Imaging in Cardiology: Far-Field Sensing of P-waves on a Standard Right Ventricular Lead

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Introduction

Automated mode switch algorithms, event counters of atrial arrhythmias, stored intracardiac electrograms, and implantable cardioverter defibrillator (ICD) implantations have stressed the importance of adequate sensing by cardiac pacemakers and ICDs, without undersensing of atrial signals and without sensing of far-field signals. The conditions for proper lead functioning should be ensured during implantation. Afterwards, limited interventions are possible, mostly by device reprogramming. In severe cases, more drastic measures can be undertaken, such as repositioning of the lead. Lead implantation, either in the atrium or in the ventricle, is guided by the four following rules: a stable position, ST elevation on the unfiltered intracardiac ECG recording, good sensing characteristics, and last but not least a good pacing threshold. Furthermore, far-field sensing of unwanted and disturbing signals of remote ventricular activity are very often seen with the atrial lead, irrespective of the tip position [1-5]. Sensing of remote atrial activity with conventional right ventricular leads is rarely described [6-8]. This article reports on the occurrence of far-field sensing of the atrium with a standard bipolar ventricular lead.

Case Report

A 76-year-old woman received a VVI pacemaker to treat symptomatic short episodes of bradycardia after her mitral valve surgery. Due to mitral valve stenosis, she underwent surgery 4 years ago with the implantation of a prosthesis in the mitral position. She had symptoms of palpitations, which were diagnosed on an ambulatory ECG as paroxysmal atrial fibrillation. It was decided to exchange the VVI pacemaker for a DDD pacemaker with preventive pacing algorithms (Stratos LA, Biotronik, Germany). The upgrade of the pacemaker system also included the implantation of two atrial leads: one standard atrial lead (Elox, Biotronik) and one special lead for pacing in the great cardiac vein (Corox LA, Biotronik).

The previously implanted ventricular lead (5054, Medtronic, USA) was tested using routine measurements, with the following results: R-wave was 18.6 mV; pacing threshold was 0.5 V at 0.5 ms; pacing impedance was 928 Ω. An intracardiac recording is always displayed on the pacing system analyzer (ERA 300B, Biotronik) and on an ECG monitor, which allows monitoring of arrhythmias, ST elevation, R-wave amplitudes, and the slope of the R-wave. In this particular case it was remarkable that a large P-wave was observed on the intracardiac ventricular ECG, which was also displayed on the IEGM screen of the pacing system analyzer (Figure 1). After adjusting the ventricular sensitivity on the pacing system analyzer, the amplitude of the far-field P-wave could be measured and was about 0.5 mV (Figure 2). In the default setting of the pacing system analyzer, low amplitude signals can be missed because the ventricular sensitivity is set to 2.5 mV. Fluoroscopy in the anteroposterior direction showed a bipolar ventricular lead, whose tip was positioned near the tricuspid valve, in the lower part of the right ventricular inflow tract (Figure 3). In this case, the ventricular electrode was left in place, and any future programming of the ventricular sensitivity should be restricted to high or nominal values; if the device is reprogrammed to an unipolar sensing configuration, sensing of the remote P-waves should be tested.

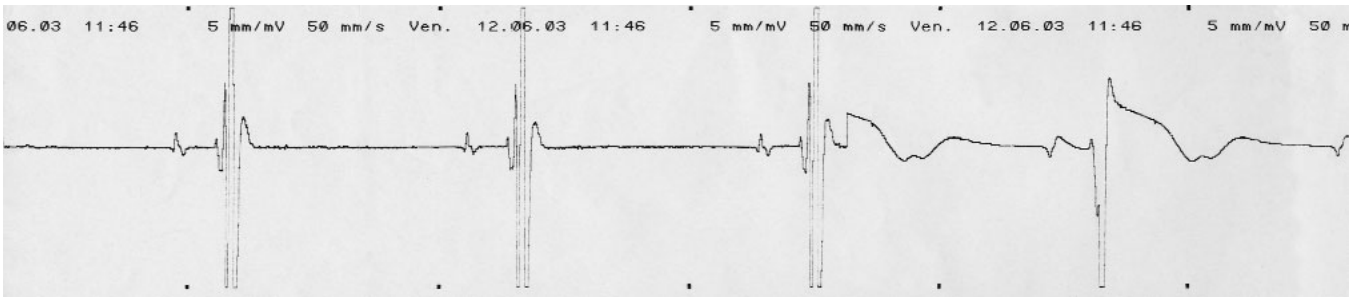

Figure 1. The bipolar ventricular intracardiac recording shows a distinct P-wave and a large R-wave. The filtered ECG is displayed on the left-hand side, and the unfiltered ECG is shown on the right-hand side. The amplitude of the far-field P-wave can be measured after adjusting the sensitivity of the ventricular channel to 0.5 mV, which is the highest ventricular sensitivity setting of the pacing system analyzer.

Cardiac Signal Measurements

Time	P-Pot.	R-Pot.	PP-RR	PQ
11:45:32	6.0 mV	19.0 mV	1138 ms	212 ms
11:46:21	--.- mV	0.5 mV	---- ms	--- ms
11:46:21	--.- mV	19.9 mV	---- ms	--- ms
11:46:22	--.- mV	18.1 mV	1162 ms	--- ms
11:46:23	--.- mV	0.5 mV	1002 ms	--- ms
11:46:24	--.- mV	19.9 mV	---- ms	--- ms
11:46:25	--.- mV	19.7 mV	1164 ms	--- ms
11:46:26	--.- mV	19.4 mV	1162 ms	--- ms
11:46:27	--.- mV	0.5 mV	994 ms	--- ms
11:46:27	--.- mV	20.2 mV	---- ms	--- ms
11:46:28	--.- mV	0.5 mV	990 ms	--- ms
11:46:28	--.- mV	17.9 mV	---- ms	--- ms
11:46:29	--.- mV	19.6 mV	1170 ms	--- ms

Figure 2. The measurements with the pacing system analyzer (ERA300B, Biotronik, Germany) are printed out and give alternating high and low values: the high values correpond to the R-waves, and the low value represents the measurement of the far-field P-wave on the ventricular electrode.

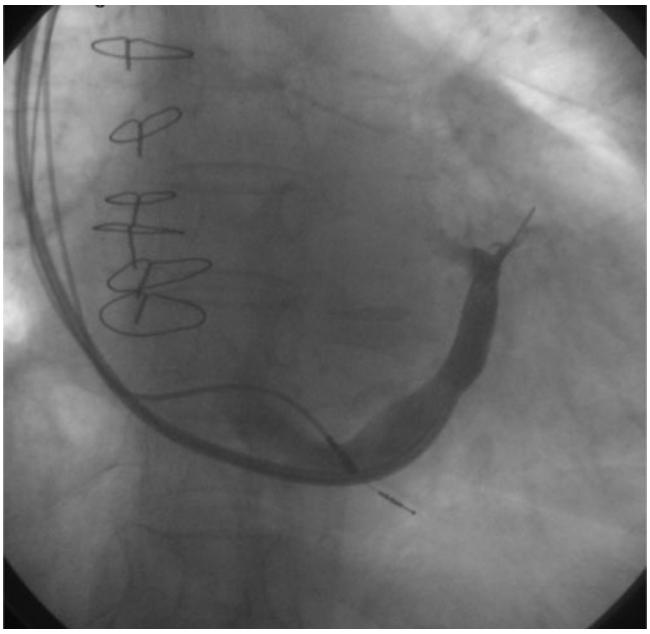

Figure 3. Fluoroscopic images of the patient in the anteroposterior direction, showing the bipolar ventricular lead. X-ray contrast is delivered through a long sheath into the coronary sinus (great cardiac vein), for positioning of the left atrial lead (Corox LA, Biotronik, Germany). Note that the tip of the ventricular lead is positioned just over the tricuspid valve, in the inflow tract of the right ventricle. The ring electrode of this lead is then in the vicinity of the right atrium. The position of the tricupid valve can also be "imagined" by the presence of the curve in the ventricular lead.

Discussion

Ventricular far-field signals being picked up by the atrial lead is conceiveable and understandable for standard leads positioned at standard locations, i.e., the right atrial appendage or high right atrium. This is in contrast to remote sensing of atrial activity with standard ventricular leads. The detection of this phenomenon has been described in only a few cases [6-8]. In most cases the intracardiac recordings are not meticulously studied. In many recordings the far-field P-wave can be identified, as is demonstrated in a study by Greenhut et al. [9]. In this exploratory study, remote sensing of the atrial activity with a standard pacing lead (4 patients) or temporary quadripolar electrophysiology catheter (16 patients) was possible with variable results. Measurements were taken in the unipolar configuration, and in most patients sensing with the proximal electrode was better than with the distal electrode. Peak far-field P-wave amplitudes varied between 0.1 and 0.7 mV or 0.2 and 0.6 (mean 0.4 mV), respectively, for the proximal and distal electrode. It has to be stressed that this study was performed during sinus rhythm, over a very short period of time, with the patient in a resting supine position. In clinical cases with implanted endocardial ventricular leads, oversensing was observed at

high sensitivity settings: 0.6 to 1.25 mV [6-8], Thus, high sensitivity settings predispose the device to sense low-amplitude, far-field signals. This can be hazardous to patients with ICDs featuring automatic adjustment of the ventricular sensitivity. This complication has been reported in one case with epicardial leads [10]. Oversensing of P-waves leads to the inhibition of ventricular pacing, and the patient developed long periods of ventricular asystole. Whenever present, high sensitivity settings should be avoided, and in case of ICDs with automatic sensitivity adjustment into the range of far-field amplitudes, the ventricular shock lead should be replaced or repositioned.

In general, the four basic rules of correct lead implantation are mechanical stability, ST elevation (> 2 mm), adequate sensing (ventricle > 5 mV), and an adequeate acute pacing threshold (ventricle < 1 V at 0.5 ms). These rules are used for the implantation of both ICD and pacemaker leads. The rule of four can, however, be extended to the rule of six. During implantation, the possibility of unwanted sensing of signals such as far-field electrical activity should be avoided as much as possible. The presence of P-waves on the ventricular lead is not acceptable for ICD patients. To complete the list of rules, rule 6 is the absence of stimulation of tissues other than the target tissue, such as phrenic nerve pacing, which can be produced by left ventricular pacing or by right atrial free wall pacing.

In this case, the tip of the electrode was positioned just over the tricuspid valve, in the inflow tract of the right ventricle. The proximal electrode is then too close to the atrium. Another factor of far-field sensing may be the long interelectrode distance, which may vary with the used electrode from 0.9 cm up to 6.6 cm. In the case report of van Gelder et al. [7], an insulation defect was presumed, but the positioning of the ventricular lead tip in the inflow tract of the right ventricle was not 100% excluded. In the patient in this case report, the interelectrode distance was average at 17 mm, and this may have played an additional role in the bipolar sensing of the remote atrial activity. A third cause of far-field P-wave sensing can be dislocation of the ventricular lead to a more "proximal" position, which may also be accompanied by an increase of the ventricular threshold. Repositioning is recommended when the remote P-waves are too large, whose absolute value is related to the implanted device. For ICD implantations, P-waves in the ventricular chanel of 0.3 mV in amplitude, or higher, are not acceptable. When remote sensing of atrial activity newly occurs in a previously implanted pacemaker or ICD system, then the possibility of an insulation defect has to be eleminated. Furthermore, unipolar sensing configurations and positions at the lower septum or in the great cardiac vein are more often associated with far-field sensing [1-5]. Far-field signals on standard ventricular leads can be observed and may play an important role in the functioning of the pacemaker or ICD. The implanting physician and supporting technicians should take notice of these signals on a routine basis; the rule of four can be changed to the rule of six.

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