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Investigation of heart rate variability in major depression patients using wavelet packet transform

Saime Akdemir Akar [a,*], Sadık Kara [a], Vedat Bilgiç [b]

[a] Institute of Biomedical Engineering, Fatih University, Istanbul 34500, Turkey
[b] Department of Psychiatry, School of Medicine, Fatih University, Istanbul 34500, Turkey

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ABSTRACT

Studies conducted in major depression (MD) patients have reported a high risk of cardiac morbidity as a result of the relationship between changed cardiovascular activity (CA) and autonomic dysfunctions. The investigation of heart rate variability (HRV) gives valuable idea about variances in autonomic CA of MD patients. To get this knowledge, frequency-domain HRV analysis is frequently performed using Fourier transformation (FT) or discrete-wavelet transformation (DWT) to decompose the data into high-frequency (HF) and low-frequency (LF) bands. Nevertheless, it has been reported that the FT is not useful for nonstationary HRV signals and the DWT does not ensure required frequency boundaries of each band. This study aims to compare the frequency-domain HRV features using wavelet-packet-transform (WPT) with absolutely excellent approximation to required band ranges between the controls and patients. In addition to LF and HF band energies, sympathovagal balance that indicates the variation of sympathetic and parasympathetic activities were compared between two groups. Patients had a significantly lower HF energy, higher values of LF energy and higher LF/HF ratio. Our results recommend that impairments in coordination between parasympathetic and sympathetic behavior in MD patients can be assessed by HRV analysis using WPT with high resolution decomposition for needed bands.

1. Introduction

Major depressive (MD) disorder is a serious and common psychiatric condition (Kim et al., 2008) affecting approximately twenty percent of the population (Kessler, 2002). According to the Diagnostic and Statistical Manual of Mental Disorders (DSM–IV), it is a type of mood disorders (American Psychiatric Association, 1994). It can be defined by main symptoms as depressed mood, loss of energy, loss of pleasure and interest, sleep disturbances, and suicidal thoughts (Andrews, 2007; Ahmadlou et al., 2012).

Accumulating clinical proof recommends that dysfunction in autonomic nervous system (ANS) activity has a significant role in depression (Agelink et al., 2002; Ehrenthal et al., 2010). It has been reported that patients usually have increased heart rate, sleep disturbances, decreased vagal tone, arrhythmias, differences in ventricular electrophysiological properties, and sympathetic tone changes (Karavidas 2008; Khawaja et al., 2009). Moreover, recent studies show that the existence of depression is related to increased rates of cardiovascular morbidity and mortality (Sayar et al., 2002; Huffman et al., 2013; Pizzi et al., 2014). Nevertheless, possible underlying mechanisms of the relationship between cardiac events and the disorder are unclear (Wang et al., 2013). Since heart rate variability (HRV) is an important index in clinical applications (Task Force Report, 1996), it has been broadly used in depression patients for evaluating the cardiac autonomic functions (Gehi et al., 2005; Sayar et al., 2002; Agelink et al., 2002; Wang et al., 2013). To date, HRV studies in depressive patients have produced discrepant results. In some of the studies, higher heart rates of patients have been found (Carney et al., 2005; Schwerdtfeger and Friedrich-Mai, 2009; Taylor, 2010) and this alteration has been defined as an important risk factor for sudden cardiac death (Whang et al., 2009). Several studies have found that as related to increased cardiac mortality, depressed patients have reduced HRV compared with controls' values (Carney et al., 2001; Glassman et al., 2007; Dao et al., 2010; Kemp et al., 2010; Wang et al., 2013). In contrast, no relationship between MD and low HRV has been reported in some other studies (Yeragani et al., 1992; Gehi et al., 2005). The discrepancy in the previous studies might be explained by the recruitment of patients showing different demographic or clinical characteristics or by methodological differences in measuring and analyzing HRV. Nevertheless, there is considerable evidence of imbalance between sympathetic and parasympathetic nervous system and impairment of autonomic cardiovascular activity in depressed patients.

* Corresponding author.
E-mail address: saimeakar@fatih.edu.tr (S.A. Akar).

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In order to clarify the variances between sympathetic and parasympathetic activity, HRV spectral analysis has been extensively used in previous depression studies (Rechlin et al., 1994; Agelink et al., 2002; Sayar et al., 2002; Robinson et al., 2008; Carney and Freedland, 2009; Wang et al., 2013). Spectral analysis of HRV is characterized by three major indices as very low frequency (VLF, up to 0.003 Hz), low frequency (LF, 0.04–0.15 Hz) and high frequency (HF, 0.15–0.40 Hz) bands. While LF band indicates a mixture of sympathetic and parasympathetic activity, HF band is affected by parasympathetic tone. The LF/HF ratio is accepted as a sensitive and important index of sympathovagal balance (SB) of the ANS activity (Task Force Report, 1996). To calculate these features, different techniques can be used. Fourier transform (FT) is the oldest and the simplest power spectrum estimation method. However, the usefulness of the FT only in the stationary signals and the inability of this technique to track separate time events in diverse frequency components have been accepted (Gamero et al., 2002). Alternatively, short time Fourier transform (STFT) that applies a sliding and limited time window, can be used to HRV data (Tsipouras and Fotiadis, 2004). However, it has been reported that STFT may fail in the analysis of HRV signals including both slowly changing elements and fast transient events (Bilgin et al., 2008). The drawback with the STFT application to HRV data is a compromise in resolutions. The narrower the window used, the better time resolution is obtained, but frequency resolution becomes bad. If a larger window is chosen, the frequency resolution will be increased, but the time resolution will be decreased (Colak, 2009). To overcome this time-frequency resolution trade-off, the wavelet transform recently becomes widely used method for HRV analysis. Discrete wavelet transform (DWT) of HRV has been implemented to find the relationship between the ANS and different cardiac problems as nonsustained ventricular tachycardia (Chen, 2002) and ventricular arrhythmias (Burri et al., 2006) in some of the previous studies. The other studies have used DWT for QRS complex detection in HRV data (Sumathi and Sanavullah, 2009; Nouira et al., 2013). However, when DWT was applied to HRV data in some studies (Kheder et al., 2007; Bilgin et al., 2008; Kheder et al., 2009), the ranges of VLF, LF, and HF bands were obtained in different frequency ranges from the described values in the literature. It means that frequency ranges of LF and HF bands are shifted to unwanted frequency ranges after DWT based HRV analysis because of the frequency decomposition problem. Therefore, to solve this issue and to determine and interpret the SB correctly, wavelet packet transform (WPT) has been suggested for spectral analysis of HRV (Tanaka and Hargens, 2004; Bilgin et al., 2008). In these studies, the successfulness of WPT application to HRV data for determination of corresponding frequency bands and calculation of SB has been demonstrated.

Considering the previous studies have confirmed that there is a correlation between the peak-to-peak (PP) intervals of PPG and RR intervals of ECG signals and HRV analysis can be performed using the photoplethysmographic (PPG) signal of participants (Lu et al., 2008; Selvaraj et al., 2008; Charlot et al., 2009; Dehkordi et al., 2013, Akar et al., 2015a). We therefore sought to compare the spectral measures of PPG signals based HRV data between patients and control subjects using WPT and to compare the effects of obtained band ranges on SB between WPT and DWT. Although the WPT has been reported as more appropriate method because of the equivalent resolution of the obtained frequency bands in HRV analysis, the implementation of this technique in the patients with MD is quite new. In our previous study (Akar et al., 2015b), we investigated the HRV features of MD patients using WPT without any performance comparison between WPT and DWT and without any symptom severity consideration. Present study purposes to examine the hypothesized relationship between spectral features of HRV and MD clearly using more appropriate methodology, WPT. Moreover, the correlation between symptom severities of patients and their HRV measures were also investigated. We hypothesized that the MD patients would have a reduced parasympathetic tone and an increased SB than the control subjects have.

2. Materials and methods

2.1. Participants and study design

Twenty-two patients (Table 1) who met the DSM-IV criteria for MD, evaluated by the Structured Clinical Interview for DSM-IV Axis-I Disorders in Sema Hospital of Fatih University by expert psychiatrist, were recruited for this study. All patients were assessed by using the Hamilton Depression Rating Scale (HAM-D) with 17-item for assessing the depressive symptoms severity. This scale consists of two parts: The first part includes 9 questions that are scored on a five-point scale; the second part includes 8 questions that are rated on a three-point scale. Therefore, the calculated total score of these two parts reflect the degree of symptom severity. According to the instructions of scoring the scores of $8 < \text{HAM-D} < 13$ are accepted as mild depression, the $14 < \text{HAM-D} < 18$ values are accepted as moderate depression and the scores of $\text{HAM-D} > 18$ are accepted as severe depression (Hamilton, 1967). The patients were taking a variety of antidepressive drugs (beta blockers and selective serotonin reuptake inhibitors) at the time of the data collection. Any history or signs of co-morbidity, cardiovascular, endocrine, neurological, or pulmonary diseases were accepted as exclusion criteria for patients. Twenty-one physically and mentally (as confirmed by a psychiatric assessments) healthy controls participated in study as comparison subjects. None of the participants was taking alcohol, tobacco or sedatives. All patients and controls were free of clinically apparent cardiovascular problems (arrhythmia and other cardiac problems). Ethics approval for the study was obtained from the University ethics committee (The number of ethics approval: 20/01) and all subjects gave their permission to be part of the study.

PPG data during spontaneous breathing were acquired from all participants with eyes-closed position in the same quiet, illuminated and temperature controlled room of the Hospital after the subject had 5 min of adaptation period in the sitting position. The PPG data were acquired using the Brainamp ExG data collection system (Brain Products GmbH, Munich, Germany) and the associated software. The blood pulse sensor was attached to subject's non-dominant hand index finger and data were recorded for totally 5 min and 250 Hz sampling rate was used for digitization of the data.

2.2. Wavelet packet transform

As an extension of DWT, WPT can provide more detailed information about data both in approximation and detail coefficients. A main difference in the decomposition of WPT, at each level both the approximation and detail spaces are further

Table 1
Characteristics of participants.

	Controls	MD patients
Participants	21	22
Male/female	10/11	12/10
Age (years ± std. deviation)	28.91 ± 4.82	30.27 ± 3.89
Medication status (beta blockers, other standard dosage of drugs)	–	100%
Baseline HAM-D score	–	23.09 ± 4.49

HAM-D: Hamilton Depression Rating Scale