The Limb Leads ECG Signal Analysis in Inferior Myocardial Infarction Patients by Rule Base

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***Abstract*— Cardiovascular disease is one of the most serious diseases in the world. The electrocardiogram is signal showing the cardiac electrical activity and use to diagnostic of Myocardial Infarction which detects abnormal wave patterns. The anatomic location of the infarcted areas; inferior, anterior, lateral is recommended for treatment decision. Electrocardiogram can predict the risk of patients and guide physician's decision making. This research purposes a limb leads; I, II and III electrocardiogram analysis algorithm using Wavelet transform to detect waveform and rule base to classify Inferior Myocardial Infarction patients. The contribution of this research is investigating the lead which relate to the Inferior infarcts, anatomic location of the infarcted area which not found in any researches. The processes in ECG signal analysis are noise elimination and baseline wander removal, R peak Detection, QRS Complex Detection, ST-segment Detection and Inferior Myocardial Infarction Classification. The results show that the Inferior Myocardial Infarction Classification algorithm has 85% accuracy. Lead III is the most relevant to inferior infarct area, 86.96% relate to inferior infarct. Second is Lead II, 47.83% relate to inferior infarct. Lead I is the less relevant to inferior infarct area, 13.04% relate to inferior infarct.**

Keywords*— *ECG Analysis, Wavelets Transform, Limb Leads, Inferior MI

I. INTRODUCTION

Cardiovascular disease (CVD) is the most common cause of death in the world [1]. Myocardial Infarction (MI) is the necrosis of heart muscle when blood flow is obstructed. A Myocardial Infarction might cause acute heart failure, and cardiac arrest. Symptoms of Myocardial Infarction patients are discomfort with chest, epigastric, arms, wrist or jaw. Although many patients have such symptoms, some patient has no symptom. Physician detected only by the Electrocardiogram, cardiac imaging and other studies [2]. The electrocardiogram is a tool in the diagnostic of Myocardial Infarction [3] which detects abnormal wave patterns. There patterns were identifying Myocardial Infarction type and use to identifying infarct area. The anatomic location of the infarcted areas; inferior, anterior, lateral is recommended for treatment decision [4]. The results can predict the risk of patient and guide physicians decision making [3]. The electrocardiogram analysis by computerize system has been interested for 10 years ago [5] and has been increasing steadily. Electrocardiogram varies in time, researchers have developed a computerize system to monitor patients heart health accurately and easily [6]. The ECG analysis topic research is divided into three main areas, preprocessing stage, waveform detection and cardiovascular disease (CVD) classification. However there are many Myocardial Infarction Classification researches, the researches which concentrated on investigate the location of infarct area is not found.

This research purposes a limb leads; I, II and III electrocardiogram analysis algorithm using Wavelet transform to classify Inferior Myocardial Infarction patients. And the contribution of this research is investigating the lead which relate to the Inferior infarcts, anatomic location of the infarcted area. This research focus on Limb leads (I, II and III) for preliminary. The three steps of electrocardiogram signal analysis are noise elimination, feature extraction and inferior Myocardial Infarction classification. Accuracy and percentage of related to inferior infarct are used to evaluate the algorithm. The remaining of the this article is organized as follows: the first section is Introduction, section 2 are Electrical Conduction System, Electrocardiogram Signal and Wavelet Transform, section 3 is Proposed method; Preprocessing Stage, Feature extraction and ECG Signal Classification, section 4 is Results and section 5 is the Conclusions.

II. BACKGROUND AND NOTATIONS

A. *Electrical Conduction System*

Sinoatrial (SA) node is the initial electrical conduction system. The electrical spreads through the Internodal Pathway to the Atrioventricular (AV) node, passing the bundle branches to the Purkinje fiber. The electrical conduction system is shown in Fig. 1.

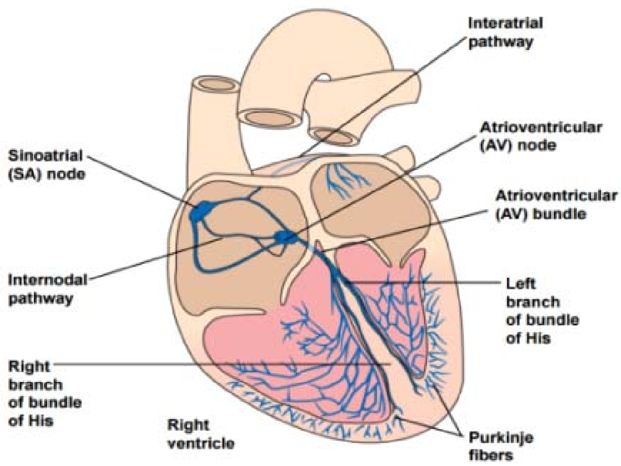

Fig. 1. Electrical Conduction System [7]

The electrical activity of the cardiac is represented by the electrocardiogram (ECG) which is detected by skin electrodes.

B. Electrocardiogram Signal

Electrocardiogram (ECG) is signal showing the cardiac electrical activity [8] that's detected by attaching electrodes to the skin on chest, arm and legs. An ECG normal waveform, the P wave occurs first, followed by the QRS complexes and the T wave. The ranges between the waves are called segments. The X-axis shows the record speed (millimeters/second), and the Y-axis shows the energy (amplitude). A normal ECG waveform is shown in Fig. 2.

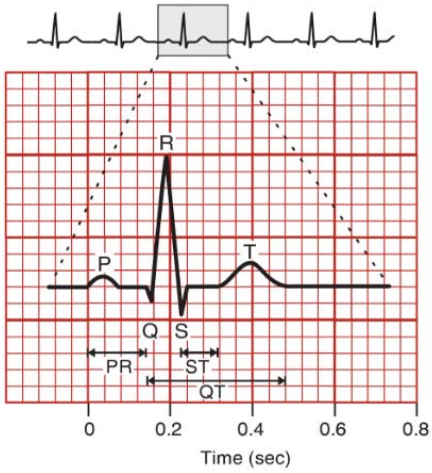

Fig. 2. Normal ECG waveform [8]

The various characteristic features of ECG are used to identify the cardiac abnormal area and support physician's treatment decisions making. In Fig. 3. shown Inferior Myocardial Infarction Electrocardiogram that in Lead II and Lead III there ST-segment elevation.

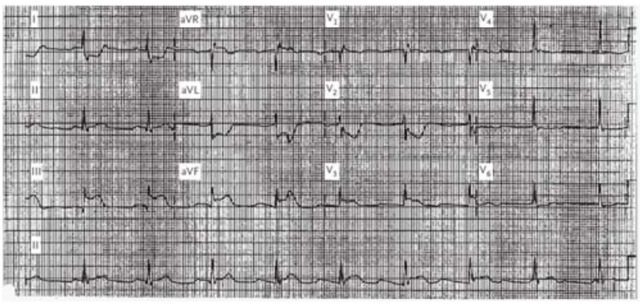

Fig. 3. Inferior Myocardial Infarction Electrocardiogram with ST-segment elevation in Lead II and Lead III [3]

C. Wavelet Transform

Wavelet transform are divided into 2 class; the continuous wavelet transform and the discrete wavelet transform. A wavelet based signal technique is an effective tool for non-stationary ECG signal analysis and characterization of local wave (P, T and QRS complex morphologies) [9].

Even if a signal is not represented well by one member of the Daubechies family, it may still be efficiently represented by another [10]. This paper, selection of the wavelet decomposition of ECG signal at level 4, using Daubechies4 is then undertaken since this waveform resembles the original ECG signal.

III. PROPOSED METHOD

According to related work, this research is Cardiovascular Disease (CVD) Classification group, purposes to classify Inferior Myocardial Infarction patients. This research focus on a limb leads; I, II and III electrocardiogram analysis algorithm using Wavelet transform to classify Inferior Myocardial Infarction patients and investigate the lead which relate to the Inferior infarcts area. The contribution of this research is investigating the lead which relate to the Inferior infarcts, anatomic location of the infarcted area which not found in any researches. This research focus on Limb leads (I, II and III) for preliminary. The processes in ECG signal analysis are noise elimination from the ECG signal, R peak Detection, QRS Complex Detection and Inferior Myocardial Infarction Classification. The ECG analysis process is shown in Fig. 4.

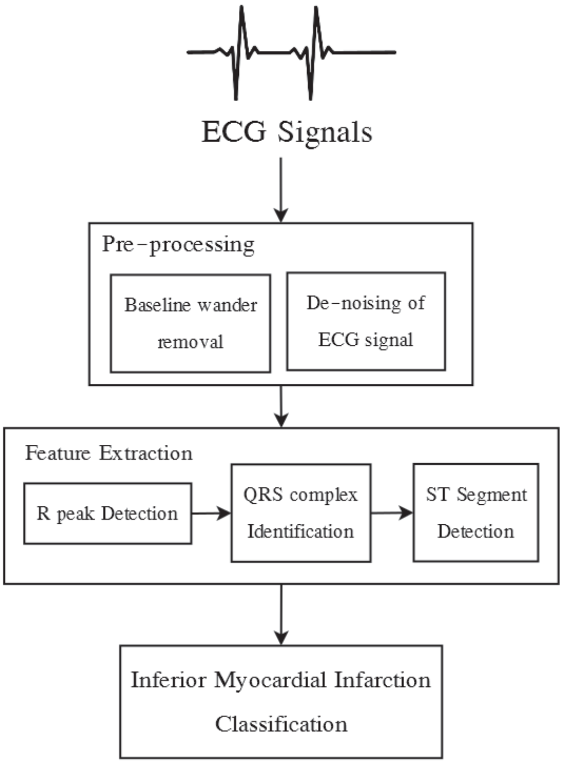

Fig. 4. ECG Analysis Process

A. Pre-processing Stage

The Electrocardiogram (ECG) signal data from the PTB Diagnostic ECG database is used to analyze ECG signal waveform [11]. The samples are 30 Inferior Myocardial Infarction patients which inferior infarct and 30 healthy controls, using all of ECG signal. Investigate the lead which related to Inferior Infarct from Limb leads; lead I, II and III. Preprocessing stage consist of 2 steps, Baseline Wander Removal and De-nosing

1) Baseline Wander Removal: ECG signal wander may cause the error in the features extraction process, so it is necessary to remove baseline wander for an accurate analysis. The original ECG signal is shown in Fig. 5.

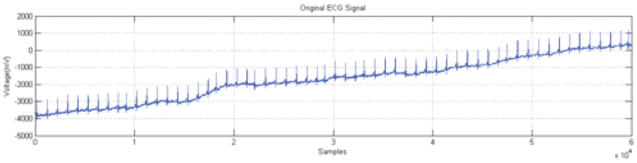

Fig. 5. Original ECG signal

In Fig. 5. show original ECG signal that contain noise and baseline wander. First, finds the coefficients of a polynomial ($\hat{x}$) by Equation. (1)

$$\hat{x} = \frac{x-u_1}{u_2} \quad (1)$$

Where $u_1 = mean(x)$ and $u_2 = std(x)$

Then, find the value of a polynomial (y) by Equation (2)

$$y = p_1x^n + p_2x^{n-1} + \cdots + p_nx + p_{n+1} \quad (2)$$

Where p is a vector of length $n+1$ and x is a ECG matrix. The results of baseline wander removal ECG signal is shown in Fig. 6

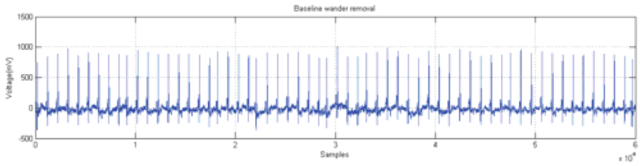

Fig. 6. Baseline wander removal ECG signal

2) De-noising: In this process, the noise is removed to improve ECG signal quality [12]. A wavelet based signal technique is an effective tool for non-stationary ECG signal analysis and characterization of local wave (P, T and QRS complex morphologies) [9]. The corresponding discrete wavelet transform (DWT) is given by Equation (3)

$$DWT_x^{\psi}(j,k) = w_{j,k} = \int_{-\infty}^{\infty} x(t)\psi_{j,k}^{*}(t)\,dt. \quad (3)$$

Selection of the wavelet decomposition of ECG signal at level 4, using Daubechies4 is then undertaken since this waveform resembles the original ECG signal. Daubechies series of ECG signals are shown in Fig. 7.

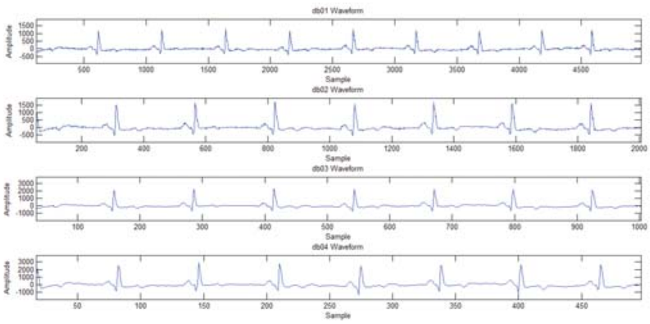

Fig. 7. Daubechies4 Waveform

B. Feature Extraction

1) R-peak Detection: R-peak detection is the most important task in ECG signal analysis as there is an obvious peak detected first [13]. Assign the threshold of R-peak. The peak which has a value in criteria range is R-peak. Defined Ra is R peak amplitude, Rx is R peak position. The R-peak detection equations are shown in Equation (4), Equation (5) and Equation (6).

$$Rxp = Rx\text{-}1 \quad (4)$$
$$Rxn = Rx\text{+}1 \quad (5)$$
$$Rpeak = (Rx, Ra) \quad (6)$$

Where Rx >Rxp and Rx >Rxn and Rx >= Threshold. The results of R-peck detection is shown in Fig. 8.

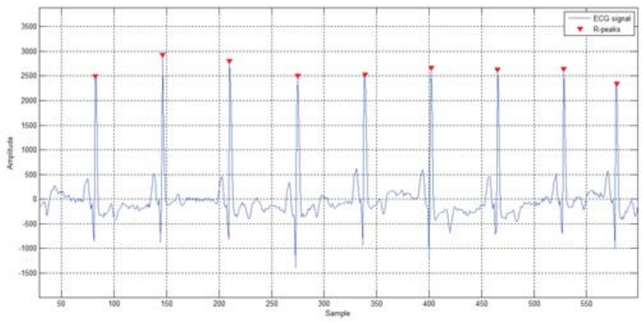

Fig. 8. R-peak detection result

2) QRS Complex Detection: QRS complex identifies by calculating the lowest point in the previous position and the next position. Defined Qa is Q wave amplitude and Qx is Q wave position. The Q wave detection equations are shown in Equation (7), Equation (8) and Equation (9).

$$Qxp = Qx - 1 \quad (7)$$
$$Qxn = Qx + 1 \quad (8)$$
$$Qpeak = (Qx, Qa) \quad (9)$$

Where Qx<Qxp and Qx<Qxn and Qx< Rx. Then, defined Sa is S wave amplitude and Sx is S wave position. The S wave detection equations are shown in Equation (10), Equation (11) and Equation (12).

$$Sxp = Sx - 1 \quad (10)$$
$$Sxn = Sx + 1 \quad (11)$$
$$Speak = (Sx, Sa) \quad (12)$$

Where Sx<Sxp and Sx<Sxn and Sx> Rx. The detection of QRS complex is shown in Fig. 9.

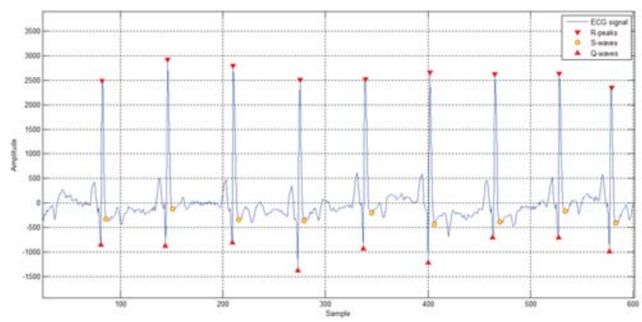

Fig. 9. QRS complex Identification result

3) ST Segment Detection: Choosing the appropriate features are very important because this will affect the classification of the ECG signal. If the feature is not appropriate, classification results in an error [14]. This research select abnormal invert T wave for classifies Inferior Myocardial Infarction patients. Defined Tx is T wave position and Ta is T wave amplitude. The ST segment detection equations are in Equation (13), Equation (14) and Equation (15).

$$Txp = Tx - 1 \quad (13)$$
$$Txn = Sx + 1 \quad (14)$$
$$Twave = (Tx, Ta) \quad (15)$$

Where Ta < Ra and Tx>Sx and Tx>Txn and Tx. The detection of ST Segment is shown in Fig. 10.

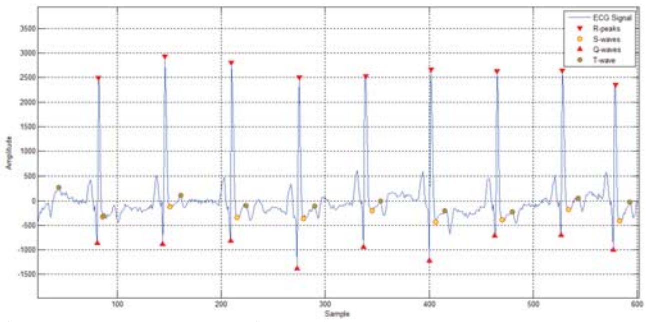

Fig. 10. ST Segment Detection result

C. ECG Signal Classifications

An analysis of the ECG signal to classify inferior Myocardial Infarction patients by detected abnormal of Q-Wave, ST-Segment and T-wave feature will be conducted. If there was a developing Q-wave, elevated ST-segment or inverted T-wave following the QRS complex, the sample is Myocardial Infarction patient. The Inferior Myocardial Infarction Classification rules are shown in Fig. 11.

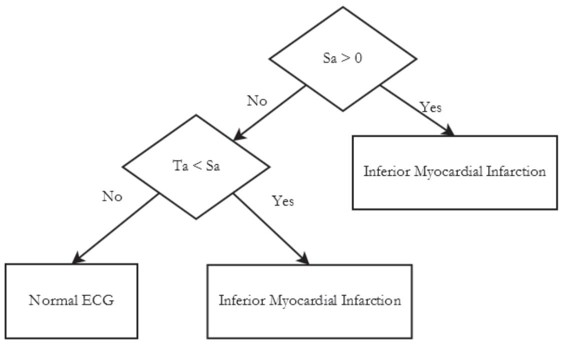

Fig. 11. Inferior Myocardial Infarction Classification Rules

The Inferior Myocardial Infarction Classification Rules consist of 2 steps. First, the Sa was verified. If Sa value is more than zero, the sample is Inferior Myocardial Infarction. If Sa value is not more than zero, Ta was considered. Second, Ta was ensured. If Ta is less than Sa, the sample is Inferior Myocardial Infarction. But if Ta is not less than Sa, the sample is Normal ECG sample.

IV. Results and Discussion

The contribution of this research is investigating the lead which relate to the Inferior infarcts, anatomic location of the infarcted area which not found in any researches. The ECG signal data from the PTB Diagnostic ECG database [11] is used to analyze ECG signal waveform. The samples are 30 healthy controls and 30 Myocardial Infarction (MI) patients which inferior infarct, using 60 seconds of ECG signal from limb leads; Lead I, II and III.

This algorithm classified 23 correctly out of 30 Myocardial Infarction patients or 76.67% accuracy of Myocardial Infarction patients, classified 28 correctly out of 30 Healthy Control or 93.33% accuracy of Healthy Control. Total accuracy is 85% of samples. The equation is shown in Equation (16).

$$\%\, accuracy = \frac{X}{N}\, x\, 100 \quad (16)$$

Defined: N is number of Samples and X is number of MI detected in each lead.

The leads that relate to inferior infarct area, investigate by %relate to inferior infarct equation. The equation is shown in Equation (17).

$$\%\, related = \frac{\alpha}{N}\, x\, 100 \quad (17)$$

Defined: N is number of sample and α is number of Inferior Myocardial Infarction detected in every lead

According to 23 Myocardial Infarction patients, some sample was detected inferior MI in more than 1 Lead. Considered the Myocardial Infarction in each Lead, the result show 3 inferior MI patients in Lead I, 11 inferior MI patients detected in Lead II and 20 inferior MI patients detected in Lead III. The result shown in Table I.

TABLE I. %Related to Inferior Myocardial Infarction

Lead	MI detected	%related
Lead I	3	13.04
Lead II	11	47.83
Lead III	20	86.96

The results shown that Lead III is the most relevant to inferior infarct area, 86.96% relate to inferior infarct. Second is Lead II, 47.83% relate to inferior infarct. Lead I is the less relevant to inferior infarct area, 13.04% relate to inferior infarct.

V. Conclusions

Electrocardiogram (ECG) is a signal showing the cardiac electrical activity. The electrocardiogram patterns were identifying Myocardial Infarction type of patient. This research purposes a limb leads; I, II and III electrocardiogram analysis algorithm using Wavelet transform to classify Inferior Myocardial Infarction patients. The contribution of this research is investigating the lead which relate to the Inferior infarcts, anatomic location of the infarcted area which not found in any researches. The steps in ECG signal analysis are noise elimination of ECG signal, R peak Detection, QRS Complex Detection and inferior Myocardial Infarction Classification.

The Electrocardiogram (ECG) signal data from the PTB Diagnostic ECG database is used to analyze ECG signal waveform, 30 healthy controls and 30 Inferior Myocardial Infarction patients. In the feature extraction stage, a threshold base is applied in the algorithm for ECG signal classification. The analysis of ECG signals to classify inferior Myocardial Infarction patient using Wavelet transform, accuracy and percentage of relate to inferior infarct are used to evaluate the algorithm.

The results show that 76.67% accuracy of Myocardial Infarction patients, 93.33% accuracy of Healthy Control, Total accuracy is 85% of samples. Lead III and Lead II are the most relevant to inferior Myocardial Infarction. Lead III and Lead II are 86.96% and 47.83% related to inferior infarct respectively. In future work, variable values in the feature extraction algorithm will be adjusted to further improve the classification performance. And investigate another related leads to identify infarcted areas.

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