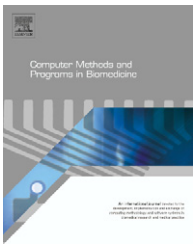
COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 104 (2011) 316–324

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



An approach based on wavelet analysis for feature extraction in the *a*-wave of the electroretinogram

*R. Barraco**, *D. Persano Adorno*[1], *M. Brai*[2]

Dipartimento di Fisica, Università di Palermo & CNISM Viale delle Scienze Ed. 18, 90128 Palermo, Italy

ARTICLE INFO

Article history:
Received 29 April 2010
Received in revised form
28 January 2011
Accepted 8 May 2011

Keywords:
Electroretinogram
a-Wave
Photoreceptoral response
Achromatopsia
Wavelet analysis

ABSTRACT

Most biomedical signals are non-stationary. The knowledge of their frequency content and temporal distribution is then useful in a clinical context. The wavelet analysis is appropriate to achieve this task. The present paper uses this method to reveal hidden characteristics and anomalies of the human *a*-wave, an important component of the electroretinogram since it is a measure of the functional integrity of the photoreceptors. We here analyse the time–frequency features of the *a*-wave both in normal subjects and in patients affected by Achromatopsia, a pathology disturbing the functionality of the cones. The results indicate the presence of two or three stable frequencies that, in the pathological case, shift toward lower values and change their times of occurrence. The present findings are a first step toward a deeper understanding of the features of the *a*-wave and possible applications to diagnostic procedures in order to recognise incipient photoreceptoral pathologies.

© 2011 Elsevier Ireland Ltd. All rights reserved.

1. Introduction

The investigation of biomedical signals is of fundamental importance in the study of the functionality of the systems that generate them and in the early diagnosis of eventual diseases. However, the information contained in biomedical signals is not immediately accessible. Processing methods are needed for detecting relevant features characterising a signal, understanding the underlying physiological processes and monitoring diagnostic occurrences. Dynamic changes that occur in the behaviour of the biological structures produce non-stationary signals, whose features are time-dependent. This implies complex time–frequency characteristics. It is hence difficult to process local variations of bio-signals. For this reason, together with consolidated analytical methods (such as FFT and STFT), wavelet analysis (WA) is gaining importance in many biomedical applications. The WA permits us to represent the signal in a time–frequency domain characterised by an increased flexibility with respect to conventional methods in the analysis of non-linear and non-stationary responses. Numerous studies have proposed the application of this processing method to various biomedical signals such as ECG, EEG, and EMG [1–5]. In these cases, the use of the WA has furnished relevant information about the time–frequency features of the signal of interest and the detection of incipient diseases.

The present paper applies the WA, to the investigation and evaluation of the status of the working photoreceptors in the human retina. The retinal photoreceptors, rods and cones, sub serve different visual functions: rods are devoted to the scotopic vision (vision in moderate levels of illumination), usually responding to relatively slow changes; cones are responsible of photopic vision (vision in higher levels of illumination), they

* *Corresponding author*. Tel.: +39 091 6615102.
E-mail addresses: rbarraco@difter.unipa.it (R. Barraco), dpersano@unipa.it (D. Persano Adorno), mbrai@unipa.it (M. Brai).
[1] Tel.: +39 091 23899086.
[2] Tel.: +39 091 23899038.

0169-2607/$ – see front matter © 2011 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.cmpb.2011.05.001

can detect rapid light fluctuations [6]. Their response to a stimulus is not uniform in time.

The investigation task is achieved through the analysis of the first component (*a*-wave) of the electroretinogram (ERG), that records the electrical response of the retina to a flash stimulation. This study is aimed to identify and compare the time–frequency components in normal and pathological *a*-waves. We here investigate and compare the responses of normal subjects with those of patients affected by a cone disease, known as Achromatopsia (ACR) that, in its incomplete form, is difficult to diagnose since it causes minor levels of colour differentiation in the vision. Incomplete Achromatopsia (partially monochromatic rods), is a disease in which only a part of the cones, varying appreciably from subject to subject, is properly working.

The features of the anomalies of *a*-wave are not always immediately detectable in a temporal diagram through an objective analysis of the ERG; consequently, the possibility of distinguishing pathological from healthy traces throughout the differentiation of their time–frequency features, represents a progress in diagnostic methods.

Recent applications of the wavelet techniques in electrophysiology concern the separation of the components of the clinical ERG [7] and the analysis of the dynamics of the oscillatory potentials in the retinal response of rat [8].

2. Materials and methods

2.1. Main features of the ERG

The electroretinogram (ERG) records the mass electrical potential setup in the retina as response to a flash stimulus. It consists of a sequence of components (*a*-, *b*-, *c*-, *d*-wave, oscillatory potentials, etc.) originated in different retinal layers and provides valuable physiological information about the retinal status in vertebrates including the living human eye [9–15]. The *a*-wave is related to the photoreceptoral activities; its shape and amplitude depend on the luminous intensity, adaptation and concentration of visual pigments in the outer segment of the photoreceptors. These work as specialized neurons that convert visual stimuli, consequent to the absorption of photons, into chemical and electrical stimuli that can be processed by the central nervous system. In a human healthy eye, about 6 million cones, located largely in the central area of the retina and about 120 million rods, located mainly around the periphery of the retina, are active. The *a*-wave contributes to the ERG as a negative potential characterised, in normal subjects, by two dips. In humans the photocurrents are thought to contribute to the *a*-wave up to 25 ms [11–15], while at greater times, it is believed the *a*-wave is obscured by the positive-going *b*-wave. Panels a, b and c of Fig. 1 display our sample of healthy *a*-waves recorded with three different values of luminance.

Disorders in the photoreceptoral system cause alterations in the chain of the physiological processes, subsequent to photo-detection and affect the whole temporal response of the system. In order to improve our knowledge of the mechanisms linked to the retinal response and how these are affected by a disease, we have focused our attention on a selective photoreceptoral pathology in which only the rod population is correctly working: the Achromatopsia. There are two forms in which ACR can subsist: incomplete and complete. In particular, we have analysed the behaviour of the *a*-waves belonging to the patients affect by incomplete ACR. In general, the eyes affected by ACR, lacking normal cone vision, are not able to adapt normally to higher levels of illumination; the ACR patients are partially colour-blind and have very poor visual acuity. Because there are many variations in the severity of the pathology among achromats, it is not easy to identify its different stages.

Panels d, e, and f of Fig. 1 show the pathological *a*-waves belonging to our set of patients. Although in these patients a small reduction of the *b*-wave is noticeable, a naked eye distinction among healthy and pathological traces is not immediate.

2.2. Wavelet analysis

The application of mathematical transforms to a generic signal is a useful tool for obtaining information non directly deducible from its temporal diagram. The description of a signal in the time-domain is not always sufficient for an accurate analysis, since significant information regarding its frequency content is often hidden. The WA gives the appropriate answer since it provides the time-scale representation of the signal through the use of functions (wavelets) localized both in time and frequency [16–20]. It is, hence, a powerful tool for describing the dynamics of complex non-linear processes characterised by interactions and correlations in the space-time framework. Upon decomposition of a temporal signal in the time-scale dominion, it is possible to identify the constituent frequencies and determine their temporal occurrence. This is achieved by using families of wavelets that are generated from a single function (mother wavelet), through the operations of scaling (stretching or shrinking the mother wavelet) and translation (moving the mother wavelet to different time locations at any scale without changing its shape). Each operation is controlled by the scale parameter σ, related to the frequency band, and by the translation parameter τ, related to the time location.

We here use the continuous wavelet transforms (CWT) whose coefficients can be calculated according to the formula:

$$WT(\tau,\sigma) = \frac{1}{\sqrt{\sigma}} \int_{-\infty}^{+\infty} x(t)\psi^* \left(\frac{t-\tau}{\sigma}\right) dt \quad (1)$$

where $x(t)$ is the signal to be analysed and ψ the chosen wavelet. The coefficient of the wavelet transform, calculated at a certain σ and τ, assumes extreme values when the signal pattern tends to become similar to that of the wavelet. Therefore, the WT may be considered as a measure of similarity (correlation) among the mother wavelet and the shape of the signal at that instant. As a consequence of the Heisenberg uncertainty relation, the WA gives good time resolution and poor frequency resolution at small scales (high frequencies), whereas it provides good frequency resolution and poor time resolution at large scales (low frequencies).

Since each wavelet has specific features in time and frequency domains, the application of a type of wavelet or

Download English Version:

https://daneshyari.com/en/article/466827

Download Persian Version:

https://daneshyari.com/article/466827

Daneshyari.com