Time-frequency analysis of QRS complex with wavelet transform in patients with triple-vessel disease

*Kei Ota, Takeshi Tsutsumi, Keisuke Kawachi, Daisuke Wakatsuki, Nobuyuki Shimizu, Fuyuki Asano, Youichi Takeyama, Yoshiwo Okamoto**

Division of Cardiology, Showa University Fujigaoka Hospital, Yokohama

*Department of Electrical, Electronics and Computer Engineering, Faculty of Engineering, Chiba Institute of Technology, Chiba, Japan

ABSTRACT

Objective: Significant Q-wave is sometimes invisible in the patients with triple vessel disease (TVD) even though TVD is a serious coronary heart disease. We offer the preliminary method to analyze the time-frequency profile of QRS in TVD patients.

Methods: Electrocardiograms (ECG) band-pass filtered through 50 to 300Hz were recorded from the persons without heart diseases (Normal group; n=24), the patients with single vessel disease (SVD group; n=12) and TVD (TVD group; n=12) and saved into PC. For each subject, the time-frequency powers of ECG (lead II) were calculated by the continuous wavelet transform (CWT) with 40 frequency bands. They were integrated during QRS to get the integrated time-frequency powers (ITFP) for all the frequency bands.

Results: The ITFP at lower frequency range (90Hz or less) were smaller in SVD and TVD groups, compared with normal group. The ITFP at higher frequency range (120 to 350Hz) were larger in patients with recurrent heart failure due to TVD. The increase in ITFP at wider frequency bands was seen with and without significant Q waves.

Conclusion: The present results that the increase in higher frequency power in TVD with recurrent heart failure may indicate the severity of myocardial damage, regardless of significant Q-wave. *(Anadolu Kardiyol Derg 2007: 7 Suppl 1; 133-4)*

Key words: frequency analysis, wavelet transform, coronary heart disease, triple vessel disease

Introduction

High frequency components (HFC) in notching and slurring of the QRS have been firstly reported by Langner and after that several authors (1-3). They noted that HFC were observed in coronary heart diseases and dilated cardiomyopathy at approximately 150 Hz or higher frequency (1-3). The lesions of patchy necrosis or tissue fibrosis in heart may be responsible for the appearance of high frequency components (2, 3). In comparison with the fast Fourier transform (FFT) that is a popular way for analyzing cyclical biological signals, the newly developed continuous wavelet transform (CWT) is more efficient tool for the analysis of non-stationary and transient changes in signal morphology (4). In our group, the time frequency analysis of QRS with CWT has been studied for detecting the micro-necroses (5, 6). The present study is a preliminary report to analyze the time-frequency profile of QRS in patients with triple-vessel (TVD) coronary heart disease.

Methods

The standard limb leads electrocardiogram (ECG) band-pass filtered through 50 to 300Hz were recorded from the persons without heart diseases (Normal group; n=24), the patients with single vessel disease (SVD group; n=12) and TVD (TVD group; n=12) and saved into PC. All patients entered to the coronary care unit under diagnosis of acute myocardial infarction underwent coronary angiography and, if necessary, percutaneous coronary intervention. Seven of 12 cases in TVD group underwent the coronary artery bypass graft surgery. Recurrent heart failure developed in five cases of TVD group. For each subject, a single QRS complex in lead II was selected from the continuous ECG records, and its time-frequency powers were calculated by means of CWT with 40 frequency or scale bands ranging from 50 to 500Hz. Then they were integrated over QRS period (80 msec in the duration) to get the integrated time-frequency powers (ITFP) for all the frequency bands and saved into PC as CSV files. All the analyses were performed by the software (BIOMAS ver.1.0β) that we had developed ourselves. For each group (normal, SVD and TVD), the dependence of ITFP on the frequency were demonstrated and compared with each other.

Results

The representative time-frequency powers from two patients of TVD group are shown in Figure 1. A single QRS enclosed by a yellow frame was selected as shown in the lower panel. The calculated wavelet signals are illustrated in the main windows. The vertical axis corresponds to the frequency and the transverse axis the passing time. The magnitude of the frequency power was expressed as a color ranging from red to blue. The standard 12 leads ECG are shown at the side of wavelet signals. The wavelet signal from the QRS of the patient with inferior myocardial infarction and TVD is shown in the left panels in which abnormal Q waves were seen in limb leads II, III. The high frequency signal

Address for Correspondence: Takeshi Tsutsumi, M.D. Division of Cardiology, Showa University Fujigaoka Hospital, 1-30 Fujigaoka, Aoba-Ku, Yokohama, 227-8501, Japan. Phone: +81-45-971-1151(Ext 6303), Fax: +81-45-972-6258 E-mail: tt-icardiol@showa-university-fujigaoka.gr.jp

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(150Hz or more) was generated around the peak of R wave. In the right panels, the wavelet signal from the patient of TVD with recurrent heart failure. Although the abnormal Q-wave was not seen in ECG waveforms, the wavelet signal was divided into two parts during QRS at the lower frequency range and the high frequency signal was chiefly generated on the former half of the QRS with longer duration that were considered to be abnormal findings.

In order to clarify the difference in ITFP, mean value of ITFP over normal group (n=24) was subtracted from individual patients with SVD or TVD. As the results, ITFP at lower frequency range (90Hz or less) was smaller in 79% of patients with SVD and TVD without recurrent heart failure, compared with normal group. The ITFP at higher frequency range (120 to 350Hz) was larger in all patients with recurrent heart failure due to TVD. In Figure 2, ITFP differences are plotted as functions of frequency for the same patients as in Figure 1 with and without recurrent heart failure. In the left panels, the ITFP differences in TVD without recurrent heart failure were decreased at the lower frequency range (90Hz or less), but in the right panels the ITFP difference was increased at the higher frequency range from 100 to 350Hz in TVD with recurrent heart failure case. The generation of larger high frequency power was not related to the appearance of significant Q-wave.

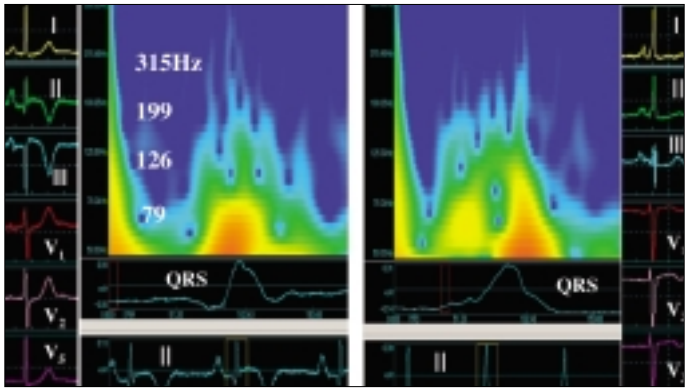

Figure 1. Examples of wavelet signals and standard 12 leads electrocardiogram In left panels, time frequency powers and ECG were measured from the patients with TVD without recurrent heart failure (67 years old male) and in the right panels those were measured from the patient with TVD and recurrent heart failure (72 years old male). The wavelet function used in the study was Morlet. See the text about the further explanation of this figure

ECG- electrocardiogram, TVD- triple-vessel disease

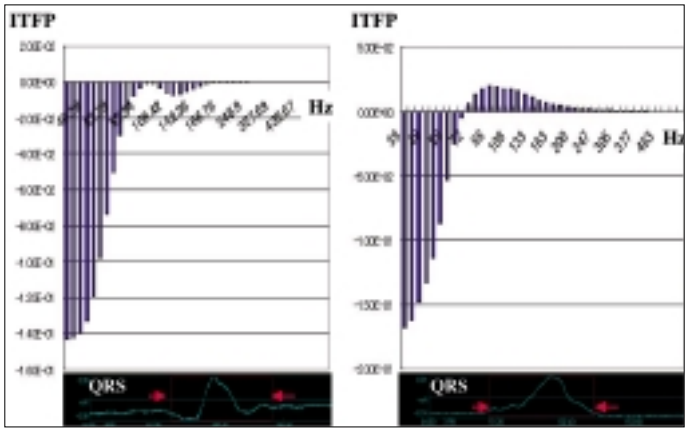

Figure 2. Integrated time frequency power and selected section of QRS complex The ITFP in this figure indicates the difference between mean normal ITFP value every 40 scales from 50 to 500Hz and the ITFP values in the individual cases of SVD or TVD groups. Accordingly, the figure shows the dependence of ITFP differences on the frequency measured from the patient. The ITFP differences in TVD without recurrent heart failure is are shown in left panels. In this case, ITFP differences were decreased at the lower (90Hz or less) to the higher frequency range (120Hz or more). In right panels the frequency distribution of ITFP differences measured from the patient with TVD and recurrent heart failure is shown. The ITFP differences in this case were increased at the higher frequency range

ITFTP- integrated time-frequency power, SVD- single-vessel disease, TVD- triple-vessel disease

Discussion

Gramatikov, et al. (7) showed in their pilot study that the time frequency distribution patterns of QRS complex calculated by wavelet analysis did not vary significantly from beat to beat during good signal quality. Moreover, they emphasized that the quantitative analysis of the signals will be needed in order to assess the information obtained from wavelet signals. Therefore, we tried to quantitatively analyze the wavelet signal. The distribution of ITFP difference proposed in this study is a way of the quantitative analysis. The ITFP was decreased in myocardial infraction patient since the change of cardiac motion force fundamentally became null in myocardial infarction lesions. In previous report, we speculated that the time dependent deformation of the shape of cardiac excitation front passing through the micro-necroses (1~2mm; od) may be a cause of the generation of the high frequency components (6). The present results on the augmentation of higher frequency power in TVD may indicate the severity of myocardial damage, and also the high frequency powers were seen regardless of significant Q-wave. Consequently, the distribution of ITFP will provide the new information of the heart diseases.

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