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MEASUREMENT AND ANALYSIS ON ECG SIGNAL

Engineering

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ABSTRACT

Cardiovascular diseases are the leading cause of death. An electrocardiogram is the basic tool to diagnose these diseases. Manual interpretation of ECG for disease diagnosis is time-consuming and tedious. Therefore automated computer-based ECG interpretation and diagnosis of cardiovascular diseases is being attempted. This may help the doctor in diagnosing diseases in less time and quick treatment. In this study, earlier work of researchers (Application software - Analysis-ECG version 2.0 developed in LabWindows CVI) for feature extraction of ECG is modified and being extended for diagnosis of Myocardial infarctions, Hyperkalemia and Ventricular hypertrophies.

KEYWORDS

Automated ECG interpretation, Cardiac diseases, ECG features extraction, Myocardial infarction.

INTRODUCTION

Electrocardiogram (ECG) gives insights about the anatomic and physiologic conditions of the heart. ECG is very helpful in the diagnosis of abnormalities of the heart and cardiovascular diseases. Myocardial infarction (also called heart attack) is a cardiac emergency and commonly occurring cardiovascular disease. It occurs when there is a lack of blood supply to the heart leading to the death of heart muscle. Early diagnosis of myocardial infarction and quick treatment is very critical in the management of myocardial infarction. Hyperkalemia is a type of electrolyte imbalance which if remain untreated leads to fatal cardiac arrest. It occurs due to elevation in the level of potassium in the blood. Right and left ventricular hypertrophies are also commonly occurring cardiovascular diseases in which the right ventricular and left ventricular wall gets thickened respectively [1].

Manual interpretation of the patient's ECG is time-consuming and tedious. Therefore automated computer-based ECG interpretation and diagnosis of cardiovascular diseases is needed. Application software (Analysis ECG version 2.0) was developed by earlier researchers for automatic extraction of ECG parameters. This work is further extended by making some modifications in the feature extraction algorithm and incorporating newly developed disease diagnosis algorithm, thus modified as Analysis ECG version 3.0.

METHODOLOGY

Analysis-ECG version 2.0

Application Software (Analysis-ECG version 2.0) developed by earlier researchers using LabWindows CVI for automatic analysis of ECG parameters of 12-lead simultaneous ECG is being used for further development. In this version Pan-Tomkins algorithm is being used for R peak detection. ECG signal in lead II is bandpass filtered, differentiated, squared and passed through moving average filter. Peak positions were found in this moving averaged signal. Considering these peaks as fiducial positions, R-peak is searched around it. The R-peak position in lead II is being considered as R peak position in other leads. Different ECG waves P, Q, S, and T along with their start and end positions were found based on peak and zero crossings in the differentiated signal. These positions were used to calculate various essential amplitudes and time intervals.

Analysis-ECG version 3.0

In this study, Common Standards for Quantitative Electrocardiography (CSE) database is being used. This extensive database contains 12 lead ECG signals sampled at 500Hz (3 leads recorded simultaneously as Lead I, II and III; aVR, aVL, and aVF; V1, V2, and V3; V4, V5 and V6 in 4 blocks). Since the database has four blocks of three leads acquired simultaneously, R-peak positions were detected for prominent leads (lead 2, aVF, V3 and V5) in the respective blocks using the same method as explained above in Analysis ECG version 2.0. Considering this as reference, R peaks for the other two leads in the particular block is being searched within a window of 40 samples around the reference.

Isoelectric point:

In version 2, the isoelectric point is being calculated from TP segment. The TP segment is elevated in some of the physiological conditions, so to achieve better accuracy isoelectric point is calculated from PR segment as explained below.

Considering, Starting point = n1+0.6*(n2 – n1)
Ending point = n2 – 0.25*(n2– n1).
Where, n1= P-peak position and n2= Q-peak position.

The average ECG value between starting and ending points is considered as an isoelectric point to measure various amplitudes.

P and T peaks

P and T waves are positive or negative deflection before and after R wave respectively. The maximum positive and negative value with respect to isoelectric point within a certain window is being calculated. From these two values, higher value is considered as P or T peak. Isoelectric value for searching P and T wave is calculated by taking an average of 10 samples before and after QRS respectively. These modifications were made in Application Software- Analysis-ECG version 3.0

QS Complex in chest leads:

In some pathological ECGs, there is single negative deflection (QS complex) in leads V1, V2, V3, and V4. So in absence of R wave, S peak position in lead V2 is detected. To detect S-peak, ECG signal in lead V2 is bandpass filtered, differentiated, squared and passed through moving average filter. With respect to peak position in an averaged signal, a minimum value within the window of 60 samples is searched as S peak in the ECG signal. S peak in V1 and V3 is searched within the window of 40 samples in accordance with S peak position in V2. To detect R peak, backward search from S peak in differentiated ECG signal is done. A sample position when a derivative change from negative to zero or more is considered as R peak. In such a case of QS complex, the amplitude of Q wave is the same as the amplitude of S wave which is equal to the amplitude of a single negative deflection. If the amplitude of the detected R wave is less than 0.015mV then proceeding negative deflection was considered as QS complex.

QRS Axis

The QRS complex represents ventricular depolarization. QRS axis is thus the average direction of ventricular depolarization current. Normally this direction is downward and leftward. This is called a normal QRS axis. Its range is from −30° to +90°. This direction can be leftward called Left Axis deviation (−30° to -90°) or rightward called Right Axis deviation (90° to 180°) or extreme axis deviation (-90° to -180°) [2]. The positive electrode of lead aVF is downward and lead I is leftward. In Quadrant Method resultant QRS amplitude in lead I and lead aVF was used to measure the QRS axis. Table 1 explains the calculation of the cardiac axis. Resultant QRS is (Q amplitude + R amplitude + S amplitude) and R is the ratio of the magnitude of resultant QRS amplitude in aVF to resultant QRS amplitude in lead I.

Table-I Calculation Of Cardiac Axis [6]

Resultant QRS (aVF)	Resultant QRS (lead I)	Range	Cardiac axis
Positive	Positive	Normal axis	$\tan^{-1}R$
Positive	Negative	Right axis deviation	$180-\tan^{-1}R$
Negative	Positive	Normal axis and Left axis deviation	$-\tan^{-1}R$
Negative	Negative	Extreme axis deviation	$-(180-\tan^{-1}R)$

Disease Diagnosis

After feature extraction from ECG, the next step is to diagnose diseases in given ECG. In myocardial infarction (MI), changes are seen in leads representing the affected wall of the myocardium [1]. The criteria for diseases like myocardial infarctions at septal anterior, lateral, inferior, posterior site; right ventricular hypertrophy; left ventricular hypertrophy and hyperkalemia used are summarized in Table 2. First few hours after onset of infarction is termed as acute phase, old phase is hours to days, subacute phase is an intermediate phase [5].

Important considerations-

1. QS complex: No R wave present and single deep negative deflection termed as QS complex.
2. qrS complex: R amplitude less than 0.2, 0.3, 0.4 and 0.5 mV in V1, V2, V3 and V4 respectively.
3. Pathological Q wave: Q amplitude greater than one-fourth of R amplitude [1].
4. Right axis deviation: Electrical axis between 90 to 180 degrees [2].
5. ST elevation: ST level of 0.1 mV or more in limb leads and ST level of 0.15 mV or more in precordial leads [4].
6. ST depression: ST level less than -0.1 mV.
7. Dominant R wave: More than 0.4, 0.6 and 1 mV in V1, V2 and V3 respectively
8. Tall T waves: T amplitude more than 0.5 mV in limb leads and more than 1mV in precordial leads [7].

RESULTS

Application Software (Analysis-ECG version 3.0) was evaluated using 25 random files of the CSE database for its sensitivity and specificity. GUI of Application Software (Analysis-ECG version 3.0) is shown in figure 1. The application allows loading of a CSE data file, lead selection and display of the same. The loaded ECG can be analyzed for disease diagnosis and ECG parameters for all the 12 leads which are displayed. This automated diagnosis is manually verified. Result for True Positive (TP), False Negative (FN), True Negative (TN), and False Positive (FP) is being obtained by comparing automated prediction manually. If the application detects a disease, it is Positive else Negative. When automated diagnosis matches actual (manual verification), it is True else False. These results are summarized in Table 3.

Calculation of sensitivity and specificity:
Sensitivity = (True positive / (True positive + False negative))* 100
= 11/ (11+1) = 91.6%.
Specificity = (True negative/ (True negative + False positive))*100
= 11/ (11+2) = 84.6%.

Table – 2 Disease Diagnosis Criteria [1] [3] [7]

	Acute phase	Old phase	Subacute phase
Septal MI	ST elevation in leads V1 and V2.	QS or qrS in V1 and QS or qrS in V2.	Both conditions present at the same time.
Anterior MI	ST elevation in leads V3 and V4.	QS or qrS in V3 and QS or qrS or pathological Q in V4.	Both conditions present at the same time.
Lateral MI	ST elevation in any 2 contiguous leads from V5, V6, aVL and lead I.	Pathological Q waves in any 2 contiguous leads from V5, V6, aVL and lead I.	Both conditions present at the same time.
Inferior MI	ST elevation in any 2 contiguous leads from lead III, aVF , lead II.	Pathological Q waves in any 2 contiguous leads from lead III, aVF, lead II.	Both conditions present at the same time.
Posterior MI	ST depression in any 2 contiguous leads from leads V1, V2 and V3.	Dominant R waves in any 2 contiguous leads from lead V1, V2 and V3.	Both conditions present at the same time.
Right Ventricular Hypertrophy	R amplitude in V1 > S amplitude in V1 and right axis deviation.		
Left Ventricular Hypertrophy	S amplitude in V1+ R amplitude in V5> 3.5mV.		
Hyperkalemia	Tall T waves in at least 2 leads.		

Table -3 Diagnosis Status

Total files=25	Predicted (by software) NO	Predicted (by software) YES
Actual (manual) NO	True Negative (11 files)	False Positive (2 files)
Actual (manual) YES	False Negative (1 file)	True Positive (11 files)

Figure 1: GUI of application software (Analysis-ECG version 3.0) showing analysis for file EA2_047 [Image courtesy-BARC]

CONCLUSION

Application Software (Analysis-ECG version 3.0) extracts features of ECG and diagnoses diseases like Myocardial infarctions at septal, anterior, lateral, inferior, posterior sites in acute, subacute ,old phases, righr and left ventricular hypertrophies and Hyperkalemia within sensitivity of 91.6% and specificity of 84.6%. Therefore this software can be reliably used for the same.

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