COMPARISON OF SPECTRAL METHOD AND COMPLEX DEMODULATION METHOD FOR T-WAVE ALTERNANS DETECTION

Ing. Marek VYKLICKÝ, Doctoral Degree Programme (1)
Dept. of Biomedical Engineering, FEEC, BUT
E-mail: xvykli00@stud.feec.vutbr.cz

Supervised by: Prof. Ivo Provazník

ABSTRACT

Detected T-wave alternans (TWA) in surface ECG signals has been recognized as a marker of electrical instability, and is hypothesized to be related with patient with increased risk of ventricular arrhythmias. Several methods for TWA detection have been proposed. In this paper comparison of the spectral method and the complex demodulation method applied to ECG signal from European ST-T database is presented.

1 INTRODUCTION

T-wave alternans (TWA) is an electrophysiological phenomenon defined as a beat-to-beat change in the shape, amplitude, and occasionally the polarity of repolarization that repeats once every other beat. Visible TWA (fig. 1) has been identified mainly in patients with long QT syndrome, Printzmetal's angina and also during acute myocardial ischemia [1]. In recent years, computerized analysis of digital recording ECG has allowed identification of microvolt-level TWA, which is below the threshold of the visible detection. It allows to identify patients at risk for sudden cardiac death (SCD). SCD is a leading cause of death, frequently attributed to sustained ventricular arrhythmias (ventricular tachycardia or ventricular fibrillation) [2].

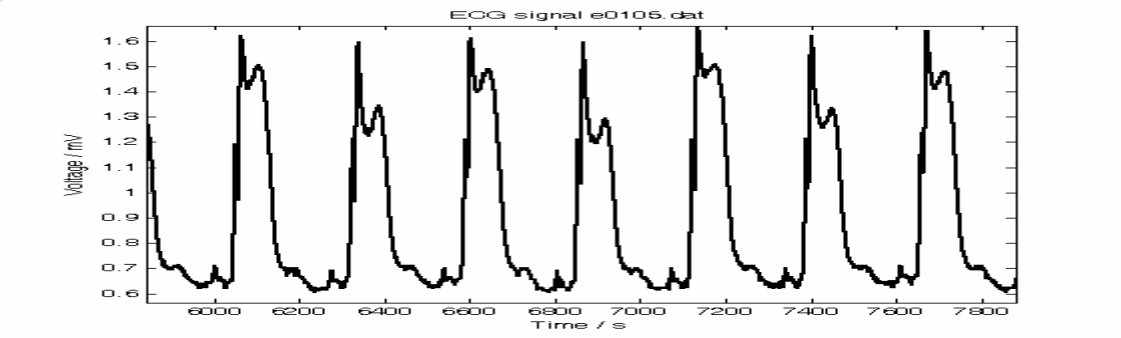


Fig. 1: *T wave alternans*

2 METHODS

2.1 SPECTRAL METHOD

With the spectral method (SM) [3] the series of 128 consecutive beats (fig. 2 top) of ECG signal are analyzed. This number provides a reasonable compromise between the ability to reduce noise and the ability to track variations in the alternans level over time. The spectral method uses measurement from time-synchronized points of consecutive T waves. Each beat is aligned by correlation with a template. A time series is then created by measuring the level at the same point in time on all 128 beats (fig. 2 bottom left). This process is repeated multiple times in the T wave and the spectra corresponding to the individual time series (fig. 2 bottom middle) are averaged to form a composite TWA spectrum (fig. 2 bottom right). Since the T wave measurements are taken once per beat, the spectrum frequencies are in the units of cycles per beat. The point corresponding to 0.5 cycles per beat indicates the level of alternation in the T wave waveform.

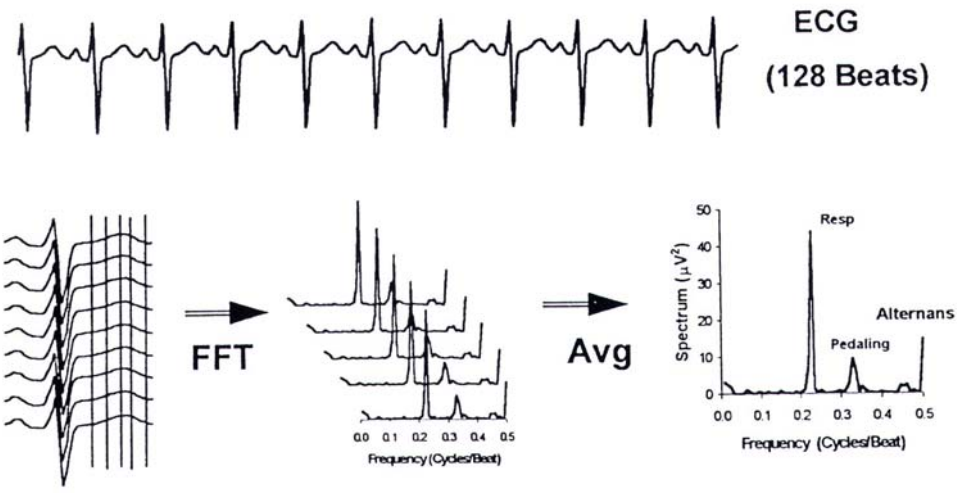


Fig. 2: *The spectral method of TWA detection (description in text above)*

2.2 THE COMPLEX DEMODULATION METHOD

The complex demodulation (CD) method [4] was proposed as an alternative to the spectral method. Each time series, obtained by identical way as in SM, is demodulated by multiplying it by the modeled TWA (as a sinus wave at the frequency f_0=0.5 cycles/beat with varying amplitude and phase) so that the frequency components around f_0 are moved to low frequencies:

$$y[k,l] = x[k,l] \cdot 2 \cdot \exp(j \cdot 2\pi f_0 \cdot k), \qquad [1]$$

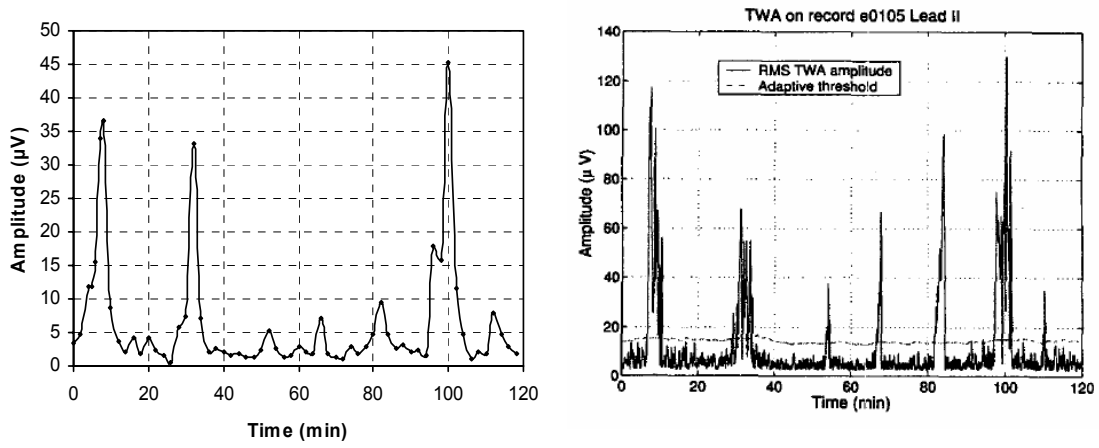
where *x[k,l]* is the *l*-th sample of the T wave of the *k*-th beat. The resulting series *y[k,l]* is low-pass filtered. Finally, the spectrum of the output series is calculated. This method allows tracking the amplitude of the TWA beat-to-beat.

3 EUROPEAN ST-T DATABASE

The European ST-T database [5] consists of 90 ECG recordings extracted from Holter tapes (2 lead ECGs) that contain ST-T episodes annotated on an individual lead basis by cardiologists. Each record is two hours in duration and contains two signals, each sampled at 250 samples per second with 12-bit resolution over a nominal 20 millivolt input range. This database is well known and research groups published many analysis of it.

4 RESULTS

We applied the SM method to the record e0105 (lead II) from the European ST-T database to present properties of the method. The series of 128 beats was selected from the whole 2 hours signal by sliding window with step of 64 beats. Composite TWA spectrum was averaged from 5 individual spectra and then the amplitude of TWA alternans was calculated. Figure 3a shows the TWA amplitude estimation during the whole 2 hours record. Figure 3b shows results of the CD method applied to the same signal by J. P. Martinéz (et al.) and published in [6].



a) b)

Fig. 3: *TWA amplitude estimation on record e0105*
a) spectral method b) complex demodulation method

5 CONCLUSION

The spectral method of T-wave alternans detection was applied to 2 hours ECG signal e0105 from the European ST-T database. Figure 3 shows that this method provides similar results as the complex demodulation method, TWA were detected in the same time. The CD method allows tracking the amplitude of TWA beat-to-beat, but under conditions of lower noise, a smaller number than 128 of beats can be analyzed by the SM method. The CD method is computationally more demanding than the SM method. The simplicity of the SM method is its main advantage.

ACKNOWLEDGEMENTS

This work has been partly supported by the grant project GAČR No. 102/04/0472, and Research Programmes of Brno University of Technology No. J22/98:262200011 and J22/01:262200022.

REFERENCES

[1] Zareba, W., Maison-Blanche, P., Locati, E. H.: Noninvasive Electrocardiology in Clinical Practise. Futura Publishing Company, Armonk, NY, 2001.

[2] Narayan, S. M., Botteron, G. W., Smith, J. M.: T Wave Alternans Spectral Magnitude is Sensitive on Electrocardiographic Beat Alignment Strategy. Proc. IEEE Conf. Computers in Cardiology, 1997, vol. 24, p. 593-596.

[3] Albrecht, P., Arnold, J.: Exercise Recordings for the Detection of T Wave Alternans. Journal of Electrocardiology, 1998, vol. 29, p. 46-51

[4] Nearing, B. D., Verrier, R. L.: Personal Computer System for Tracking Cardiac Vulnerability by Complex Demodulation of the T Wave. Journal of Applyied Physiology, 1993, vol. 74, p.2607-2612

[5] Taddei, A., Distante, G., Emdin, et al.: The European ST-T Database: Standards for Evaluating Systems for the Analysis of ST-T Changes in Ambulatory Electrovardiography. European Heart Journal, 1992, vol. 13, p. 1164-1172

[6] Martinéz, P.J., Olmos, S., Laguna, P.: Simulation Study and Performance Evaluation of T Wave Alternans Detectors. Proc. EMBS Conf., 2000, vol. 22, p.2291-2297