Automated Detection of Vascular Leakage on Fluorescein Angiography

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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 with 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

Example of relatively high algorithm-ground truth concordance

Clinician 1 vs 2

Average Dice Similarity Coefficient

0.374

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

Crop Window Sizes Loss Function Image Enhancement Epochs Avg DSC

672×672 Binary Cross Entropy No 20 0.482

672×672 Binary Cross Entropy No 20 0.493

672×672 Binary Cross Entropy No 50 0.528

672×672 Dice Coefficient Loss Yes 200 0.572

1334×1334 Dice Coefficient Loss Yes 50 0.505

1334×1334 Binary Cross Entropy No 50 0.459

1334×1334 Dice Coefficient Loss No 50 0.465

1792×1792 Binary Cross Entropy No 100 0.471

1792×1792 Dice Coefficient Loss No 100 0.455

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