Longitudinal Tracking of Biomarkers of Age-related Macular Degeneration Using Deep Learning-based Object Detection in Optical Coherence Tomography

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Abstract.

Recent researches on deep learning-based analysis on biomarkers have been popular in Ophthalmology. Among them, quantification and localization of biomarkers of age-related macular degeneration (AMD) has typically dependent on semantic segmentation using deep learning models. However, acquisition of fine annotation of AMD biomarkers is harshly time-consuming, which limits to collect not only enough amount but also various kinds of AMD biomarkers. In this paper, we suggest a new paradigm and possibility of quantification of AMD biomarkers based on deep convolutional object detection algorithm. We annotate typical AMD biomarkers in B-scans of optical coherence tomography (OCT) by drawing bounding box, which allows to label a variety of biomarkers compared to semantic segmentation. Region-based two-stage object detection algorithm learns location and class of each AMD biomarker. Finally, the model infers OCT B-scans collected in longitudinal period, which produces dynamics of relative amount on detected AMD biomarkers. With this experiment, we demonstrate the relevance between clinical treatments in real world and meta-analysis of relative amounts for AMD biomarkers.

Ⅰ. Introduction

Optical coherence tomography (OCT) has been widely used to diagnose and assess abnormality of retina structures [1]. However, its acquisition and long-term follow-up have been time-consuming and bottleneck for both patients and ophthalmologists [2]. Deep learning based semantic segmentation of OCT volume or B-scan image has been researched to automate localization and quantification of biomarkers of eye diseases, e.g. age-related macular degeneration (AMD) and diabetic retinal edema (DME) [3]. However, annotation of segmentation is known as time-consuming.

We here propose an alternative approach of quantification of age-related macular degeneration (AMD) biomarkers based on deep convolutional object detection algorithm. Labeling AMD biomarkers with bounding boxes allows to annotate various kinds of biomarkers due to its simpler nature compared with segmentation. Deep convolutional two-stage object detector learns location and class of biomarkers. Finally, we inference the trained model on longitudinal OCT B-scans, which generates trends of relative amount on detected biomarkers in long-term follow-up cases. From case study, we demonstrate the relation between real clinical treatments and quantitative changes of AMD biomarkers before and after treatments.

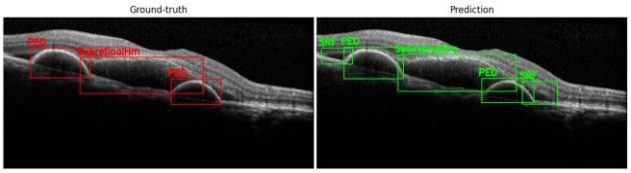

Fig. 1 Object detection results (left: ground-truth, right: prediction of the trained model)

Ⅱ. Method

2.1 Dataset

We organized OCT B-scan dataset as our previous work [4], which contains 99 eyes by normal groups and 238 by AMD patient groups. Each B-scan nearby macular were selected and labeled with bounding box and class of AMD biomarkers, which covered over 15 AMD biomarkers, such as drusen, subretinal drusenoid deposits, and etc. From those biomarkers, we chose five biomarkers-PED, subretinal hemorrhage (SRHM), intraretinal fluid (IRF), and subretinal fluid (SRF), and polyp- as evidence of requirement for clinical treatment, e.g. anti-VEGF injection. After annotation, total 1,038 OCT B-scans containing biomarkers were chosen to train and test the model, 875 as training set and 208 as test set.

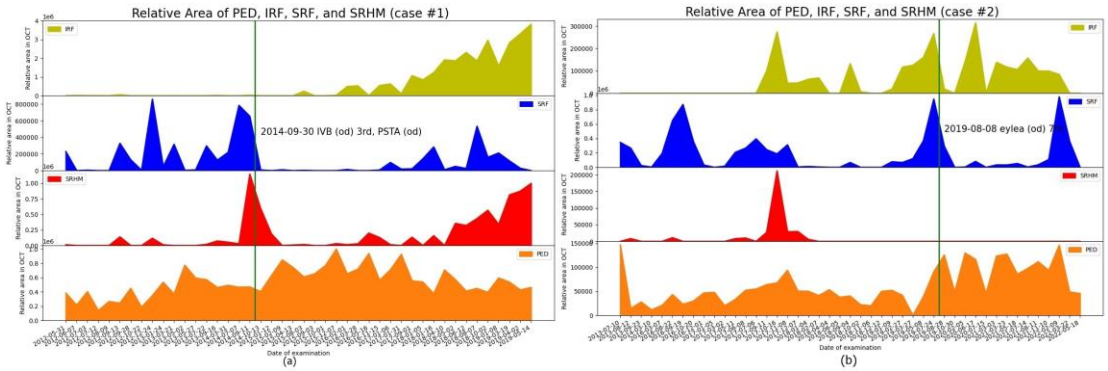

Fig. 2 Case study of object detection-based long-term follow-up of AMD biomarkers (yellow: IRF, blue: SRF, red: SRHM, orange: PED, green line: a day of clinical treatment in real world)

2.2 Model Selection

We adopt publicly available region-based object detection model, which is Faster R-CNN [5] with pretrained ResNet-50 feature pyramid networks [6] as backbone layer, fine-tuning the model for AMD biomarkers. Unlike our previous work trained the model just binary classes [4], we train multiple biomarkers to discriminate major lesions related to anti-VEGF treatment and analyze them separately.

Table. 1 Long-term AMD follow-up cases
(OS: left eye, OD: right eye)

	Case 1	Case 2
Patient visit	44	45
Target eye	OD	OD
OCT volume	44	45
OCT B-scan	1,100	1,125
Follow-up period	May 2014 ~May 2019	July 2013 ~May 2022

2.3 Experiments

In this section, we report quantitative and qualitative performance of the trained model on test set, and apply the model into two long-term follow up cases of AMD patients. The trained model achieves mAP@0.5:0.95, mAP@0.5, and mAP@0.75 0.26, 0.52, and 0.21 respectively on the test set. Fig. 2 compares ground-truth with predicted biomarkers in OCTB-scans.

Furthermore, we sample two cases of long-term OCT examinations for AMD as shown in table 1. After detecting all the B-scans, area of detected boxes for each biomarker throughout an OCT volume are calculated. We repeat this process to the whole OCT volumes, and finally visualize them as a trend of relative area of each biomarker during follow-up period as described in Fig. 3. SRHM and SRF drops sharply after the real clinical treatment record in 30 November 2014 in Fig. 3 (a) and 8 August 2019 in Fig. 3 (b). These observations suggest that the relative dynamics of biomarkers generated by the object detection model represents relevance to real clinical treatments. It demonstrates possibility for data-driven object detector to follow-up retinal abnormality automatically and to provide clinically meaningful meta data to ophthalmologists.

Ⅲ. Conclusion

In this paper, we propose a longitudinal tracking method for multiple biomarkers of AMD based on deep convolutional object detector. The proposed method shows that object detection model can play a role of meta-analyzer for OCT by detecting biomarkers and calculating trends of them automatically from existing long-term examinations. The case study performed in this paper demonstrates that detected box of biomarkers from the trained object detector is relevant to clinical treatments in real world.

ACKNOWLEDGMENT

This research was supported by the MSIT(Ministry of Science and ICT), Korea, under the ITRC(Information Technology Research Center) support program(IITP-2022-2020-0-01808) supervised by the IITP(Institute of Information & Communications Technology Planning & Evaluation).

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