Evaluation of Sub-Frequency Regions of Heart Rate Variability in Supraventricular Tachyarrhythmia Patients

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Abstract

Supraventricular tachyarrhythmia (SVTA) which occurs on the atria placed above the ventricles is the most frequently encountered cardiac arrhythmias. Heart rate variability (HRV) is an important indicator for diagnosis and classification of cardiac disturbances. Besides, computer based analytical tools which are proposed as new methods and algorithms on HRV produce effective parameters for diagnosis of heart disease. The wavelet packet transform (WPT) is an efficient tool for analysis of non-stationary signals like HRV. This study presents critical frequency ranges for HRV analysis in SVTA patients. Sub-frequency regions are determined and analyzed in HRV data obtained from 78 half-hour ECG recordings in MIT-BIH (Massachusetts Institute of Technology-Beth Israel Hospital) supraventricular arrhythmia database. Each data is decomposed into sub-frequency regions using 9 levels wavelet packet transform and these regions are analyzed and evaluated for each SVTA recordings. The results of this study show that especially the mean energy values of sub-frequency regions in very low frequency (VLF) band for each patient are higher than others included low frequency (LF) and high frequency (HF) bands. In addition, the mean energy values of the regions in LF band are higher than in HF bands as usual. 0.00390625 - 0.03125 Hz sub-frequency range in VLF band, 0.039625-0.0625 Hz and 0.093751-0.10938 sub-frequency ranges in LF band have higher energy values than other sub-frequency regions. However, the sub-frequency regions of HF band reflect the heterogeneous energy distribution.

1. Introduction

SVTA that is an abnormally fast heart rhythm originated from a region in the atrium or AV (atrioventricular) node undertaking the normal rhythm is the most frequently encountered cardiac arrhythmias [1,2]. HRV defined as duration between consecutive heart beats on Electrocardiogram (ECG) records obtained from electrical activities of heart is an important tool for diagnosis and classification of cardiac arrhythmias [3]. Usually, ECG and HRV records can not be an effective indicator for diagnosis of heart disease. Therefore, the mathematical analysis of these signals is very important. Fourier analysis is conventional methods for evaluation of HRV signals.

This method is efficient for whole of the signal but sometimes, it is needed that smaller parts of the signal must be observed. Hence, The WPT is an effective tool in lower frequency zones for analysis of non-stationary signals like HRV [4]. This study presents critical frequency ranges for HRV analysis in SVTA patients by using WPT analysis.

2. Methods

2.1. Preparing of data

In this study, HRV data is obtained from 78 half-hour ECG recordings in MIT-BIH (Massachusetts Institute of Technology-Beth Israel Hospital) supraventricular arrhythmia database [5]. The outline of this study is explained in fig.1.

At first, ECG records obtained from the database converted to HRV data using librasch program. HRV data obtained from this program consist of variations of R-R interval with respect to beat numbers. Because this form is not convenience for spectral analysis, x axis must be converted as time. This process can be done using equation (2.1) as

$$t(n) = rr(n) + t(n-1) \quad n \in [1, N] \;, \qquad t(0) = 0 \;\; and \;\; n \in Z^{+} \tag{2.1}$$

ISSN 0276−6574

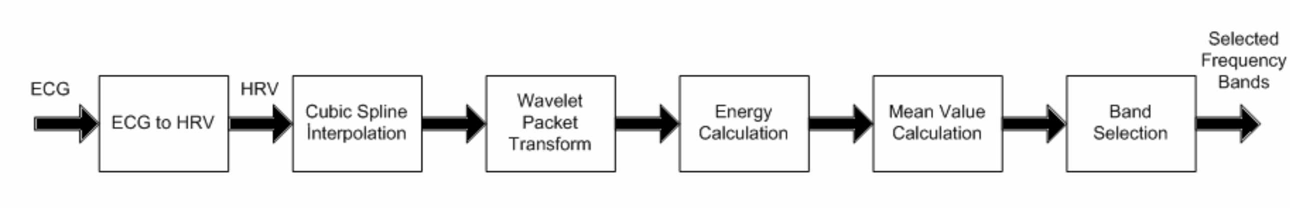

Figure 1. Outline of the study

Where t represents time and N denotes number of beats.

Here, n is index of interested beat number, rr is R-R interval and t (n) is time in n^{th} beat. However, this signal includes ectopic beats. These ectopics are removed using sliding window average filter [6]. Then, obtained data is interpolated and resampled in 4 Hz for wavelet packet applications.

2.2. The wavelet packet transform

Then, each data in this database is decomposed into sub-frequency regions using WPT in 9 levels. Wavelet packet process has been applied using db4 that is a type of Daubechies wavelet family and has 8 filter coefficients.

2.3. Calculation of energy values

The energy values of the wavelet packets are calculated using Equation (2.2).

$$w_{rms,m,j} = \sqrt{\frac{1}{N}\sum |w_{m,j}(r)|^2} \qquad (2.2)$$

Where, N is total number of elements in the packet, r is an index for elements of the packet and $j \in$ N denotes node index in each m level. The $w_{RMS,m,j}$ is RMS values of decomposition components and total energy is calculated as equation (2.3)

$$E_{w_{rms},m,j} = \sum_{j=0}^{2^M-1} |w_{rms,m,j}|^2 \qquad (2.3)$$

Where, M is the last decomposition level and $E_{w_{rms},m,j}$ is explained as the total energy of the packet that is placed at m and j index [7,8].

2.4. Calculation of mean values

Mean energy values of each node are calculated as depending on energy values using equation (2.4)

$$E_{mean,m,j} = \frac{1}{k}\sum_{i=1}^{k} E_{w_{rms},m,j}(i) \qquad (2.4)$$

Where, k is the number of patients. In this study, the number of patient is 78.

2.5. Band selection

Calculated mean energy values are compared with each other for each node. So, the highest ones are selected in base bands.

3. Results

Mean energy values are determined for each node using 78 datasets. Then, the nodes having the highest mean energy values are selected. These nodes refer to frequency ranges in WPT.

These Frequency characteristics of WP can be calculated as equation (3.1)

$$f_m = \frac{(j+1)f_s}{2^{m+1}} \qquad m = 1,..,M-1 \qquad (3.1)$$

where f_m is frequency in m^{th} level, f_s is sampling frequency. Range of j is denoted as $j=0,1,\ldots,2^m-1$.

According to this formula, frequency ranges are shown in table 1. In this table, The mean energy values of nodes in each frequency band are compared to others in the same frequency band and the highest values are selected.

The results obtained from this study show that mean energy values in some bands are higher than others. Mean energy values of nodes for all bands are shown in fig.2. According to fig. 2 (a) mean energy values of nodes in VLF band is higher than them in other bands. Fig. 2 (b) shows VLF band node-energy distribution, fig. 2 (c) shows LF band node-energy distribution, fig. 2 (d) shows HF band-energy distribution. It is clear that nodes having higher energy have been seen.

Table 1. Frequency ranges of bands

Frequency Bands	Node Numbers	Level and Index $w_{rms,m,j}$	Total Number of Nodes	Frequency Ranges (Hz)
VLF	512-520	$w_{rms,9,1}$ - $w_{rms,9,9}$	9	0.00390625-0.0390625
LF	521-549	$w_{rms,9,10}$ - $w_{rms,9,38}$	29	0.0390625-0.15235
HF	550-613	$w_{rms,9,39}$ - $w_{rms,9,102}$	64	0.15235-0.40235

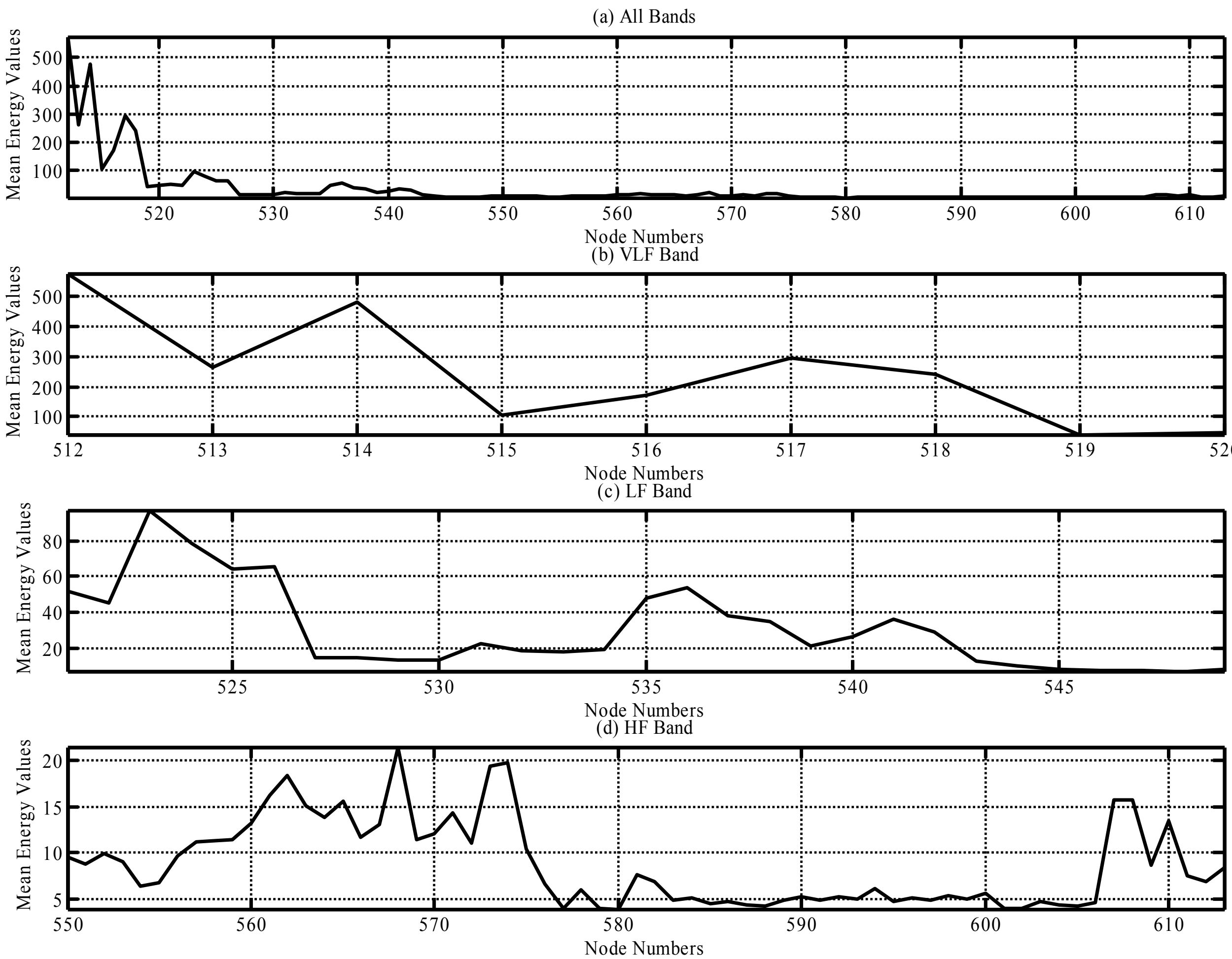

Figure 2. Mean energy values for (a) all bands (b) VLF band (c) LF band (d) HF band

4. Discussion and conclusions

When the results are evaluated, it is clear that VLF band is higher than other bands in SVTA patients. The energy amount of frequency band between 0.00390625 Hz and 0.03125 Hz is more dominant in VLF band. However, frequency zone including 519 and 520 nodes referring to between 0.03125 Hz and 0.0390625 Hz frequency range is smaller. And also, frequency zone between 521 and 526 nodes referring to 0.039625 Hz - 0.0625 Hz and frequency zone between 535 and 538 nodes referring to 0.093751 Hz - 0.10938 Hz sub-frequency ranges in LF band have higher energy values than other sub-frequency regions. HF band shows a heterogenic distribution. It is seen that the frequency band containing 0.25782 Hz and 0.3711 Hz between 577 and 605 nodes has least energy amounts. The obtained results can be used for diagnosis and classification by comparing with other ailments.

Acknowledgements

The research has been supported by the Research Project Department of Akdeniz University, Antalya, Turkey. This study is a part of studies held by Akdeniz University Industrial and Medical Applications Microwave Research Center (IMAMWRC), signal and image processing laboratory and Mehmet Akif Ersoy University Golhisar Vocational School of Higher Edu., Burdur Turkey.

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