Far-Field R-Wave Sensing in a DDD(R) Pacemaker with a Mode Switching Algorithm

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Summary

Optimal functioning of modern dual-chamber pacemakers requires adequate atrial sensing. Undersensing and oversensing in the atrium must be avoided, especially when mode switching algorithms are applied to prevent atrial arrhythmias from being conveyed to the ventricles by the pacemaker. Atrial oversensing is usually caused by sensing of myopotentials and far-field R-waves. It may lead to fast and irregular ventricular pacing rates or false positive mode switching resulting in asynchronous atrioventricular pacing. We studied clinical feasibility of high atrial sensitivities in the bipolar atrial sensing configuration. The incidence of both far-field R-wave sensing and myopotential sensing was evaluated in 55 patients implanted with dual-chamber pacemakers allowing 0.1 mV steps in the programming of atrial sensitivity. Comparative results in the unipolar and bipolar sensing configuration showed that bipolar sensing was superior in avoiding oversensing of both far-field R-waves and myopotentials. A bipolar atrial sensitivity of 0.3 mV was 100 % safe in the prevention of atrial oversensing.

Key Words

Atrial sensitivity, myopotential sensing, far-field sensing, mode switching

Introduction

Atrial sensing is a key feature in the optimal functioning of DDD pacing systems. Atrial oversensing usually results from myopotential sensing, defined as the sensing of muscle potentials by the atrial channel [1-2], or from far-field QRS sensing, [3-11] defined as sensing of the ventricular depolarization by the atrial channel of the pacemaker. Myopotential sensing in the atrial channel of a dual-chamber pacemaker may result in fast and irregular ventricular pacing rates or false positive mode switching to asynchronous atrial and ventricular pacing. Far-field R-wave sensing usually occurs no later than 150 ms after the ventricular event [8]. Since this basically falls within the post-ventricular atrial refractory period (PVARP), it is usually of no practical concern as long as no mode switching algorithm is involved.

In modern DDD(R) devices that utilize mode switching algorithms, atrial sensed events occurring during the PVARP are used to 'feed' the mode switching algorithm. Therefore, far-field R-wave sensing has become an important issue, since failing to avoid it may lead to false positive mode switching [12-13]. Also, in a dual-chamber defibrillator, far-field QRS sensing was found to cause delivery of inappropriate atrial antitachyarrhythmic therapies [14]. In this in vivo study, we focused on the incidence of both myopotential and far-field R-wave sensing when using high atrial sensitivities (< 0.5 mV).

Materials and Methods

We studied 55 patients (29 male, 26 female), aged 44 - 89 years (mean age 71 years). All patients received a dual-chamber device (Actros DR, Biotronik, Germany) that allowed programming of atrial sensitivities down to 0.1 mV. The post-ventricular atrial blanking period (PVAB) in this pacemaker is fixed at 56 ms. All patients were implanted with a bipolar tined atrial J-shaped lead with a ring-tip distance of 14 mm (Synox SX 53 JBP, Biotronik, Germany). The atrial lead was

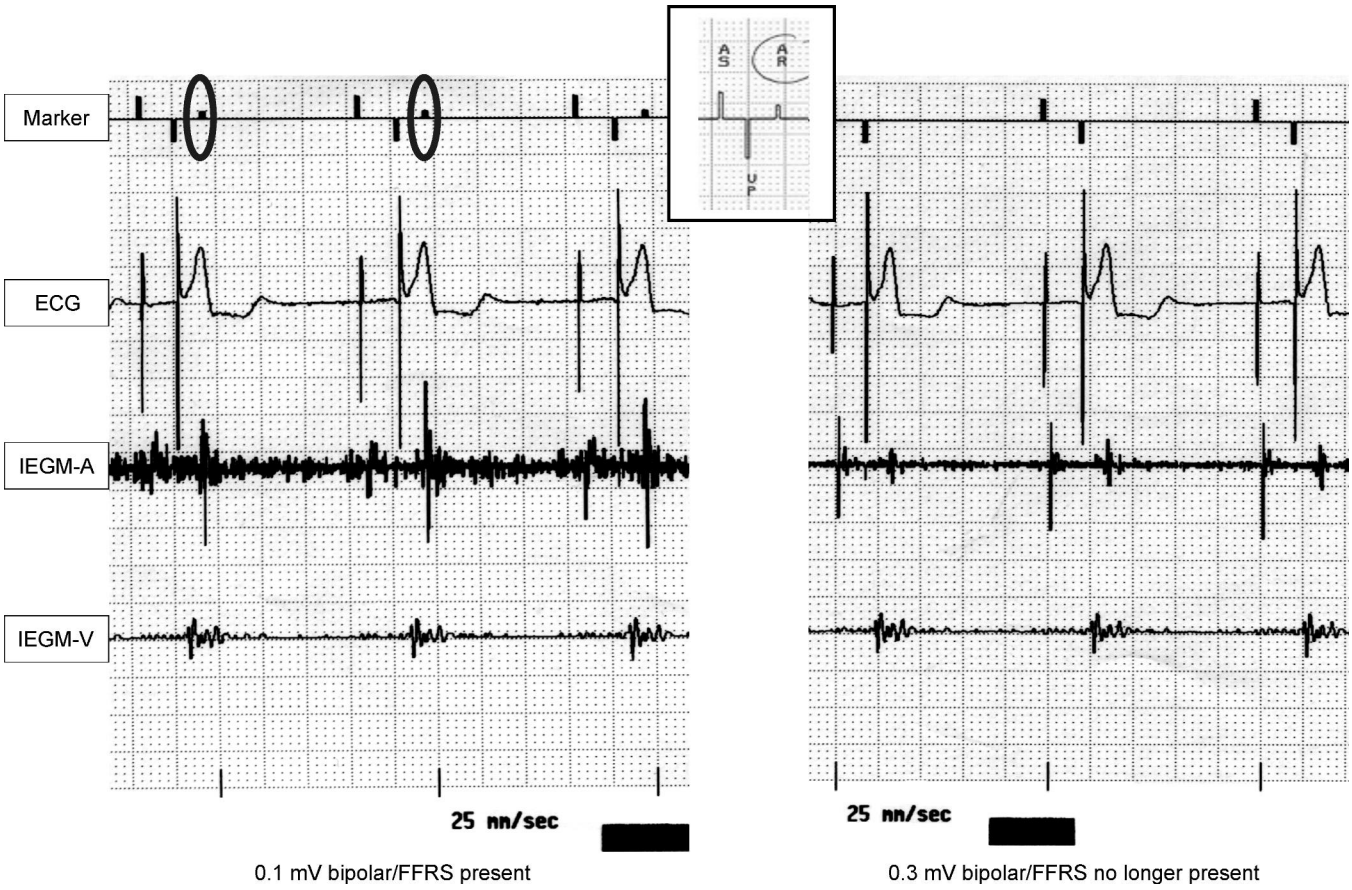

Figure 1. FFRS test at atrial sensitivities of 0.1 mV and 0.3 mV in the bipolar sensing configuration.

preferably positioned in the right atrial appendage under fluoroscopic guidance. Ventricular leads were either of the unipolar tined type (Polyrox PX 60-UP, n = 53, Biotronik, Germany), or of the bipolar tined type (Synox SX 60 BP, n = 2, Biotronik, Germany). All patients were tested either at the time of hospital discharge or at the first routine follow-up. Prior to the 'specialized testing', both pacing and sensing thresholds were determined. When testing far-field R-wave and myopotential oversensing, all pacemakers were programmed to the DDD mode, unipolar ventricular pacing at 3.6 V/0.4 ms and fixed AV delay of 100 ms in order to ascertain ventricular pacing.

Far-field R-wave sensing (FFRS) and myopotential sensing (MS) were evaluated at different atrial sensing polarities (unipolar/bipolar). The FFRS threshold was defined as the highest atrial sensitivity setting without far-field detection of the paced R-wave by the atrial sensing amplifier. During both FFRS and MS testing, simultaneous recording of the atrial and ventricular IEGMs (intracardiac signals), marker channels (A&V), and surface ECG was done by means of the pacemaker programmer (PMS 1000 C, Biotronik, Germany). Far-field R-wave sensing was evaluated during AV synchronous ventricular pacing, applying a PVAB of 56 ms during which the atrial channel of the pacemaker is completely 'blinded'. As illustrated in the left panel of Figure 1, FFRS could clearly be demonstrated by the presence of a refractory atrial sense marker within the first 200 ms. The test was repeated at the next lower sensitivity setting in each case, until FFRS was no longer present (right panel in Figure 1)

Myopotential testing was conducted by provoking pectoral muscle potentials by performing a typical 'push/pull' maneuver at the pacemaker site. As illustrated in the left panel of Figure 2, the presence of multiple atrial sensing markers not related to atrial activity was the indicator for myopotential sensing. In contrast to FFRS testing, this testing was not always started at the most sensitive setting of 0.1 mV, but at a setting

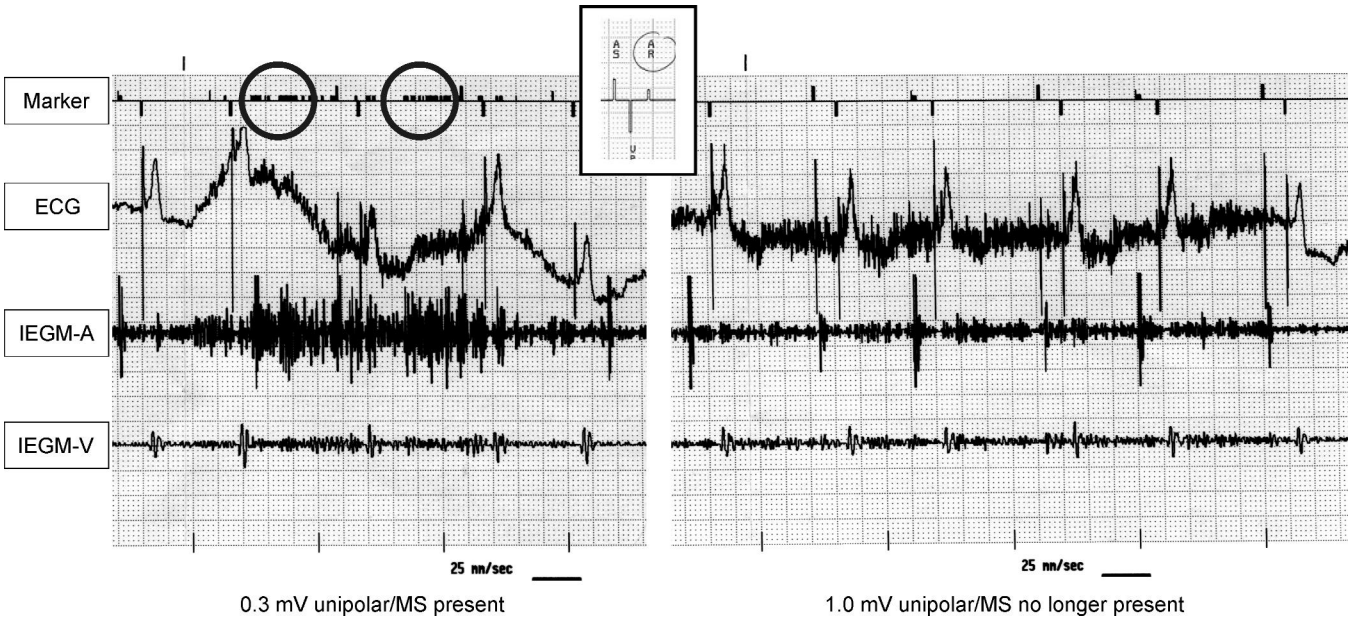

Figure 2. MS test at atrial sensitivities of 0.3 mV and 1.0 mV in the unipolar sensing configuration.

corresponding to the FFRS threshold as determined by the FFRS test. In a manner similar to the FFRS testing described above, MS testing was repeated at the next lower sensitivity setting in each case until MS was no longer present (see Figure 2, right panel).

Results

At follow-up, the mean P-wave amplitude measured in the bipolar sensing configuration was 3.42 ± 1.28 mV (n = 53, range 0.9 - 6.4 mV). R-wave amplitudes measured in the unipolar sensing configuration were 13.8 ± 4.07 mV (n = 48, range 6.7 - 23.4 mV). Unipolar atrial pacing thresholds were 0.50 ± 0.35 V at 0.4 ms (n = 54, range 0.1 - 1.4 V) and unipolar ventricular pacing thresholds 0.64 ± 0.32 V (n = 52, range 0.3 - 1.9 V). The impedance values of the atrial and ventricular leads were 843 ± 197 Ω (n = 53, range 595 - 1250 Ω) and 631 ± 122 Ω (n = 53, range 406 - 1080 Ω), respectively (Table 1).

The results of FFRS testing are shown in Table 2, representing the cumulative percentage of patients free from far-field R-wave sensing for unipolar and bipolar modes and different values of the programmed atrial sensitivity. As expected, susceptibility to FFRS was significantly higher in the unipolar sensing configuration. Mean values for the 'FFRS threshold' (where FFRS was no longer seen), was 0.34 ± 0.19 mV in the

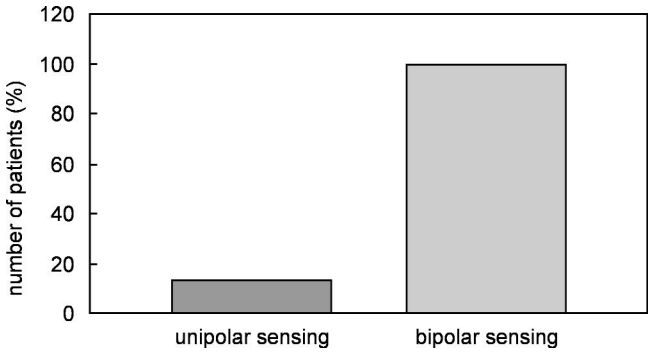

Figure 3. Percentage of patients free from myopotential sensing at FFRS threshold.

	Atrial mean ± SD	Ventricular mean ± SD
Sensing (mV)	3.42 ± 1.28	13.8 ± 4.07
Pacing threshold (V)	0.50 ± 0.35	0.64 ± 0.32
Pacing impedance (Ω)	843 ± 197	631 ± 122

Table 1. Pacing and sensing values at follow-up.

		Atrial sensitivity (mV)										
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1
Cumulative percentage of patients	Unipolar sensing	4	31	72	81	88	92	96	96	98	98	100
	Bipolar sensing	17	87	100	100	100	100	100	100	100	100	100

Table 2. Cumulative percentage of patients free from far field R-wave sensing.

unipolar and 0.21 ± 0.06 mV in the bipolar sensing configuration. At a setting of 0.3 mV/bipolar, all patients were free from FFRS. With unipolar sensing, FFRS was still seen in one patient at 1.0 mV. Figure 3 represents the percentage of patients free from myopotential sensing at the previously determined 'FFRS-threshold' (for both uni- and bipolar sensing configuration). As expected, myopotential sensing was only observed in the unipolar sensing mode. In the majority of cases (84.1 %), the unipolar myopotential-sensing threshold was found to be higher than the unipolar FFRS threshold. The average unipolar sensing threshold for those patients was 0.61 ± 0.26 mV. In one patient, myopotential sensing only disappeared at atrial sensitivities above 1.3 mV.

Discussion

Our study illustrates that a bipolar sensing configuration is clearly superior in avoiding far-field R-wave sensing. The use of high atrial sensitivities in combination with unipolar sensing should be avoided, given the high incidence of both myopotential and far-field R-wave sensing. With bipolar sensing, high atrial sensitivities (below 0.5 mV) can be used safely: in our configuration, an atrial sensitivity of 0.3 mV/bipolar combined with a short PVAB of 56 ms has proven to be a reliable setting in all patients both in terms of far-field and myopotential sensing. Some concerns exist in terms of reliability and duration of bipolar leads. Exner et al. suggest that unipolar leads can be used safely if isometric maneuvers are used to assess the myopotential sensing threshold [15]. However, as our results indicate, this often means programming atrial sensitivities of more than 1.0 mV, possibly compromising adequate atrial sensing of P-waves and atrial arrhythmias. Bipolar sensing characteristics are clearly superior in avoiding the sensing of unwanted signals [16].

If the far-field R-wave sense falls outside the technical refractory period, a special kind of pacemaker-mediated tachycardia could arise. This phenomenon is usually not observed with standard pulse generator settings. However, possible problems could arise with far-field R-wave sensing when refractory atrial senses become important, which is the case with mode switching algorithms. Far-field QRS senses could give rise to false positive mode switching episodes [12-13]. Various approaches can be used to avoid this problem. Simple prolongation of the PVAB is not helpful because this can cause mode switching failure; particularly in the case of slow atrial flutter, there is a risk that every other P-wave will be blanked within the PVAB [17]. Therefore, keeping a short PVAB in combination with an atrial sensitivity setting slightly above the FFRS threshold should be the preferred choice.

Lead design and position could also play a role. As our results indicate, bipolar sensing also reduces the risk of far-field R-wave sensing. The distance between the two poles of bipolar atrial leads influences the occurrence of FFRS, as the far-field QRS amplitude has been shown to increase with a longer spacing between tip and ring [18]. As far as optimal lead position (lateral or medial parts of the right atrium) is concerned, the data are conflicting [10]. Selective atrial signal detection could be obtained with appropriate atrial filtering because the slew rates of P-waves and far-field R-waves are different [5]. However, this attempt has not yet been shown to be suitable.

Conclusion

Our results show that in the studied bipolar pacing system, the combination of a short PVAB and high atrial sensitivities can be used effectively to avoid far-field R-wave sensing. Further testing is advised to evaluate the impact of other parameters such as lead position,

ring-tip distance on the atrial lead, and filtering characteristics of the device used.

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