RESPIRATORY ARRHYTHMIA AS AN ENCOURAGEMENT OF INAPPROPRIATE ICD THERAPY

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Abstract
Implantable cardioverter-defibrillators (ICDs) are active cardiac implants for immediate treatment of ventricular arrhythmias. They provide life-saving therapy, but may also deliver inappropriate therapy. These two cases demonstrate a possibility of ICD therapy detection or induction encouraged by physiological patient breathing. The cases of 64-year-old and 30-year-old women patients are reported. The first one has received some therapy, the second one has not. The devices records did not show any abnormalities in trends or electrical parameters. As a solution, the detection parameters of the devices were optimized, with reference to individual physiologically reachable heart rates of the patients.

Keywords
implantable cardioverter-defibrillator; respiration; inappropriate shock

Introduction

Respiratory sinus arrhythmia is one of the physiologic interactions between respiration and circulation. It is heart rate variability in synchrony with respiration, by which the R-R interval on an ECG is shortened during inspiration and prolonged during expiration. [1]

Inappropriate ICD therapy is probably the most often adverse event caused by implantable cardiac devices. It can be commonly triggered by supraventricular tachycardia [2], or by other physiological sources [3], non-physiological sources [4] or device programming issue [5]. Inappropriate shock therapies are painful, anxiety-inducing, and impair patient quality of life [6]; they may also worsen the prognosis due to myocardial damage caused by repeated shock therapies. [7]

For reduction of inappropriate therapy, the supraventricular tachycardia (SVT) discriminators have been implemented in the detection process. The discriminators may have different approaches at arrhythmia discrimination, like analysis of the interval patterns (onset, stability, atrium to ventricle rate relationship) or morphologic analysis of the intracardiac electrogram (EGM). The morphology discrimination is based on the algorithmic comparison of the ventricular EGM during ventricular tachycardia or suspending ventricular tachycardia with a stored reference template obtained during baseline rhythm. [8] Although some similarities exist, the functioning of discriminators is different across manufacturers. [9] Nevertheless, the proper device programming after implant and during routine follow-ups is the key for patient protection and successful living without fear from improper shock interventions.

The aim of this paper is to show the importance of the individual patient programming and proper use of morphology discrimination algorithms. Both cases show the false detection of sinus respiratory arrhythmia as ventricular arrhythmia, first even with some unsuccessful and useless defibrillation shocks.

Methods

Both cases were observed during routine ambulatory patient follow-up. For the case 1, the dual chamber ICD device was programmed according to current clinical recommendations. The bradycardia pacing mode DDD with a lower rate limit of 50 min^{-1}, pulse output of 2.0 V and 0.5 ms for the right atrium and ventricle. Tachycardia detection zones were 150 min^{-1} (VT) and 200 min^{-1} (VF). In discussed VT zone, the

initial detection duration was 2.5 s then ATP and shocks therapy. For the case 2, the single chamber ICD device was programmed to bradycardia pacing mode VVI with a lower rate limit of 40 min^{-1}, pulse output of 2.0 V and 0.4 ms for the right ventricle. Tachycardia detection zones were 180 min^{-1} (VT) and 220 min^{-1} (VF). In discussed VT zone, the initial detection duration was 2.0 s then ATP and shocks therapy.

Event	Date/Time	Type	Therapy	Duration hh:mm:ss
V-23	17 Mar 2015 20:02	NonSustV	Nonsustained	00:00:07
V-22	02 Mar 2015 20:40	VT	No Therapy	00:02:33
V-21	02 Mar 2015 20:37	VT	No Therapy	00:01:02
V-20	02 Mar 2015 20:35	VT	No Therapy	00:02:06
V-19	02 Mar 2015 20:34	VT	No Therapy	00:00:32
V-18	02 Mar 2015 20:30	VT	No Therapy	00:00:31
V-17	02 Mar 2015 20:29	NonSustV	Nonsustained	00:00:15
V-16	02 Mar 2015 20:29	VT	No Therapy	00:00:21
V-15	02 Mar 2015 20:28	NonSustV	Nonsustained	00:00:17
V-14	02 Mar 2015 20:19	VT	No Therapy	00:01:02
V-13	02 Mar 2015 20:17	NonSustV	Nonsustained	00:00:24
V-12	02 Mar 2015 20:16	NonSustV	Nonsustained	00:00:25
V-11	24 Jan 2015 15:29	NonSustV	Nonsustained	00:00:36
V-10	18 Dec 2014 20:03	NonSustV	Nonsustained	00:00:36
V-9	24 Nov 2014 20:22	NonSustV	Nonsustained	00:01:08
V-8	20 Nov 2014 18:34	NonSustV	Nonsustained	00:00:13
V-7	16 Sep 2014 16:42	NonSustV	Nonsustained	00:00:09
V-1	19 Aug 2013 12:42	VF	Induced: No Therapy	00:00:14

Fig. 1: Example of the arrhythmia list stored in the device. Date, type, duration and relevant therapy are provided.

The type of programmer used was a Boston Scientific Zoom Latitude model 3120. Described episodes originated between last and current ambulatory follow-up were stored in the device. The device diagnostic (Fig. 1) offers checking of the recorded arrhythmia episodes stored in the device and display and print the EGMs.

Case report 1

A sixty-four-year-old woman patient with ischemic cardiomyopathy, atrial flutter and bundle brunch block (BBB), has history of sustained ventricular fibrillations. A dual-chamber ICD with integrated bipolar dual coil lead for the right ventricle was implanted. The ICD was programmed into two zones: 150 min^{-1} for ventricular tachycardia (VT zone) and 200 min^{-1} for ventricular fibrillation (VF zone). After the testing of sufficient intrinsic R-wave amplitude at the implant, the ventricular sensitivity was programmed to a value of 0.6 mV with automatic gain control. The programmed therapies were burst and ramp ATPs, 26 J, 36 J and multiplied 41 J shocks for the VT zone, and antitachycardia pacing (ATP) up to 250 min^{-1} plus 36 J shocks then multiplied 41 J shocks for the VF zone.

During the routine follow-up, the device memory has shown two sequences of ATP and six shocks without

any therapeutic effect. The EGM printout did not show any useful information; sequential atrial/ventricular sensing indicated the accelerated supraventricular (sinus) tachycardia. The interval analyzing, offered by this type of device, showed up interesting graphical relation of consecutive cardiac intervals.

An episode stored in the device memory is shown in Fig. 2. This is the EGM interval diagram time course of the tachycardia. The full dots stand for sensed events, the empty ones for paced events (not appropriate here except the ATPs). As the VT zone cut-off rate 150 min^{-1} (interval 400 ms) is quite low, the increase of heart rhythm during inspiration caused the cardiac interval to pass this value and to start the tachycardia detection process. The atrial (round dots) and ventricular (square dots) cardiac cycles are of the same duration, so the recorded rhythm is a sinus tachycardia. Definitely, it cannot be known before, but the variation of heart rate below (during expiration) and above (during inspiration) the VT zone cut-off rate is unique. Respiratory rhythm can be seen also in the further course of tachycardia, which was accelerated to higher heart rate. The susceptibility for the heart rhythm to the respiratory and therapy resistance show also evidence for sinus tachycardia.

As a solution, the VT zone cut-off rate was moved to 165 min^{-1} and monitoring zone was establish from 140 min^{-1} to 165 min^{-1}.

Case report 2

A thirty-year-old woman patient with no structural heart disease received a single-chamber ICD with integrated bipolar dual coil lead for primary prevention. The ICD was programmed into two zones: 180 min^{-1} for ventricular tachycardia (VT zone) and
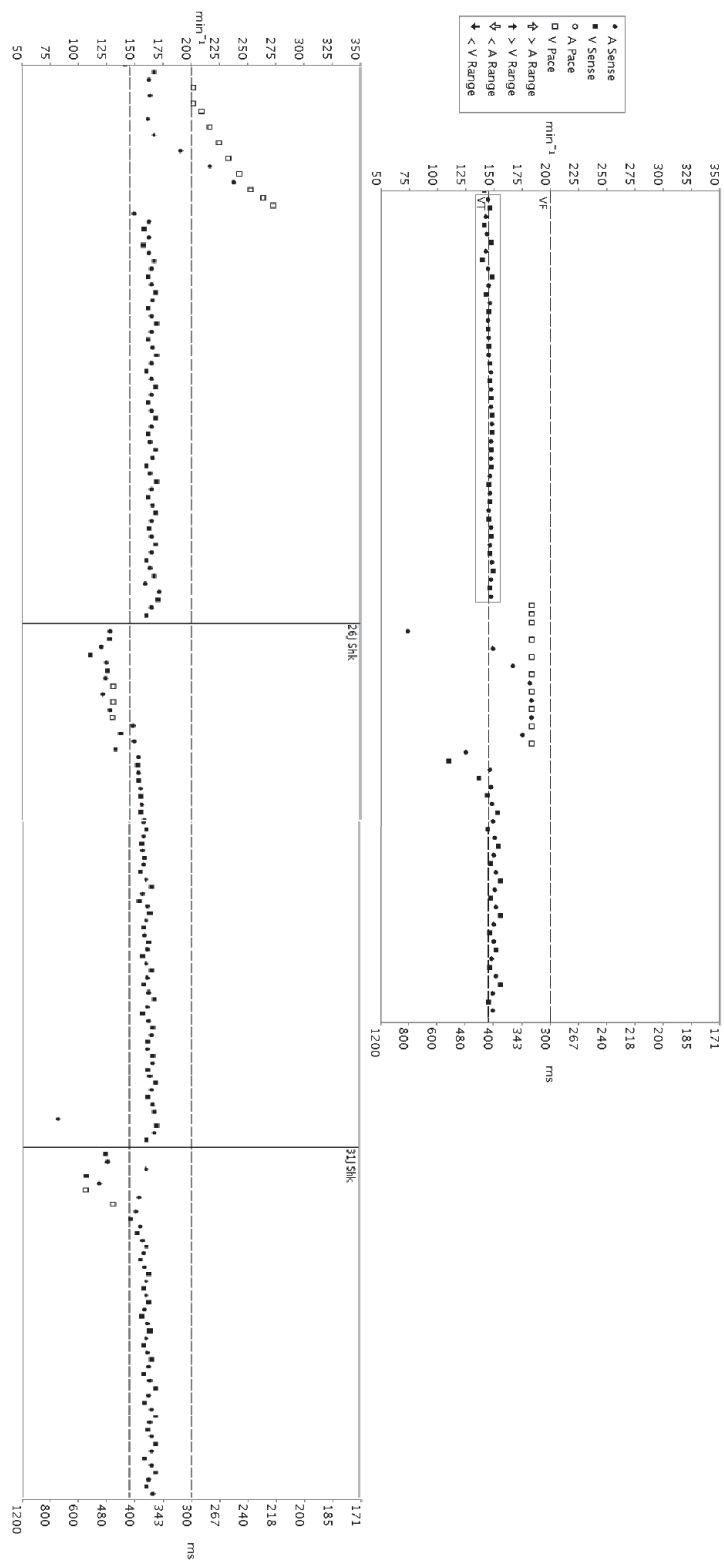
Fig. 2: Interval diagram of stored arrhythmia for case report 1. Each dot is the graphic representation of one cardiac cycle (round for P-P interval and square for R-R interval), e.g. the differences between adjacent P waves or R waves. See the legend provided on the upper left side. The left axis shows the heart rate in min⁻¹, the right one shows the interval in ms. Cut-off rate 150 min⁻¹ for VT and 200 min⁻¹ for VF zone (dashed lines). Burst and Ramp ATP can be seen, than the unsuccessful shocks. Note the respiratory-affected onset of the tachycardia in the box.
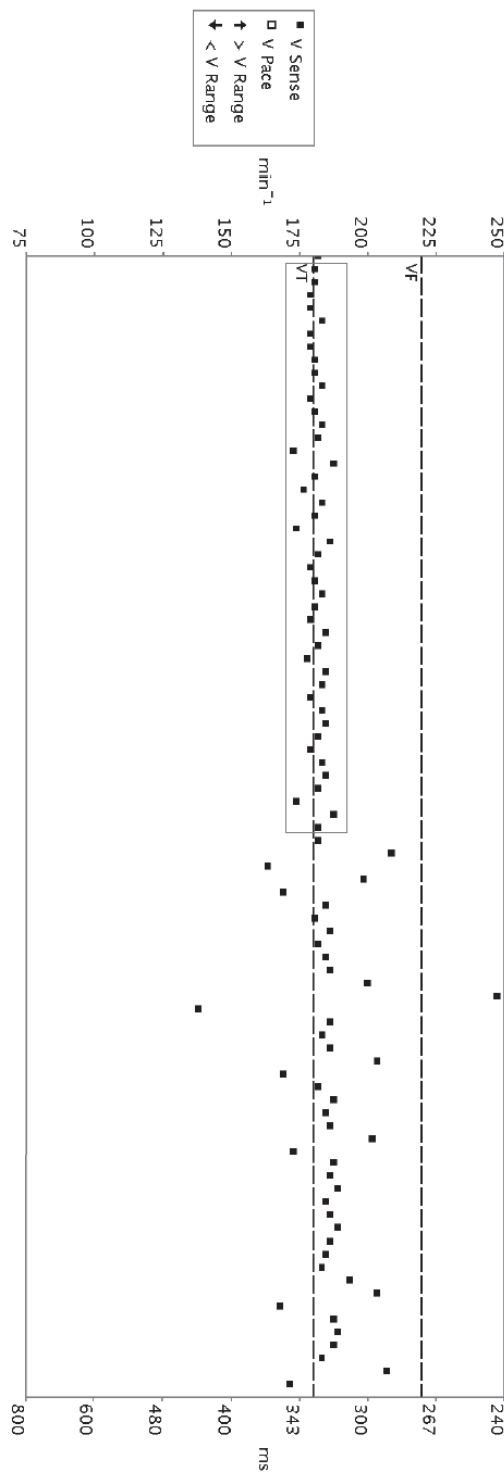
71

Fig. 3: Interval diagram of stored arrhythmia for case report 2. Each dot is the graphic representation of one cardiac cycle (just R-R intervals in this case) e.g. the difference between the adjacent R waves. See the legend provided on the left side. The left axis shows the heart rate in min^{-1}, the right one shows the interval in ms. Cut-off rate was 180 min^{-1} for VT and 220 min^{-1} for VF zone (dashed lines). Note the respiratory-affected onset of the tachycardia in the box.

220 min^{-1} for ventricular fibrillation (VF zone). After the testing of sufficient intrinsic R-wave amplitude at the implant, the ventricular sensitivity was programmed to a value of 0.6 mV with automatic gain control. The programmed therapies were three scan bursts of ten pulses, three ramps of ten pulses, 21 J, multiplied 41 J shocks for the VT zone and ATP up to 250 min^{-1} plus multiplied 41 J shocks for the VF zone.

During the additional follow-up, the device memory has shown eleven consecutive nonsustained VT episodes just around the VT zone cut-off rate. As the device was just the single chamber ICD, EGM printout cannot provide more details. The interval analyzing showed up graphical relation of consecutive cardiac intervals.

A typical episode stored in the device memory is shown in Fig. 3. The Figure description is similar as in the previous case. As this young patient can still physiologically reach the VT zone cut-off rate 180 min^{-1} (interval approx. 333 ms), the increase of heart rhythm during expiration caused the cardiac interval to pass this cut-off rate and start the tachycardia detection process. As a solution, the VT zone detection duration was extended to 7 s.

Results

These two patients received the defibrillation system from the same manufacturer. However this can be observed for all ICD systems which are not correctly individually programmed. This individual programming covers individual setting of tachycardia cut-off zones and its regular evaluation during routine follow-ups.

The reason for this inappropriate ICD therapy and detection was passing the VT zone cut-of rate due to sinus rhythm close to this VT zone cut-off rate accelerated by respiration. This was also proved by analyzing the EGM and interval printouts. These cases show that this phenomenon can occur as for lower cut-off rate (150 min^{-1}), as for higher cut-off rate (180 min^{-1}) programming.

Conclusion

This case report emphasizes the need for proper programming of detection zones cut-off rates and other therapy detection parameters. For final programming of the devices, the individual physiologically reachable heart rates should always be considered. Today implanted systems offer many diagnostics features for device programming optimization. Especially the recorded trends and rate histograms for each heart chamber can be helpful. The device programming should never be "final". We would recommend using the stored histograms for the regular check of patient maximum heart rate. This can be helpful for establishing the ventricular tachycardia cut-off rate zones, which should be at least 10 min^{-1} above the maximum patient heart rate. Many of tachycardia leading to inappropriate ICD therapies may also have the supraventricular origin, as the both described in these two case reports. Using of morphology algorithms and challenging setting for detection durations up to tens of seconds can protect patients from inappropriate therapies.

Acknowledgement

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