COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 130 (2016) 65–75

journal homepage: www.intl.elsevierhealth.com/journals/cmpb

Automated anterior segment OCT image analysis for Angle Closure Glaucoma mechanisms classification

Swamidoss Issac Niwas[a,*], *Weisi Lin*[a], *Xiaolong Bai*[b,c], *Chee Keong Kwoh*[a], *C.-C. Jay Kuo*[d], *Chelvin C. Sng*[f], *Maria Cecilia Aquino*[e], *Paul T.K. Chew*[f]

[a] *School of Computer Engineering, Nanyang Technological University (NTU), 639798 Singapore, Singapore*
[b] *The State Key Laboratory of Fluid Power Transmission and Control, Zhejiang University, Hangzhou 310027, People's Republic of China*
[c] *School of Electrical and Electronics Engineering, Nanyang Technological University (NTU), 639798 Singapore, Singapore*
[d] *Ming Hsieh Department of Electrical Engineering, Signal and Image Processing Institute, University of Southern California, Los Angeles, CA 90089, USA*
[e] *Eye Surgery Centre, National University Health System (NUHS), 119228 Singapore, Singapore*
[f] *Department of Ophthalmology, Yong Loo Lin School of Medicine, National University of Singapore (NUS), 119228 Singapore, Singapore*

ARTICLE INFO

Article history:
Received 25 November 2015
Received in revised form
10 February 2016
Accepted 17 March 2016

Keywords:
Angle closure glaucoma
Compound image transforms
Feature selection
Segmentation-free method
Machine learning classifier

ABSTRACT

Background and objectives: Angle closure glaucoma (ACG) is an eye disease prevalent throughout the world. ACG is caused by four major mechanisms: exaggerated lens vault, pupil block, thick peripheral iris roll, and plateau iris. Identifying the specific mechanism in a given patient is important because each mechanism requires a specific medication and treatment regimen. Traditional methods of classifying these four mechanisms are based on clinically important parameters measured from anterior segment optical coherence tomography (AS-OCT) images, which rely on accurate segmentation of the AS-OCT image and identification of the scleral spur in the segmented AS-OCT images by clinicians.

Methods: In this work, a fully automated method of classifying different ACG mechanisms based on AS-OCT images is proposed. Since the manual diagnosis mainly based on the morphology of each mechanism, in this study, a complete set of morphological features is extracted directly from raw AS-OCT images using compound image transforms, from which a small set of informative features with minimum redundancy are selected and fed into a Naïve Bayes Classifier (NBC).

Results: We achieved an overall accuracy of 89.2% and 85.12% with a leave-one-out cross-validation and 10-fold cross-validation method, respectively. This study proposes a fully automated way for the classification of different ACG mechanisms, which is without intervention of doctors and less subjective when compared to the existing methods.

* *Corresponding author*. Tel.: +65 98677034.
E-mail addresses: issacniwas@ntu.edu.sg (S.I. Niwas), wslin@ntu.edu.sg (W. Lin), mebaixl@gmail.com (X. Bai), asckkwoh@ntu.edu.sg (C.K. Kwoh), cckuo@sipi.usc.edu (C.-C. Jay Kuo), chelvin@gmail.com (C.C. Sng), mcdaquino@gmail.com (M.C. Aquino), ophchewp@nus.edu.sg (P.T.K. Chew).
http://dx.doi.org/10.1016/j.cmpb.2016.03.018

Conclusions: We directly extracted the compound image transformed features from the raw AS-OCT images without any segmentation and parameter measurement. Our method provides a completely automated and efficient way for the classification of different ACG mechanisms.

1. Introduction

Glaucoma is a kind of optic neuropathy disorder which makes a gradual loss of eye vision due to the damages of retinal cells and retinal nerve fiber layer in the eye [1]. It is mainly associated with increased intraocular pressure (IOP) of fluid inside the eye [2]. If it is left untreated, the damaged optic nerves will not be recovered, leading to eventual blindness; however, reducing IOP may slow disease progression. It is the second major cause of visual impairment and blindness worldwide. Globally, the number of glaucoma patients is estimated as 60.5 millions in 2010, which may increase to almost 80 millions by 2020 [3]. The timing of interference is a key element in glaucoma treatment and it is usually asymptomatic in its early stage; so early diagnosis is required to slow down the disease progression toward complete vision loss.

There are mainly three types of glaucoma, namely, angle closure glaucoma (ACG), open angle glaucoma and developmental glaucoma. ACG is a specific type of glaucoma in which a sudden rise in IOP is experienced, usually as a result of poor drainage due to the eye, producing more aqueous humor than it can remove, hence causing a build-up of fluids [4]. ACG is more prevalent than the other two types. An eye that is susceptible to ACG usually has noticeable features which can be identified upon visual examination [5]. Anterior chamber angle (ACA) assessment is mainly used for the detection of ACG, and it can be visualized and quantified by anterior segment optical coherence tomography (AS-OCT) imaging technique [6,7].

It has been observed that ACG could be the result of one or more mechanisms in the anterior segment of the eye, such as exaggerated lens vault (L), pupil block (PB), thick peripheral iris roll (PIR), and plateau iris (PL) [6]. Laser peripheral iridotomy (LPI) is performed at an early and appropriate time for the eyes with anatomically narrow angles. Ophthalmologists and clinicians have found that the LPI is not always suitable for treating ACG patients with different mechanisms, and many patients continue to have appositional angle closure after treatment using LPI [7]. The optimal treatments for ACG patients with different mechanisms should be different. Therefore, it is important to classify these four mechanisms of ACG effectively, in order to not only provide different treatments for patients with different mechanisms, but also help the doctors tailor the best treatment for each mechanism accordingly.

It has been demonstrated that these four mechanisms of ACG have different patterns of angle configurations with different anterior chamber (AC) parameters [7]. AS-OCT provides excellent repeatability and reproducibility for imaging the anterior segment of eyes. AS-OCT was used to measure the AC parameters in the above mentioned four different mechanisms of ACG [6]. Wirawan et al. used some key parameters which were provided by customized software measured from the segmented AS-OCT images such as scleral spur-to-scleral spur distance, anterior chamber depth, anterior chamber angle and area [8]. Some reliable selected features were fed into Adaboost classifier and it was found to be clinically important to distinguish the four mechanisms of ACG [8]. In another study [9], the selected features are cross examined with four types of ACG mechanisms. In [10], various supervised and unsupervised features selection methods are used to find the reliable features and achieve the classification of different ACG mechanisms. However, the measurement of AC parameters relies on the accurate identification of the scleral spur in the segmented AS-OCT images by the clinicians, which is subjective and may not be reliable, introducing additional noise to the features. In [11], a new ensemble learning method based on error-correcting output code (ECOC) is proposed with application to classification of four ACG mechanisms and it is shown as an effective approach for multiclass classification. The existing methods for the classification of different ACG mechanisms are still not fully automated, requiring the help of the clinicians in feature extraction.

In this paper, our study is motivated by providing a fully automated expert system for the classification of different ACG mechanisms. We attempt to directly extract the features from the raw AS-OCT images without segmentation and parameter measurement. It is less subjective without the intervention of doctors. Specifically, in the proposed method, compound transform [12] is applied to the raw AS-OCT images to extract around three thousand different morphological features, from which a small set of discriminative features is selected for classification.

In the rest of this paper, Section 2 reviews related literature on general glaucoma diagnosis methods. The proposed method is presented in Section 3, followed by experimental results in Section 4. The conclusion is made with future works highlighted in the last section.

2. Related methods

During the past one decade, several studies have investigated the usefulness of the computer-based expert support systems for the early detection of glaucoma using different imaging modalities as listed in the literature [13–18]. From the fundus images, using image processing techniques, the optic disk and blood vessels were extracted which could provide useful information to diagnose glaucoma. Higher order spectra features and textural features of fundus images combined with a random-forest classifier resulted with an