Comparison of Normal and Abnormal Conditions in ECG Using RR Variablity and Spectral Density

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Abstract

Abnormality of the heart is monitored by Electrocardiograph (ECG). The ECG waveform is formed of PQRS pattern. Differentiation of the abnormalities based on the ECG signal is simple algorithm for diagnosis. ECG data of normal, atrial fibrillation and congestive heart failure is obtained from a authorized database. R peak from the QRS complex is detected using Pan-Tompkins algorithm for analysis. Mean RR and heart rate variability parameters are extracted from the QRS complex detected. With these results, the difference in the three ECG signals can be determined. For further detailed comparison, frequency component variation is analysed using power spectral density. Based on density spectrum, the differentiation of normal and abnormal ECG signals can be determined.

Keywords: *Atrial Fibrillation; Congestive Heart Failure; Heart rate Variability; Power Spectral Density.*

1. Introduction

An electrocardiogram is the graphical representation of the electrical activity of the heart. ECG is used for examining abnormality from heart rate, rhythm of the heart. An ECG (electrocardiogram) is a safe and painless test which usually takes a few minutes. The standard ECG has 10 leads which is nothing but electrodes. These electrodes are attached to the skin on arms, legs and chest for recording the signals from the heart. The signals are recorded and visualised with the help of electrocardiograph (ECG machine).

ECG waveform consists of P wave, T wave, PR interval, QT interval, QRS complex, ST segment and the infrequent U wave. The Sino-atrial node (SA node) is positioned in the right atrium and this initiates the electrical signal causing atrial depolarisation. The atrium is anatomically divided into two parts but electrically they function as one part. Atria produce a wave of small amplitude by having very little muscle activity called the P wave. The PR segment is the subsequent part after the P wave and occurs as the electrical impulse which is conducted through the atrio-ventricular node (AV node), bundle of His and Purkinje fibres. The PR interval can be defined as the time between the onset of ventricular depolarisation and the onset of atrial depolarisation. The QRS complex occurs after PR segment that is generated by the depolarisation wave. This impulse travels through the intra ventricular septum via the bundle of His and bundle branches and reaches the ventricular myocardium via the Purkinje fibre network. The ST segment starts where the QRS complex ends. The ST segment which lies before the onset of the T wave, represents the period between the end of ventricular depolarisation and repolarisation [3].

Based on the ECG waveform the abnormalities in the functioning of the heart can be identified. RR interval and amplitude parameters of the QRS complex illustrate the abnormal conditions. RR interval can be defined as measuring of time between the R wave of one heartbeat and the R wave of the preceding heartbeat. RR intervals are normally regular, but with sinus node disease and supraventricular arrhythmias it can be irregular. Normal values for RR interval are from 0.6-1.2 seconds. The rapid heart rate can be calculated from the time between any two QRS complexes that is the RR interval.

Fig. 1. ECG waveform with RR interval alternatively shaded
Pic.Courtesy : https://www.cardionetics.com/images/cardiology/ecg_rr_interval.jpg

In this paper, comparison between two different abnormal conditions such as congestive heart failure and Atrial fibrillation with the normal waveform is performed using spectral analysis. Comparison features are obtained from the RR interval of each waveform. ECG data for all conditions used for analysis is obtained from the standardised database. First abnormal condition considered for analysis, Congestive heart failure (CHF) is a chronic progressive condition that affects the pumping power of heart muscles. CHF develops when the ventricles are inefficient in pumping the volume of the blood to the body. Left sided CHF is the most common type. CHF caused by various reasons like hypertension, coronary artery disease, valve conditions and other conditions which is not related to heart like diabetes, thyroid disease and obesity. Signs and symptoms commonly include shortness of breath, excessive tiredness, and leg swelling [6].

Next abnormality for analysis, atrial fibrillation is an abnormal or irregular heart beat that can increase risk of stroke, heart failure and other heart-related complications. This type of fibrillation is caused in the atria of the heart. The Ventricles and the AV node

will get affected by the irregular electrical impulses frequently [7, 11]. Comparison is performed to analyse the abnormal conditions and to define a prototype of easy detection and diagnosis of different abnormal conditions.

2. Literature Review

Sachin singh, Nethaji Gandhi.N (2010) describes a research about occurrence, amplitude and duration analysis of different ECG signal using Pan Tomkins algorithm. Pan-Tompkin's output of different ECG signal is mapped step by step. The real time process or system operation is shown through MATLAB language. The disadvantage of this analysis is that the detection of QRS wave still needs improvement for implementing in technical applications [4].

Shreya das and Dr. Monisha Chakraborty (2011) compares the power spectral density (PSD) of normal and abnormal ECG's in a graphical representation which is known as periodogram. The difference between the frequency components of QRS complexes has been compared between normal and diseased ECG's wave form using power spectrum density. For distinct differences for different heart diseases QRS complexes have been selected to detect arrhythmia [2].

Kritika bawa, Pooja sabherwal (2014) describes the research on R peak detection by modified pan Tompkins method. using modified formula they have calculated total error detection rate and sensitivity for different RCG signals .They have made use of a standard database called physionet [5].

P.Tirumala Rao, S.Koteswarao Rao, G.Manikanta, S.Ravi Kumar (2016) defines the research on comparison of normal and abnormal of ECG signals. Pan Tompkins algorithm is used here for the extraction of QRS complex from the ECG signal. They extracted the QRS complex to determine whether arrhythmia exist are not. The analysis of QRS complex of an ECG signal does a vital role in identifying the physical conditions of heart. In this methodology comparison of QRS complex is used to identify and diagnose the abnormal conditions of the heart. These can be identified in detail by comparing the clinical and statistical parameters [3].

3. Methodology

In this paper, the ECG of normal and two abnormal conditions such as atrial fibrillation and congestive heart failure are considered for analysis. ECG waveform for these conditions is derived from the standard and authorized database PhysioNet which possess different types of bio signals in different formats. Comparison between the normal and abnormal state of the ECG defined by detecting the R peak from the QRS complex extracted. Clinical and statistical parameters such as mean RR interval and heart rate variability are determined from the extracted R wave for all three conditions and compared. Further analysis of the abnormal conditions based on frequency component variations is carried out with the help of power spectral density which effectively differentiates the three different conditions of the ECG signals.

3.1. Pan Tompkins Algorithm

Pan Tomkins algorithm is a real time algorithm used to find higher accuracy for various beat in the ECG. In simple terms, the algorithm helps in the detection of R peak. The algorithm makes use of various processing techniques like band pass filter, differentiator, integrator, derivatives, squaring function and moving window [4,5]. The band pass filter is a combination of high pass filter and low pass filter. The purpose of band pass filter is mainly to reduce muscle noise. The frequency signal passes through the both low pass and high pass filter. By subtracting the output of low pass

filter will be resulting in high pass filter. After filtering the signal differentiates to provide QRS complex slop information, then the signal is squared point by point. The usage of moving window integration is to obtain waveform feature information in addition to the slope of the R wave [1]. Therefore Pan Tompkins algorithm is used to obtain the QRS complex and R peak for the both abnormal and normal conditions of ECG signals obtained from the database. From the resultant, signal features are extracted for further analysis and comparison process. Raw ECG, filtered ECG signal based on Pan Tompkins Algorithm and the QRS complex with R wave highlighted of the filtered signal derived from all three different ECG conditions considered for analysis which is shown in the figure 2 (a), 2(b) and 2 (c) respectively.
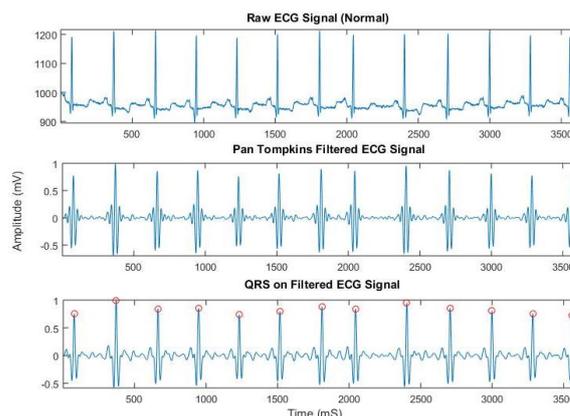

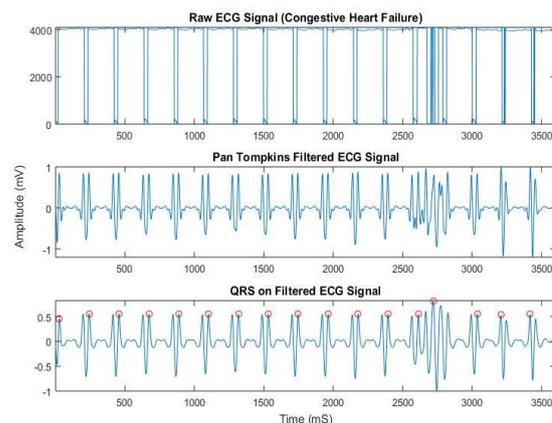**Fig.2(a).** Filtered QRS complex of Normal ECG signal.

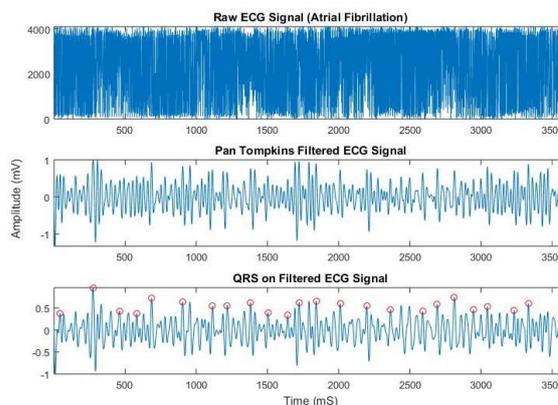**Fig. 2(b).** Filtered QRS complex of Congestive heart failure ECG

Fig. 2(c). Filtered QRS complex of Atrial Fibrillation ECG

3.2. Feature Extraction

Pan Tomkins algorithm is applied to the different types of ECG signals and the QRS complex is determined from which various diagnostic features are extracted. Mean RR interval and Heart rate

Variability is used for comparison of the abnormal and normal ECG signals.

3.2.1. Mean RR Interval

Time between RR interval beats is used to calculate heart rate.The normal range of RR segment is 0.6 to 1 sec and heart rate is 60 – 100 bpm.The RR interval is the time between QRS complex.Identify the R peak landmarks in consecutive beat at a particular seconds and add the number of consecutive beats and divide it by n number of consecutives [8].

3.2.2 Heart Rate Variability (HRV)

Heart rate variability (HRV) can be defined as the changes or variations of beat to beat interval which is termed as RR variability. RR variability is a physiological parameter that is simply based on the change in time interval of the heart rate. This parameter derived from ECG signal can be used to analyse different abnormalities of the heart [9, 10]. Mean RR interval and heart rate variability are derived from the QRS complex of the three different ECG signals. The variations in the values of these parameters are graphically illustrated in the figure 3 which shows that mean RR is high for the abnormalities and heart rate varilabilty to be low and very low for atrial fibrillation and congestive heart failure when compared to normal ECG signal.
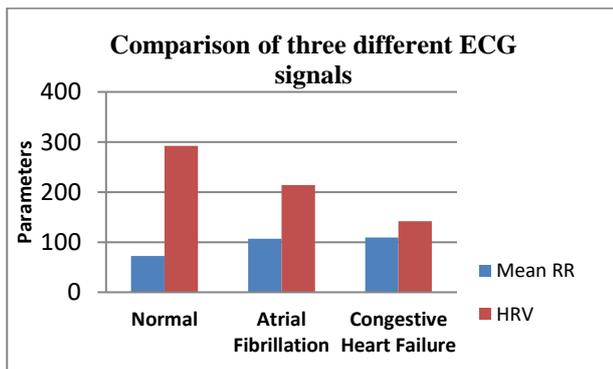
Fig.3. Comparison of the Paramters of three different ECG signals

3.3 Power Spectral Density (PSD)

Power spectral density (PSD) is nothing but the power of a signal is distributed over frequency (or) can be defined as distribution of power into frequency components forming that as signal. PSD is a type of random signal which is independent of time [2, 12]. Power spectral density is used differentiate the frequency component variations in the three different ECG signals in which one is Normal ECG and the other two are ECG of abnormal conditions of the heart. Power spectral densities of the three different ECG signals are shown in the figure 4(a), 4(b) and 4(c).
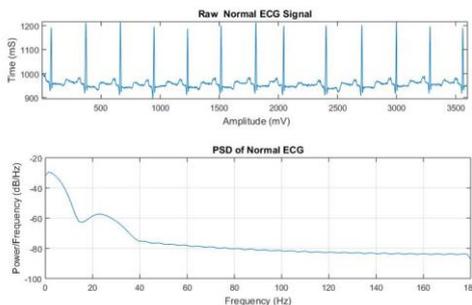
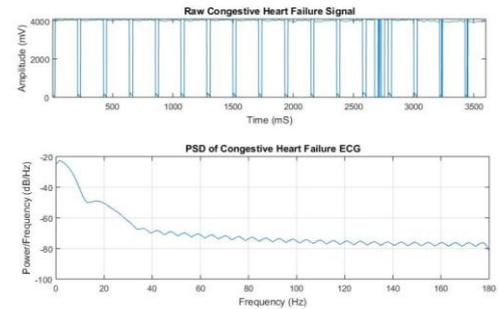Fig. 4(a). Power Spectral Density of Normal ECG signal

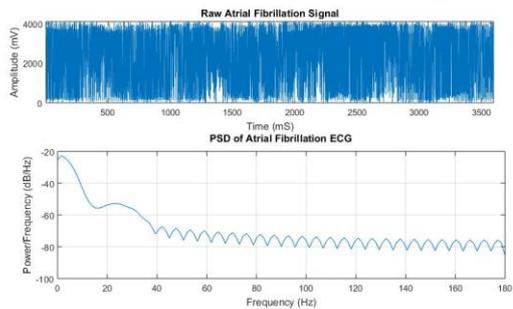**Fig. 4(b).** Power Spectral Density of Congestive Heart Failure

Fig. 4(c). Power Spectral Density of Atrial Fibrillation

From these results, variations in the power spectral density of three different ECG signals are determined. Based on these variations in the spectral densities, they can be differentiated more absolutely into their respective category. From this analysis, Power Spectral Density of atrial fibrillation shows deep peaks and elevations with increased variations in frequency components. Thus the differentiation between all the three different signals is obtained using RR variability and Power Spectral Analysis [13].

4. Conclusions

Analysis and differentiation of different ECG signal is necessary for early diagnosis and treatment of the abnormalities of the heart. ECG data is gathered from the standard database for analysis. Normal and two abnormal ECG data such as atrial fibrillation and congestive heart failure are considered from which the QRS complex is extracted by using Pan Tompkins algorithm. From the QRS complex, R wave is detected for extraction of time domain components or parameters like mean RR and Heart rate Variability. Comparison of three different ECG signals is carried with the time domain components that are graphically represented. Variations in the parameters determine the difference between the ECG signals. Later, frequency component variations are analysed and studied using power spectral density for all the three different Electrocardiographic signals. Power spectral density show drastic change in the components of the signals derived for analysis. Thus the difference and variation among the three different ECG signals, one normal and two abnormal are analysed and determined.

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