

# Cardiac Aliasing in Atrial Rate Variation Response to Fixed-rate Ventricular Pacing

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## Abstract

*It is found that the frequency components of atrial rate variation (ARV) of AV-block patient with fixed-rate ventricular pacing vary irregularly with the pacing rates. We attempt to learn about the relationship between the oscillation frequency of ARV and the blood pressure (BP) pattern in this study.*

*The beat-to-beat ARVs extracted from esophageal ECG and noninvasive BP waveforms of seven AV-block patients were recorded. Each patient was paced under 60, 90, 120 beats/min of three ventricular rates. Results reveal that the oscillation frequency of ARV does not correlate to the variation frequency of systolic or diastolic BP or respiration frequency. Instead, it may be an aliasing phenomenon of BP pulse frequency exactly equal to ventricular rate when the mean atrial rate is considered as the sample rate of ARV signal. This study suggests that the BP pulse dominate the ARV in AV asynchronous situation*

## 1. Introduction

Two main frequency components of heart rate variation (HRV) in low frequency (0.04~0.15 Hz) and high frequency (0.15~0.4 Hz) bands, respectively, have been identified and used to clinical assessment of autonomic balance in cardiac control. The high frequency oscillation of HRV correlating to the respiration has been verified. But the origin of low frequency oscillation is more complicated and still under investigation.

The heart rate variation expresses the dynamics in the feedback system of heart rate control. To observe the atrial rate variability (ARV) of AV-block patient paced with different fixed ventricular pacing rate will help to understand the heart rate control mechanism. Recently, we have used the PP intervals on an esophageal lead for analysis of ARV in patients with AV block [1]. It was shown that AV block patients had ARV differing from

normal subjects. Some studies also have reported that ventricular rate and AV-delay have marked influences on ARV [2-4]. Moreover, we found that the frequency components of ARV of AV-block patient with fixed-rate ventricular pacing vary irregularly with the pacing rates in a pilot study [5]. Hence we hardly figured out any conclusion for the influences of ventricular rates and AV-delays to ARV. Some evidences have reveal that the blood pressure (BP) variations play an important role in HRV [6,7]. Therefore, we attempt to learn about the relationship between the oscillation frequency of ARV and the BP pattern in this study.

## 2. Materials and methods

### 2.1. Patients

Seven AV block patients loaded with VDD pacemakers were included in this study. All these patients demonstrated normal atrial activity in surface ECG and absence of ventriculo-atrial conduction during ventricular pacing. Patients lay on a table and breathed normally. During the whole experimental procedure, the breathing rate had no marked change.

### 2.2. Methods

An esophageal lead was used to non-invasively record the atrial ECG. PP intervals on the atrial ECG were acquired with the method used in a previous study [1].

The ARVs of each patient at three different fixed ventricular pacing rates (VVI mode, 60, 90 and 120 bpm) were collected. The time interval for each pacing mode was six minutes. In each pacing mode, the ARV was not collected until one minute after the pacing mode was programmed in order for the hemodynamics to reach a steady state.

A Non-invasive continuous blood pressure (NICBP)

device (Colin MP7000) was applied to record the BP waveforms of subjects. The esophageal ECG and NICBP were simultaneously recorded and sampled at 500 Hz for further analysis.

### 2.3. Data analysis

Nearly 300 consecutive PP intervals in each ventricular pacing experiment were used for ARV analysis. Their correspondent NICBP waveforms were down sampling to 20 Hz for spectral analysis. The mean values of all PP intervals were calculated to obtain mean atrial rate (MAR). The fast Fourier transform (FFT) method was used to compute the power spectra of ARV and NICBP. The dominant frequency components of ARV and NICBP were considered as the most significant peak in the power spectra. The relationship between the dominant frequencies of ARV and NICBP were analyzed.

## 3. Results

### 3.1. ARV and NICBP waveform and their power spectra

The typical ARV and NICBP waveforms and their power spectra computed by AR model are shown in Figure 1. The dominant frequency components on ARV and NICBP are about 0.52 Hz and 1 Hz, respectively. They are significantly different.

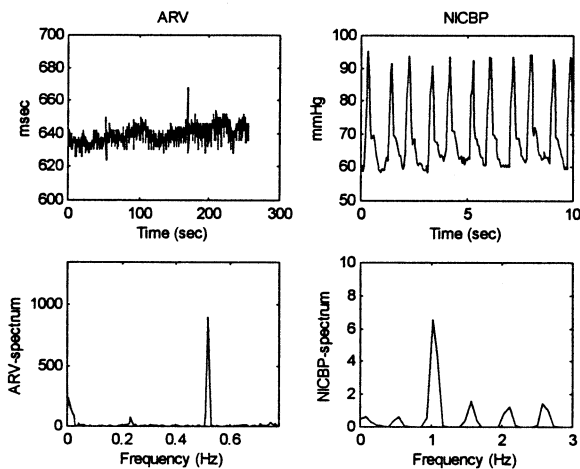


Figure 1. The ARV and NICBP waveforms and their spectra of one of AV-block patients paced at 60 bpm ventricular rate. The NICBP spectrum shows a dominant frequency component at 1 Hz equal to the pacing rate. The dominant frequency component on ARV spectrum is about 0.52 Hz.

Figure 2, 3, 4 show the spectra of ARV (solid lines) and NICBP (dotted lines) under 60, 90, 120 bpm

ventricular pacing, respectively. Both spectra were normalized to illustrate the relationship more clearly. Moreover, the equivalent frequency of 1/2 mean atrial rate is also shown.

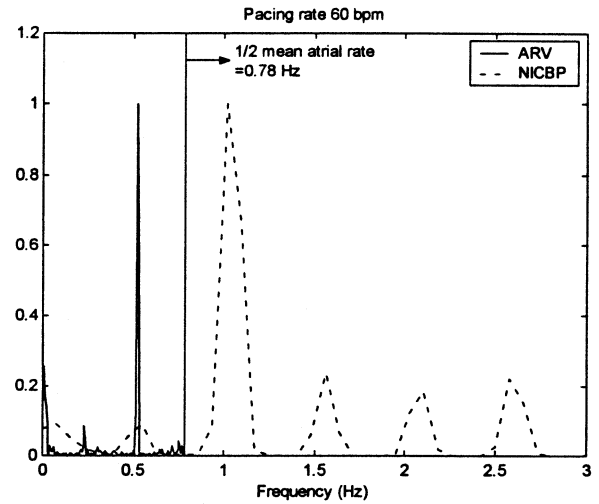


Figure 2. The spectra of ARV (solid) and NICBP (dotted) under 60 bpm ventricular pacing. In this situation, the mean atrial rate is 1.56 Hz and a half of it is 0.78 Hz which is the highest frequency we can measure for ARV. The dominant frequency components of ARV and NICBP are 0.52 Hz and 1 Hz, respectively.

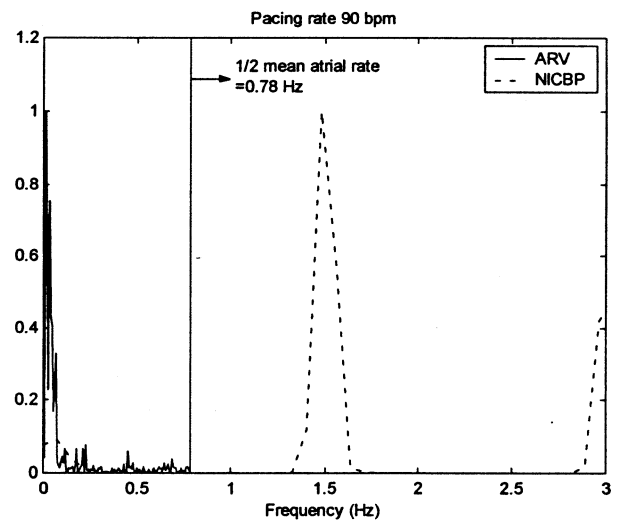


Figure 3. The spectra of ARV (solid) and NICBP (dotted) under 90 bpm ventricular pacing. In this situation, a half of mean atrial rate is 0.78 Hz. The dominant frequency components of ARV and NICBP are 0.06 Hz and 1.5 Hz (equal to 90 bpm), respectively.

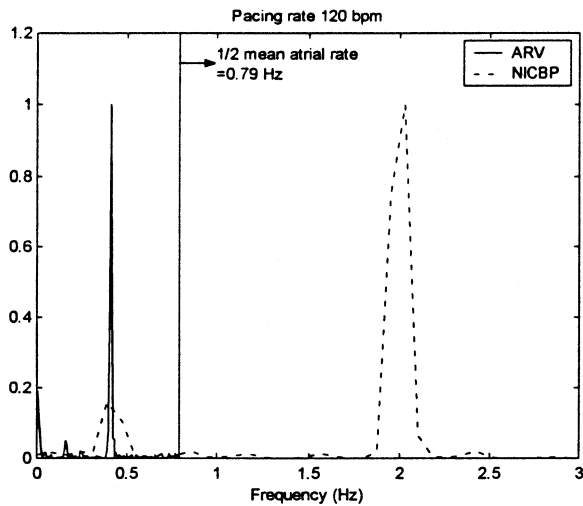


Figure 4. The spectra of ARV (solid) and NICBP (dotted) under 120 bpm ventricular pacing. In this situation, a half of mean atrial rate is 0.79 Hz. The dominant frequency components of ARV and NICBP are 0.41 Hz and 2 Hz (equal to 120 bpm), respectively.

### 3.2. Relationship between the dominant frequency components of ARV and NICBP

According to figure 2 and 3, we found that the dominant frequency components of ARV and NICBP kept the same distance from the 1/2 mean atrial rate. In figure 4, they still kept a certain relation. All seven patients' dominant frequencies of ARV and NICBP as well as 1/2 mean atrial rate are listed in table 1. The relationship among three parameters, dominant frequency of ARV ( $f_a$ ), dominant frequency of NICBP ( $f_b$ ) and 1/2 mean atrial rate ( $f_m$ ) were derived. There are three main relationship existed:  $f_b+f_a=2*f_m$ ,  $f_b-f_a=2*f_m$  and  $f_b+f_a=4*f_m$ . Such relationship is similar to the effect of aliasing that occurs at a sampling procedure while the sampling rate is lower than Nyquist rate. The result showed that ARV signal may reflect the certain type of sampling to BP waveform signal with a sampling rate equal to mean atrial rate.

## 4. Discussion and conclusion

In this study, we found that the oscillation frequency of ARV did not correlate to the variation frequency of systolic or diastolic BP or respiration frequency. Instead, it may be an aliasing phenomenon of BP pulse frequency exactly equal to ventricular rate when the mean atrial rate is considered as the sample rate of ARV signal. Some studies have observed similar phenomena induced by the frequent respiration in neonates and rabbits [8,9]. This

phenomenon does not be observed in normal subject because the atrial rate is equal to BP pulse rate such that the aliasing will be located at 0 Hz. This study suggests that the BP pulse dominate the ARV in AV asynchronous situation.

Table 1. Relationship among the dominant frequencies and mean atrial rate.

Dominant frequency of ARV ( $f_a$ ) (Hz)	Dominant frequency of NICBP ( $f_b$ ) (Hz)	1/2 mean atrial rate ( $f_m$ ) (Hz)	Relation
0.07	1.0	0.52	$f_b+f_a \doteq 2*f_m$
0.47	1.5	0.51	$f_b-f_a \doteq 2*f_m$
0.25	2.0	0.56	$f_b+f_a \doteq 4*f_m$
0.15	1.0	0.57	$f_b+f_a \doteq 2*f_m$
0.41	1.5	0.56	$f_b-f_a \doteq 2*f_m$
0.52	1.0	0.78	$f_b+f_a \doteq 2*f_m$
0.06	1.5	0.78	$f_b+f_a \doteq 2*f_m$
0.41	2.0	0.79	$f_b-f_a \doteq 2*f_m$
0.45	1.0	0.73	$f_b+f_a \doteq 2*f_m$
0.20	1.5	0.66	$f_b-f_a \doteq 2*f_m$
0.59	2.0	0.71	$f_b-f_a \doteq 2*f_m$
0.22	1.5	0.63	$f_b-f_a \doteq 2*f_m$
0.65	2.0	0.67	$f_b+f_a \doteq 4*f_m$
0.09	1.0	0.54	$f_b+f_a \doteq 2*f_m$
0.46	1.5	0.52	$f_b-f_a \doteq 2*f_m$
0.37	1.5	0.57	$f_b-f_a \doteq 2*f_m$
0.30	2.0	0.58	$f_b+f_a \doteq 4*f_m$

## References

- [1] Hsiao HC, Chiu HW, Lee SC, Kao T, Chang HY, Kong CW. Esophageal PP intervals for analysis of short-term heart rate variability in patients with atrioventricular block before and after insertion of a temporary ventricular inhibited pacemaker. *Int J Cardiol* 1998, 64: 271-276.
- [2] Robinson JL, Farr WC, Grupp G. Atrial rate response to ventricular pacing in the unanesthetized A-V blocked dog. *Am J Physiol* 1973, 224: 40-45.
- [3] Nowak B, Voigtlander T, Himmrich E, Liebrich A, Poschmann G, Epperlein S, Treese N, Meyer J. Cardiac output in single-lead VDD pacing versus rate-matched VVIR pacing. *Am J Cardiol* 1995, 75: 904-907.
- [4] Simantirakis E, Skalidis E, Parthenakis F, Chrysostomakis S, Manios E, Kochiadakis G, Vardas P. Impact of atrioventricular delay on heart rate variability of paced patients with and without heart failure. *Int J Cardiol* 1995, 52: 235-239.
- [5] Chiu HW, Kao T, Hsiao HC, Kong CW. Atrial Rate

Variations in Atrioventricular Block Patients: Influences Of Ventricular Rate and Atrioventricular delay. Computers in Cardiology 1999. :555-557.

- [6] Taylor JA, Eckberg DL. Fundamental relations between short-term RR interval and arterial pressure oscillations in humans. Circulation 1996, 93: 1527-1532.
- [7] Laitinen T, Hartikainen J, Niskanen L, Geelen G, Lansimies E. Sympathovagal balance is major determinant of short-term blood pressure variability in healthy subjects. Am J Physiol 1999, 276: H1245-H1252.
- [8] Rother M, Witte H, Zwiener U, Eiselt M, Fisher P. Cardiac aliasing - a possible cause of misinterpreting cardiorespirographic data in neonates. Early hum Developm 1989, 20: 1-20.

- [9] Zwiener U, Luthke B, Bauer R, Richter A, Hoyer D. Forms of physiological aliasing within the heart rate fluctuations by higher frequent respiratory movements. J Physiol Pharmacol 1994, 45; 563-572.

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