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ROptool analysis of images acquired using a noncontact handheld fundus camera (Pictor)—a pilot study

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Abstract

The presence of plus disease is the primary indication for treatment of retinopathy of prematurity (ROP), but its diagnosis is subjective and prone to error. ROptool is a semiautomated computer program that quantifies vascular tortuosity and dilation. Pictor is an FDA-approved, noncontact, handheld digital fundus camera. This pilot study evaluated ROptool's ability to analyze high-quality Pictor images of premature infants and its accuracy in diagnosing plus disease compared to clinical examination. In our small sample of images, ROptool could trace and identify the presence of plus disease with high accuracy.

Retinopathy of prematurity (ROP) is a leading cause of blindness in children in the industrialized world.¹ Treatment depends on timely screening and diagnosis, but there are too few ophthalmologists available to screen for ROP worldwide.² One strategy to overcome this barrier includes an ROP screening system using semiautomated analysis of retinal photographs to identify infants that may need treatment. Prior studies have shown that ROptool analysis of images captured by RetCam and video indirect ophthalmoscopy (VIO) can diagnose plus disease with high accuracy compared to clinical diagnosis.^{3–8} The Pictor camera (Volk Optical, Mentor, OH) is considerably less expensive than Retcam and can capture still images of higher quality than VIO. A recent study showed that the Pictor camera can capture retinal images of premature infants with sufficient quality for grading of pre-plus or plus disease by two ROP experts with high sensitivity (79% and 85%) and specificity (100% and 83%).⁹ The present pilot study evaluates the feasibility and accuracy of analyzing high-quality Pictor images with ROptool for plus disease.

Methods

This pilot study was approved by the Duke Health System Institutional Review Board and complied with regulations of the US Health Insurance Portability and Accountability Act of 1996. A subset of Pictor images graded by two pediatric ophthalmologists experienced in

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ROP screening (SFF and DKW) for image quality (good, fair, or poor) in a previous study were retrospectively analyzed.⁹ The images were obtained without a lid speculum during ROP rounds at Duke University Hospital Neonatal Intensive Care Nursery from December 2011 to May 2012. For an infant to be included in the present study, an image of at least one eye had to be considered of fair or good quality by both graders and to have at least one major vessel visible for one disk diameter in length from the optic nerve in all quadrants. For each infant, the best image from one eye based on the above criteria was selected.

We used ROPtool v2.1.8 to analyze the Pictor images in random order. An image was “traceable” by ROPtool if all four quadrants were traceable; a quadrant was “traceable” if it contained one vessel at least one disk diameter in length that could be traced by ROPtool. The most tortuous major vessel in each quadrant was traced. Because the diagnosis of plus disease requires sufficient dilation and tortuosity in at least two quadrants, the second most tortuous vessel in each image was analyzed. One of the authors (LAV) performed all ROPtool analysis.

Analyses was limited to the ROPtool indices tortuosity and tortuosity weighted plus (TWP), which is a combined measure of dilation and tortuosity that gives more weight to dilation as tortuosity increases.⁵ Receiver operating characteristic (ROC) curves were calculated to determine the accuracy of ROPtool in assessing the presence of plus or “pre-plus or plus” disease compared to the reference standard clinical examination diagnosis given by one of two ROP experts (SFF and DKW) on the same date the photographs were obtained.

All statistical analysis was performed with SAS v.9.1.3 (SAS Institute Inc, Cary, NC).

Results

Of the 48 infants included in the previous study, all had fair or good quality images in at least one eye (47 [98%] right eye images and 44 [92%] left eye images), 37 (77%) infants had an image of at least one eye with fair or good quality with one major vessel visible for at least one disk diameter length from the optic nerve in all quadrants. Of these 37 images, 35 (95%) were traceable, that is, had four quadrants traceable by ROPtool.

Of the 35 traceable images, 3 (8.6%) had plus and 1 (3%) had pre-plus disease based on the reference standard clinical examination. Using the ROPtool parameters of tortuosity and TWP, the area under the curve (AUC) of the ROC curve for the diagnosis of plus disease was 0.99 for tortuosity and 0.99 for TWP; for pre-plus or plus disease the AUC was 1.0 for tortuosity and 0.98 for TWP (Figure 1).

Discussion

High-quality Pictor images of the retina of premature infants are traceable and can be analyzed using ROPtool with high accuracy for diagnosing plus disease. This is the first study showing ROPtool’s ability to accurately analyze images obtained using a handheld, noncontact camera.

The ROPtool parameters tortuosity and TWP both show high accuracy for diagnosing plus disease in Pictor images. We considered tortuosity alone as one parameter because previous studies found that ROPtool can accurately measure retinal tortuosity in high-quality RetCam images^{5,7,10} and tortuosity alone has been shown to be highly correlated with plus disease diagnosis.⁴ We investigated TWP because as a combined measure, TWP has high accuracy to diagnose plus disease in RetCam images.⁵ Future studies should investigate how well the ROPtool parameters of tortuosity and TWP perform using lower quality Pictor images.

Semiautomated diagnosis of plus disease in ROP using images acquired from a handheld, noncontact camera advances efforts to increase the objectivity, automation, safety, and efficiency of ROP screening. RetCam requires contact with the cornea, and VIO requires an examiner trained in indirect ophthalmoscopy (eg, an ophthalmologist or optometrist). By contrast, a less qualified imager (eg, nonophthalmologist healthcare worker) can capture fundus images using Pictor with less risk for damage to the cornea (eg, corneal abrasion or infection), because no corneal contact is involved. ROPtool analysis of Pictor images could also be carried out by trained non-physician healthcare workers, increasing automation and objectivity in screening while expanding our screening workforce beyond ophthalmologists. As more of the ROP screening process is shown to be safely and accurately carried out by non-ophthalmologists, ophthalmologists may focus their efforts on infants requiring treatment.

This pilot study is limited by the relatively small number of images and inclusion of only high-quality images. Also, ROPtool depends on user input to define the border of the optic nerve head and center of the macula, which introduces interuser variability in analysis. To address these limitations, future studies should include a larger number of images of varying image quality and multiple ROPtool users to simulate a semiautomated ROP screening process.

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FIG 1.

Receiver operating characteristic curves for Pictor images using tortuosity and tortuosity weighted plus (TWP) compared to clinical diagnosis of plus disease (A), or “pre-plus or plus” disease (B) as the outcome. *AUC*, area under the curve.