Influence of Postural Position, Respiratory Maneuvers and Exercise on Atrial Electrograms

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Summary

To evaluate the variations of P-wave amplitudes (PWA) during daily activities and to determine the modifications of PWA and slew rate (SR) during exercise, 15 patients (11 male and 4 female) with a mean age of 70.5 ± 10.5 years (range: 45 to 85 years) were studied before pacemaker implantation. Temporary atrial leads were implanted in all patients in the right atrial appendage and in the right lateral atrium; a dual-chamber analyzer evaluated the filtered beat-to-beat PWA and SR signals during exercise. During respiratory maneuvers, the average one-minute PWA decreases during relaxation after the Valsalva maneuver (2.84 ± 1.30 mV vs. 3.13 ± 1.39 mV, p < 0.002). During postural changes, the PWA increases (3.49 ± 1.19 mV in the sitting position and 3.53 ± 1.19 mV in the standing position, ns), and the highest PWA signal is located at rest in the right atrial appendage vs. the right lateral atrium (3.08 ± 1.50 mV vs. 2.74 ± 1.0 mV, p < 0.02). The mean decrease in voltage of PWA between exercise and rest reaches 28.5% ± 12.2 (from 3.08 ± 1.50 mV to 2.18 ± 1.01 mV, p < 0.0001). The reduced atrial electrogram amplitude can explain the loss of atrial sensing during exercise in patients with low PWA at rest.

Key Words

P-wave amplitude, slew rate, changes in postural position, respiratory maneuvers, exercise test

Introduction

Adequate atrial sensing has always been important for dual-chamber pacemakers. Inappropriate atrial sensing has the potential to induce pacemaker-mediated tachycardia, atrial arrhythmias and, as a consequence, atrial fibrillation [1]. The ability of pacemakers to sense P-waves is predicated on the amplitude (size of the P-wave) and the slew rate [2]. These parameters can be influenced by various physical factors (e.g., body position and respiration). In an experimental study, Bricker et al. [3] showed that the mean decrease was 15% for a unipolar atrial electrogram and 11% for a bipolar atrial electrogram during orthostatic and respiratory maneuvers. Fröhlig et al. [4,5] and Ross et al. [6] demonstrated that abnormal atrial sensing and attenuation of atrial electrogram size may occur during vigorous exercise. The aim of this study was to evaluate the variations in P-wave amplitudes and slew rates during postural changes and respiratory maneuvers. In addition, the atrial electrogram (with respect to P-wave amplitudes and slew rates) was monitored at rest and during exercise in active patients before pacemaker implantation with the goal to optimize the atrial sensitivity setting.

Materials and Methods

Patient selection

Fifteen patients (11 male and 4 female) with a mean age of 70.5 ± 10.5 years (range: 45 to 85 years) who were to receive a DDD pacemaker were included in this study. Ten patients had sick sinus syndrome, and 5 patients, second- or third-degree AV block. Patients with atrial flutter or atrial fibrillation, junctional rhythm, severe sinus bradycardia (less than 30 bpm), severe coronary artery disease, and the inability to perform the exercise tests were excluded from this study.

Protocol

Temporary two J-shaped, atrial bipolar leads (Cordis) were introduced in all patients before the implantation of a permanent DDD pacemaker: The first lead was placed in the right atrial appendage, the second lead in

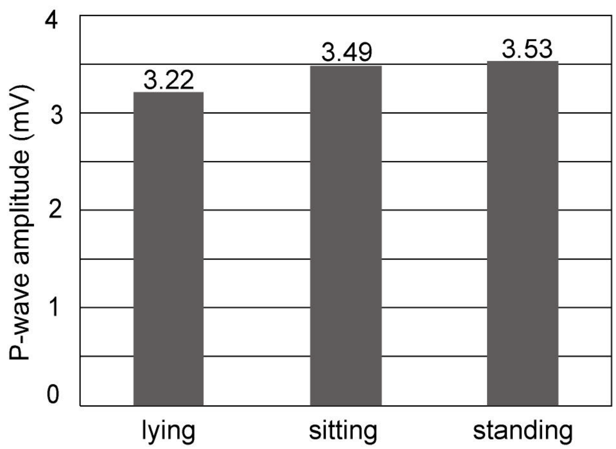

Figure 1. Influence of position on P-wave amplitude.

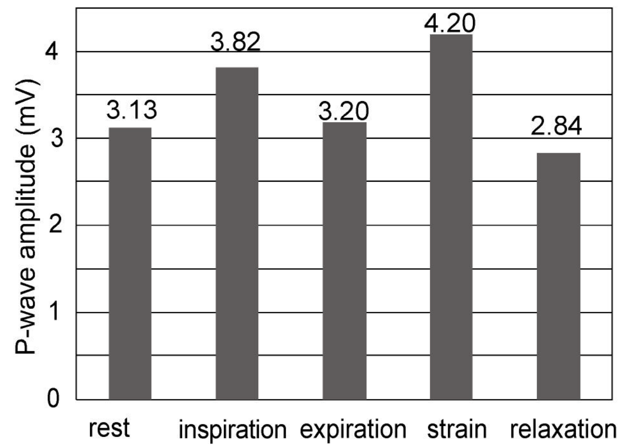

Figure 2. Influence of respiratory on P-wave amplitude.

the right lateral atrium. A dual-chamber threshold analyzer with a real-time intracardiac electrogram (ERA 300, BIOTRONIK, Germany) evaluated the unfiltered signal beat-to-beat and measured the P-wave amplitudes (PWA) and slew rates (SR). The mean values of PWA and SR for each test (posture and exercise tests) were calculated from 10 to 13 beats, and 2 independent observers studied the results. In random order, the PWA and SR were recorded in different postures (lying, sitting and standing positions) with patients performing quiet breathing. During the Valsalva maneuver, 3 consecutive atrial electrograms were studied at the end of the strain phase and at the beginning of the relaxation phase. The PWA and SR were recorded at the end of each minute of exercise (with an increase in load of 10 Watts per minute) as well as during the recovery period.

Statistical analysis

This study was prospective and controlled with each patient being his or her own control. Results were expressed as mean ± standard deviation. Analysis of PWA and SR measurements was based on a paired Student's t-test. A p-value < 0.05 was considered statistically significant.

Results

P-wave amplitude and slew rate monitoring

1) Influence of different postures

Variations in PWA and SR were found in different postures (Figure 1). The mean PWA was lower during a lying position (3.22 ± 1.41 mV) and increased by 7.7% in a sitting position and by 9.6% in a standing position. The variations in SR were similar with the increase from a lying to a sitting position (from 1.97 ± 0.69 V/s to 2.11 ± 0.61 V/s, ns) and to a standing position (2.12 ± 0.57 V/s, $p < 0.03$).

2) Influence of respiratory maneuvers

The influence of respiration revealed that the PWA increased with inspiration (+ 22%) and expiration (+2.2%) (Figure 2). However, the more significant test for evaluating the changes in PWA was performed with the Valsalva maneuver, which showed an increased PWA (+34.2%) during the strain phase. The lowest signal was obtained during the relaxation phase (-9.3%). The modifications of the SR are comparable with an increase during inspiration (from 1.95 V/s ± 0.67 at rest to 2.53 ± 0.72 V/s, $p < 0.00001$) and a significant decrease compared to SR at rest during the relaxation phase (1.81 ± 0.61 V/s, $p < 0.01$).

3) Influence of exercise and recovery period

A voltage decrease in the PWA was found in all patients during the exercise test. The timing pattern of electrogram decreased with varied exercise. Most patients showed a continuous reduction in signal amplitude as exercise progressed, but some patients had chiefly a decrease in the atrial electrogram voltage with the initiation of exercise. During the first minute of the recovery period, however, PWA increased to the initial values. Comparing the mean PWA during rest and during maximum exercise revealed a significant difference in all patients (3.08 ± 1.50 mV at rest vs. 2.18 ± 1.01 mV at the end of exercise, $p < 0.0001$). The mean percentage of decrease in

Patient	Resting Voltage (mV)	Max. Exercise Voltage (mV)	Decrease in Voltage (mV)	% Change from Resting
1	2.65 ± 0.06	2.30 ± 0.06	0.35	13.2%
2	4.03 ± 0.27	2.07 ± 0.06	1.96	48.6%
3	2.85 ± 0.47	2.18 ± 0.17	0.67	23.5%
4	1.61 ± 0.19	0.98 ± 0.24	0.63	39.1%
5	2.30 ± 0.31	2.10 ± 0.22	0.20	8.7%
6	5.53 ± 0.36	3.51 ± 0.52	2.02	36.5%
7	2.50 ± 0.20	1.80 ± 0.30	0.70	28%
8	5.72 ± 0.26	3.35 ± 0.33	2.37	41.4%
9	2.55 ± 0.13	2.10 ± 0.10	0.45	17.6%
10	2.10 ± 0.15	1.65 ± 0.47	0.45	21.4%
11	1.36 ± 0.25	1.01 ± 0.16	0.35	25.7%
12	5.35 ± 0.88	4.16 ± 0.57	1.19	22.2%
13	2.25 ± 0.55	1.38 ± 0.17	0.87	38.7%
14	4.10 ± 0.40	3.33 ± 0.71	0.77	18.8%
15	1.30 ± 1.10	0.72 ± 0.40	0.58	44.6%
Mean	3.08 ± 1.50	2.18 ± 1.01	0.90 ± 0.68	28.5% ± 12.2

Table 1. Atrial electrogram amplitude change with exercise.

PWA was 28.5 ± 12.2%, but the variations were variable (Table 1). For patient 2, the decrease in PWA reached 48.6% with a good atrial electrogram at rest. However, for patients 11 and 15 who showed low PWAs at rest, the amplitude change, 25.7% and 44.6%, respectively, might explain the loss of sensing at the end of exercise (1.01 mV and 0.72 mV, respectively). The results obtained with SR were similar with a decrease in the mean SR during maximal exercise (from 1.93 ± 0.78 V/s at rest to 1.42 ± 0.62 V/s, $p < 0.00001$).

4) Influence of the location of the atrial lead

The variations of PWA and SR were similar during respiratory maneuvers and postural positions in the right atrial appendage and right lateral atrium (increase between 17 and 24%). The mean PWA in the right atrial appendage was better at rest as compared with the mean PWA in the right lateral atrium (3.08 ± 1.50 mV vs. 2.74 ± 1 mV, $p < 0.02$). The decrease in the mean PWA was comparable at the end of the exercise (-28.5% in the right atrial appendage and -24.1% in the right lateral atrium) (Figure 3).

Discussion

This study demonstrated that respiratory maneuvers and postures have an effect on the PWA and SR. Variations in P-wave amplitudes during respiration have been previously described in the literature [8,9]. A mean variation of 9.7% was noted in the unipolar PWA during various phases of respiration [8]. Similar results were obtained in the bipolar PWA (11.5% respiratory variation). In another study, the maximal percentage respiratory change supine was 9.5%, and the full inspiratory and expiratory PWA were higher than the baseline PWA [7]. Rosenqvist et al. [9] demonstrated the substantial fluctuation of ventricular electrogram size and slew rate during the Valsalva maneuver

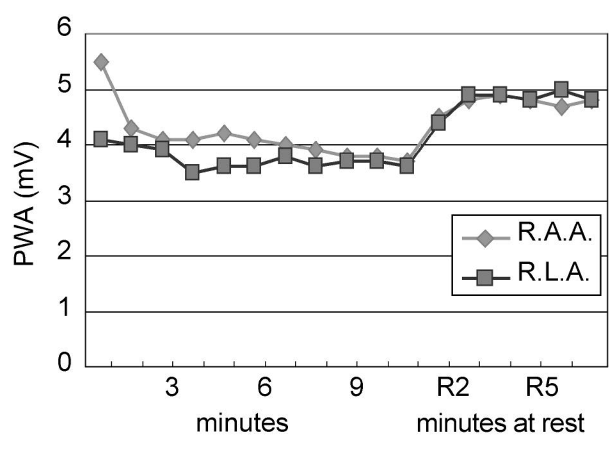

Figure 3. Variations of PWA in the right atrial appendage and the right lateral atrium (patient 6).

at the time of pacemaker replacement. At the end of forced inspiration, an increase in the ventricular electrogram amplitude (from 5 to 70%) was noted from the baseline, whereas a decrease from 15 to 50% was present during relaxation. Gao et al. [10] documented similar PWA variation in chronically implanted atrial leads with a mean change of -24% to +36% during the strain phase, and +36% to -25% during the relaxation phase. During the strain phase of the Valsalva maneuver, venous return is reduced and the increase in the thickness of the cardiac wall may enhance PWA. The relaxation with an increase in venous return has opposite effects. The modifications of the intrathoracic volume may change the direction of depolarization wave, inducing a change in the sensed electrogram. As the magnitude of variation in the PWA was larger during the Valsalva maneuver than the changes induced by posture, this test may represent a means to assess the adequacy of the safety margin for programmed atrial sensitivity [8,9].

Different results were obtained with variations of posture [11,12]. Shandling et al. [12] found that the mean PWA increased upon assuming the erect position (from 3.25 ± 1.2 mV to 3.49 ± 1.3 mV, $p < 0.001$). However, Gao et al. [10] showed a maximal attenuation of 6% (in the unipolar mode) and 8.8% (in the bipolar mode) in PWA during upright versus sitting positions.

During the exercise test, we observed a decrease in the mean PWA. Ross et al. [6] demonstrated a 1.64 mV mean PWA decrease (33.8% reduction) with passive or screw-in atrial leads in 11 young patients. In another study, Fröhlig [4,5] reported poor atrial sensing in 44% of the adults who underwent bicycle ergometry. The atrial electrograms decreased by 11.8% on average in a subset of 19 patients. Exercise testing with atrial electrogram data obtained through telemetry seems to be helpful in determining appropriate atrial sensitivity in selected patients. Obtaining the higher amplitude of PWA and SR during implantation is very important for avoiding the loss of atrial sensing during exercise. The mechanism behind the changes in the atrial electrogram voltage during exercise remains unclear. Changes in the respiratory pattern produced by exercise (hyperpnea) change the electrogram electrode axis affecting the vector of the signal seen by the lead. A change in atrial volume and atrial wall thinning can perhaps explain the variations of PWA and SR during exercise. The decrease in the atrial electrogram size may be exacerbated by various filtering techniques of pacemakers, and narrow band pass filtering may accentuate the loss of the sensed atrial electrogram [5]. The variations of PWA during the exercise test were confirmed by the modifications of the atrial electrogram during daily life activities. Boute et al. [13] demonstrated that a single measurement of the PWA had only a low predictive value of the distribution of PWA that might be seen during daily activities. Analysis of the PWA histograms obtained by telemetric measurements enables the programming of an appropriate atrial sensitivity and avoids atrial undersensing.

In patients implanted with permanent pacemakers, we have demonstrated that the mean decrease in PWA between rest and the end of exercise was -35.6% at the hospital discharge and -35.4% at the third month follow-up [14]. There was no significant variation of mean PWA between the acute and chronic periods after implantation.

Conclusion

Respiratory maneuvers, especially the Valsalva test, should be used as a screening test to assess the adequacy of a programmed atrial sensitivity level. In this study, the right atrial appendage seems to be the better location for atrial sensing. Atrial electrograms and slew rates appear to decrease significantly with exercise. The reduction in the atrial electrogram amplitude can explain the loss of atrial sensing during exercise in patients with low P-waves at rest. Bicycle or treadmill exercise testing may be helpful in patients with permanently implanted systems that normally function in an atrial-tracking mode to ensure atrial sensing with exercise. Autosensing in future devices must account for changes in atrial amplitudes during exercise.

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