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Application of different imaging modalities for diagnosis of Diabetic Macular Edema: A review

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ABSTRACT

Diabetic Macular Edema (DME) is caused by accumulation of extracellular fluid from hyperpermeable capillaries within the macula. Diabetic Macular Edema (DME) is one of the leading causes of blindness among Diabetes Mellitus (DM) patients. Early detection followed by laser photocoagulation can save the visual loss. This review discusses various imaging modalities viz. biomicroscopy, Fluorescein Angiography (FA), Optical Coherence Tomography (OCT) and colour fundus photographs used for diagnosis of Diabetic Macular Edema (DME). Various automated Diabetic Macular Edema (DME) grading system using retinal fundus images, associated retinal image processing techniques for fovea, exudate detection and segmentation are presented. We have also compared various imaging modalities and automated screening used for Diabetic Macular Edema (DME) grading. The reviewed literatures indicate that Fluorescein Angiography (FA) and Optical Coherence Tomography (OCT) identify Diabetic Macular Edema (DME) related changes accurately. Fluorescein Angiography (FA) is an invasive method, which uses fluorescein dye, and Optical Coherence Tomography (OCT) is an expensive imaging method compared to fundus photographs. Moreover, using fundus images Diabetic Macular Edema (DME) can be identified and automated Diabetic Macular Edema (DME) grading algorithms can be implemented for

Abbreviation: DM, Diabetes Mellitus; DR, Diabetic Retinopathy; NPDR, Non-Proliferative Diabetic Retinopathy; PDR, Proliferative Diabetic Retinopathy; ME, Macular Edema; MA, Microaneurysms; HA, Haemorrhages; CWS, Cotton Wool Spots; VB, Venous Beading; NV, Neovascularization; DME, Diabetic Macular Edema; ETDRS, Early Treatment Diabetic Retinopathy Study; CSME, Clinically Significant Macular Edema; NCSME, Non-Clinically Significant Macular Edema; FA, Fluorescein Angiography; OCT, Optical Coherence Tomography; RGB, Red Green Blue; OD, Optic Disk; ON, Optic Nerve; SVD, Singular Value Decomposition; STARE, STructured Analysis of the Retina; *k*-NN, *k*-Nearest Neighbour algorithm; DRIVE, Digital Retinal Images for Vessel Extraction; MESSIDOR, Méthodes d'Evaluation de Systèmes de Segmentation et d'Indexation Dédiées à l'Ophtalmologie Rétinienne; GMM, Gaussian Mixture Model; DIARETDB0, DIAbetic RETinopathy DataBase Calibration level 0; DIARETDB1, DIAbetic RETinopathy DataBase Calibration level 1; HE, Hard Exudates; FCM, Fuzzy C-Means; NN, Neural Network; GA, Genetic Algorithm; FLDA, Fishers linear discriminant analysis; SVM, Support Vector Machine; HEI-MED, Hamilton Eye Institute Macular Edema Dataset; CAD, Computer Aided Diagnosis; FAR, Foveal Avascular Region; HEI-MED, Hamilton Eye Institute Macular Edema Dataset; AUC, Area Under receiver operator characteristics Curve; GDD, Gaussian Data Description; PCADD, Principal Component Analysis Data Description; FD, Fractal Dimension; LME, Laws Mask Energy; LBP, Local Binary Pattern; FS, Fourier Spectrum; GW, Gabor Wavelet; AMD, Age-related Macular Degeneration; CLAHE, Contrast Limited Adaptive Histogram Equalization; RTA, Retinal Thickness Analyser; RTM, Retinal Thickness Map; SD, Standard Deviation; SRD, Serous Retinal Detachment; RT, Retinal Thickness; CMT, Central Macular Thickness; DWT, Discrete Wavelet Transform; GLCM, Grey Level Co-occurrence Matrix; HMA, Haemorrhages with or without microaneurysms; HD, High-Definition; GCC, Ganglion Cell Complex; FD, Fourier Domain; CRVO, Central Retinal Vein Occlusion; PPV, Positive Predictive Value; PS, Polarization Sensitive; VA, Visual Acuity; FAZ, Foveal Avascular Zone; RNFL, Retinal Nerve Fiber Layer; CME, Cystoid Macular Edema; GCL, Ganglion Cell Layer; UTHSC-SA, University of Texas Health Science Center in San Antonio; AM, Amplitude Modulation; FM, Frequency Modulation; IA, Instantaneous Amplitude; IF, Instantaneous Frequency; DT-CWT, Dual Tree Complex Wavelet Transform; KLD, Kull-back Leibler Divergence; ONL, Outer Nuclear Layer; ARIA, Automated Retinal Image Analysis; EHD, Edge Histogram Descriptor; PSO, Particle Swarm Optimization; HRF, High Resolution Fundus; HOS, Higher Order Spectra; NB, Naive Bayes; DD, Disc Diameter; CNV, Choroidal Neovascularization; CDR, Cup-to-Disc Ratio; ANOVA, Analysis of variance; CI, Confidence Interval; ANFIS, Adaptive Neuro-Fuzzy Inference System; FAF, Fundus Autofluorescence

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telescreening. Hence, fundus imaging based Diabetic Macular Edema (DME) grading is a more suitable and affordable method compared to biomicroscopy, Fluorescein Angiography (FA), and Optical Coherence Tomography (OCT).

Contents

1. Introduction

Diabetes Mellitus (DM) is a chronic medical condition characterized by impaired glucose metabolism caused due to destruction of pancreatic β-cell. It is mainly classified into type-I (insulin deficiency) and type-II (insulin resistance) diabetes [1–3]. In 2008, global prevalence of diabetes is estimated to be 2.8% and it may elevate to 4.4% by 2030 [4]. Globally, 171 million people are affected with diabetes and it is estimated to rise to 366 million by 2030 [4–6]. Primarily, diabetes affects the important organs viz. heart, kidneys, feet and eyes [2,5]. The cross section of retina is shown in Fig. 1. It has various layers and different types of neurons viz. receptors, horizontal cells, bipolar cells, amacrine cells and ganglion cells [7]. The optic nerve contains axons of ganglion cells which is connected to the brain. Moreover, the blood vessels are entered through Optic Disk (OD) to vascularize different layers of retina and neurons [7]. Diabetic Retinopathy (DR) is a damage of the retinal blood vessels due to diabetes and is classified into Non-Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR) [8]. Diabetic Macular Edema (DME) may appear in patients with Non-Proliferative Diabetic Retinopathy (NPDR) or Proliferative Diabetic Retinopathy (PDR) [2,5] (Fig. 2). Q3

DME is one of the major causes of central vision loss in diabetes patients [9]. Worldwide 93 and 17 million people are affected by DR and PDR respectively. Moreover, 21 million people are affected by DME [10]. Globally, the prevalence of DR, PDR and DME are

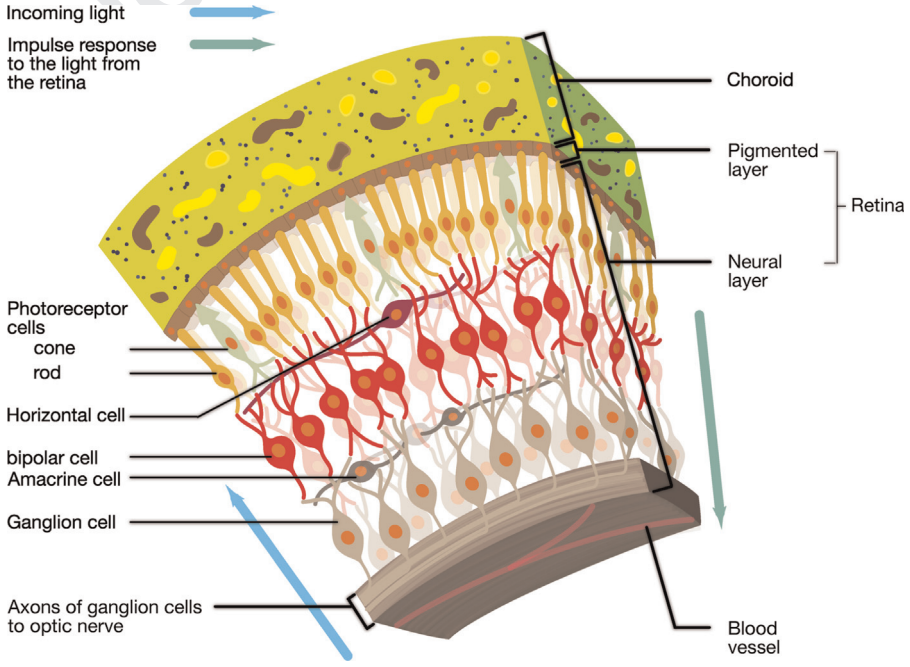

Fig. 1. Cross section of the human retina.

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