A. JAMES CLARK SCHOOL OF ENGINEERING

THE FISCHELL DEPARTMENT of BIOENGINEERING

UNIVERSITY OF MARYLAND

Erythrocyte Mediated Angiography Verification with Phantom Eye

Danielle Firer, Matthew Kim, Rachel Luthcke, Richard Silcott, Drew Vogel

Clinical Mentor: Dr. Osamah Saeedi, University of Maryland Medical Center

Faculty Advisor: Dr. Giuliano Scarcelli, Robert E. Fischell Department of Bioengineering, University of Maryland

Clinical Need

Motivation:

Glaucoma, Diabetic Retinopathy, and Age-Related Macular Degeneration are three leading causes of blindness linked to impaired ocular blood flow [1] [2] (Fig. 1)

Figure 1. Prevalence of ocular pathology.

Problem:

- Ocular blood flow is a potentially important biomarker for early onset ocular pathologies.
- Current measurement techniques depend on erythrocyte mediated angiography (EMA) using a Heidelberg Retinal Tomograph (HRT) (Fig. 2)
- HRT uses a patient's native cornea for magnification, but the assumption that it's dimensions does not affect angiography measurements is not well characterized.

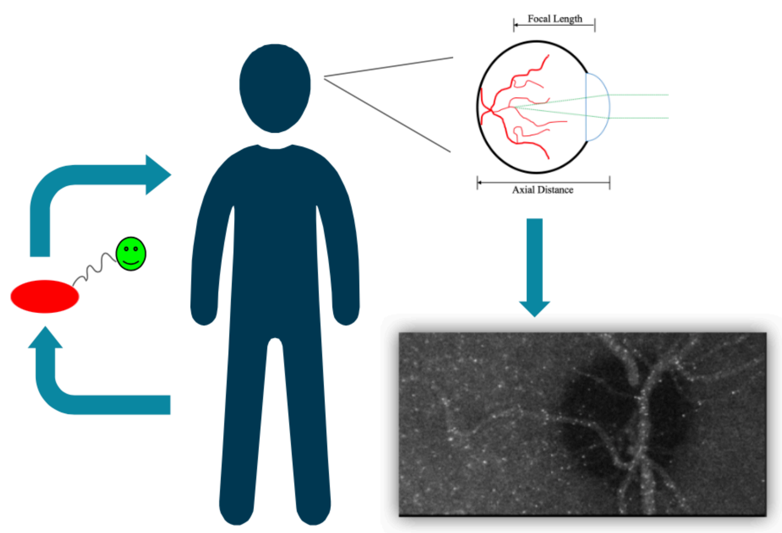

Figure 2. EMA imaging chain.

Objective:

This project aims to create a device to investigate HRT measurements for multiple lens strengths and axial distances by comparing incident red blood cell speed.

Phantom Eye Concept

Our Approach:

Our phantom eye is a testing platform to assess the HRT's ability to measure ocular blood cell speed for different lens powers and axial distances. Two main components on our 3D printed phantom provide precise control of these parameters:

1. **Lens position** - Triangular lens holder slides into a slot that centers the lens at a fixed x, y, and z position.
2. **Axial distance** - 3D printed capillary holder slides into a rack with sawtooth indents from 18mm to 32mm at 2mm increments.

Silicon tubing with inner diameter of 100μm was used to model an ocular blood vessel.

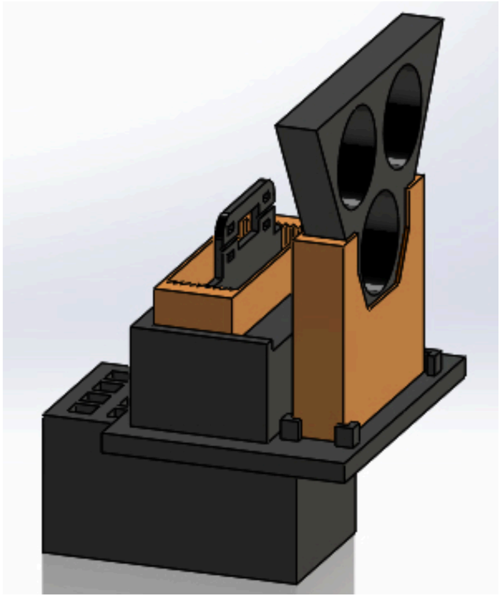

Figure 3. Phantom dimetric view. Capillary holder at 22mm.

Figure 4. Bottom lens centered and aligned with viewing window. (Lenses omitted)

Data Collection

Lens Alignment (Fig. 5):

- Lens holder clamped into a calibrated laser breadboard
- USAF chart group 6 centered in field of view
- Capture image before and after resetting the triangular lens holder
- Measure change in smallest resolvable element and x-y shift (Fig. 7-8)

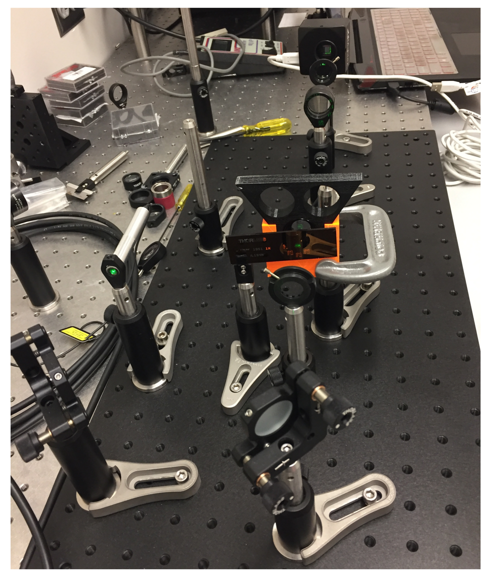

Figure 5. Lens alignment characterization setup, provided by Dr. Giuliano Scarcelli

Angiogram Collection (Fig. 6):

- Phantom eye clamped onto HRT chinrest
- Syringe loaded with fluorescent labeled blood cells
- Tubing fixed onto capillary holder and placed into rack
- Syringe pump turned on and set to 0.005 mL/min flow rate
- Align HRT camera and collect 10 sec angiogram
- Repeat for next rack position and each lens
- Manually track blood cells in ImageJ to estimate speed (Fig. 9-10)

Figure 6. Angiogram collection set up on HRT

Results

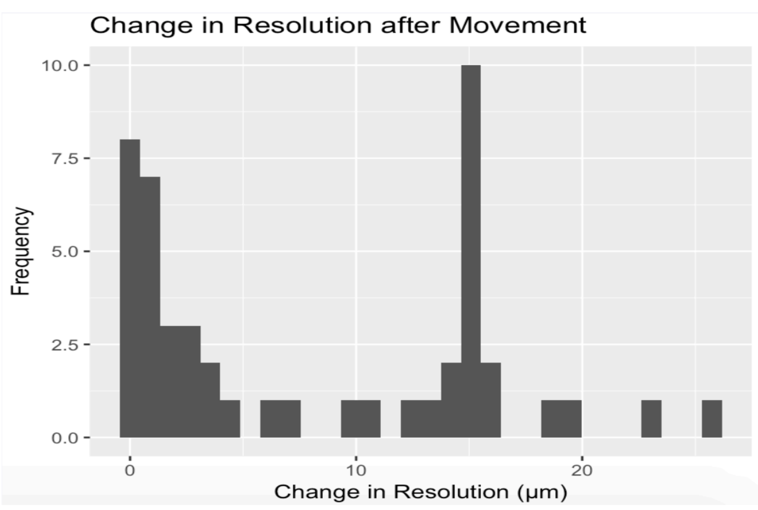

Figure 7. Histogram of change in size of smallest resolvable element after resetting lens holder.

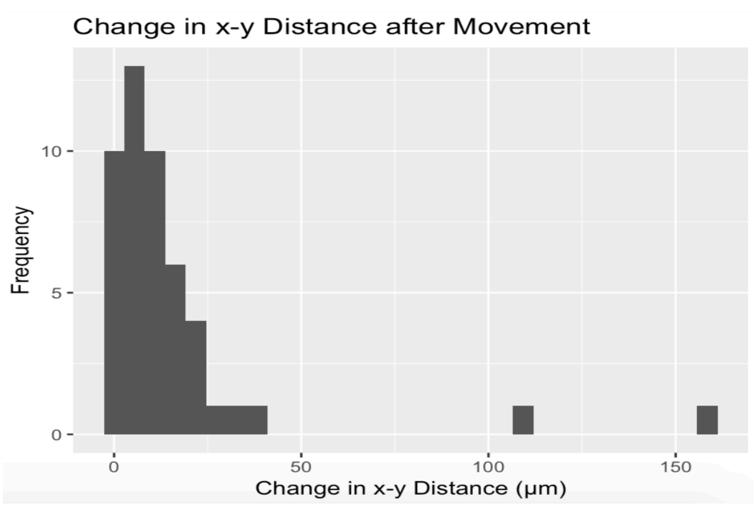

Figure 8. Histogram of change in x-y position after resetting lens holder.

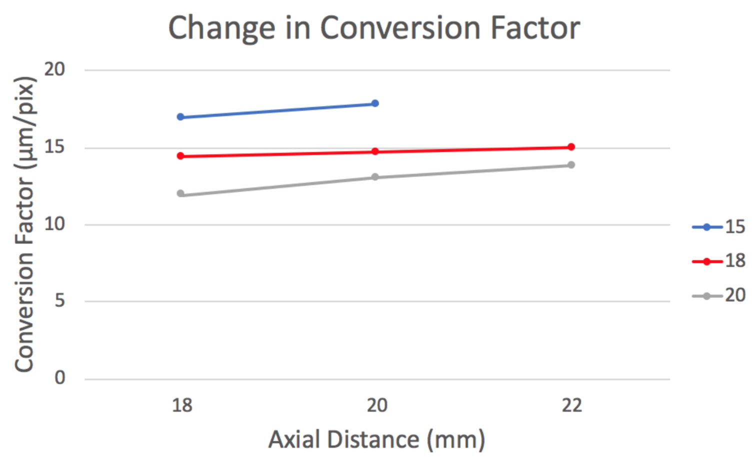

Figure 9. Measured conversion factor at each axial distance and lens power.

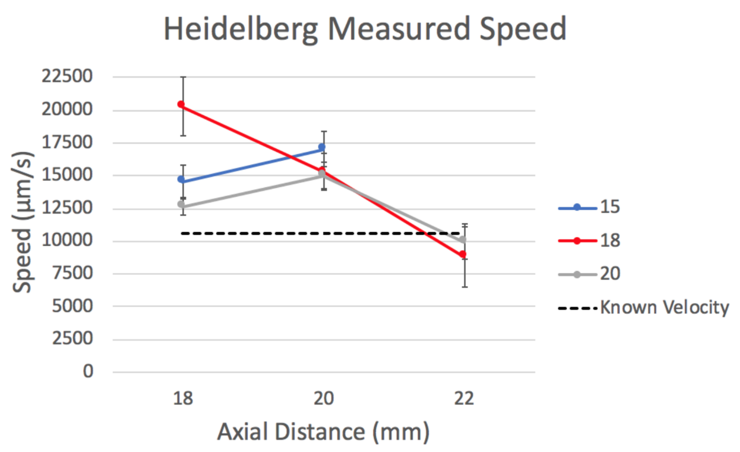

Figure 10. Measured blood cell speed at each axial distance and lens power.

Discussion

Conclusions:

- Resolution changes from resetting the lens could be eliminate by adjusting the HRT camera and x-y shifts were minimal.
- The increase in conversion factor as axial distance increased and focal length decreased was expected
- Surprisingly, the measured velocity was within one standard deviation of the expected speed (10610.33μm/s), only at an axial distance of 22mm.
- Further testing is needed to comprehensively characterize the effect of axial distance and lens power on HRT image quality.

Ethical Implications:

- Pave the way for more quantitative and personalized diagnosis of ocular pathologies through impaired blood flow.
- Positively impact the accuracy of diagnosing major causes of blindness worldwide.
- Specifically making a positive impact on the early diagnosis and monitoring of patients who have Glaucoma, Diabetic Retinopathy, or Age-Related Macular Degeneration.
- Not a risk to patients as our device will not be in contact with human subjects.

Future Work:

1. Develop more physiologically accurate capillary tube (inner diameter, convolution, and material)
2. Add lower powered lenses
3. Apply of pulsatile flow through the capillary tube
4. Refine procedure to diagnose ocular pathology based on impaired blood flow

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References:

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3. Ctori, I., Gruppetta, S. & Huntjens, B. (2015). The effects of ocular magnification on Spectralis spectral domain optical coherence tomography scan length. Graefe's Archive for Clinical and Experimental Ophthalmology, 253(5), pp. 733-738. doi: 10.1007/s00417-014- 2915-9