Comparative Study of Different Methods and Constraints in Heart Rate Variability Spectrum Estimation

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Abstract

In this work a series of tests associated with the determination of the optimal AR order for HRV spectrum estimation are conducted. The usability of information criteria is observed, but all criteria tend to underestimate the real process order. The influence of the AR order and interpolation methods on spectral indices is analyzed in quality and effects on diagnostic parameters. The results obtained from AR spectrum estimation are compared to spectra obtained using a classic FFT approach.

1 Introduction

The analysis of Heart Rate Variability (HRV) serves as a risk marker for sudden cardiac arrest. For calculating the Power Spectrum Density (PSD) of short-term HRV the use of Fast Fourier Transform (FFT) is not particularly suitable. Autoregressive (AR) modelling is an attractive method for power spectral analysis, provided there is an agreement on the order to use.

2 Methods

2.1 Usability of information criteria

Several information criteria can be used to find a specific “best” trade-off between model order and prediction error when observing a time series of length N. In our study a process of known order p=16 is used to determine whether the model order is overestimated or underestimated by the following information criteria:

- Akaike Information Criteria [1]
- Final Prediction Error [1]
- Bayesian Information Criteria [1]
- Hannan-Quinn Information Criteria [1]
- Parzen’s Criterion Autoregressive Transfer function [2]
- Minimum Description Length [2]
- Rissanen’s Minimum Description length [3]

The process is generated by extracting a fixed number of AR model parameters via Burg’s method out of given beat annotations [4].

2.2 Spectral estimation methods

The influence of the AR order in spectral indices is investigated in quality and effects on diagnostic parameters, and is also compared with the Fourier Power Spectrum. Segments of 300 s were averaged over the entire 24-h period for the records used to obtain the final measures.

2.3 Effects of interpolation methods

RR-tachograms are divided into segments with a length of 300 seconds and are analyzed in order to determine the effects of interpolation method to diagnostic parameters. A fixed resampling rate of 4Hz is used. The four interpolation methods used are:

- Cubic Spline Interpolation (CSI)
- Derivate of Cubic Spline Interpolation (DCS)
- Berger Interpolation (BI)
- Instantaneous Heart Rate Interpolation (IHR)

3 Results

3.1 Optimal order for AR modelling

As Figure 1 shows, all information criteria tend to underestimate the true order of an AR model in case of HRV signal modelling. Therefore a designation of model order on the basis of information criteria seems to be not useful. A fixed model order should be used.
3.2 Influence on spectral indices and diagnostic parameters

The shape of the spectral power density plot changes significantly over the model order used. Therefore, also the values of LF and HF change considerably, especially for small orders. Figure 2 shows this effect for the LF-to-HF ratio that has been suggested as an index of sympathovagal balance. The influence of the model order on this diagnostic parameter becomes insignificant for \( p \) greater 16. For FFT compatible results can be obtained. LF/HF values vary significantly between different data records.

3.3 Influence of different interpolation methods

Using different interpolation methods has got effects on the ratio of LF/HF components as well. IHR and Berger Interpolation match the mean of the different interpolation methods best (Figure 3). All interpolation methods relax from model order \( p=20 \) on.

4 Conclusions

Spectra and diagnostic parameters obtained from RR tachograms using autoregressive modelling must be interpreted cautiously. The model order used should be at least 16. To get comparable results the whole chain of processing steps has to be taken into account, because also the interpolation method used has effects on diagnostic parameters.

5 Literature