Automated Detection of Vascular Leakage on Fluorescein Angiography

LeAnne Young1,2, Jongwoo Kim PhD3, Mehmet Yakin MD1, Henry Lin MD PhD1,4, David Dao MD1,5, Shilpa Kodati MD1, Sumit Sharma MD6, Aaron Lee MD MSc7, Cecilia Lee MD MS7, H. Nida Sen MD MHSc8

1National Eye Institute, Bethesda MD ● 2 Cleveland Clinic Lerner College of Medicine, Cleveland OH ● 3National Library of Medicine, Bethesda MD ● 4Northwest Permanente, OR ● 5Department of Visual Sciences, University of Chicago, Chicago IL ● 6Cole Eye Institute, Cleveland OH ● 7University of Washington, Seattle WA

Background

Uveitis is a heterogeneous group of inflammatory eye diseases responsible for causing an estimated 10-15% of blindness in the United States1. Fluorescein angiography (FA) is the current gold standard for imaging retinal vasculature in uveitis. However, clinician interpretation of FAs can be subjective. We aimed to quantify variability of clinician FA segmentation. We also hypothesized that a deep learning algorithm can:

1. Segment FAs for vascular leakage, and
2. Detect clinically significant change in vascular leakage between FAs

Methods

Ground Truth

200 uveitis patient FA images were obtained from a uveitis biobank with prospectively enrolled patients. A 2-clinician team annotated (segmented) images for vascular leakage. Before beginning, all graders met and discussed the definition of leakage, and agreed on a segmentation protocol defined by the senior clinician.

Algorithm

Deep Learning Algorithm with a modified U-net architecture was trained to segment leakage. 5-fold cross validation was used, each fold with 80% training and 20% testing

Statistics

The Dice Similarity Coefficient (DSC) was used to compare the algorithm’s segmentation results to the ground truth segmentation (the DSC ranges from 0 to 1, 0 denotes no overlap between 2 segmentations and 1 denotes perfect overlap)

Inter-rater Variability

For inter-rater variability, 2 clinicians independently segmented 20 images and the average Dice Similarity Coefficient (DSC) was calculated.

Clinically Significant Change in Vascular Leakage

20 pairs of FA images were used to detect clinically significant changes in leakage (the gold standard being an expert uveitis specialist’s assessment). For each pair, the difference in percentage of the image occupied by the algorithm’s leakage segmentation was calculated and used to create a ROC curve and to determine a threshold for clinically significant change.

Results

Inter-rater variability was assessed with 2 clinicians each segmenting 20 images

Example of good clinician concordance

Clinician 1 Segmentation

Clinician 2 Segmentation

Average Dice Similarity Coefficient

Clinician 1 vs 2

0.374

Figure Color Coding Legend

● Red: denotes areas where algorithm and ground truth segmentation overlap

● Yellow: "false positive": Denotes areas where the ground truth segmentation did not detect vascular leakage, but the algorithm did

● Pink: "false negative": Denotes areas where the ground truth segmentation detected vascular leakage, but the algorithm did not

A variety of algorithm parameters were tested and algorithm performance measured. The best algorithm achieved an average DSC of 0.572

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<th>Image Enhancement</th>
<th>Epochs</th>
<th>Avg DSC</th>
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Example of algorithm segmentation results of the same patient’s eye at two different timepoints. 20 pairs were used

Conclusions

FA leakage segmentation is a difficult computer vision problem to solve. In this project, we quantified variability between clinician segmentation of vascular leakage. We also developed a preliminary deep learning algorithm that was able to segment vascular leakage in the fluorescein angiograms of uveitis patients with modest results. However, the algorithm was able to determine clinically significant change in vascular leakage with high accuracy.

Future Directions

Efforts to develop an improved deep learning algorithm, training and testing on fluorescein angiograms from other institutions and testing the algorithm on non-uveitis causes of vascular leakage are underway.

References