Spectral Analysis of Blood Pressure Variability in Atrial Fibrillation

VDA Corino[1], LT Mainardi[1], S Belletti[2], F Lombardi[2]

[1]Politecnico di Milano, Milan, Italy
[2]University of Milan, Milan, Italy

Abstract

Atrial fibrillation (AF) is a common arrhythmia characterized by desynchronization of atrial electrical activity causing a consequent irregular ventricular response. Blood pressure (BP) fluctuates in a complex mode composed of both short-term and long-term variability. In AF, the beat-to-beat variation of BP is increased because of variations in filling time and in contractility. However, a few studies have analysed short-term BP variations in AF being the interest mainly addressed to 24-hour variations. Aim of this study was to describe BP variability spectrum during AF in short-term recordings. Fifteen patients, referred for electrical cardioversion, with persistent AF were included in the study. An harmonic LF component was observable in all patients' BP spectra, even during AF, i.e., in presence of a very irregular RR series.

1. Introduction

Atrial fibrillation (AF) is the most common arrhythmia encountered in clinical practice and it is characterized by an irregular atrial depolarization that causes an irregular but not completely random ventricular rhythm as well [1]. The exploration of autonomic modulation of sinus node impulse activity via heart rate (HR) variability analysis is a widely used method. However, the typical irregularity of ventricular response during AF has been considered a factor preventing HR variability analysis. In fact a high number of spectral peaks are present in AF spectrum which result of difficult interpretation.

In AF, the beat-to-beat variation of blood pressure (BP) is increased because of variations in filling time and in contractility. Only a few studies [2, 3] have evaluated whether rhythmical components could be identified in HR and systolic arterial pressure variability during AF. At variance with sinus rhythm where a low (LF) and a high (HF) frequency components can be consistently recognized in both variability signals and reflect autonomic modulation of sinus node [4], the irregularity of ventricular response hence the lack of stationary data have been considered a factor opposing to a frequency analysis of short-term systolic BP and HR variability. Even if a respiratory related HF component of systolic BP variability has been recently observed during AF even in absence of a respiratory sinus arrhythmia [3], there is lack of information on the possible existence of LF component.

Aim of the present study was to describe BP variability spectrum during AF in short-term recordings in patients with persistent AF.

2. Methods

2.1. Study protocol

Fifteen patients (9 male, mean age 67 $\pm$ 7 years) with persistent AF (median duration 3 months; range 1-12 months) were included in the study.

Three orthogonal leads, a periodic reference arterial pressure measurement and a continuous beat-to-beat non-invasive recordings of arterial pressure were obtained with a Task Force Monitor (CNSystem; Austria) recording system. Surface ECG and BP signals were recorded for about 10 minutes before electrical cardioversion. The sampling frequency was 1 kHz for the ECG signal and 100 Hz for the continuous arterial pressure recording. Electrical cardioversion was performed in fasting state during deep sedation with intravenous propofol (1-2 mg/Kg). Biphasic DC shock (Life Pack 12 defibrillator, Medtronic Inc., Minneapolis, USA) was delivered with rising energies when needed, starting from 100 J (single shock in almost all cases).

2.2. Series extraction

An automatic QRS detection algorithm was used to locate R waves on the ECG and an interactive graphic interface allowed the operator to visually identify and correct missed/misdetected beats.

During AF, the search for the systolic values cannot be performed looking for the maximum after the R wave, as

during sinus rhythm. In fact, some R waves of ECG may not be coupled with effective left ventricular output enough to generate discrete pulses in arterial pressure. An example is shown in Figure 1, where an anticipated beat (indicated by an arrow) is not able to elicit a pressure pulse.

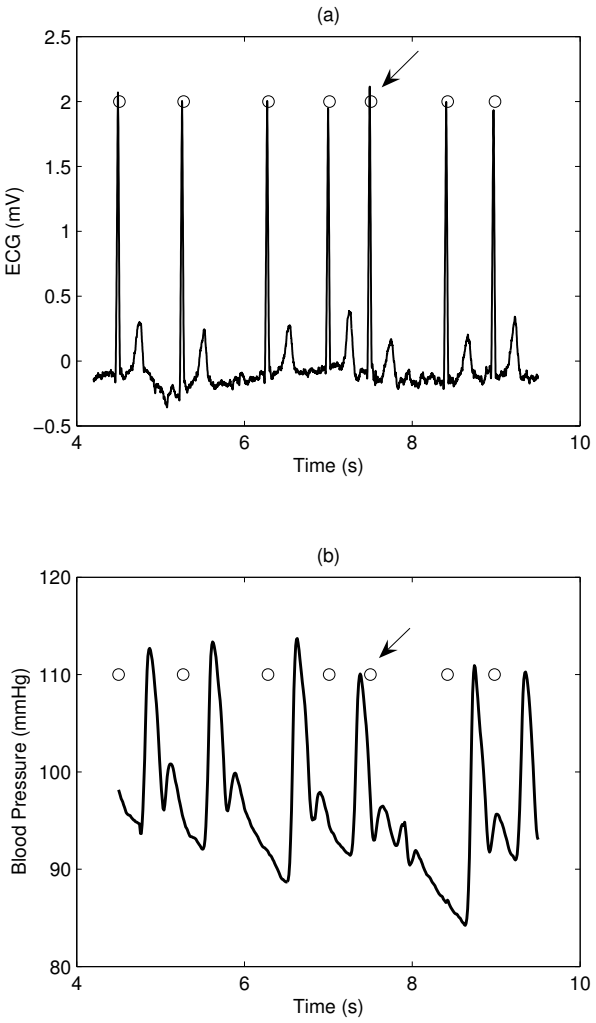

Figure 1. (a) ECG signal (solid line) with superimposed the QRS timing (circles). (b) Blood pressure signal (solid line) with superimposed the QRS timing (circles). The arrow shows a QRS complex that is not followed by a discrete pulse.

Therefore, in order to identify the systolic arterial pressure values, the following steps were performed. First, the pressure signal was low-passed (cut-off frequency 1 Hz) and the timing of its local maxima evaluated (t_i). The systolic arterial pressure values were then computed as local maxima in temporal windows centered on t_i whose cross-correlation with a template exceeded the threshold 0.90. The first pulse cycle in the signal was selected as template. Visual checking of the template was performed to guarantee the reliability of the waveform.

The RR and systolic BP series thus obtained could be of different length and unevenly sampled. Therefore, in order to obtain two series with the same length and to perform frequency analysis, the final RR and systolic BP series were obtained by interpolation (using cubic splines) and resampling at 2 Hz.

2.3. Spectral analysis

Power spectral analysis was performed on the RR intervals and systolic BP signals by means of an autoregressive model, whose coefficients were estimated using the Levinson Durbin algorithm; Anderson's test [5] was used to check the validity of the model and the model order was selected by use of the Akaike Information Criterion [6], starting from a minimum order of 7 up to a maximum order of 20. A spectral decomposition algorithm [7] was used to measure the centered frequency and the area below the spectral peak in the LF (0.03 - 0.15 Hz).

2.4. Statistical analysis

The data are given as mean values $\pm$ one SD.

A Students t test for paired data was used to evaluate the differences between parameters before and after electrical cardioversion. A value of $p < 0.05$ was considered significant.

3. Results

Figures 2 and 3 show an example of the RR and the systolic BP series, respectively, and the corresponding power spectrum during AF. It can be noted in Figure 2(a) the typical irregularity of the RR series, which is reflected in the power spectrum (Figure 2(b)), resembling a white noise spectrum, with many peaks, which make difficult their interpretation. On the other hand, the series of the systolic BP is less erratic. As a consequence, a clear LF component is present at 0.071 Hz in the systolic BP spectrum (Figure 3(b)). This harmonic components are present at level of systolic BP variability even in presence of erratic RR series.

All the analyzed patients' systolic BP series presented a peak in the LF range (0.069 $\pm$ 0.022 Hz; mean $\pm$ SD) during AF.

In Table 1, BP parameters are shown as mean $\pm$ one SD for all the patients.

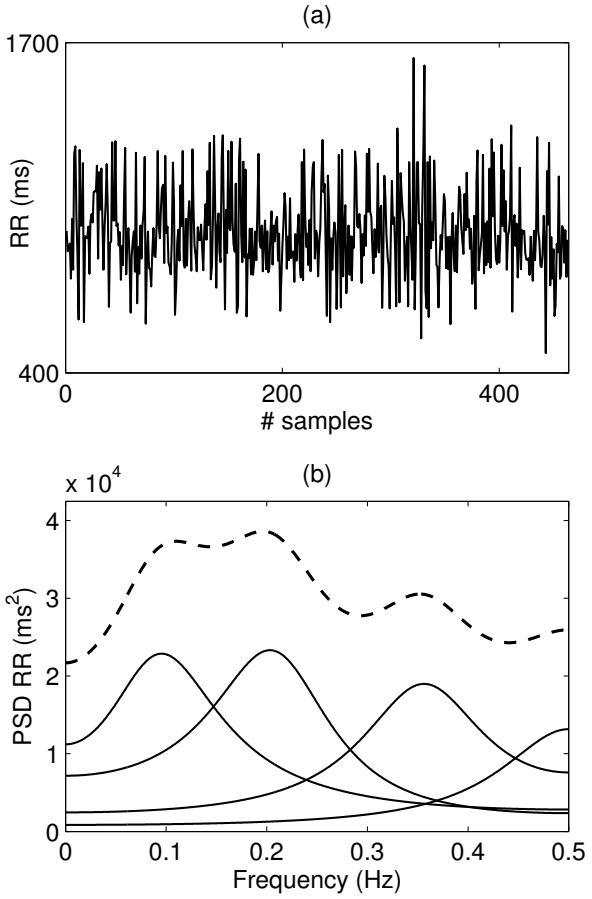

Figure 2. (a) Example of one patient's RR series and (b) the corresponding power spectrum, where many peaks are observable.

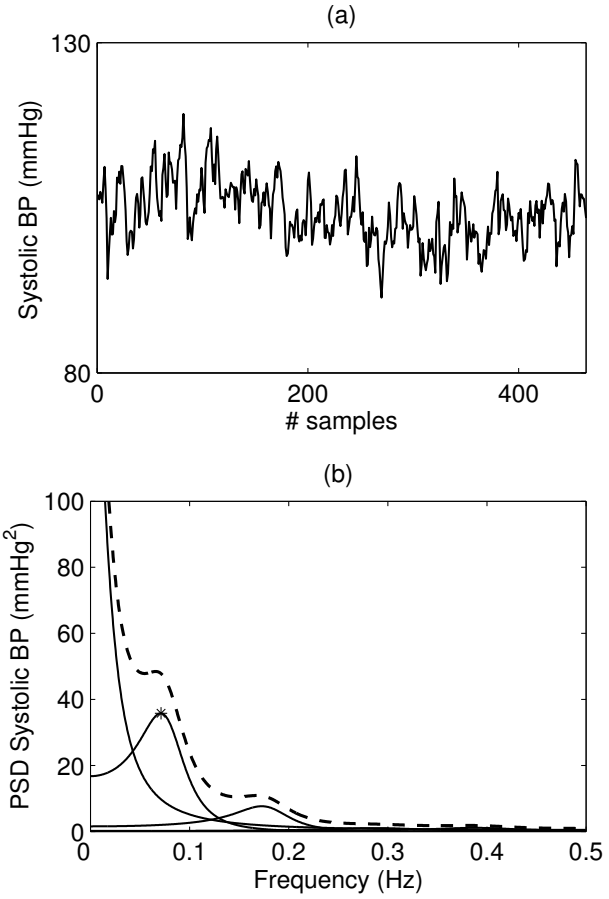

Figure 3. (a) Example of one patient's systolic BP and (b) the corresponding power spectrum, where a discrete LF peak is indicated by *.

Table 1. Pressure variables during AF.

sys (mmHg)	109 ± 19
dia (mmHg)	81 ± 17
min (mmHg)	95 ± 20
max (mmHg)	117 ± 19
LF freq (Hz)	0.069 ± 0.022
LF power ($mmHg^2$)	1.31 ± 0.60

Table 2 shows the results regarding ventricular response during AF.

Table 2. Ventricular response variables during AF.

mean (ms)	756 ± 113
sd (ms)	139 ± 38

4. Discussion and conclusions

In the present study, we reported for the first time the presence of LF oscillation in systolic BP variability in patients with AF, i.e., in a condition characterized by an irregularity of the RR interval time series. In these patients, when the variability of the RR series is analyzed with spectral techniques, a white noise pattern without any identifiable discrete components along the frequency axis becomes evident.

The presence of LF component of systolic BP variability in patients with AF is, in our opinion, of particular interest as it provides additional information on the origin and physiological meaning of this oscillation. This finding confirms that the 0.1 Hz oscillatory component of systolic BP variability may be present in absence of a correspon-

dent fluctuation in the RR interval time series. Indeed, one could consider AF a natural experimental model to eliminate the influence of rhythmical components of RR variability on systolic BP variability. It was however evident that presence or absence of RR interval irregularity had major effect on systolic BP variability, as it was increased during AF.

This finding evidences the capability of autonomic nervous system in maintaining LF oscillations in BP even in presence of an irregular ventricular electrical and mechanical activity.

These results are preliminary. Further studies will help in better understanding BP characteristics during AF and in defining the nature of this LF oscillation during AF. In particular, it could be interesting to investigate if this rhythm is present after restoration of sinus rhythm (i.e., as the one obtained by electrical cardioversion) or if this rhythm is modulated (in AF) by autonomic stimula (i.e., stress-test or tilt). In conclusion, this result paves the way to a better understanding of cardiovascular control mechanisms during non-sinusal rhythms,

Acknowledgements

The research was partially supported by grant n° 2006063135_002 of MIUR.

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Address for correspondence:

Valentina Corino
Department of Bioengineering, Politecnico di Milano
via Golgi 39, 20133 Milano, Italy
valentina.corino@polimi.it