

Continuous Atrial Rate Monitoring for Atrial Rate Variability Measurements with an Implanted Dual-Chamber Pacemaker

A. SCHUCHERT, T. MEINERTZ

University Hospital Eppendorf, Department of Cardiology, Hamburg, Germany

S. M. WAGNER

Department of Biomedical Engineering, Erlangen-Nuremberg, Germany

Summary

Heart rate variability indices are used to evaluate the sympathovagal balance. The present approach is to determine the ventricular heart rate (RR) variability from Holter-recordings. The aim of the study was to evaluate whether RR-variability reflects sinus node rate (PP) variability. The study included 8 patients who had received the Logos DDD pacemaker due to intermittent AV-block ($n = 4$) or intermittent sick sinus syndrome ($n = 4$). The atrial and ventricular signals, as well as the pacemaker markers, were continuously transmitted from the implanted pacemaker for 21 ± 4 minutes and recorded on an external Holter-recording device. For the duration of the study, all pacemakers were programmed to DDI pacing with a fixed AV delay of 244 ± 14 ms with the goal of recording the intrinsic electrical activity. The correlation coefficients between the RR- and PP-intervals, between the AV- and PP-intervals and the time domain parameter "standard deviation of all NN intervals" were evaluated in order to determine the heart rate variability. All recorded RR- and PP-signals could be analyzed. The mean atrial and ventricular heart rate was 68 ± 13 bpm. The PP- and RR-intervals had a correlation coefficient of $r = 0.99$ and the AV- and PP-intervals had a correlation coefficient of $r = 0.60$. The standard deviation of all NN intervals was 36.9 ± 11.5 ms for the PP-intervals and 37.6 ± 12.1 ms for the RR-intervals. RR-variability and the ventricular heart rate variability excellently reflects sinus node rate variability indicating that RR-variability assesses the sympathovagal balance of the sinus node.

Key words

Cardiac pacemaker, long-term ECG recording, heart rate variability

Introduction

Heart rate variability is currently determined from 24-hour Holter recordings [1]. The measurement of heart rate variability has an important clinical impact, because a decrease in heart rate variability predicts mortality beyond the evaluation of traditional risk factors [2,3]. In addition, decreased heart rate variability is a well-established risk factor for subsequent arrhythmic events [4]. The basis for its predictive value is that heart rate variability excellently reflects the sympathovagal balance. Changes in the cardiac autonomic tone induce phase modulations in the heart rate, which are expressed in terms of the different indices of heart rate variability. A low heart rate variability indicates a lack of central modulation.

Actually the term "heart rate variability", as presently used, describes the ventricular rate variability. Precisely locating the P-wave in a surface ECG recording is almost impossible with current technology. As a consequence, little is known about the atrial (PP) and atrioventricular (PR) rate variability [10]. A benefit of atrial rate variability in comparison to ventricular rate variability could be the exclusion of the modulation coming from the AV node conduction.

Recent technical improvements in extended diagnostic pacemaker counters make it possible to record electrograms and to use these recordings to determine indices of heart rate variability [7-9]. Such pacemakers allow separate measurement of PP- and RR-rates.

The goals of the study were to describe a method for recording the beat-to-beat atrial rate, to determine the atrial rate variability from these recordings, and to compare the atrial and ventricular rate variability.

Patients and Methods

Patients

The study included 8 patients (8 m; 64.6 ± 15.6 years) who had received the Logos dual-chamber pacemaker (Biotronik, Germany) due to intermittent AV-block or intermittent sick sinus syndrome in 4 cases each.

Pacemaker

The DDD pacemaker Logos offers all regular features of present-day dual-chamber devices. In addition, the pacemaker has an extended memory so that additional software can be temporarily downloaded to the device. The atrial and ventricular signals, as well as the pacemaker markers, are regularly transmitted from the device to the programmer during a pacemaker interrogation, and depicted on the programmer screen. During the study, these intracardiac electrograms (IEGM) were continuously transmitted from the implanted pacemaker to the Unilyzer external Holter-recording device (Biotronik). Because of the filters, the pacemaker transmits the data from the atrial and ventricular signals to the external device within a frequency range from 0.5 Hz to 200 Hz. The scan frequency of the IEGM comes to 333 Hz. The signals were then transmitted to a computer and further analyzed with a specially developed software program.

Study Protocol

The patients had to lie down in a quiet room. The recording time was 21 ± 4 min for each patient. The pacemakers were programmed during that time to the DDI pacing mode with a lower pacing rate of 40 ppm and a fixed AV delay of 244 ± 14 ms. The aim for the specific pacemaker programming was to record exclusively intrinsic and not paced rhythm.

Analysis

All PP-intervals, along with the subsequent PR- and RR-intervals, were analyzed after the premature atrial and ventricular contractions were excluded. The atrial and ventricular data were filtered with a frequency range from 4.5 to 110 Hz. These filtered signals were analyzed by a threshold trigger. The PP- and RR-inter-

vals were correlated to each other, as were the PP- and PR-intervals. The "standard deviation of all NN intervals" (SDNN) was determined for the PP- and the RR-intervals as an example for the time domain indices of the heart rate variability.

Statistical analysis

Continuous data are summarized as a mean and with SD when appropriate. The significance of the correlation coefficient was analyzed by the linear fitting method, which use the linear least squares fitting. The difference between the SDNN determined for the PP- and that determined for the RR-intervals was assessed with a two-sided paired test. P-values less than 0.05 were considered statistically significant.

Results

All patients underwent the study protocol as described above. They had continuous sinus node activity and intrinsic AV node conduction. None of the patients revealed any advanced AV-block during the recording time. There were 10,661 PP-signals, which could be properly analyzed. The mean atrial as well as the ventricular heart rate was 68 ± 13 bpm. As an example, Figure 1 demonstrates a part of the atrial and ventricular signals, which were stored by the Unilyzer. The markers of the external trigger are depicted on the top of the signals.

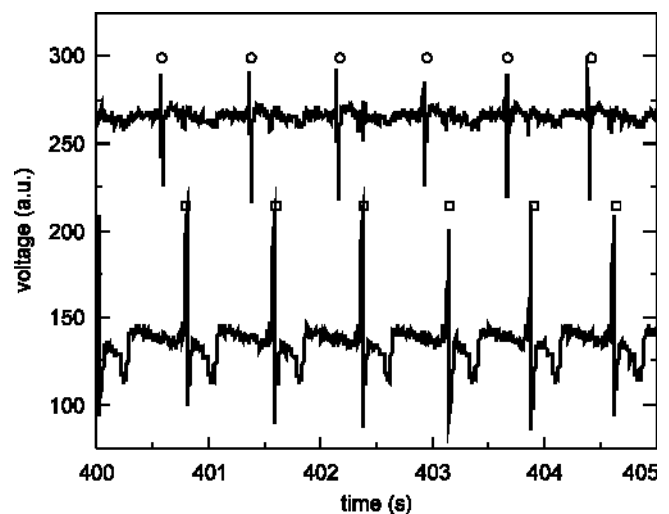


Figure 1. A short interval of the analyzed IEGM. The markers of the external trigger are marked over the IEGM.

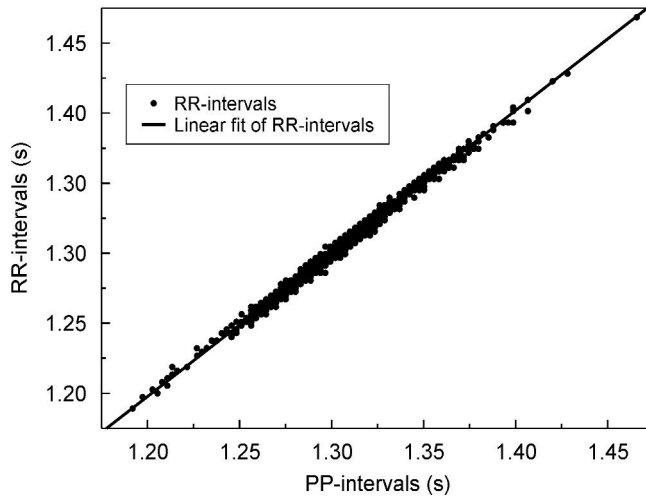


Figure 2. Correlation between PP- and RR-intervals of one patient.

The PP-intervals showed a significant correlation ($p < 0.0001$) with the subsequent RR-intervals, with $r = 0.99$ (Figure 2). The correlation coefficient between the PP- and PR-intervals was also significant ($p < 0.0001$) with $r = 0.60$ (Figure 3). Figure 2 and 3 show the example of one patient.

The standard deviation of all NN intervals was 36.9 ± 11.5 ms for the PP-intervals 37.6 ± 12.1 ms for the RR-intervals. The difference between the PP-intervals and the RR-intervals was not significant.

Discussion

The present study describes a method of recording the beat-to-beat PP-interval non-invasively and of using this recording to determine the atrial rate variability. The main findings of the study are that atrial and ventricular rate variability behave similarly under rest conditions. In spite of this, the correlation between the PP- and PR-intervals was also statistically significantly weaker compared to that of the PP- and RR-interval. The latter need additional evaluation. For clinical impact, heart rate variability obtained from ventricular long-term ECG recording reliably reflects the sympathovagal balance of the sinus node.

Despite the intrinsic automaticity of cardiac tissue, the heart rate and rhythm is under the control of the autonomous nervous system. The fine-tuning of the beat-to-beat control mechanisms leads to the well-

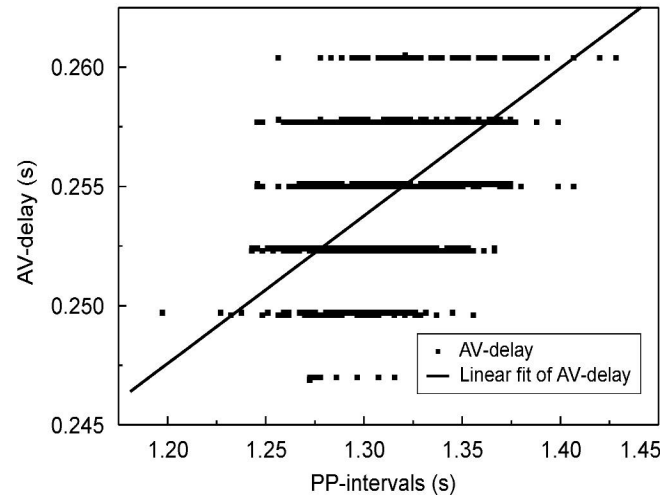


Figure 3. Correlation between PP- and PR-intervals of one patient.

known interval variations. A selective vagal denervation of sinus and AV nodes as well as atria decreases the heart rate variability [6]. The stretch of the sinoatrial node reduces the high-frequency heart rate variability [5]. In general, the atrial rate variability reflects the state and function of central oscillators, the sympathetic and vagal efferent activity, and humoral effects. In addition, the ventricular rate variability is modulated by the AV node conduction.

The detailed analysis of the PP and PR autonomic modulations is feasible with the present method. Under rest conditions, there were no significant differences between atrial and ventricular rate variability. Therefore, atrial rate variability mainly determines ventricular rate variability. The AV node has little or no modulating effects on ventricular rate variability. Nevertheless, additional investigations are still required to attain a better understanding of the interplay between atrium, AV node and ventricle [1].

References

- [1] Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Heart rate variability. Standards of measurements, physiological interpretation and clinical use. *Circulation*. 1996; 93: 1043-1065.
- [2] Algra A, Tijssen JG, Roelandt JR, et al. Heart rate variability from 24 hour electrocardiography and the 2-year risk for sudden death. *Circulation*. 1993; 88: 180-185.

-
- [3] Tsuji H, Vendetti FJ, Manders ES, et al. Reduced heart rate variability and mortality risk in an elderly cohort. The Framingham Study. *Circulation*. 1994; 90: 878-883.
- [4] Stein PK, Kleiger RE. Insights from the study of heart rate variability. *Annu Rev Med*. 1999; 50: 49-61.
- [5] Horner SM, Murphy CF, Coen B, et al. Contribution to heart rate variability by mechanoelectric feedback. Stretch of the sinoatrial node reduces heart rate variability. *Circulation*. 1996; 94: 1762-1767.
- [6] Chiou CW, Zipes DP. Selective vagal denervation of the atria eliminates heart rate variability and baroreflex sensitivity while preserving ventricular innervation. *Circulation*. 1999; 98: 360-368.
- [7] Nowak B. Taking advantage of sophisticated pacemaker diagnostics. *Am J Cardiol*. 1999; 83: 172D-179D.
- [8] Waktare JE, Malik M. Holter, loop recorder, and event recorder capabilities of implanted devices. *PACE*. 1997; 20: 2658-2669.
- [9] Malik M, Padmanabhan V, Olson WH. Automatic measurement of long-term heart rate variability by implanted single-chamber devices. *Med Biol Eng Comput*. 1999; 37: 585-594.
- [10] Hsiao HC, Chiu HW, Lee SC, et al. 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.