was fairly consistent between graders, although grader 2 graded more photos as “ideal quality” compared to grader 1. The inter-rater reliability (0.61, or moderate) was lower than reported in the FOTO-ED study (0.84-0.87, or strong)[27]. There are several possible explanations for that. Dark rooms were rarely available at Floating Doctors clinics, and, although specific data were not collected on pupil size, the authors observed that many patients had miotic pupils that were difficult to image; the FOTO-ED study reported small pupils as a predictor of poor image quality[27]. Age greater than 40 years was also associated with poor image quality in this study[15], and our study population was almost entirely composed of older individuals, although again demographic data was not collected. Furthermore, approximately 25% of patients had suspected cataracts, and

the image quality was an average of 1.02 points worse in these patients than in those without. Indeed, a study on DR screening by Murgatroyd *et al*[28] found that posterior subcapsular cataract (P=0.004) and reduced near-vision (P=0.006) predicted ungradable status of nonmydriatic photographs. Notably, the prevalence of cataracts may be higher in our sample as we primarily imaged individuals with ocular complaints.

One possible solution to improving image quality obtained in rural Panama is to dilate the pupils. Although non-mydriatic fundus photography has been established as effective in screening for diabetic retinopathy (sensitivity 64%-97.9%, specificity 65.6%-98%)[15], and previous work has shown that image quality is higher in dilated eyes compared to non-dilated eyes[15,29], dilating the eye would almost certainly improve image quality at the expense of causing patient discomfort and disruption to clinic flow. The imaging protocol in this study required no more than five minutes, inflicted minimal discomfort to the patient, and can occur during the natural waiting period between initial intake (where ocular complaint or history of uncontrolled diabetes was ascertained) and the visit with the provider. This seamless incorporation into clinic flow maximized value to the Floating Doctors while minimizing distraction. Dilating the eye complicates screening and may limit widespread implementation of an ophthalmologic telemedicine program in a busy clinic. Although the Pictor Plus has an eye cup that blocks light into the eye that is being imaged, an eye patch may be placed over the contralateral eye to limit the consensual pupillary reflex and improve nonmydriatic imaging in bright lighting conditions. A non-mydriatic camera with a wider view angle may also improve image utility by virtue of imaging a larger retinal area to reveal pathology beyond the 45-degree field[21,29-30].

The most common retinal findings included torturous vessels, cotton wool spots, drusen, optic nerve pallor, enlarged cup-to-disc ratio and peripapillary atrophy. Neovascularization and hemorrhage were not seen, but there were several patients with chorioretinal scars. While there is no gold standard to compare these results with, this suggests that retinal imaging to screen for disease may improve adverse visual outcomes in Bocas del Toro (Panama), and a hand-held nonmydriatic fundus camera in the hands of minimally trained medical students may successfully achieve this goal.

In conclusion, addressing the significant global burden of eye disease is especially challenging in remote areas without routine access to eye care. Retinal pathology such as DR and macular degeneration are two diseases increasing in prevalence as the global population ages and the prevalence of diabetes increases. This study described the quality of images obtained through a telemedicine screening program for retinal disease among rural island communities comprising an archipelago in Bocas del Toro, Panama. We obtained retinal images using a hand-held nonmydriatic digital camera and reported high image quality in both eyes of only 17% of patients, possibly due to small pupillary diameters. Further improvements are necessary to acquire higher quality images more reliably.

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