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Automated diagnosis of macular edema and central serous retinopathy through robust reconstruction of 3D retinal surfaces

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ABSTRACT

Background and objectives: Macular diseases tend to damage macula within human retina due to which the central vision of a person is affected. Macular edema (ME) and central serous retinopathy (CSR) are two of the most common macular diseases. Many researchers worked on automated detection of ME from optical coherence tomography (OCT) and fundus images, whereas few researchers have worked on diagnosing central serous retinopathy. But this paper proposes a fully automated method for the classification of ME and CSR through robust reconstruction of 3D OCT retinal surfaces.

Methods: The proposed system uses structure tensors to extract retinal layers from OCT images. The 3D retinal surface is then reconstructed by extracting the brightness scan (B-scan) thickness profile from each coherent tensor. The proposed system extracts 8 distinct features (3 based on retinal thickness profile of right side, 3 based on thickness profile of left side and 2 based on top surface and cyst spaces within retinal layers) from 30 labeled volumes (10 healthy, 10 CSR and 10 ME) which are used to train the supervised support vector machines (SVM) classifier.

Results: In this research we have considered 90 OCT volumes (30 Healthy, 30 CSR and 30 ME) of 73 patients to test the proposed system where our proposed system correctly classified 89 out of 90 cases and has promising receiver operator characteristics (ROC) ratings with accuracy, sensitivity and specificity of 98.88%, 100%, and 96.66% respectively.

Conclusion: The proposed system is quite fast and robust in detecting all the three types of retinal pathologies from volumetric OCT scans. The proposed system is fully automated and provides an early and on fly diagnosis of ME and CSR syndromes. 3D macular thickness surfaces can further be used as decision support parameter in clinical studies to check the volume of cyst.

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1. Introduction

Macular diseases are the collective group of diseases that affect the central vision. If they are left untreated, they can cause severe visual impairments or even blindness. Unfortunately due to lack of health resources in developing countries like Pakistan, the rate of visually impaired people are increasing day by day [1]. Globally, macular diseases are the second major cause of blindness following cataract [2]. The most common macular diseases are macular edema (ME) and central serous retinopathy (CSR). ME occurs due to retinal swellings within macular pathology where these swellings are mainly due to diabetes and cataract surgeries [3]. CSR is another variation of macular disorders that damage the central vision of a person. CSR is due to the rapture in the retinal pigment epithelium (RPE) which leads to the accumulation of serous fluid beneath neurosensory retina [4,5]. Fig. 1 shows the OCT image of a healthy person and a patient with macular disorders where the foveal thickness between ILM and choroid is indicated for both cases.

A number of articles have presented detailed clinical literature on ME and CSR using OCT images. Shrestha et al. [6] found the usefulness of OCT imaging after ME surgeries. They consider a dataset of 60 patients in their study. Hannouche and Ávila [7] compared the different eye testing techniques and concluded that OCT imaging is more effective in early macular syndromes. Mokwa et al. [8] also compared different eye testing techniques for grading of age related macular degeneration (AMD) and choroidal neovascularization (CNV) and they concluded that OCT is more efficient than fundus fluorescein angiography (FFA) to diagnose early symptoms of macular pathology; however, it cannot fully replace FFA. Zhang et al. [9] gave an overview of OCT imaging system and also its usage for diagnosing and treating diabetic macular edema (DME). Ferrara et al. [10] used 15 eyes of 13 patients to extract different features of retinal pigment epithelium (RPE) and choroid to diagnose CSR positive candidates. Helmy and Allah [11] used the dataset of 104 eyes of 86 patients to detect cystoid macular edema (CME). The sample population was from the age group of 50 to 71 years. In their study, they concluded that OCT imaging is a very useful non-invasive technique to detect early pathological changes and cyst spaces within macula. Teke et al. [12] compared fundus auto fluorescence (FAF) and OCT imaging on a dataset of 100 CSR candidates and concluded that both techniques are quite effective in clinically diagnosing CSR. Wani et al. [13] used OCT and FFA to diagnose 48 CSR candidates and they concluded that OCT is the good alternative to fluorescein angiography (FA) for diagnosing CSR. Mitarai et al. [14] used a dataset of 26 patients with 23 to 3 men and women ratio and they have detected the variations in fluid leakage points in CSR candidates. Ahlers et al. [15] considered 18 patients suffering from CSR and they concluded that OCT gives an objective evaluation of retinal pathology under CSR symptoms. Apart from this, some researchers have also proposed automated algorithms to detect ME from OCT images. Zhang et al. [16] segmented retinal layers to diagnose CME from macular pathology using adaptive boosting (AdaBoost) algorithm and they achieved the accuracy of 98.60%. Wilkins et al. [17] used a dataset of 16 subjects and detected inter-retinal fluid by manually annotating inner limiting membrane (ILM) and retinal pigment epithelium (RPE) with the sensitivity and specificity ratings of 91% and 96% respectively. Srinivasan et al. [18] automatically diagnosed diabetic macular edema (DME), AMD and healthy pathology within macular region and they achieved the accuracy of 100%, 100% and 86.67% respectively. Sugruk et al. [19] proposed a fully automated method to diagnose AMD and DME. For AMD, they detect RPE abnormalities within macular scan and to detect DME, they extracted cyst segments with the accuracy of 100% and 86.6% respectively.

To the best of our knowledge, no technical paper related to automated detection of CSR was found in literature except Ref. [20] in which we proposed a structure tensor based automated detection of CSR, ME and healthy pathology from OCT B-scans. We achieved an overall accuracy of 98.88% for correctly classifying ME, CSR and healthy scans. Here, we propose an extension of the fully automated algorithm proposed in Ref. [20] to detect ME and CSR by reconstructing 3D retinal thickness surfaces and cyst cavity from OCT volumes. The robust reconstruction is based on adaptive de-noising filter [21] and coherent tensors. Afterwards the proposed system uses SVM to distinguish between healthy, CSR and ME subjects. The rest of the paper is organized as follow: section 2 is about the in-depth description of proposed methodology, section 3 demonstrates our results and accuracy for automatically classifying macular subjects, section 4 is about the discussion on our proposed implementation and section 5 outlines conclusions and future directions.

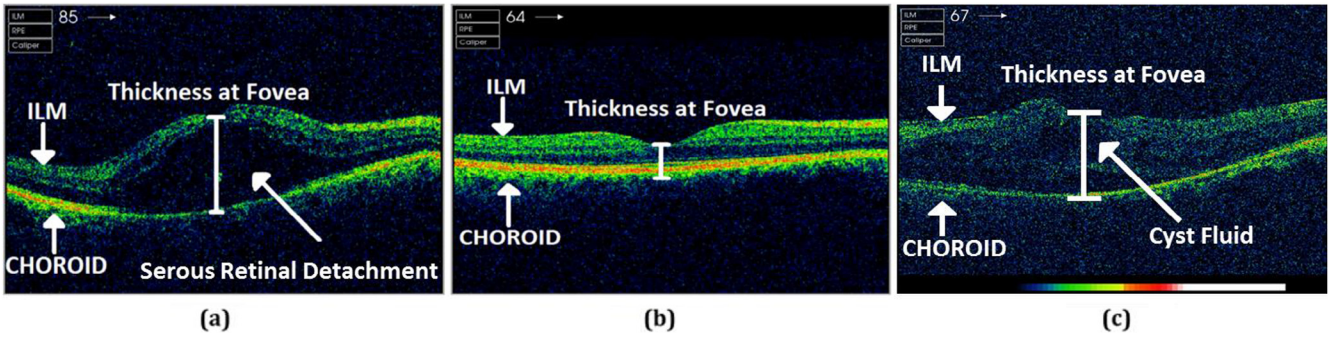

Fig. 1 – Macular analysis: (a) CSR affected OCT scan; (b) normal macular OCT scan; (c) ME affected OCT scan.