Research on Atrial Fibrillation frequency analysis used ICA methods

Bo Tang

School of Mechatronic Engineering, Xi'an Technological University, Xi'an, Shaanxi, China

heartbluetang@qq.com

Abstract

Atrial fibrillation (AF) is one of the most common sustained arrhythmias in clinical practice associated with serious morbidity and mortality. With increasing survival rates of cardiovascular diseases and aging of population, it is predicted that AF will be one of the most prevalent cardiovascular diseases in the next half century. Sinus rhythm restoration and overall rate control are two main treatments for AF and help to relieve clinical symptoms significantly. However, both of them have little progress in reducing the rate of recurrence or morbidity of AF, inclining to induce further arrhythmias, strokes, myocardial detriments or cardiac dysfunctions. By applying modern signal processing technique to analysis ECG and Atrial electrograms, the usable characteristic indices reflecting atrial activity are exected and can afford a rather efficiently noninvasive way for the administrations of AF patients and lead clinician to make individual decisions.

Keywords

Atrial Fibrillation; Atrial electrograms; Data correction.

1. Introduction

Dominant frequency (DF) of electrophysiological data is an effective approach to estimate the activation rate during Atrial Fibrillation (AF) and it is important to understand the pathophysiology of AF and to help select candidate sites for ablation. Frequency analysis is used to find and track DF. It is important to identify the evolution of the frequency composition of the signal with time. The first part of the work looks specifically at the DF evolution for ventricular fibrillation from the surface of the left ventricle (animal studies). [1] The evolution can be represented by spectrograms using short segment data analysis.

The work looks specifically at different techniques that can be used for DF estimation of AF data. Fast Fourier Transform (FFT) approaches of modified periodogram and Blackman-Tukey (BT) technique are categorised as non-parametric (classical) methods, the Autoregressive (AR) approach is categorised as a parametric method and Multiple Signal Classification (MUSIC) is categorised as subspace method. It is important to minimise the catheter insertion time in the atria as it contributes to the risk for the patient. This is due to the possible complications during the procedure such as cardiac tamponade (dramatic fall in blood pressure), blood stream infection, pulmonary vein stenosis, etc. As longer ablation procedure time implies higher risk to the patient, DF estimation needs to be obtained as quickly as possible.[2] A comparison of computation times taken for spectrum estimation analysis is presented in this study. The time to produce DF was measured for each method. The method which takes the shortest time for analysis without jeopardizing

2. Electrophysiology of the heart

The cardiac conduction system consists of sinoatrial node, internode bundle, atrioventricular node, atrioventricular bundle, left and right atrioventricular bundle branches and Purkingje fibers. The sinoatrial node is the origin of normal cardiac impulse, which is located at the junction between the superior vena cava and the right ventricle, as shown here. The internode bundle is the conduction path between the sinoatrial node and the atrioventricular node, which is divided into three conduction bundles of the anterior, middle and posterior. [3] The atrioventricular node, the right posterior part of the ovary, extends downward to the atrioventricular bundle, the atrioventricular node and the atrioventricular bundle constitute the atrioventricular junction area, and then extends downward to the interventricular septum, and divides into the left and right atrioventricular bundle branches, which are located at the left and right intima of the interval. The left bundle branch in the left ventricular septum is divided into two bundles of anterior and posterior branches. The right bundle branch descends along the right side of the ventricular septum until the apex is at the tip of the heart that begins to branch into Purkinje fiber. The branches of the two sides of the ventricle are divided into myriads of Purkinje fibers and myocardial fibers.

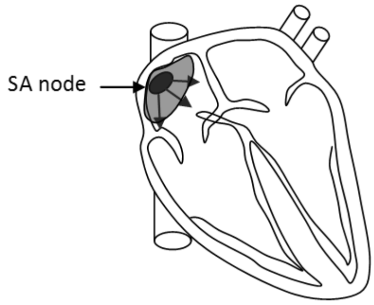

Fig.1. Excited state of heart

Under normal circumstances, the heart excited originated in the sinoatrial node, the node between the beam and the conduction system by the atrial atrial depolarization, then through the channel between the normal atrioventricular to the atrioventricular node slow afferent atrioventricular bundle and the left and right bundle branch, Purkinje fiber, and finally achieve the ventricular depolarization in ventricular myocytes. Each of the atrium and ventricle is contracted and diastolic once, that is, a cardiac cycle is completed. If the heart is excited from the sinoatrial node a, and regularly exciting frequency is 60~100 / min, is called normal sinus rhythm. When the cardiac excitation is produced outside the sinoatrial node, or the abnormal conduction of cardiac conduction, or the change of cardiac rhythm and speed caused by both of them, and the change of conduction time and sequence, it is commonly referred to as arrhythmia.

3. Research progress on signal processing technology

The occurrence of atrial fibrillation is closely related to atrial effective refractory period, electrical excitation in the conduction velocity of atrial muscle and the physiological factors such as turn back wavelength. The electrophysiological remodeling induced by atrial fibrillation will make these physiological characteristics change to varying degrees. [4] The power spectrum and time frequency analysis of atrial fibrillation signal can be used to extract the characteristics of the degree and changes of atrial fibrillation. At present, there are three main methods: template matching , blind processing and primary frequency analysis.

(1) the template matching method is divided into the fixed template method and the adaptive template method. The essence of the fixed template method is an Average Beat Substraction (ABS) technique. The method has been improved many times and gradually evolved into an adaptive template method. Subsequently, Stfidh J and other scholars should carefully arranged the vector loop technology, the introduction of the temporal calibration complex QRS (Spatiotemporal QRST Cancellation STC) technology to further improve the accuracy of template extraction of AF signal, then gradually become the mainstream technology of template method. In spite of this, the template matching method has its inherent defects. It can not get the unified atrial fibrillation signal from multi-channel ECG, and it can not deal with the influence of QRS waveform change caused by breathing and other changes of ECG axis, the artifacts and ectopic heartbeat caused by electrode movement.

(2) blind source separation and blind source extraction are used in blind processing. The premise condition of using the method: the real wave and wave signal can be considered to be statistically independent; real waves and waves are non Gauss; the observed body surface ECG signal can be regarded as the combination of instantaneous real wave and wave mixing chamber, the unknown

coefficient depends on the electrode placement position and body tissue conduction rate. Rieta J and other scholars put forward the algorithm of fast independent component analysis (Fast Independence Component Analysis, Fast ICA); Casterlls F researchers using time correlation, AF signal known real (Atrial Action, AA) dynamic and dynamic (Ventricular action VA) the probability distribution characteristic, put forward a method of separation blind source based on maximum likelihood. Blind methods are able to find the atrial fibrillation wave after separation of the signal from the source. However, the precondition of this method is harsh. As a complex electrophysiological process, atrial fibrillation is often difficult to meet many prerequisites. Therefore, the feasibility and effectiveness of the blind signal processing method in practical application is very difficult to guarantee.

(3) Dominant frequency (DF) analysis method is to study atrial rapid excitation, pathophysiology and the rate of change of excitation rate after studying the corresponding frequency of the maximum power spectrum of ECG. Among them, the primary frequency analysis of the body surface electrocardiogram (ECG) signal is widely used to estimate the atrial activation rate.

4. Analysis based on BSS and ICA

Usually, BSS and ICA are used confusing. Although they use the same model, the objectives of the two are different. The purpose of BSS is to estimate the original source signal and do not impose independence on the source signal; ICA makes the estimated signal as independent as possible. ICA uses higher order statistics in many cases, and BSS can solve the problem by using only two order statistics. The use of the two order statistics needs to assume that the source signal has a certain time structure, while the higher order statistics require statistical independence between the source signals. The only use of the two - order statistics is not enough to solve the ICA problem. Because the statistical properties of Gauss signals are completely determined by mean vectors and covariance matrices, there is redundancy for high-order statistics for Gauss signals, but there is no redundancy for the two order statistics. Therefore, ICA can be seen as a very effective BSS solution.

Independent component analysis (ICA) is an important blind source separation solution. [5] The basic hypothesis of independent component analysis has the following three conditions: first, each source signal is statistical independent. Based on the assumption of statistical independence, the effective estimation of the independent component can be completed. Secondly, only one of the source signals obeys the Gauss distribution. The linear transformation of the random variables of Gauss distribution is still the Gauss variable, while the mixing process and the mixing process are all linear transformation processes. The source signal can only obey one Gauss distribution. The standard independent component analysis method is used to separate the source signals through non Gauss properties.

In the actual calculation, the L group is often sampled from the signal, and. It is assumed that at the time, the sampling value is the L group sampling data matrix of the $s(t_i)$.

$$\mathbf{S} = [s(t_1), s(t_2), \dots, s(t_L)] \tag{1}$$

In the same way, the L group sampling data matrix is

$$\mathbf{X} = [x(t_1), x(t_2), \dots, x(t_L)] \tag{2}$$

Processing signal is

$$\mathbf{X} = \mathbf{AS} \tag{3}$$

Formula (2-4) is usually used for adaptive (online) algorithm, and formula (2-7) is applied to batch processing (off-line) algorithm. In order to solve the problem of independent component analysis, a mixed matrix W is obtained through a certain learning algorithm, which makes the components of the output of the system independent.

$$y(t) = [y_1(t), y_2(t), \dots, y_n(t)]^{\mathrm{T}} \tag{4}$$

In the formula, the estimation vector of the source signal usually requires that the recovered signals are independent of each other.

When the mixed matrix W is the inverse of the mixed matrix A, the source signal can be extracted accurately. In fact, there is a transformation between the permutation and the scale.

$$\mathbf{WA} = \mathbf{P\lambda} \tag{5}$$

In the formula, P is a displacement matrix matrix and a scale matrix.

Feature information is only hidden in the waveform of the signal, and the characteristic information is not related to sorting and amplitude. The two uncertainties do not affect the characteristic analysis of the signal data. The ICA method can eliminate QRS waves, and AF signals not only take advantage of these two points, but also more importantly, because the sources of biophysical signals are usually irrelevant and independent. In addition, ICA can separate the atrial fibrillation signal, but the sort uncertainty makes it difficult for the machine to judge which signal is a atrial fibrillation signal.

5. Conclusion

In this paper, a three-dimensional reconstruction plotting system of atrial reconstruction is designed, which is characterized by the frequency of the atrial fibrillation signal. The system can display the real-time change of various parts of atrial main frequency through real-time mobile detection system, the main frequency of atrial fibrillation, can provide preoperative selection of appropriate ablation position reference for physicians, and can provide quantitative indicators in the process of operation, in order to reduce the difficulty of operation, but also can provide the effect analysis and two times of ablation risk assessment for surgery. The result of case analysis shows that the adaptive power threshold can reduce the candidate range of further ablation and improve the treatment efficiency after the correction of the primary frequency.

Acknowledgements

This paper was supported by these fundation: Shaanxi Provincial Education Department, 2013JK1012, Digital model of atrial fibrillation and less freedom parallel mechanism system;

Shaanxi provincial science and Technology Department natural fund, 2013JQ4038, Atrial fibrillation signal analysis and ablation treatment auxiliary methods;

Fundation: Shaanxi Provincial Education Department, 2013JK1012, Digital model of atrial fibrillation and less freedom parallel mechanism system;

Shaanxi provincial science and Technology Department natural fund, 2013JQ4038, Atrial fibrillation signal analysis and ablation treatment auxiliary methods;

References

[1]GO, A. S., Prevalence of Diagnosed Atrial Fibrillation in Adults National Implications for Rhythm Management and Stroke Prevention: the Anticoagulation and Risk Factors In Atrial Fibrillation (ATRIA) Study. JAMA,Vol. 2011(2) 237-245.

[2]PRASHANTHAN SANDERS, Changes in Atrial Fibrillation Cycle Length and Inducibility During Catheter Ablation and Their Relation to Outcome. Circulation,Vol. 2012(2) 307-313.

[3]LUKAS KAPPENBERGER & HENRIQUEZ, C. S. Modeling Atrial Arrhythmias: Impact on Clinical Diagnosis and Therapies. IEEE Reviews in Biomedical Engineering, (2008)1, 94-114.

[4]KANNEL, W., WOLF, P., EJ, B. & D, L. Prevalence, incidence, prognosis, and predisposing conditions for atrial fibrillation: Population-based estimates.(2010) Am J Cardiol 2N-9N.

[5]MARPLE, L. A New Autoregressive Spectrum Analysis Algorithm. IEEE Transactions on Acoustics, Speech, and Signal Processing, (2015) Vol. ASSP-28, 441-454.