ELSEVIER

Computers in Biology and Medicine 37 (2007) 836–841

Computers in Biology and Medicine

www.intl.elsevierhealth.com/journals/cobm

Classification of macular and optic nerve disease by principal component analysis

Sadık Kara[a,*], Ayşegül Güven[b], Semra İçer[c]

[a]Department of Electronics Engineering, Erciyes University, 38039 Kayseri, Turkey
[b]Department of Electronics, Civil Aviation School, Erciyes University, 38039 Kayseri, Turkey
[c]Department of Biomedical Devices Technology, Erciyes University, 38039 Kayseri, Turkey

Received 20 February 2006; received in revised form 20 August 2006; accepted 30 August 2006

Abstract

In this study, pattern electroretinography (PERG) signals were obtained by electrophysiological testing devices from 70 subjects. The group consisted of optic nerve and macular diseases subjects. Characterization and interpretation of the physiological PERG signal was done by principal component analysis (PCA). While the first principal component of data matrix acquired from optic nerve patients represents 67.24% of total variance, the first principal component of the macular patients data matrix represents 76.81% of total variance. The basic differences between the two patient groups were obtained with first principal component, obviously. In addition, the graphic of second principal component vs. first principal component of optic nerve and macular subjects was analyzed. The two patient groups were separated clearly from each other without any hesitation. This research developed an auxiliary system for the interpretation of the PERG signals. The stated results show that the use of PCA of physiological waveforms is presented as a powerful method likely to be incorporated in future medical signal processing.

Keywords: Macular disease; Optic nerve disease; Pattern electroretinography; Principal component analysis

1. Introduction

The macula is located roughly in the center of the retina, temporal to the optic nerve. It is a small and highly sensitive part of the retina responsible for detailed central vision. The macula allows us to appreciate detail and perform tasks that require central vision such as reading. The macula can be affected by a number of disorders including trauma, infection, degeneration, vascular, and inflammatory problems. It can also be further subdivided into those with and without choroidal neovascularization [1,2].

The optic nerve transmits electrical impulses from the retina to the brain. It connects to the back of the eye near the macula. A problem anywhere along the optic nerve or damage to the areas at the back of the brain that sense visual information can result in loss of vision. A common cause of damage to the optic nerve is a tumor of the pituitary gland that presses on the nerve [2,3].

Several procedures may be used to separate macular or retinal from optic nerve disease. Some of these procedures are easy to perform and include the Amsler grid, color vision testing, pupillary reflexes, light–brightness comparison, and macular dazzle. Other procedures require a greater degree of sophistication and include fluorescein angiography, the visual evoked potential (VEP), pattern electroretinogram (PERG), and electroretinograms (ERG) [1,2]. The visual electrophysiology tests (including PERG, ERG, EOG, and VEP) will tell how well the macula and optic nerve work. The visual electrophysiology diagnostic tests reflect retinal, optic nerve and visual pathway function, and provide important information for ocular disease diagnosis and treatment. Currently, it is regarded as the only objective way to determine retina and optic nerve dysfunction [4]. More detailed reports of PERGs in optic nerve or macular disease have subsequently appeared [5].

The PERG is an established test for investigating many pathological conditions affecting the proximal layers of the

* Corresponding author. Tel.: +90 352 4374901x32228; fax: +90 352 4375784.
E-mail address: kara@erciyes.edu.tr (S. Kara).

0010-4825/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compbiomed.2006.08.024

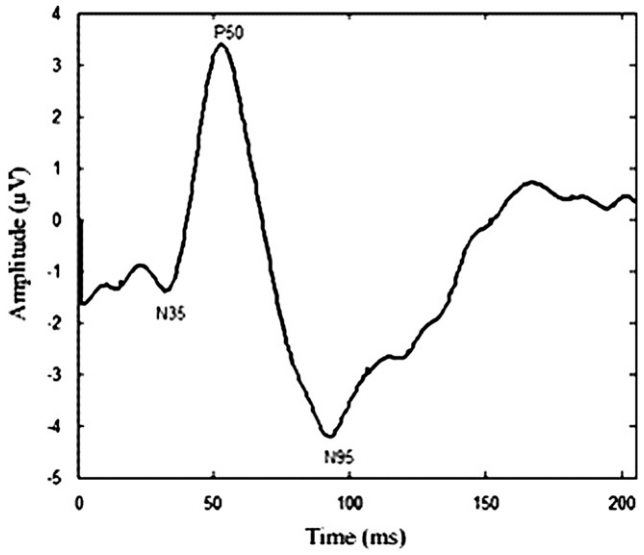

Fig. 1. Normal PERG with the components labeled.

retina [2]. The electrical signals in the visual system elicited by different visual stimuli are recorded in the PERG analysis. These voltage changes vary with time and can be plotted as a waveform. The terms *implicit time* (latency) and *amplitude* describe the timing (in m/s) and size (in microvolts), respectively. The complex electrophysiological waveforms consist of those positive and negative signals which are generated from different cells. Normal neuron or non-neuronal cells generate responses within a range, while in a diseased eye these signals may be smaller in size and slower in timing [1,4]. The normal response consists of at least three waves (Fig. 1). The first, small, cornea-negative wave arises with a delay of about 35 ms and is called N35; the second, a major positive wave, peaks at about 50 ms (P50); and the last is a negative wave at 95 ms (N95) [2,3]. For the PERG, amplitude measurements are made between peaks and troughs. The P50 amplitude is measured from the trough of N35 to the peak of P50. In some patients the N35 is poorly defined; in these cases N35 is replaced by the average between time zero and the onset of P50. The N95 amplitude is measured from the peak of P50 to the trough of N95. It should be recognized that measuring in this way, N95 includes the P50 amplitude [1].

The PERG provides an objective measure of central retinal function, and has become an important element of clinical visual assessment. The P50 amplitude is affected by macular dysfunction with concomitant reduction in N95. The PERG, therefore, complements the Ganzfeld ERG in the assessment of patients with retinal disease. In contrast, the ganglion cell origins of the N95 amplitude allow electrophysiological evaluation of ganglion cell function both in the primary disease and in dysfunction secondary to optic nerve disease, where selective loss of N95 can be observed. Both macular dysfunction and optic nerve disease can give abnormalities in the visual evoked cortical potential (VEP) [6].

Several papers have reported good results during the last decades on the diagnostic performance of signal analysis of the electrophysiological waveform [7–11]. In our literature study, we have seen that principal component analysis (PCA) can be applied to signal processing for electrophysiological eye signals. PCA (also called eigenvector decomposition) is often used to approximate data vectors having many elements with a new set of data vectors having fewer elements, while retaining most of the variability and information of the original data. The new data vectors are called principal component score vectors. Because they consist of the components of the original data vector in an orthogonal coordinate system, the elements of a given principal component score vector are independent of each other (unlike the original spectrum). A major area of application for PCA is the biomedical time series analysis, with benefits in both basic research and in medical diagnosis and treatment [12,13]. Zhang and Hood [14] studied multifocal visual evoked potentials (mfVEP) with PCA. Li and Chutatape [15] developed novel methods to extract the main features from color retinal images (color retinal photography is a tool to detect various eye diseases) using PCA. Landis et al. [16] used PCA to characterize specific properties of the peripheral vasculature in the method in dynamic optical tomography.

The aim of this study is to determine if PCA of PERG signals can be used to diagnose and separate macular and optic nerve disease.

2. Methods

2.1. Subjects

In this study, PERG signals were obtained from 70 subjects consisting of 38 females and 32 males with ages ranging from 38 to 51 years (mean $\pm$ SD $= 46 \pm 5.2$). Electrophysiological devices were used and the signals were analyzed. According to examination results 37 of 70 subjects suffered from optic nerve disease and the rest were macular disease subjects. The group having optic nerve disease consists of 20 females and 17 males with a mean age 45 ± 5.1 years while the macular disease subjects consisted of 18 females and 15 males with a mean age of 43 ± 4.2 years.

2.2. Measurement of PERG signals

We used the Tomey Primus 2.5 electrophysiology unit in the ophthalmology department of Erciyes University Hospital for PERG signals acquisition (Fig. 2). The PERG is measured by an electrode embedded in a contact lens, which is placed on the subject's left cornea. A full field (Ganzfeld) light stimulus is recommended. The recording electrodes

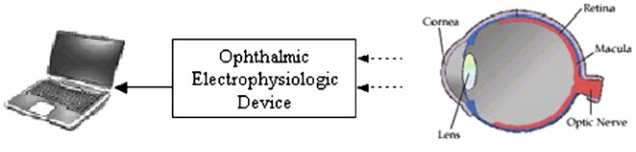

Fig. 2. Block diagram of the system.