



DETECTION OF CARDIAC ARRHYTHMIA USING DYNAMIC FEATURES AND MORPHOLOGICAL PATTERNS OF ECG SIGNAL

Cardiology

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ABSTRACT

Heart diseases require early detection and long term monitoring to save life's of Cardiac patients. Measurement of abnormalities found in heart rate due to disturbances in electrical activity of heart, is the easiest way to detect cardiac diseases. The best electronic machine for this purpose is ECG, which plays a vital role in the discrimination of normal heart beat from abnormal one, it is called ECG arrhythmia. This paper is based on automatic detection and classification of various cardiac arrhythmia which is illustrated in dynamic features and morphological patterns of ECG signals. MIT BIH arrhythmia database is used for ECG input from literature.

KEYWORDS

Arrhythmia, ECG, Cardiac Diseases, Morphological ECG features.

Introduction

Cardiac arrhythmia, a type of Cardiac Vascular Disease (CVD) represents disturbances found in cardiac cycle and may prove fatal if not detected in its early stage or interpret properly. Arrhythmias can be divided into two main groups, the first including life-threatening arrhythmias such as ventricular tachycardia (VT) and ventricular fibrillation (VF). They need to be immediately terminated by a defibrillator [1]. Various studies on automatic VT and VF detectors have been carried out [2-4]. The second group of arrhythmias including premature ventricular contraction (PVC) does not need immediate treatment but still needs therapy to prevent further complications. Recent studies showed that PVC is an indicator for increased risk of sudden cardiac death. Globally 17.3 million people died of CVDs in 2008 which was about 30% of all the deaths in the world. It is estimated that such causalities may grow further to 23.3 million by 2030 [1]. Cardiovascular diseases, especially coronary heart disease (CHD), are epidemic in India. The Registrar General of India reported that CHD led to 17% of total deaths and 26% of adult deaths in 2001-2003, which increased to 23% of total and 32% of adult deaths in 2010-2013. According to World Health Organization (WHO), almost 67% of cardiac deaths occur due to misinterpretation of early

symptoms [2].

For, noninvasive health monitoring, i.e signal is measured from the surface of human body, Electrocardiogram (ECG), is the best primary diagnosis method to measure electrical activity of heart and give complete information of each event that took place in cardiac cycle. It record bio- potentials on the body surface over a period using standard electrodes placed on fixed locations. In addition, following information can be obtained from ECG recorded signal:

- Relative size and position of heart chambers.
- Origin of electrical impulse and its propagation in heart.
- Changes in ionic concentration of myocardial membrane.

ECG signal is characterize by its various features of morphological pattern include RR- intervals, onset/offset point of waves, presence/absence of wave, duration of QRS complex, amplitudes, segments, waves intervals, etc [7]. Thus by analyzing these morphological patterns of ECG waveform, minor threats in heart functioning can be interpreted that can prove fatal in future. Fig 1 and fig 2, shows ECG signal with corresponding events in cardiac cycle.

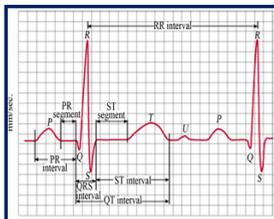


Fig 1: General representation of ECG signal

Classification of ECG arrhythmia is done using ECG dynamic and morphological features, ny apply various biomedical signal processing techniques and machine learning algorithms, like wavelet transform, neural networks, fuzzy logic. The Association for the Advancement of Medical Instrumentation (AAMI) and ANSI/AAMI EC57:1998/(R)2008 (ANSI/AAMI, 2008), recommended classification of heart beat according to representation of disturbances found in cardiac cycle. They are, 1. N (Normal Beat), 2. S (Supraventricular ectopic beat), 3. V (Ventricular ectopic beat), 4. F Fusion Beat, 5. Q Unknown Beat, where ectopic beat refer abnormal/irregular rthym [8]. The mapping of AAMI/ANSI standard with MIT-BIH database of arrhythmia is used to classify different classes of arrhythmias, which is shown in Table 3, with ECG morphological pattern. Each type of arrhythmia is associated with a unique pattern, and therefore it is possible to identify and classify them. The first category of arrhythmias formed by a single irregular heartbeat and the other category consists of arrhythmias formed by a set of irregular heartbeats. These heartbeats produce alterations in the morphology or time-frequency characteristics in ECG signal, and they are identified by the clinical expert [5].

- P wave** : Atrial Contraction/Depolarization
- R wave** : Left Ventricular Contraction
- QRS complex**: Ventricular de polarization
- PR Segment** : Hold electrical signal at Atrial-Ventricular (AV) node
- T wave** : Ventricular Re-polarization/Relaxation
- RR interval**: One complete Cardiac cycle

Fig 2: Electrical activity of heart with ECG waveform

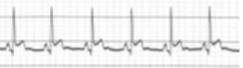
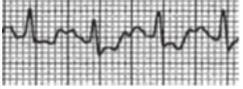
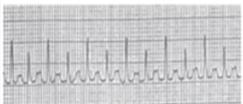
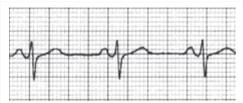
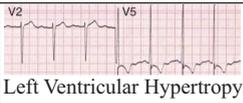
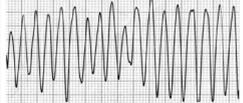
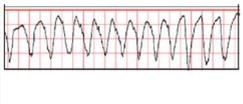
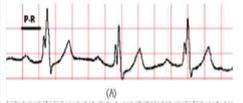
Issues in ECG Arrhythmia Classification

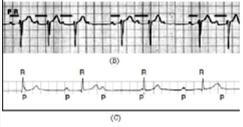
- Inconsistency of the ECG feature: Stress, Exercise, Blood Pressure and other physical activity or life style define ECG patterns for individual.
- Individuality of the ECG patterns: for same cardiac diseases, inter patients have different ECG patterns.
- Lack of standardization / non existence of classification rules.
- Motion artifacts: ECG is change when patient is moving, sleeping, running, laughing, walking and other artifacts.
- Various Noise sources.

Classification of Cardiac arrhythmia

According to heart rate (beats per minute) and morphological pattern of electrical signal waves in heart during cardiac cycle, heart disease can be broadly classify in five categories, 1. Sinus Arrhythmia (HR 60 to 100 bpm), 2. Sinus Bradycardia slow heart rate (below 60bpm), 3. Sinus Tachycardia fast heart rate (above 100 bpm in resting adults), 4. Fibrillation is a very rapid irregular contraction of the heart's muscle, 5. Flutter is contraction of Atria is very much rapid 250 -350 beats.

Table 3: list of cardiac arrhythmia with ECG wave interpretations [15,16]

Heart Diseases	Heart Beat Rate/min	Heart anatomy (dynamic- feature)	ECG waveform analysis	Morphology pattern or ECG wave-form
1.Sinus Arrhythmia [8] a. Sinus Bradycardia b. Sinus Tachycardia	60-100 < 50 >100	Irregular Ventricular rate	Long R-R interval. Constant PR interval, PP interval varies. P wave get merge with the T waves of the preceding beats	 A. Sinus Bradycardia  B. Sinus Trachycardia
2.Atrial Arrhythmias (Out side SA node in atrial) [9,10] A) Premature Atrial Contractions (PAC) B)Atrial Tachycardia C. Atrial flutter D. Atrial fibrillation	SVEB Beat >100 240-360; Regular/ Irregular, Volt. 300 350-450, Volt varies	A beat occurs early in the atria causing the heart to beat before the next regular beat. Rate of depolarization decreases from top to bottom Originate within Atria but outside Sinus node multiple atrial contraction for every Ventricular contraction) Rapid irregular, uncoordinated activation of atrial signal ,Irregular ventricular rate	Abnormal P-wave shape No P-wave Abnormal P-waves occur regularly, like saw tooth wave Narrow QRS complex, and	 A. Premature-Atrial Contraction  B Atrial Tachycardia  C Atrial Flutter  D Atrial Fibrillation
3.Premature Junctional Contractions (PJC) [11]	Normal or accelerate	Premature Cardiac impulses originating from junction (AV node) not from Sinus node.	Premature appearance of QRS complex without preceding P-wave	
4.Ventricular Arrhythmias A.Premature Ventricular contraction (PVC) B.Ventricular Tachycardia		Ventricles contract before signals reached AV node	QRS complex become wide and bizarre in shape QRS complex become abnormally wide in different directions as compare to its normal shape	 A. Premature Ventricular Contractions B. Ventricular Tachycardia
5.Ventricular Hypertrophy Left chamber of heart (Ventricle) get thickened [12]		Prolonged depolarization and delayed re-polarization	Increased R wave peak time > 50 ms .ST-segment depression and T wave inversion in the left-sided leads:	 Left Ventricular Hypertropy
6.Ventricular flutter (extra systole occur in ventricle) [13,14]	250-350	Loss of organized electrical activity	No P wave is found, merging of QRS and T wave	
7.Ventricular fibrillation [14]	>500	Failure of heart to pump blood, rapid ,irregular electrical activity. Ventricle unable to contract in synchronized manner	Saw-tooth ECG wave	 Ventricular fibrillation
8.Atrio-ventricular blocks (AV blocks) [15] 1 st degree- AV block		Disturbances in electrical conduction Signal not reach from atria to ventricle	PR interval > 200 ms, No of P-wave	 1 st AV block

2 nd degree-AV block (no conduction of Ventricle)		Signals not reaching the ventricle	PR interval progressive lengthens before dropped beat and shorten before dropped beat.	
3 rd degree-AV block		No signals reaching ventricles.	Complete lack of synchronism between the P wave and QRS complex Narrow QRS complex < 0.12 sec	B 2 nd AV block C 3 rd AV block
8.Bundle branch blocks Disturbances of the ventricular conduction) [16]	QRS > 120 ms QRS > 120 ms	Block ventricular stimulation. Depolarize from right to left not from left to right. Affects the terminal phase of ventricular activation	Absence of Q wave, poor R wave progression, inversion T wave, Displacement of ST segment, Deep and broad S wave	
a.Left bundle branch (LBBB) (left ventricle not activated) i. b.Right bundle branch (RBBB) right ventricle not activated		Depolarization of left ventricle is carried out from right ventricle Activation of right ventricle is delayed		Bundle branch block

From the table, it is clear that due to cardiac arrhythmia changes occur in heart beat, origin / sinking node of electrical impulses, cardiac conduction time and many more factors. Additionally, there are some arrhythmias in which heart beat is normal but huge abnormality found in cardiac system. Those can be only analyzed through ECG waveforms and its morphological patterns.

Conclusions and future recommendations

ECG arrhythmia can be easily identifying from its shape which is visualized in ECG morphological pattern. Detection of cardiac arrhythmia is based on feature set of cardiac cycle like RR interval, P, Q, R, T wave, amplitude, segments, intervals, and mapping these features with various classes of arrhythmia. Further, accuracy of detection of cardiac disease can be analyzed efficiently if ECG system is properly designed with issues and challenges. Therefore, healthcare communities are emphasize to set on the design and development of continuous heart monitoring devices for analyzing the risk of any unknown disturbance in cardiac cycle, automatically.

References

- [1] P.de Chazal, M.O. Duyer, and R.B. Reilly, "Automatic classification of heartbeat using ECG morphology and heart beat interval features," Biomedical Engineering, IEEE Transactions, vol. 51, pp. 1196-1206, 2004.
- [2] Ripley KL, Bump TE, Arzbaecher RC. Evaluation of techniques for recognition of ventricular arrhythmias by implanted devices. IEEE T Bio-Med Eng 1989; 36: 618-624.
- [3] Zhang XS, Zhu YS, Thakor NV, Wang ZZ. Detecting ventricular tachycardia and fibrillation by complexity measure. IEEE T Bio-Med Eng 1999; 46: 548-555.
- [4] S. Luz et.al, " ECG-based heartbeat classification for arrhythmia detection: A survey," Journal of Computer methods and Programs in bio medicine, Elsevier, 127(2016), 144-164.
- [5] André Rodrigues," Bundle Branch Block: Right and Left Prognosis Implications", Interventional Cardiology journal, Vol2,2016, pp 1-6.
- [6] D. DURHAM, L. I. G. WORTHLEY, "Cardiac Arrhythmias: Diagnosis and Management. The Tachycardias", Critical Care and Resuscitation 2002; Vol 4, pp 35-53.
- [7] Jaya Prakash Sahoo "Analysis of ECG signal for Detection of Cardiac Arrhythmias", M.Tech Thesis, National Institute Of Technology, Rourkela, Orissa, INDIA,2011.
- [8] Tony Basil, Choudur Lakshminarayan, and C. Krishna Mohan, "Detection of Classes of Heart Arrhythmias based on Heartbeat Morphology Patterns," SIAM 2nd International Workshop on Analytics for Cyber-Physical Systems, 2013.
- [9] P. de Chazal, R.B. Reilly, "A patient-adapting heartbeat classifier using ECG morphology and heartbeat interval feature," IEEE Trans. Biomed. Eng. vol. 53, pp. 2535-2543, 2006.
- [10] S.T.Sanamdikar et. al, "A Literature Review on Arrhythmia Analysis of ECG Signal", International Research Journal of Engineering and Technology, Volume: 02 Issue: 03, pp 307-312, June 2015.
- [11] R.JOE NOBLE: Clinical Methods, The History, Physical, and Laboratory Examinations, 3rd edition, Chapter 33, Electrocardiography, 1990.
- [12] K. Vimala and Dr.V.Kalaivani, "Classification of Cardiac Vascular disease from ECG signals for enhancing modern health care scenario", Health Informatics- An International Journal (HIJ) Vol.2, No.4, pp 63-72, Nov 2013.
- [13] Golitsyn SP. Borders between benefits and risks in the treatment of ventricular disturbances of cardiac rhythm. International Journal of Medical Practice 2000;(10) 56-64.
- [14] Trayanova N. Concepts of ventricular defibrillation. Phil. Trans. R. Soc. Lond. A 2001; (359) 1327-1337; DOI: 10.1098/rsta.2001.0834.
- [15] Joseph D Bronzino, Donald R. Peterson: Biomedical Engineering Fundamentals:The Biomedical Engineering Handbook, 4th Edition, 2015, pp 38-1 to 46.
- [16] Gertech , M : The ECG A Two-Step Approach to Diagonis, 2004, pp 19-33.