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Time-Frequency Analysis of Heart Rate Variability Signal in prognosis of Type 2 Diabetic Autonomic Neuropathy

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Abstract. The analysis of the heart rate variability (HRV) signal is an important tool for studying the autonomic nervous system, as it allows the evaluation of the balance between the sympathetic and parasympathetic influences on the heart rhythm. Time-frequency analysis of HRV makes it easier for us to evaluate how this balance varies with time. Heart disease occurs eventually in majority of patients with diabetes mellitus and to be the outstanding factor in over all diabetes morbidity and mortality rates. Thus the timely detection of diabetic autonomic neuropathy and the use of effective means to improve autonomic nervous system function become of almost significance. In this work Electrocardiogram (ECG) data of 20 Diabetes Mellitus (DM) and 20 normal control volunteers were recorded and autonomic nervous system activity is quantified by means of frequency and time domain analysis. Time domain measures, Standard deviation of NN interval (SDNN), Successive NN intervals differing more than 50ms (NN50) , Percentage value of NN50 count (pNN50), HRV triangular index, show a lower variation in the DM patient group compared to normal subjects and p value <0.01. The frequency domain measures indicate significant differences in very low frequency (VLF), low frequency (LF) power and high frequency (HF) power.

Keywords: Heart rate variability, Time domain and Frequency domain analysis, Autonomic nervous system, Diabetes Mellitus.

1. INTRODUCTION

1.1. Heart rate variability

The HR (heart rate) information is normally derived from the ECG signal. The HRV often mirrors the effects of the underlying control activities. The fluctuations in the HR are due to imbalance in the sympathetic and parasympathetic autonomic nervous systems and these contractions give continuous variations in the heart rate [1, 2]. In normal subjects, sympathetic and parasympathetic tone fluctuates throughout the day [3]. HRV parameter such as the ratio of low frequency (LF) to high frequency (HF) power has been used to sympathovagal balance. In the absence of any sympathetic or parasympathetic input sinus node fires at its intrinsic rate. The heart rate decreases when vagal effect predominate, and increases when sympathetic input to the sinus node predominates. The HR series is formed by a sequence of values at different time instances, and at time, it is a function of the previous R-R interval. This time series is not evenly sampled since the time occurrence of the heart beat does not follow a perfect regular pattern. It worth nothing that R-R series is not constant but is characterized by oscillations of up to 10% around its mean value. These oscillations are not casual but are the effect of the action of the autonomic

nervous system in controlling the heart rate. For investigations of normal physiology and disease, the HRV has become a topic of considerable interest.

1.2. Prevalence of Diabetes

Type 2 DM [noninsulin dependent diabetes mellitus (NIDDM)] is a fast growing and one of the most prevalent health issues [4]. It doubles the risk for stroke 2 to 3 fold. It wipes out the relative protection that normal young females have against compared to their male counterpart, so that diabetic males and females are at equal risk, with the males two to three times the nondiabetics males, and the diabetics females 20 times the no diabetic females [5, 6]. Among the various forms of autonomic disorders, Diabetic Cardiovascular Autonomic Neuropathy (DCAN) is a dreadful complication of diabetes. The degree of autonomic dysfunction associated with DM is related to the severity and duration of the disease. Reduction of HRV parameters seems to carry not only a negative prognostic value but also precedes the clinical expression of cardiovascular autonomic neuropathy. With the purpose of speeding up the execution and evaluation process we designed a computer based system for the real time acquisition and elaboration of Heart Rate Variability signals.

2. SUBJECTS AND METHODS

ECG data were collected from a group of 20 patients with type 2 diabetes mellitus and 20 healthy volunteers following the directions of panel of doctors. The DM group was age and sex matched with the control group. The subjects under study were in the age group of 45-65 years and the duration of diabetes for the diabetes mellitus group was 5-15 years. First the subjects were asked to sit and breathe naturally for 2mins in order to be stable. Recording of all subjects were done by the same person. The electrocardiographic (ECG) recording system has been designed and developed for real time data acquisition. The ECG signal obtained from 2 lead electrodes, is amplified and sampled at 500Hz by the 10 bit A/D converter. The digitized ECG signal is preprocessed by Pan and Tompkinson's algorithm, DADiSP and MATLAB software [7]. The ectopic bits or artifacts were manually edited. The Time domain and frequency domain analysis is done onto the series of successive R-R interval values.

2.1. Time Domain and Frequency Domain Analysis

Time –domain parameters are associated mostly with the overall variability of the R-R intervals over the time of recording. They are Mean-R-R, Standard deviation of all NN intervals (SDNN), square root of the mean of the sum of the squares of differences between adjacent NN intervals (RMSSD), number of adjacent NN intervals differing more than 50 msec (NN50 count), percentage of differences between adjacent NN intervals differing more than 50 msec (pNN50 %), RR triangular index, standard deviation (STD) of the mean heart rate per minute [8]. The HRV signal is a slowly varying signal with a band width of 0-0.5 Hz. The previous studies reveal three different frequency components in HRV signal; the first one a high frequency component (HF) i.e. spectral component around the respiratory frequency (approximately 0.3 Hz)and mainly related to vagal activity, the second one a low frequency component (LF)and generally centered around 0.1 Hz and having power variations related to sympathetic activity, and the third one a very low frequency component (VLF) associated with the slow regulation mechanism such as thermoregulations [9]. We have analyzed the LF peak, LF power, HF peak, HF power, and the ratio of LF/HF, LF normalized unit, HF normalized unit, LF / HF normalized unit. Frequency domain analysis was done by non-parametric, Fast Fourier Transform (FFT) based method. The HRV data is preprocessed by equidistant sampling and windowing (Hanning window) before calculating the spectral density [10].

3. RESULTS

Time domain and frequency domain parameters of HRV were computed for the 20 DM patients and 20 healthy volunteers 500 R-R interval series. Table.1. summarizes the result of time domain analyses for normal controls and DM patients. All time domain parameters SDNN, RMSSD, NN50 count, pNN50 count, Triangular index, TINN were significantly decreased in DM patient group compared to normal controls. Mean heart rate of the DM patients was significantly higher than that of the control group. Table.2. summarizes the results of the frequency domain analysis based on FFT. Results shows that VLF power, LF power, LF %power, LF power, LF % power, HF power of the HRV data of DM patients were significantly lower than control group. There was no significant difference in LF peak, HF peak, and LF/HF ratio. The two spectra from figure.1 and figure.2 are analyzed separately and the comparison obtained between indexes for each segment is shown in Table.2 and from these figures it can be seen that for the diabetes patient the power spectral density is shifted towards low frequency side.

Table: 1. Summary of the Results for the Time Domain analysis of R-R series

Parameters	**Normal control Group**	**Diabetes Mellitus Group**	**P-Value**
Mean RR(msec.**)**	892 ± 133	721 ± 68	< 0.00011
STD RR(msec.**)**	47.8 ± 19	26 ± 29	< 0.0001
Mean HR(/min)	67.20 ± 7.46	83.87 ± 7.8	<0.0001
STD HR(1/min)	3.843 ± 1.2	3.29 ± 4.89	0.56
RMSSD	38.23 ± 18.14	23.2 ± 40.9	0.21
NN 50 Count	128 ± 121	36.5 ± 53	<0.0001
PNN 50 Count	18.65 ± 21.16	5 ± 9.7	<0.0001
TINN(msec**)**	212 ± 57.3	158 ± 117	0.0043
HRV Triangularindex	9.6± 4.3	4.6 ± 1.8	<0.0001

Table: 2. Summary of the Results for the frequency Domain analysis of R-R series

Parameters	**Normal control (Mean ± SD)**	**Diabetes Mellitus (Mean ± SD)**	**P-Value**
VLF Peak (0-0.04 Hz)	0.0217 ± 0.0063	0.0196 ± 0.0072	0.52
VLF power (ms^2)	368 ± 372	53 ± 82	0.017
VLF% power	33 ± 12	38 ± 17	0.24
LF(0.04-0.15Hz)	0.062 ± 0.018	0.045 ± 0.0078	0.067
LFpower (ms^2)	480 ± 315	53 ± 127	0.01
LF % power	43 ± 16	25 ± 17	0.008

LF power(nu**)**	63 ± 13	51± 16	0.01
HF peak (0.15-0.4Hz)	0.28 ± 0.086	0.25 ± 0.08	0.45
HF power (ms^2)	258 ± 243	78 ± 208	0.01
HF% power	19.96 ± 10.13	31± 17	0.58
HF power(nu**)**	33 ± 8	50 ± 18	0.015
LF/HF	2.47 ± 1.37	2.01±1.6	0.11

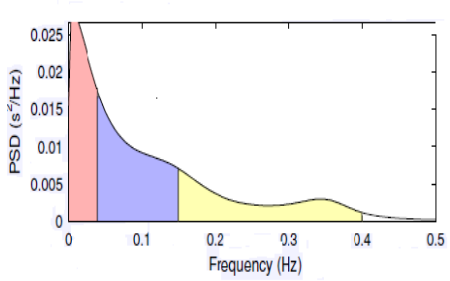

Fig.1. Power Spectral Density of the HRV Data of 50 year old normal control

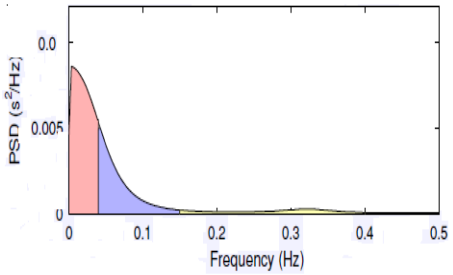

Fig. 2. Power Spectral Density of the HRV Data of 62 year old Diabetes Mellitus Patient

4. DISCUSSION

In recent years it has been proved that HRV time domain and frequency domain analysis is an important method for identifying different pathological conditions. In neuropathy associated with diabetes mellitus characterized by alteration of small nerve fibers, heart rate variations decreases. We can say that, both findings and analysis in this work were similar with previous studies conducted.

5. CONCLUSION

Heart rate variability signal analysis using time domain and frequency domain method shows that, there is significant difference in these parameters for DM patients group and normal control group. Therefore it is important to note that the reduction in parameters of HRV shows clinical expression of autonomic neuropathy in DM. The results show that the main objective of this work has been achieved and we expect that the findings here can be used as a tool for diagnostic purpose.

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