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Medtronic

Cardiac Resynchronization Therapy

Case studies based on Medtronic Tracings

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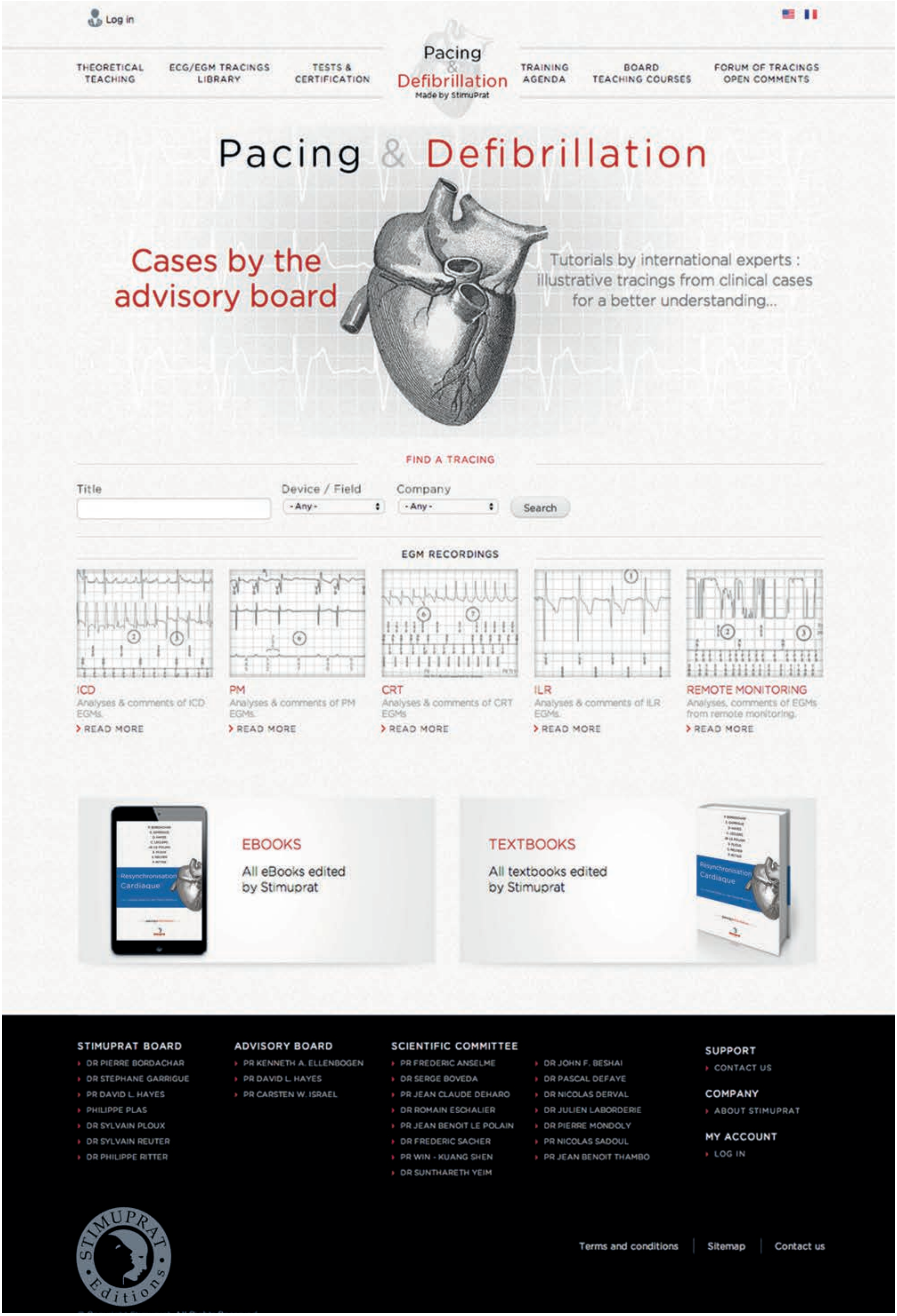
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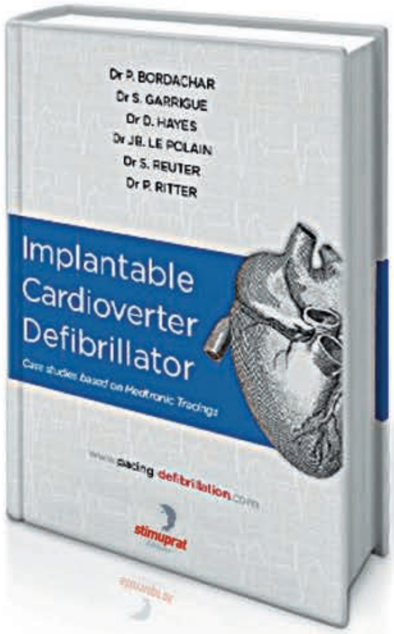

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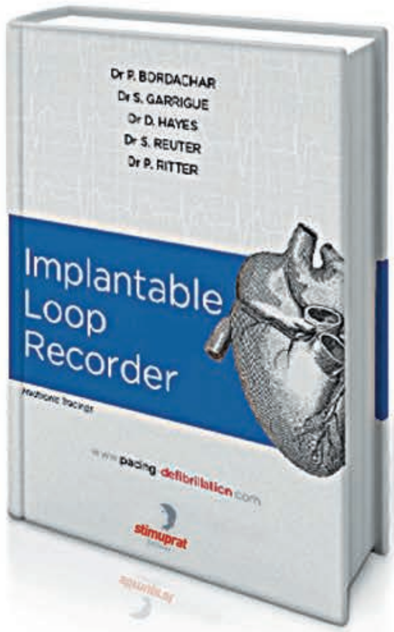

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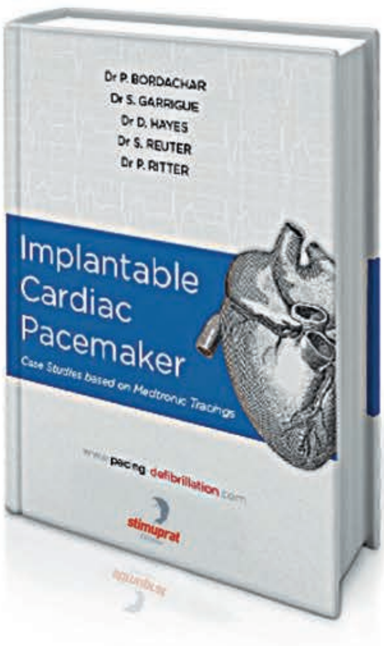

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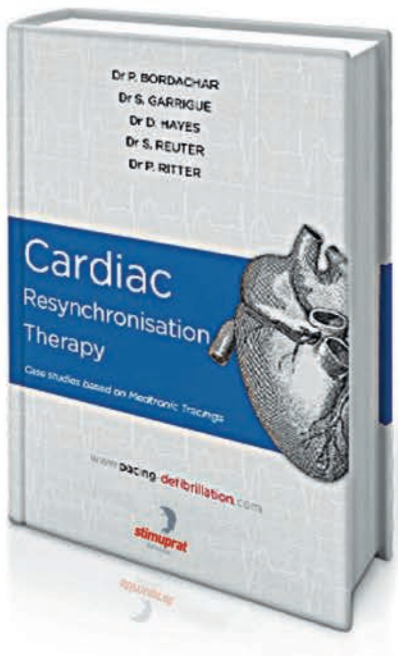


CRT

Summary

Foreword

The authors of the Stimuprat team are privileged to offer you this monograph devoted to the interrogation and programming of the resynchronization devices built by Medtronic. This is the third part of this series, which follows the interrogation of pacemakers and defibrillators.
Biventricular resynchronization is a therapy currently recommended for patients presenting with heart failure (HF) and conduction defects. Various options have been proposed to decrease the proportion of non-responders, which remains the principal limitation of this invasive therapy. The follow-up of recipients of resynchronization devices cannot be optimized without a thorough understanding of the specific details of the interrogation and programming of the various devices. We present several clinical cases illustrating the details of cardiac resynchronizing pacemakers (CRT-P) and defibrillators (CRT-D), including the confirmation of consistent biventricular capture, the specific details of left ventricular stimulation, the programming of the atrioventricular and interventricular delays, their optimization during exercise and management of arrhythmias.

The contents of this monograph are partially accessible free of charge, in French and in English, on the «www.pacingdefibrillation.com» website. This site reviews the state of the art and the specific characteristics of the various pacing, defibrillation and resynchronization devices. It might also promote an exchange of ideas in a discussion forum, enabling the exchange of tracings, as well as debate the most appropriate diagnostic and therapeutic options.

We wish you a pleasant learning experience.

Chapitre 1

Interrogation

Introduction

The follow-up of recipients of CRT devices requires a multidisciplinary approach that gathers the specific contributions of experts in the fields of cardiac pacing, heart failure and echocardiography. It brings together the clinical follow-up of heart failure and the regular interrogations of pacemakers or defibrillators during face-to-face ambulatory visits, or by remote monitoring. CRT-P or CRT-D recipients undergo a history and physical examination, electrocardiogram, echocardiogram and device interrogation with a specific programmer for each model. The operation of a triple chamber device resembles that of single or dual chamber pacemakers or defibrillators with several characteristics that one needs to be familiar with in order to obtain the best cardiac resynchronization.

Clinical follow-up

Recipients of CRT devices are usually followed every 3 months. The history and physical examination are similar to those implemented in patients presenting with heart failure without an implanted device, though the latter includes an inspection of the pocket and the confirmation of proper wound healing and absence of phrenic stimulation, particularly disabling in some patients. An estimation of the New York Heart Association (NYHA) functional class and daily exercise capacity provides a simple assessment of the degree of clinical response.

Biventricular resynchronization, by optimizing hemodynamic function, systemic blood pressure and heart rate, often enables the optimization of medical therapy and an increase in the doses of medications. Efforts should be made toward the observance of dietary and hygienic recommendations, as they are often neglected after the appearance of the initial clinical benefits. Finally, it is recommended to continue the monitoring of standard laboratory tests. Measurements of natriuretic peptides, for example, contribute valuable information regarding the response to treatment and enable the optimization of medical therapy.

Electrocardiographic follow-up

The electrocardiogram is indispensible for the follow-up of CRT devices recipients. It helps in the preliminary identification of lead dislodgement and loss of LV capture before the diagnosis can be definitively confirmed by interrogation of the device and by a chest radiograph. The follow-up by the referring cardiologist can be facilitated by the availability of a baseline electrocardiogram recorded during a) spontaneous rhythm, b) RV capture, c) LV capture, and d) BiV capture. By comparing these tracings, the diagnosis of loss of capture is greatly facilitated. The width and morphology of the QRS associated with the various stimulation configuration change minimally over time, despite considerable remodeling of the ventricular volumes.

Loss of capture on the electrocardiogram can be diagnosed on the basis of distinct characteristics: the QRS morphology during Biventricular stimulation depends on the fusion of activation originating from RV and LV leads. That morphology varies among patients depending on a) the position of the 2 leads, b) the amount of myocardium depolarized by the right- and left-sided leads, respectively, c) the patients' electrical and anatomical substrate, and d) the amount of fusion with spontaneous activation.

The most common and diagnostically important clinical occurrence is loss of LV capture. Compared with RV or LV stimulation, the QRS duration is usually shortened by Biventricular stimulation, though this observation alone is not discriminating enough to confirm a loss of capture. The diagnosis is easier when the RV lead is implanted at the apex. In a majority of cases, apical RV stimulation is, indeed, associated with a positive QRS in lead I and negative QRS in the inferior leads. The QRS axis is usually deviated leftward and the QRS is nearly never positive in lead V1. A negative QRS complex in lead I, a positive complex in lead V1, or both, should be looked for, since their presence confirms effective LV capture. A morphology consistent with single RV stimulation does not, on the other hand, exclude effective LV capture, as this may be due to the predominant influence of the right-sided lead on the QRS morphology. The QRS duration is often shortened during Biventricular pacing compared

with single RV stimulation. When the RV lead is implanted in the high septum or in the infundibulum, the diagnosis of loss of LV capture is considerably more challenging, as the morphology in leads V1 and I is much less predictable.
The loss of RV capture is less frequent and hemodynamically less deleterious. The QRS complex during LV stimulation is often very wide. The QRS axis is deviated to the right or indeterminate. Its morphology depends on the position of the LV lead. The more lateral the lead, the more negative the QRS complexes in lead I with a right bundle branch block morphology. The more apical the lead, the more negative the QRS complex in the inferior leads.

Exercise test

A hall walk test in the outpatient department is a simple means of evaluating the quality of the rate response during daily exercise. A cardio-respiratory exercise test objectively measures the exercise capacity and allows the verification of a reliable BiV capture at peak exercise.

Echocardiography

Echocardiography is performed once per year in general, but more often as is clinically indicated in patients who are non-responders or have a sub-optimal response. Echocardiography provides valuable information about the response to treatment and LV remodeling, changes in ejection fraction, end-systolic and end-diastolic volumes, and the evolution of mitral regurgitation. An evaluation of the filling pressures helps in the adaptation of the doses of diuretics. The degree of AV, VV and intraventricular dyssynchrony can be estimated and may prompt, if necessary, an optimization of the device's programming.

Device interrogations

The first device interrogation and programming, at the end of the implant procedure, are usually followed by an interrogation of the device's functions before discharge of the patient from the hospital. The time spent in the hospital can be used to explain device function to the patient, as well as its constraints and follow-up requirements. The next interrogation is scheduled after complete wound healing, between the first and third months. Thereafter, the devices are usually interrogated between 2 and 4 times a year. The rate of interrogations increases near the device's end of life in absence of remote monitoring.
The aims of these various interrogations are:

- standard follow-ups of pacemaker or defibrillator to optimize the device's longevity, test the function of the implanted lead(s), interrogate the memory and evaluate the arrhythmic burden;
- to verify the quality of resynchronization, including the percent of LV stimulation, reliability of capture, phrenic nerve stimulation threshold and optimization of AV and VV delays;
- to follow the patient's hemodynamic status, using the data collected by the device, and anticipate and prevent the development of cardiac decompensation.

Quick Look II report

Patient

This 73-year-old man received a triple chamber defibrillator in the context of ischemic cardiomyopathy with a 25% LVEF, NYHA functional class III and LBBB. This was a first implant, with placement of a left lateral LV lead via the coronary sinus and early dislodgement of the lead, which was re-implanted in an antero-lateral vein, though dislodged again rapidly. An endocardial LV lead was implanted transseptally in a medio-lateral location. Within 3 months after its implantation, the LV volumes and NYHA functional class had decreased and the exercise capacity had increased. The patient was seen for a routine follow-up and the defibrillator was interrogated. The various steps of a standard interrogation will be reviewed in upcoming pages. The Quick Look II screen provides a rapid summary of the device function and of the patient's status. It automatically displays the information divided in 6 sections after the onset of the patient's session.

1: Battery status: on this home screen, the estimated residual longevity is shown graphically with the Recommended Replacement Time (RRT) displayed in red and the estimated remaining longevity shown in green. In this patient who recently underwent device implantation, the low stimulation thresholds allowed the programming of low stimulation pulse amplitudes. He has had no arrhythmia in the interim. The mean estimated residual longevity is 8.9 years and the green bar is filled. The device estimates automatically the remaining duration up to the RRT, based on the daily automatic measurements of the battery voltage, the time elapsed since the implantation, the settings of the programmable parameters, and the events recorded by the device. Within 2 weeks after device implantation, the programmer can estimate the residual life expectancy of the device, corresponding to the number of years expected to elapse before the battery reaches the RRT. The longest, shortest and average duration of residual life are displayed on the screen, based on a statistical analysis of the data of accelerated depletion of the battery. The estimates of maximum and minimum residual life duration correspond to the values of the 95th percentile, calculated from the distribution of these data. RRT is reached by 95% of devices before the maximum value, and 95% of devices reach RRT after the minimum indicated value. The device measures the battery voltage automatically a) when telemetry is established in the beginning of a session, b) when lead impedance is measured, and c) daily at 02:15h. The daily, automatic measurements of battery voltage are used in the calculation of RRT.

2: leads function: this home screen shows a) the last automatically measured pacing and high-voltage leads impedance, b) atrial and RV sensing, (LV is not sensed), and c) capture thresholds in the 3 chambers. All values are normal. The capture thresholds are low and enabled the programming of stimulation pulse amplitude guaranteeing a sufficient safety margin and low power consumption.

3: summary of the programmed settings: the home screen displays the main programmed a) pacing parameters, including mode, rates, AV delays, b) detection of arrhythmias, including number of zones and their rate boundaries, and c) discrimination and therapies of arrhythmias.

4: clinical status and Cardiac Compass® trends: the home screen shows numerical or graphic information regarding treated arrhythmias (no arrhythmic episode in this patient), monitored arrhythmias (no episode) and daily activity.

5: percent stimulation: this patient had 99.1% ventricular stimulation (representing the combined LV and BiV percentage), 96.3% A sensed – V stimulation, and 3.6% A paced-V stimulation. The 0.8% difference represents the RV stimulation time, ventricular safety pacing and the search for the atrial and ventricular threshold.

6: observations: the observations defined by the system indicate unexpected conditions and suggest means of optimization of the device's settings. They are based on an analysis of the programmed parameters and data collected since the last session. The following types of observations may be displayed:

1) Device status observations indicate when it approaches RRT or end of service (EOS). An

observation is also reported when a charge circuit irregularity or device reset has occurred;

2) observations pertaining to the lead status warn of all potential problems related to the sensing integrity of the leads, their dislodgement, and of inconsistent results in capture management, as well as in the programming of leads polarity. In this patient, for example, the safety margin for the programmed RV stimulation amplitude was of foremost importance, and might have justified a re-programming with a view to spare the battery of the defibrillator;
3) the parameters observations warn of all inconsistencies in the programming of the detection and therapy parameters. In this patient, for example, the VF zone was programmed at 214 bpm (> 200 bpm), such that the device considered that it might cause a delay in detection of a VF episode;
4) diagnostic data observations highlight noteworthy arrhythmic events;
5) the Medtronic CareAlert observations might report the performance conditions of the system or device, as well as some conditions of the heart rhythm;
6) observations pertaining to the clinical status warn of an abnormal state of the patient, such as low levels of exercise, inappropriately fast heart rates, heavy arrhythmic burden or fluid accumulation.

Quick Look II Report

Device: **Viva XT CRT-D DTBA2D1**

ID:

Device Status (Implanted: 09-Jan-2013)

Remaining Longevity	8.9 years	(09-Apr-2013)

ears
(based on initial interrogation)

(1)

Atrial		**RV** **SVC**	**LV**
Pacing Impedance	494 ohms	418 ohms	589 ohms
Defibrillation Impedance		RV=40 ohms SVC=51 ohms	
Capture Threshold	0.750 V @ 0.40 ms	0.375 V @ 0.40 ms	0.625 V @ 0.40 ms
Measured On	09-Apr-2013	09-Apr-2013	09-Apr-2013
Programmed Amplitude/Pulse Width	1.50 V / 0.40 ms	2.00 V / 0.40 ms	2.25 V / 0.20 ms
Measured P/ R Wave	2.6 mV	16.8 mV	
Programmed Sensitivity	0.30 mV	0.30 mV	

(2)

Parameter Summary

Mode	DDD	Lower Rate	50 bpm	AdaptivCRT	Nonadaptive CRT
Mode Switch	171 bpm	Upper Track	130 bpm	V. Pacing	LV->RV
		Upper Sensor	120 bpm	Paced AV	130 ms
				Sensed AV	100 ms

(3)

Detection		**Rates**	**Therapies**
AT/AF	Monitor	>171 bpm	All Rx Off
VF	On	>214 bpm	ATP During Charging, 35J x 6
FVT	via VT	182-214 bpm	Burst(3), 15J, 35J x 4
VT	On	150-214 bpm	Burst(3), Ramp(3), 10J, 35J x 3

Enhancements On: AF/Afl, Sinus Tach, 1:1 SVT, Wavelet, TWave, Noise(Timeout)

Clinical Status **Since 14-Feb-2013**

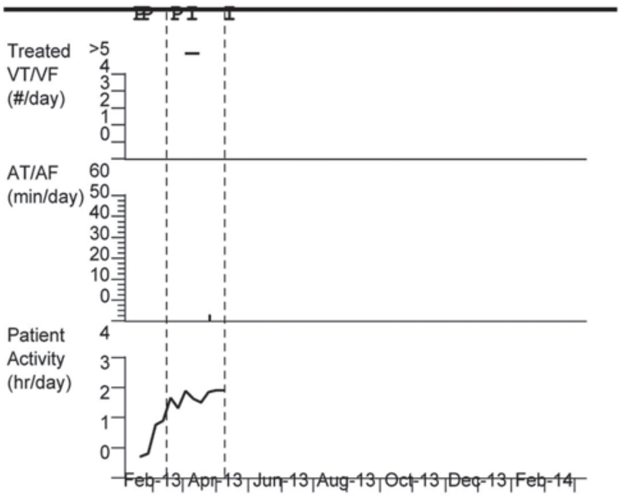
Treated	
VF	0
FVT	0
VT	0
AT/AF(Monitor)	

Monitored	
VT (Off)	
VT-NS (>4 beats, >150 bpm)	0
High Rate-NS	0
SVT: VT/VF Rx Withheld	0
V. Oversensing-TWave Rx Withheld	0
V. Oversensing-Noise Rx Withheld	0
AT/AF	0
Time in AT/AF	<0.1 hr/day (<0.1%)

Functional	**Last Week**
Patient Activity	2.9 hr/day

(4)

Cardiac Compass Trends (Jan-2013 to Apr-2013)



Therapy Summary	**VT/VF**	**AT/AF**
Pace-Terminated Episodes	0	0
Shock-Terminated Episodes	0	0
Total Shocks	0	0
Aborted Charges	0	0

Pacing	**(% of Time Since 14-Feb-2013)**
Total VP	99.1 %
AS-VS	<0.1 %
AS-VP	96.3 %
AP-VS	<0.1 %
AP-VP	3.6 %

(5)

Quick Look II Report

Device: **Viva XT CRT-D DTBA2D1**

\- - -

OBSERVATIONS (2)

· RV Capture Management: Actual safety margin (5.3 X) > programmed margin (2.0 X).
· VF detection may be delayed: VF Detection Interval is faster than 300 ms (200 bpm).

(6)

RV lead Function

1 and 2: evolution of the automatically measured RV pacing thresholds:

The ventricular pacing thresholds are stable and <0.5 V/0.4 ms, enabling a programming at 2.0 V/0.4 ms, guaranteeing a sufficient safety margin at the cost of a moderate power consumption.

3 and 4: evolution of the RV impedance:

One can program 2 configurations for RV pacing and sensing: true bipolar between the anode and the cathode and integrated bipolar (distal/spire); in this patient, the values of impedance are stable (near 400 Ohms) and nearly the same with both configurations without recording of excessively low or high values.

5: automatic measurement of the R wave:

Ventricular sensing was satisfactory in this patient with values systematically above 12 mV; in a triple chamber defibrillator, a RV sensing of high quality is indispensable for the detection and discrimination of arrhythmias, as well as for the function of resynchronization (RV undersensing can lower the percentage of BiV stimulation).

6: impedance of defibrillation:

This patient was implanted with a double coil lead and the device measured automatically the defibrillation impedance on the distal coil (RV impedance of defibrillation) and on the proximal coil (VCS impedance of defibrillation).

7 and 8: RV threshold

7) this test is performed in RVI mode (VVI on the programmer though sensing is atrial) at 90 bpm. The pacing threshold can be measured in VVI, RVI or DDD mode with a short AV delay, to prevent fusion with the spontaneous ventricular activity.
8) loss of RV capture (the 0.5 V/0.4 ms threshold corresponding with the thresholds measured automatically).

9: measurement of the R wave amplitude in real time:

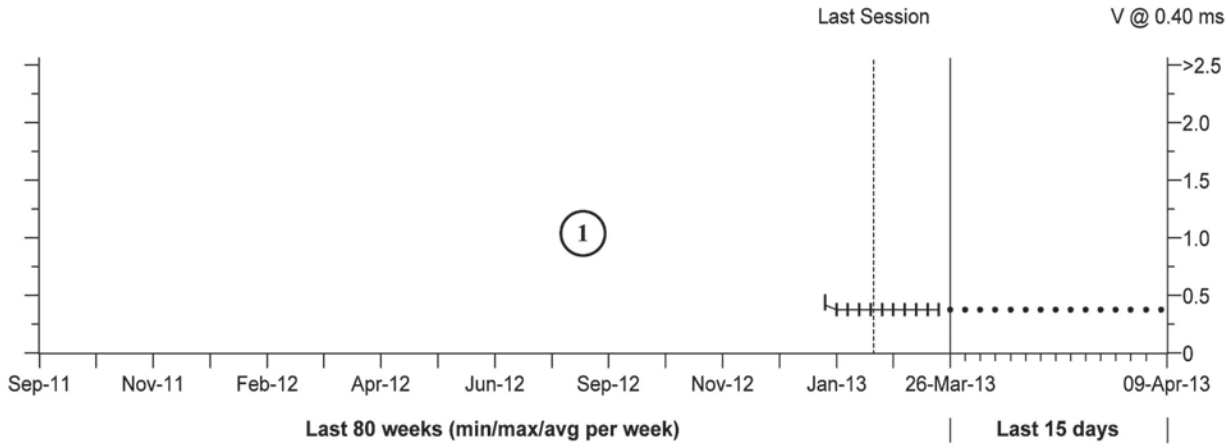
The measured value also corresponded with the values measured automatically.

Lead Trend - RV Threshold 15 Days Detail

Device: **Viva XT CRT-D DTBA2D1**

ID:

Amplitude	2.00 V	Capture	Adaptive
Pulse Width	0.40 ms	Safety Margin	2.0 X
Last Measured	0.375 V @ 0.40 ms 09-Apr-2013	Min. Adapted Amplitude	2.00 V
Pace Polarity	Bipolar		



Date	Time hh:mm	Threshold V @ 0.40 ms	Amplitude (V)	Actual Safety Margin (X)	Notes
09-Apr-2013	01:00	0.375	2.00	5.3	Measurement OK
08-Apr-2013	01:00	0.375	2.00	5.3	Measurement OK
07-Apr-2013	01:00	0.375	2.00	5.3	Measurement OK
06-Apr-2013	01:00	0.375	2.00	5.3	Measurement OK
05-Apr-2013	01:00	0.375	2.00	5.3	Measurement OK
04-Apr-2013	01:00	0.375	2.00	5.3	Measurement OK
03-Apr-2013	01:00	0.375	2.00	5.3	Measurement OK
02-Apr-2013	01:00	0.375	2.00	5.3	Measurement OK
01-Apr-2013	01:00	0.375	2.00	5.3	Measurement OK
31-Mar-2013	01:00	0.375	2.00	5.3	Measurement OK
30-Mar-2013	01:00	0.375	2.00	5.3	Measurement OK
29-Mar-2013	01:00	0.375	2.00	5.3	Measurement OK
28-Mar-2013	01:00	0.375	2.00	5.3	Measurement OK
27-Mar-2013	01:00	0.375	2.00	5.3	Measurement OK
26-Mar-2013	01:00	0.375	2.00	5.3	Measurement OK

2

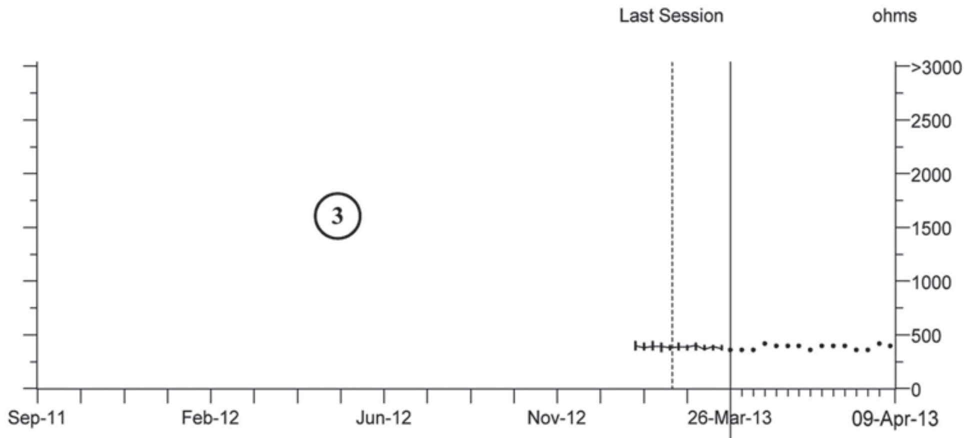
Lead Trends - RV

Device: **Viva XT CRT-D DTBA2D1**

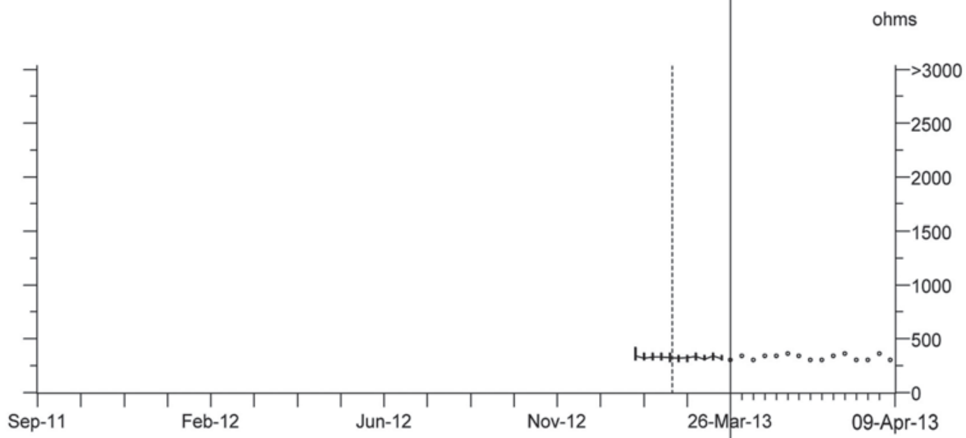
ID:

RV Pace Polarity	**Bipolar**
RV Sense Polarity	**Bipolar**

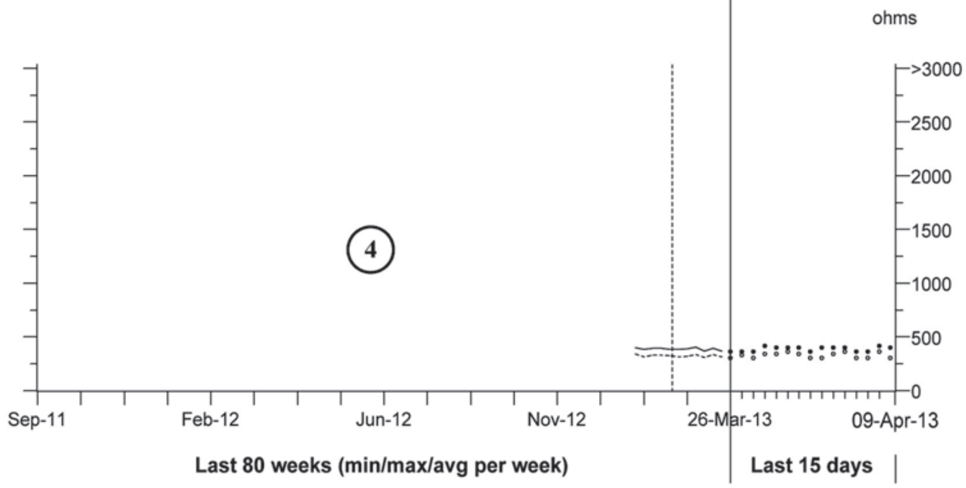
RV Impedance (bipolar)
Last Measured 418 ohms



RV Impedance (tip to coil)
Last Measured 342 ohms



RV Impedance
Bipolar
Tip to Coil



Lead Trends - RV

Device: **Viva XT CRT-D DTBA2D1**

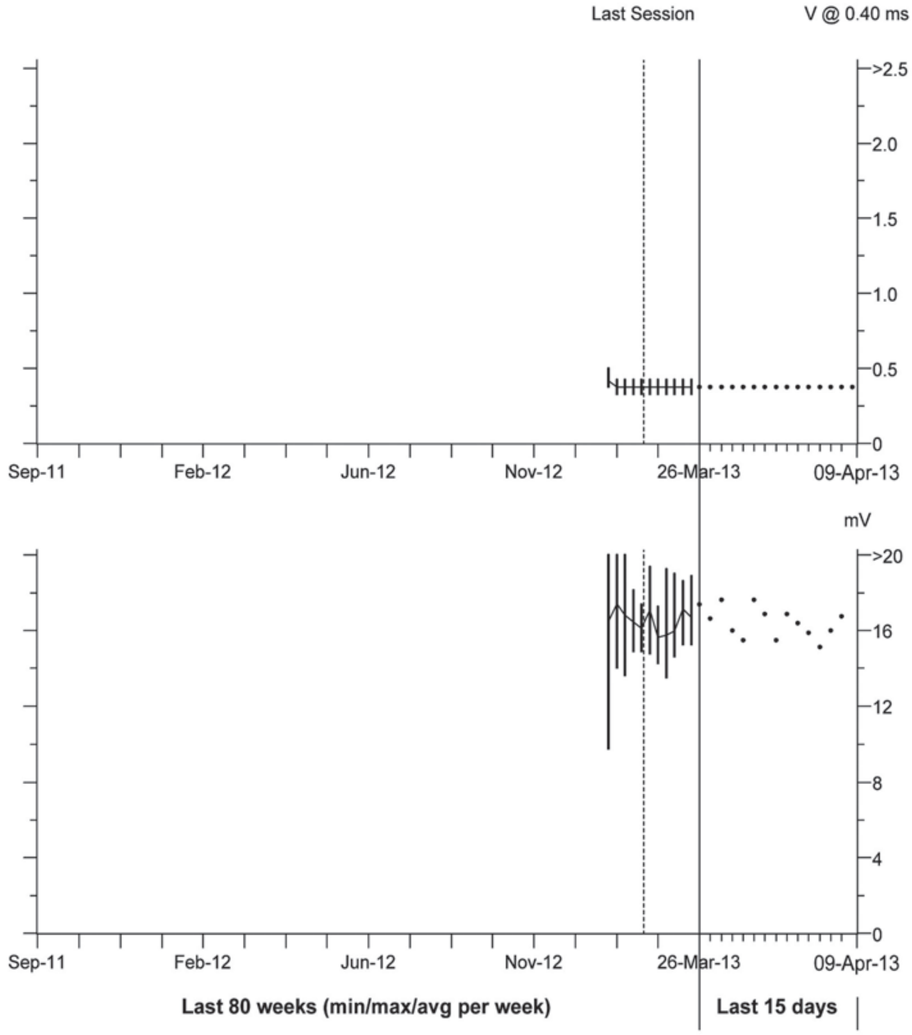
ID:

RV Threshold

Capture	Adaptive
Amplitude	2.00 V
Pulse Width	0.40 ms
Last Measured	0.375 V @ 0.40 ms
Measured On	09-Apr-2013

R-Wave Amplitude

Sensitivity	0.30 mV
Last Measured	16.8 mV



Sensing Test Report

Device: **Viva XT CRT-D DTBA2D1**

-

Sensing Test

	Test Value	Permanent
Mode	DDD	DDD
AV Delay	250 ms	130 ms
Lower Rate	50 bpm	50 bpm

Last Sensing Measurement

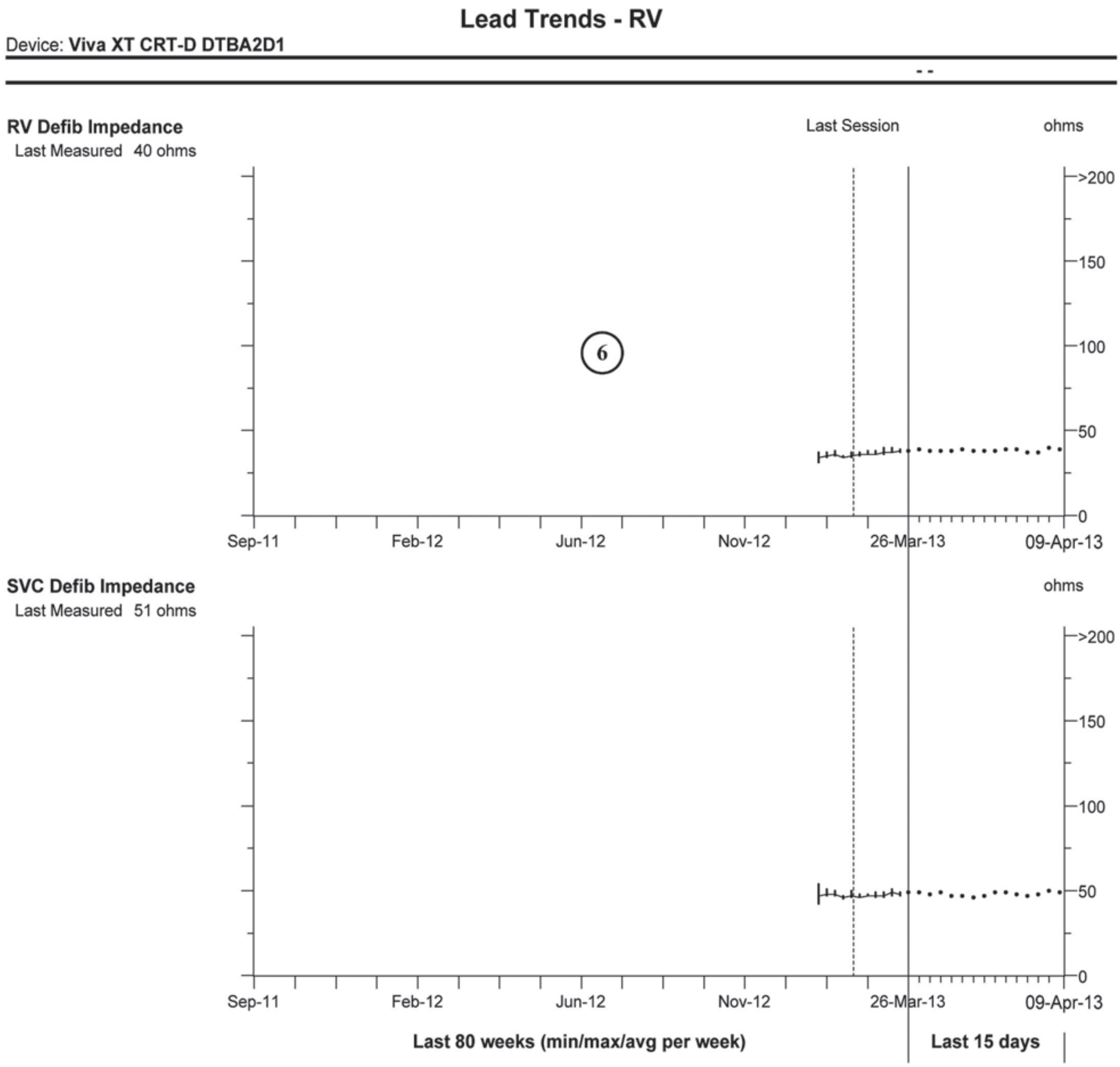
09-Apr-2013

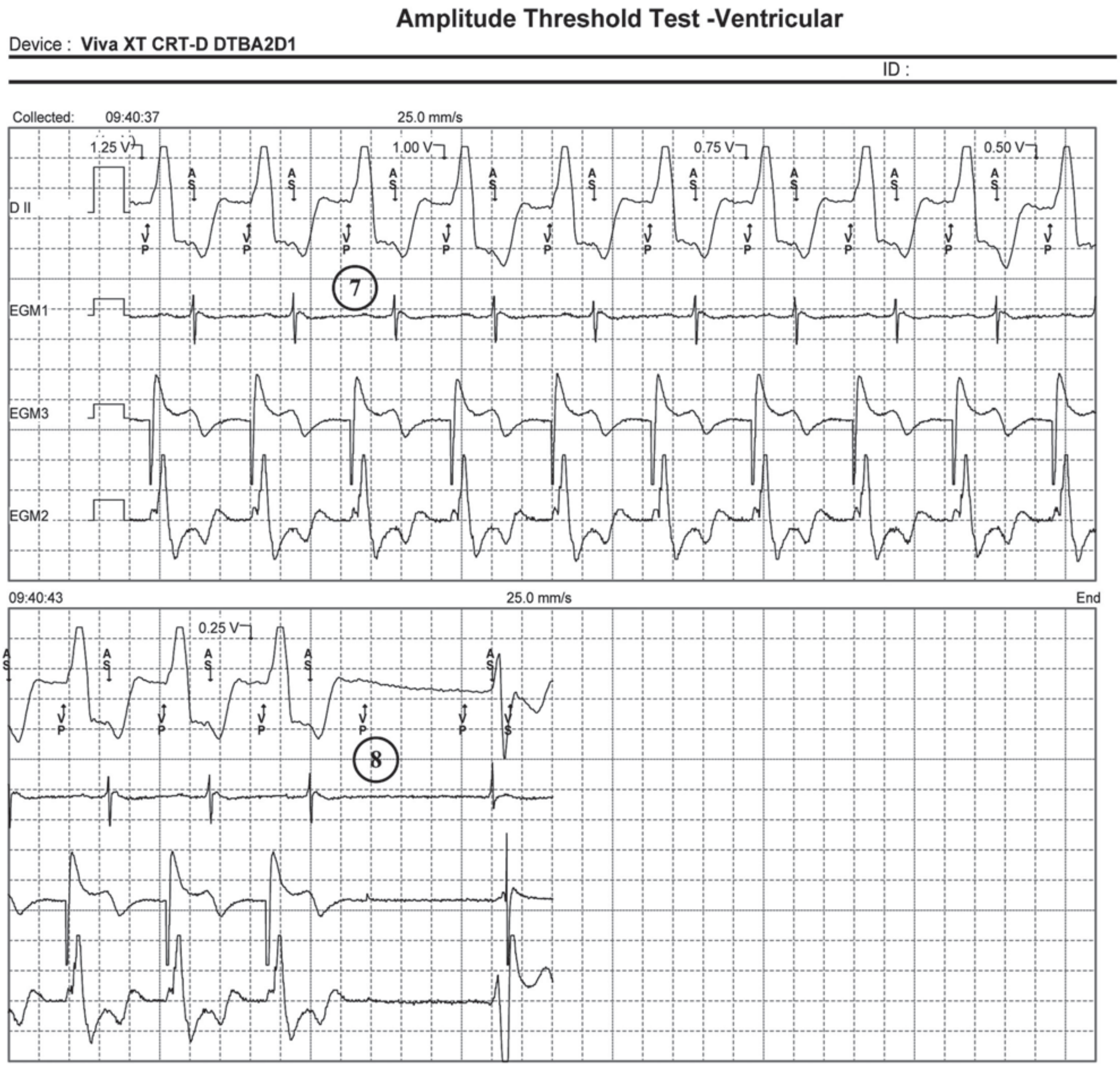
P-Wave Amplitude	3.0 mV
R-Wave Amplitude	15.1 mV

(5)

Sense Polarity

P-wave	Bipolar
R-wave	Bipolar


Lead Trends - RV
Device: Viva XT CRT-D DTBA2D1
- -
RV Defib Impedance
Last Measured 40 ohms
Last Session
ohms
>200
150
100
50
0
6
Sep-11
Feb-12
Jun-12
Nov-12
26-Mar-13
09-Apr-13
SVC Defib Impedance
Last Measured 51 ohms
ohms
>200
150
100
50
0
Sep-11
Feb-12
Jun-12
Nov-12
26-Mar-13
09-Apr-13
Last 80 weeks (min/max/avg per week)
Last 15 days



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Left ventricular lead function

1: evolution of the left ventricular impedance:

The LV impedance in this patient was stable. It is particularly noteworthy that the lead diameters and technology vary widely among the multiple implanted device models, which might cause wide variations in impedance.

2: evolution of the left ventricular threshold:

The stimulation thresholds are usually higher at the LV leads, implanted sub-epicardially. In this patient, the threshold was 0.6 V/ 0.2 ms a low value due to the direct LV endocardial fixation of the lead.

3 and 4: real-time measurement of the left ventricular threshold:

3) threshold measured in DVI mode at 90 bpm, with presence of retrograde conduction.
4) loss of capture at 0.75 V/0.4 ms, consistent with the automatic measurements of thresholds. It is noteworthy that the Wedensky effect, i.e. the measurement of a lower threshold when decreasing than when increasing the pulse strength, is often more prominent with LV than RV leads, perhaps explaining the differences observed between the thresholds measured automatically, by gradually increasing the pulse strength, and the measurements made in real time, by gradually decreasing the pulse amplitude.

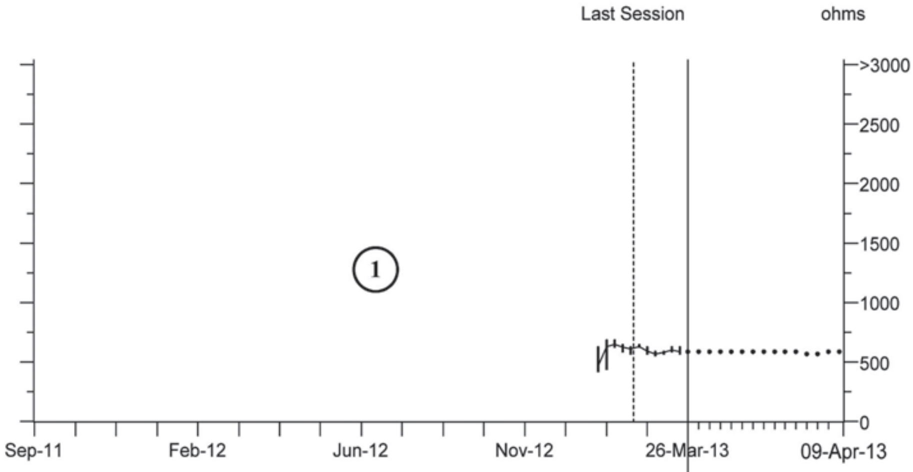
Lead Trends - LV

Device: **Viva XT CRT-D DTBA2D1**

ID:

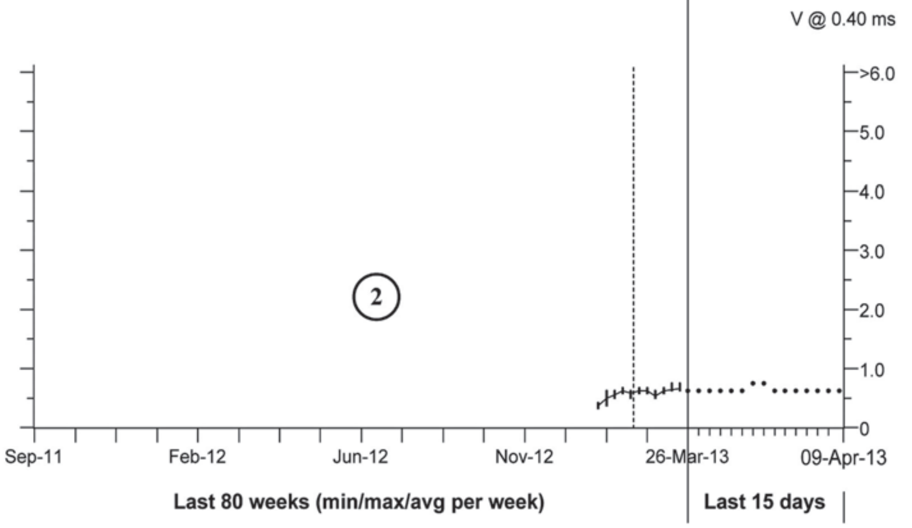
LV Pace Polarity **LVtip to LVring**

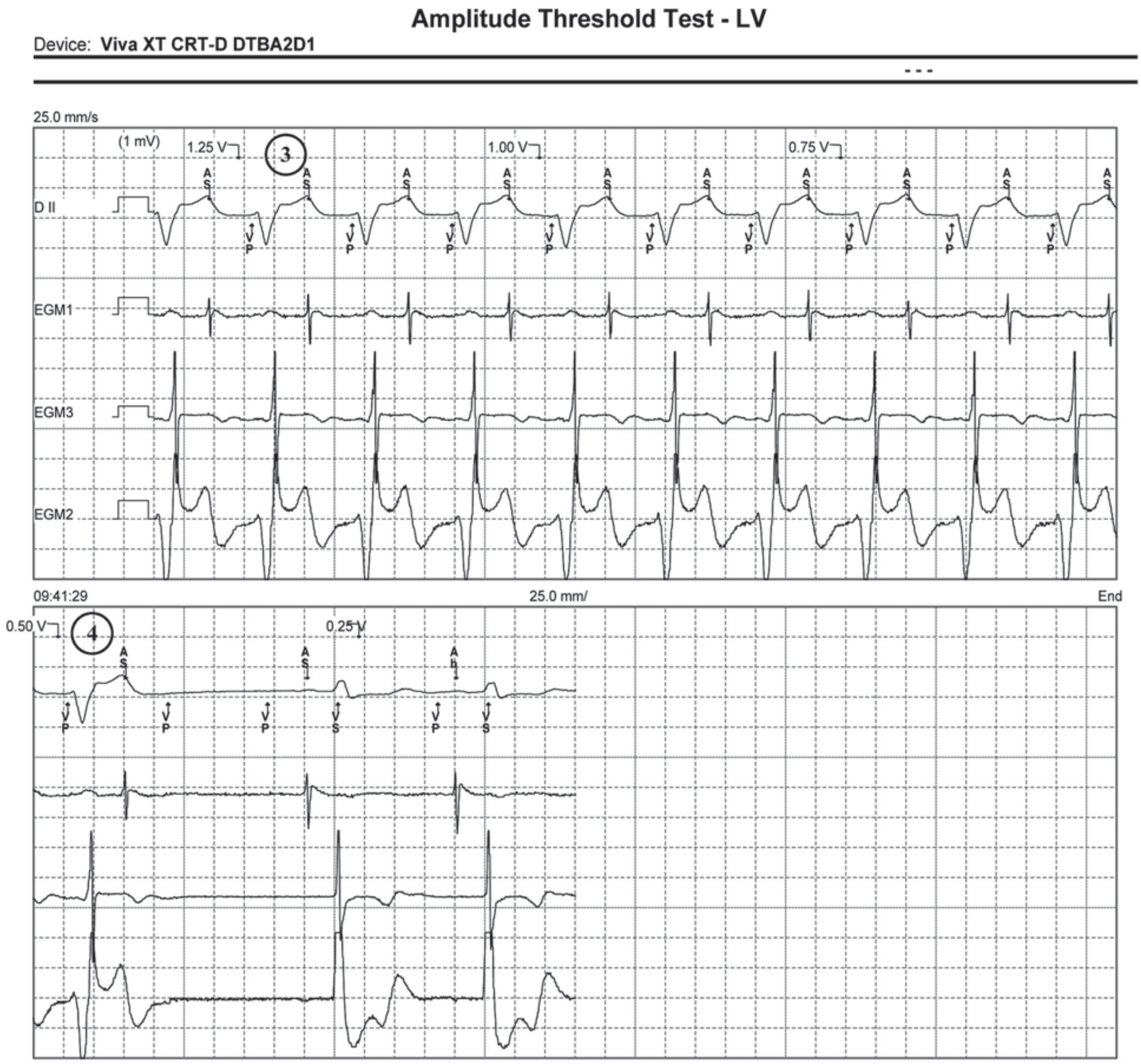
LV Impedance
(LVtip to LVring)
Last Measured 589 ohms



LV Threshold

Capture	Adaptive
Amplitude	2.25 V
Pulse Width	0.20 ms
Max. Adapted	6.00 V
Last Measured	0.625 V @ 0.40 ms
Measured On	09-Apr-2013





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Atrial lead function

The analysis of the implanted leads function is an important step in the interrogation of pacemakers or defibrillators, including measurements of the capture and sensing thresholds, and impedance. The proper right atrial and RV leads function is indispensable for the detection, discrimination and therapies of arrhythmias, as well as for accurate resynchronization.

1 and 2: evolution of the atrial threshold:

The absolute values of the last 15 days' thresholds are presented as a graph and table. The pulse duration remained set at 0.4 ms, while the threshold was automatically measured by varying the pulse strength. The atrial capture thresholds were consistently <1 V. The mean, minimum and maximum weekly measurements made in the 15 days prior, and up to a maximum of 80 weeks, can also be viewed.

3: evolution of the atrial lead impedance:

This measurement is an indicator of lead integrity. A very low value suggests insulation breakdown, while an inordinately high measurement is in favor of a fracture of the conductor. The absolute value of the impedance, whether low, normal or high, must be measured, as well as its variations over time, looking for abnormal values. The evolution of its curve offers an accurate overall vision, which, in this patient, remained stable and within normal limits (near 500 ohms) without excessively low or high values.

4: evolution of the P wave:

The automatic measurements of atrial sensing were consistently >2.0 mV, allowing the preservation of a sufficient safety margin with regard to the programmed sensitivity. In a triple chamber defibrillator, the reliable sensing of the right atrial signal is indispensable in the discrimination of arrhythmias as well as for the quality of resynchronization. Right atrial undersensing at rest or during exercise may lower the percentage of BiV stimulation.

5 and 6: atrial threshold testing:

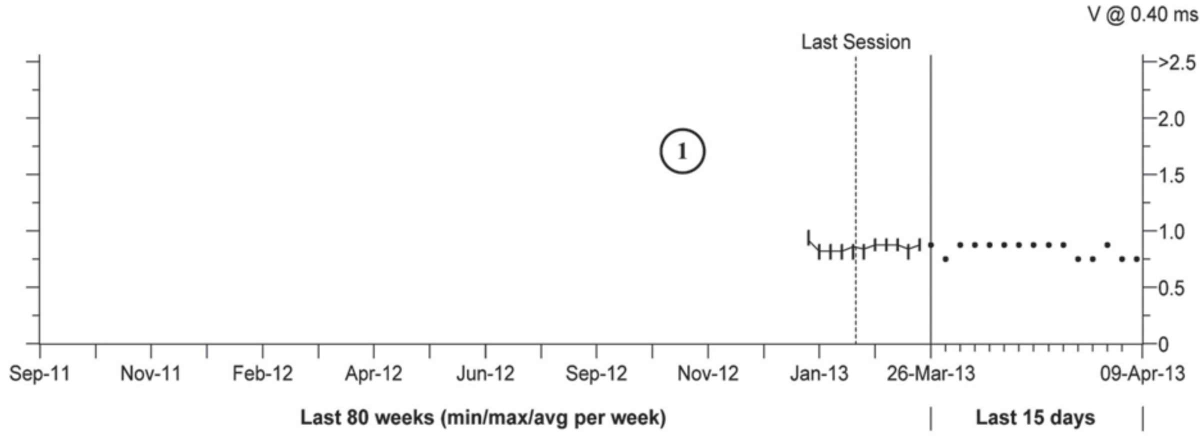
5) test of threshold in mode ADI, i.e. in AAI mode on the programmer, though sensing was ventricular. Sensing of a ventricular event confirmed the atrial capture.
6) loss of capture: a 1.0 V/0.4 ms threshold was the last measurement made that was associated with consistent capture.

Lead Trend - Atrial Threshold 15 Days Detail

Device: **Viva XT CRT-D DTBA2D1**

ID: ---

Amplitude	1.50 V	Capture	Adaptive
Pulse Width	0.40 ms	Safety Margin	2.0 X
Last Measured	0.750 V @ 0.40 ms 09-Apr-2013	Min. Adapted Amplitude	1.50 V



Date	Time hh:mm	Threshold V @ 0.40 ms	Amplitude (V)	Actual Safety Margin (X)	Notes
09-Apr-2013	01:01	0.750	1.50	2.0	Measurement OK
08-Apr-2013	01:01	0.750	1.75	2.3	Measurement OK
07-Apr-2013	01:01	0.875	1.75	2.0	Measurement OK
06-Apr-2013	01:01	0.750	1.50	2.0	Measurement OK
05-Apr-2013	01:01	0.750	1.75	2.3	Measurement OK
04-Apr-2013	01:01	0.875	1.75	2.0	Measurement OK
03-Apr-2013	01:32	0.875	1.75	2.0	Measurement OK
02-Apr-2013	01:01	0.875	1.75	2.0	Measurement OK
01-Apr-2013	01:01	0.875	1.75	2.0	Measurement OK
31-Mar-2013	01:01	0.875	1.75	2.0	Measurement OK
30-Mar-2013	01:01	0.875	1.75	2.0	Measurement OK
29-Mar-2013	01:01	0.875	1.75	2.0	Measurement OK
28-Mar-2013	01:02	0.875	1.75	2.0	Measurement OK
27-Mar-2013	01:01	0.750	1.75	2.3	Measurement OK
26-Mar-2013	01:02	0.875	1.75	2.0	Measurement OK

(2)

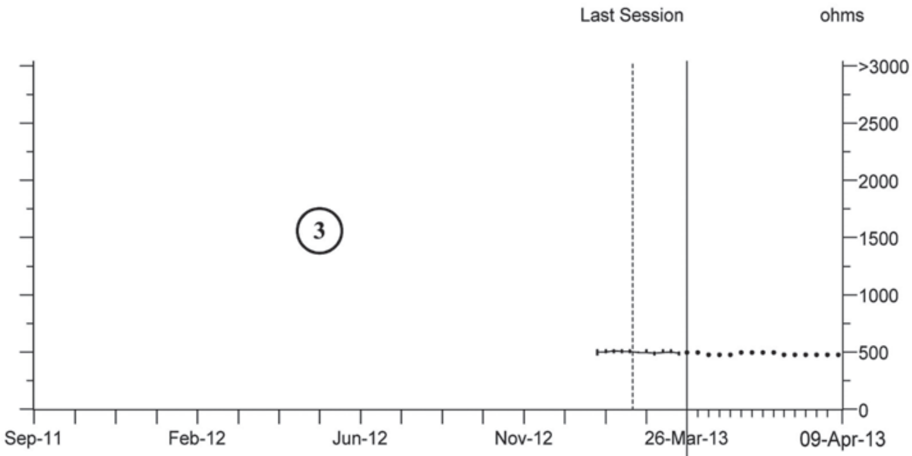
Lead Trends - Atrial

Device: **Viva XT CRT-D DTBA2D1**

- -

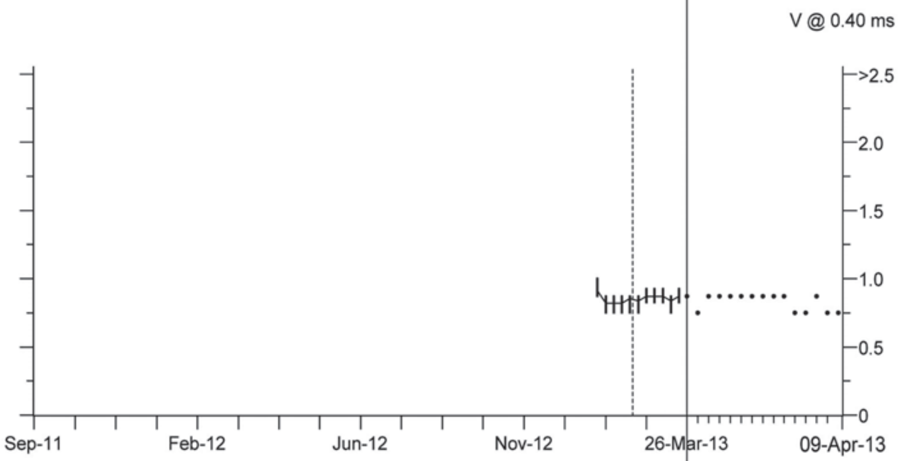
A. Impedance (bipolar)

Last Measured 494 ohms



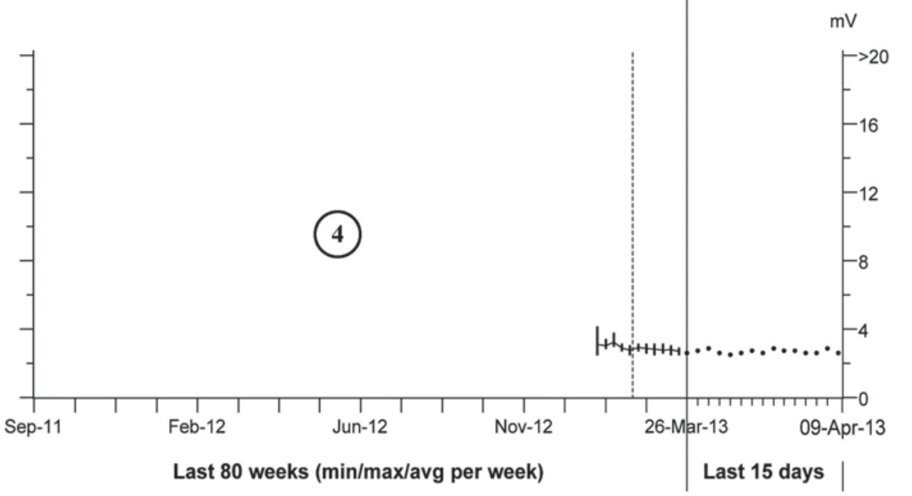
A. Threshold

Capture	Adaptive
Amplitude	1.50 V
Pulse Width	0.40 ms
Last Measured	0.750 V @ 0.40 ms
Measured On	09-Apr-2013



P-Wave Amplitude

Sensitivity	0.30 mV
Last Measured	2.6 mV



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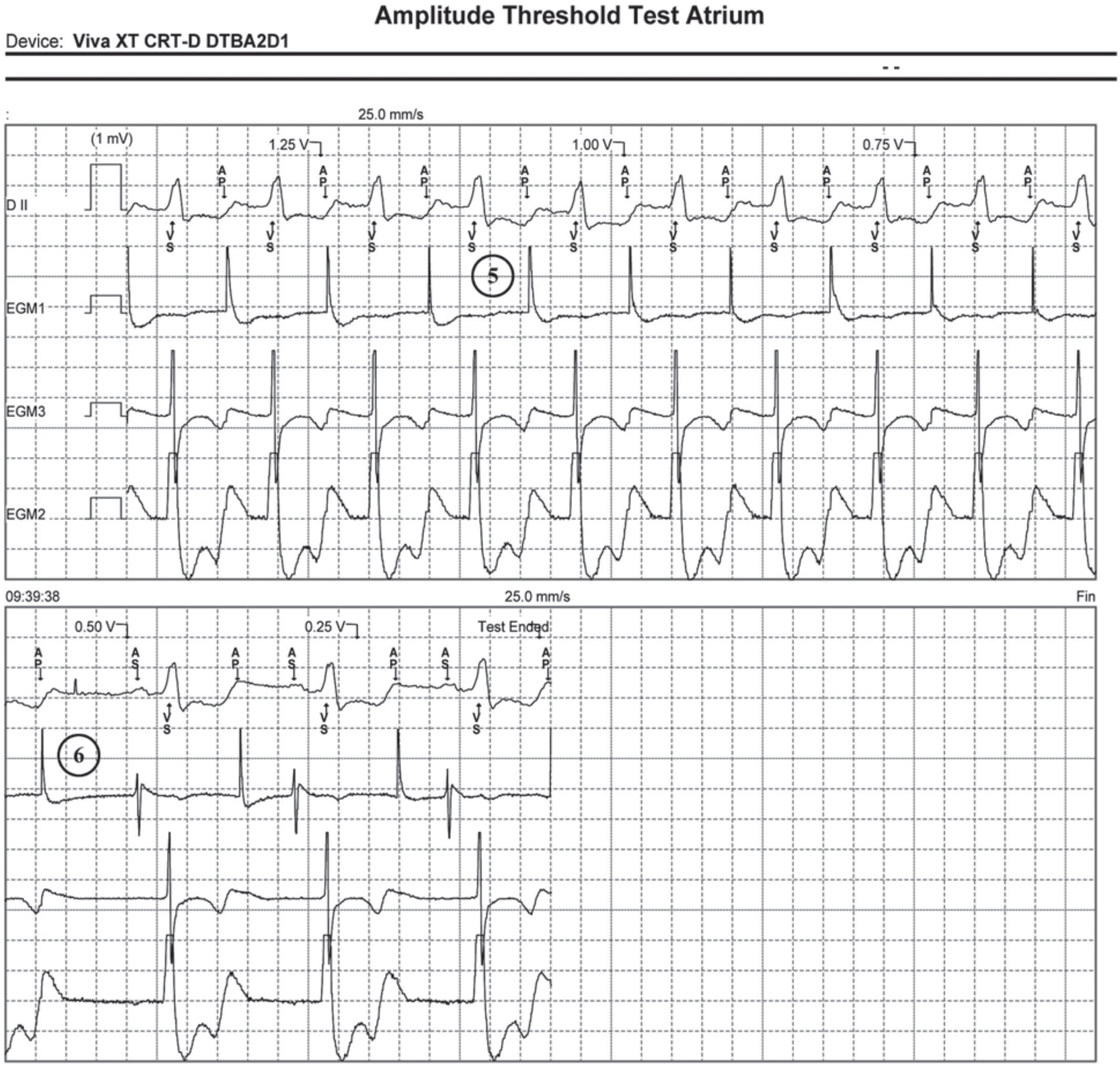

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Programmed parameters

1: summary of the pacing parameters:

The summary is the same as that offered on the home screen.

2: details of the pacing parameters:

The operations of the right atrial and RV threshold interrogations, and of the LV threshold interrogation have several similarities and a few differences. For the 3 leads, the interrogation is on "Auto", indicating that the device measures the capture threshold daily at 1 a.m., and then sets the pulse strength and duration for the remainder of the day. The pulse amplitude (1.5 V for the right atrium, 2 V for the right ventricle and 2.25 V for the left ventricle) and duration (0.4 ms for the right atrium and ventricle, and 0.2 ms for the left ventricle) correspond to the values in effect at the time of interrogation. For the right atrium and ventricle, the lowest safety margin amplitude must be set at twice the measured threshold. For the left ventricle, instead of a multiple of the measured threshold, the safety margin is an absolute value (in this case 1.5 V). On the right-sided leads, the maximum amplitude cannot exceed 5 V/1.0 ms, regardless of the value of the measured threshold. On the LV lead, the maximum pulse strength is programmable (in this case 6 V).

3: AV therapies:

The adaptable AV delay is programmed. It allows to 1) shorten the paced and sensed AV delays when the heart rate increases, 2) simulate the physiologic shortening of the PR interval during exercise, 3) postpone the 2:1 point, and 4) guarantee a BiV capture during exercise in pacemaker non-dependent patients. In this patient, the AV delay began to shorten at 90 bpm and ended at 130 bpm, with a 30 ms difference between the shortest and longest AV delay, whether the AV delay is paced or sensed.

4: rate response:

The programmed mode was DDD, i.e. without rate response. The programmed rate response parameters were those applied in a mode switch, where the mode was DDIR.

5: refractoriness/blanking:

We will review later the specific properties of various programmable blanking periods. The Auto PVARP also allows the postponement of the 2:1 point by shortening automatically as the heart rate increases, up to its minimum value (250 ms in this patient). The 3 programmable PVAB methods are "Partial", "Partial+", and "Absolute". The post atrial pacing ventricular blanking period is not programmable.

6: therapeutic interventions for arrhythmias:

Several algorithms can be programmed to terminate an atrial arrhythmia or promote LV stimulation. Stabilization of the atrial rhythm adapts the pacing rate in response to an atrial extrasystole to suppress long sinus pauses after a short cycle. Rapid, post mode switch pacing can be added to the mode switch function to pace the atrium rapidly upon return to DDD mode after an atrial arrhythmic episode. It regularizes the ventricular rate during an episode of atrial fibrillation and prevents the occurrence of long diastolic intervals. The preferred atrial pacing overdrives consistently the atrial activity, slightly above the spontaneous rate. The response to a sensed ventricular event consists of stimulating both ventricles (ventricular tracking mode). It restores atrial synchrony, should it be lost because of several consecutive atrial events falling in the refractory period of the sensed ventricular events. Non-Competitive Atrial Pacing (NCAP) prevents premature atrial pacing after an atrial event sensed in the refractory period by delaying the next scheduled atrial paced event.

7: post-shock pacing:

The strength and duration of the atrial and RV pulse can be programmed differently after the delivery of DC shocks, because of the transient risk of a rise in the pacing threshold.

8: other algorithms:

Several supplemental algorithms can be programmed. It is noteworthy that the anti pacemaker-mediated tachycardia algorithm is nominally in the OFF position and must be systematically programmed ON.

9: device information and comments:

As described earlier, this patient received an endocardial LV lead in the context of the Alsync study (transseptal implantation of the left lead) which examined the feasibility and safety of this type of procedure.

10: detection zones:

3 zones of detection and therapies and a monitor only zone can be programmed with these devices.

11: discrimination:

These devices offer a new discrimination platform: T wave discrimination, discrimination of lead fracture, addition of the MorphoLog to the PR Logic analysis.

12: therapies:

On triple chamber defibrillators, during anti-tachycardia pacing, RV, LV or BiV stimulation can be programmed.

13: Atrial tachycardia/fibrillation detection:

In this patient, the atrial arrhythmias detection zone begins at 350 ms. The atrial arrhythmia therapies were not programmed.

14: Data recording configuration:

In this patient, the atrial and RV bipolar EGM were being monitored, probably offering the best compromise between understanding of the arrhythmic episode (A/V relationship) and understanding of the device function (the visible signals are those analyzed by the defibrillator). In this patient, the EGM recording before the onset of arrhythmia was programmed OFF, as its incessant recording shortens the device’s life expectancy. When programmed ON, the device records up to 10 seconds of EGM data before the sudden onset of a) VT/VF, b) VT Monitor, or c) the detection of episodes of sustained VT (SVT). When the “EGM recording before the onset of arrhythmia function” is de-activated, the device begins the recording of EGM information for VT/VF, Monitor only VT and SVT episodes after the 3rd tachyarrhythmic event. While the EGM are not recorded before the onset of arrhythmia, up to 20 sec of data, consisting of measurements of intervals and annotations of event markers, are nevertheless recorded by the device before the sudden onset or the detection of the episodes.

15: Medtronic CareAlert configurations:

Several alerts followed by remotely transmitted messages, or ringtone audible by the patient, or both are programmable. In this patient, all ringtones were de-activated.

Final: Parameters

Device: **Viva XT CRT-D DTBA2D1** Serial Number:

Pacing Summary

Mode		Rates			CRT	
Mode	DDD	Lower	50 bpm		AdaptivCRT	Nonadaptive CRT
Mode Switch	171 bpm	Upper Track	130 bpm	(1)	V. Pacing	LV->RV
		Upper Sensor	120 bpm		V-V Pace Delay	0 ms
					Paced AV	130 ms
					Sensed AV	100 ms

Pacing Details	Atrial	RV	LV	
Amplitude	1.50 V	2.00 V	2.25 V	
Pulse Width	0.40 ms	0.40 ms	0.20 ms	
Capture Management	Adaptive	Adaptive	Adaptive	
Amplitude Margin	2.0 X	2.0 X	+ 1.5 V	(2)
Min. Adapted Amplitude	1.50 V	2.00 V		
Max. Adapted Amplitude			6.00 V	
Acute Phase Remaining	Off	Off		
Acute Phase Completed	09-Jan-2013	09-Jan-2013		
Sensitivity	0.30 mV	0.30 mV		
Pace Polarity	Bipolar	Bipolar	LVtip to LVring	
Sense Polarity	Bipolar	Bipolar		

AV Therapies

Rate Adaptive AV	On	
Start Rate	90 bpm	(3)
Stop Rate	130 bpm	
Min PAV	100 ms	
Min SAV	70 ms	

Rate Response

ADL Rate	95 bpm	
Optimization	On	
ADL Response	3	
Exertion Response	3	(4)
Activity Threshold	Medium Low	
Activity Acceleration	30 sec	
Activity Deceleration	Exercise	
ADL Setpoint	8	
UR Setpoint	19	

Refractory/Blanking

PVARP	Auto	
Minimum PVARP	250 ms	
PVAB Interval	150 ms	
PVAB Method	Partial+	(5)
A. Blank Post AP	200 ms	
A. Blank Post AS	100 ms	
V. Blank Post VP	200 ms	
V. Blank Post VS	120 ms	

Arrhythmia Interventions

A. Rate Stabilization	Off	
A. Preference Pacing	Off	
Post Mode Switch	Off	(6)
V. Sense Response	Off	
Conducted AF Response	On	
Response Level	Medium	
Maximum Rate	110 bpm	
V. Rate Stabilization	Off	

Post Shock Pacing

Post Shock Pacing*		
A. Amplitude	4 V	
A. Pulse Width	1.50 ms	
V. Amplitude	6 V	(7)
V. Pulse Width	1.50 ms	
* Settings for first 25 beats post shock		
Post VT/VF Shock Pacing	Off	

Additional Features

Atrial Tracking Recovery	On	
Rate Drop Response	Off	
Sleep	Off	
Non-Comp Atrial Pacing	On	
NCAP Interval	300 ms	(8)
PMT Intervention	On	
PVC Response	On	
V. Safety Pacing	On	

Device Information

Device	Medtronic	Viva XT CRT-D DTBA2D1	BLJ600764S		Implanted: 09-Jan-2013
Atriale	Guidant	4054	448876	(9)	Implanted: 24-Jan-2006
VD/VCS	Medtronic	6947 Sprint Quattro Secure	TDG132463V		Implanted: 24-Jan-2006
VG	Medtronic	3830	LFF071976V		Implanted: 09-Jan-2013

Notes

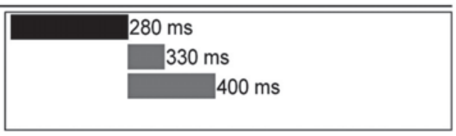
protocole alsync

Final: Parameters

Device: **Viva XT CRT-D DTBA2D1**ID:

VT/VF Detection

		V. Interval (Rate)	Initial	Redetect
VF	On	280 ms (214 bpm)	24/32	12/16
FVT	via VT	330 ms (182 bpm)		
VT	On	400 ms (150 bpm)	16	12
Monitor	Off	450 ms (133 bpm)	28	



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PR Logic/Wavelet		Other Enhancements		Sensitivity	
AF/Afl	On	Stability	Off	Atrial	0.30 mV
Sinus Tach	On	Onset	Off	RV	0.30 mV
Other 1:1 SVTs	On	High Rate Timeout			
Wavelet	On	VF Zone Only	Off		
Template	09-Jan-2013	All Zones	Off		
Match Threshold	70 %	TWave	On		
Auto Collection	Off	RV Lead Noise	On+Timeout		
SVT V. Limit	280 ms	Timeout	0.75 min		

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VF Therapies	Rx1	Rx2	Rx3	Rx4	Rx5	Rx6
VF Therapy Status	On On On On On On					
Energy	35 J	35 J	35 J	35 J	35 J	35 J
Pathway	B>AX AX>B B>AX AX>B B>AX AX>B					

ATP During Charging

Deliver ATP if last 8 R-R >= 240 ms,Burst, Pulses = 8, R-S1 = 88 %, Decrement = 10 ms

ChargeSaver = On(1 episodes), SmartMode = On

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FVT Therapies	Rx1	Rx2	Rx3	Rx4	Rx5	Rx6
FVT Therapy Status	On On On On On On					
Therapy Type	Burst	CV CV CV CV CV				
Energy		15 J	35 J	35 J	35 J	35 J
Pathway		B>AX AX>B B>AX AX>B B>AX				
Initial # Pulses	10					
R-S1 Interval=(%RR)	88 %					
S1S2(Ramp+)=(%RR)						
S2SN(Ramp+)=(%RR)						
Interval Dec	10 ms					
# Sequences	3					
Smart Mode	Off					

VT Therapies	Rx1	Rx2	Rx3	Rx4	Rx5	Rx6
VT Therapy Status	On On On On On On					
Therapy Type	Burst	Ramp	CV CV CV CV			
Energy			10 J	35 J	35 J	35 J
Pathway			B>AX B>AX AX>B B>AX			
Initial # Pulses	10	8				
R-S1 Interval=(%RR)	88 %	91 %				
S1S2(Ramp+)=(%RR)						
S2SN(Ramp+)=(%RR)						
Interval Dec	10 ms	10 ms				
# Sequences	3	3				
Smart Mode	Off	Off				

Shared V. ATP	
V-V Minimum ATP Interval	200 ms
V. Amplitude	8 V
V. Pulse Width	1.5 ms
V. Pace Blanking	240 ms
V. Pacing	RV

Shared V. Therapies	
Active Can/SVC Coil	Can+SVC On
Progressive Episode Therapies	Off
Confirmation+	On

Final: Parameters

Device: **Viva XT CRT-D DTBA2D1**

ID:

AT/AF Detection

Detection		A. Interval (Rate)		
Monitor				
	AT/AF	350 ms (171 bpm)	No Rx	350 ms

(13)

AT/AF Therapies

CV therapies have priority over pacing therapies.

AT/AF ATP	Rx1	Rx2	Rx3
AT/AF Rx Status	Off	Off	Off

Shared A. ATP

A-A Minimum ATP Interval	150 ms
A. Pacing Amplitude	6 V
A. Pacing Pulse Width	1.5 ms

Patient Activated CV

Patient Activated CV Status	Off

AT/AF Automatic CV	Rx4	Rx5
Automatic CV Status	Off	Off

Shared CV

Minimum R-R Interval	500 ms (120 bpm)
Active Can/SVC Coil	Can+SVC On

Stop Atrial Therapies After

Disable all A. Rxs if A. lead position is suspect? No

Atrial Lead Position Check

No measurement since reset.

Final: Parameters

Device: **Viva XT CRT-D DTBA2D1**

ID:

Data Collection Setup

Source		**Range**
LECG	Can to SVC	+/- 2 mV
EGM 1	Atip to Aring	+/- 8 mV
EGM 2 (Wavelet)	Can to RVcoil	+/- 12 mV
EGM 3	RVtip to RVring	+/- 8 mV

Monitored	EGM1 and EGM3
Pre-arrhythmia EGM	Off

(14)

V. Sensing Episodes

V. Senses to Detect	10 senses
V. Paces to Terminate	3 paces

Device Date/Time	09-Apr-2013 09:33
Holter Telemetry	Off

Medtronic CareAlert Setup

Patient Home Monitor Yes

(15)

Alert Conditions	**Enable-Urgency Tone / Monitor**	**Threshold**
OptiVol 2.0 Fluid Settings	Off / Off	60
AT/AF Daily Burden Settings	Off / Off	6 hr
Avg. V. Rate During AT/AF Settings	Off / Off	6 hr at 100 bpm
Number of Shocks Delivered in an Episode	Off / On	3
All Therapies in a Zone Exhausted	Off / On	
RV Lead Integrity	Off / On	
RV Lead Noise	Off / On	
A. Pacing Lead Impedance Out of Range	Off / On	<200 or >3000 ohms
RV Pacing Lead Impedance Out of Range	Off / On	<200 or >3000 ohms
LV Pacing Lead Impedance Out of Range	Off / On	<200 or >3000 ohms
RV Defibrillation Lead Impedance Out of Range	Off / On	<20 or >200 ohms
SVC Defib Lead Impedance Out of Range	Off / On	<20 or >200 ohms
Low Battery Voltage RRT	Off / On	2.73 V(RRT)
Excessive Charge Time EOS	Off / On	
VF Detection OFF, 3+ VF or 3+ FVT Rx Off.	Off / On	

Cardiac Compass report

1: programming and interrogation report:

This report shows when the device was interrogated or programmed in order to correlate changes in device programming and clinical evolution. When the patient is seen, the report indicates an "I" on the day of interrogation of the device and a "P" on the day when parameters are re-programmed, unless the changes are only temporary. If the device is interrogated and re-programmed on the same day, the report displays a "P" only. This patient was followed remotely in a Medtronic CareLink (telemedicine) session, which was recorded as an underlined "I" in the report.

2: treated episodes of VT/VF:

Ventricular rate during VT/VF, non-sustained episodes of VT/VF, overall duration (in minutes) of AT/AF, ventricular rate during AT/AF, mean diurnal and nocturnal ventricular rate: the diurnal and nocturnal heart rate provide information, which might predict cardiac decompensation. A day is defined by the internal clock of the device as the 12-h period between 8 a.m. and 8 p.m., and a night is a 4-h period between midnight and 4 a.m.

3: percentage of A and V stimulation:

This graph shows the percentages of pacing over time.

4: activity:

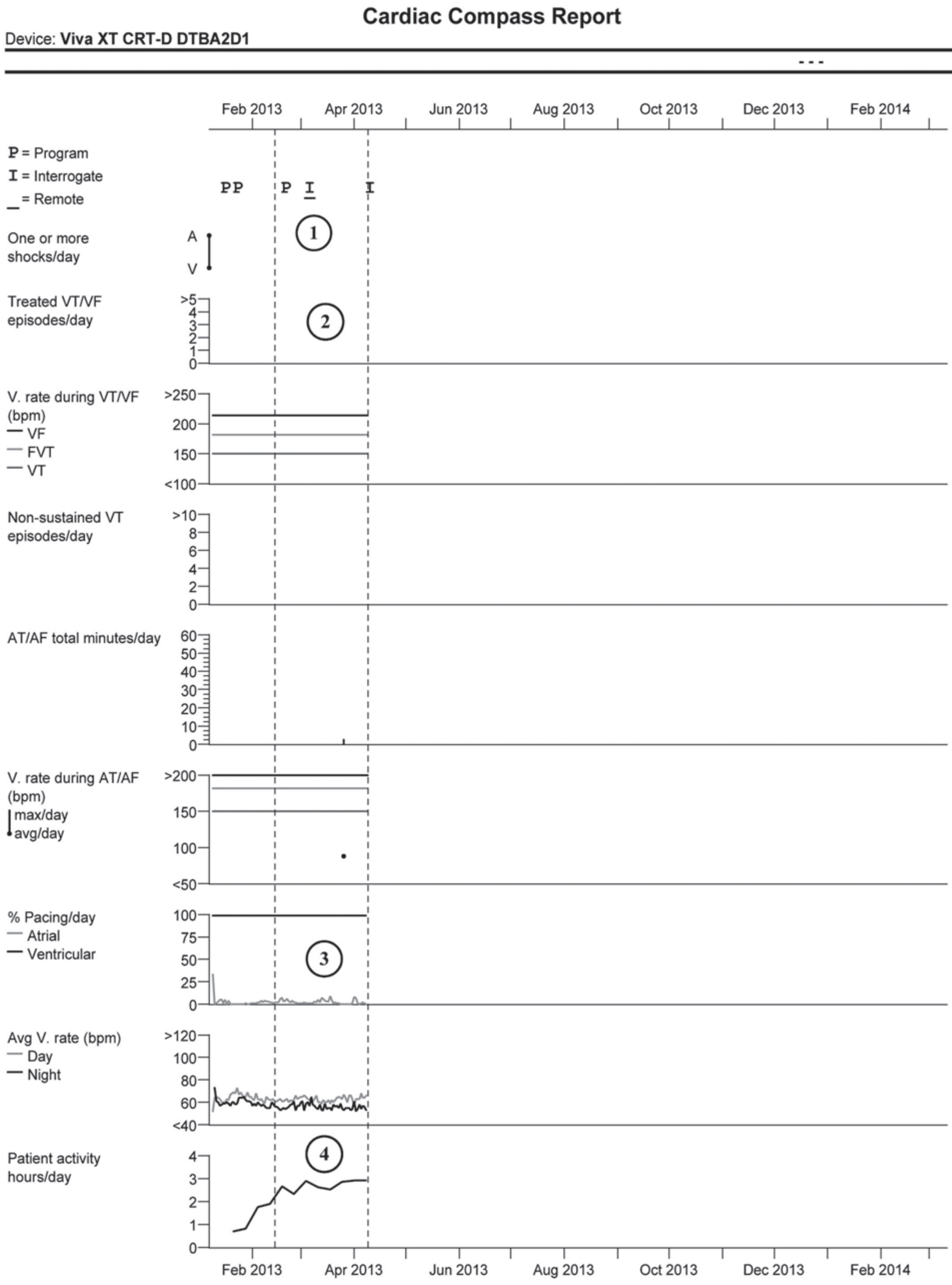
A decrease in patient activity might be a sign heralding the development of cardiac decompensation (fatigue and, consequently, a decrease in physical activity). The evolution of the activity corresponds to a mean of 7 days of data extracted from the rate responsive accelerometer of the device.

5: index of pulmonary overload:

The graphs of the index of pulmonary overload, OptiVol 2.0, and of the thoracic impedance are data collected over the last 14 months (since the device implant in this patient). This patient was a clear responder to resynchronization, and the index of pulmonary overload remained below the programmed threshold.

6: heart rate variability:

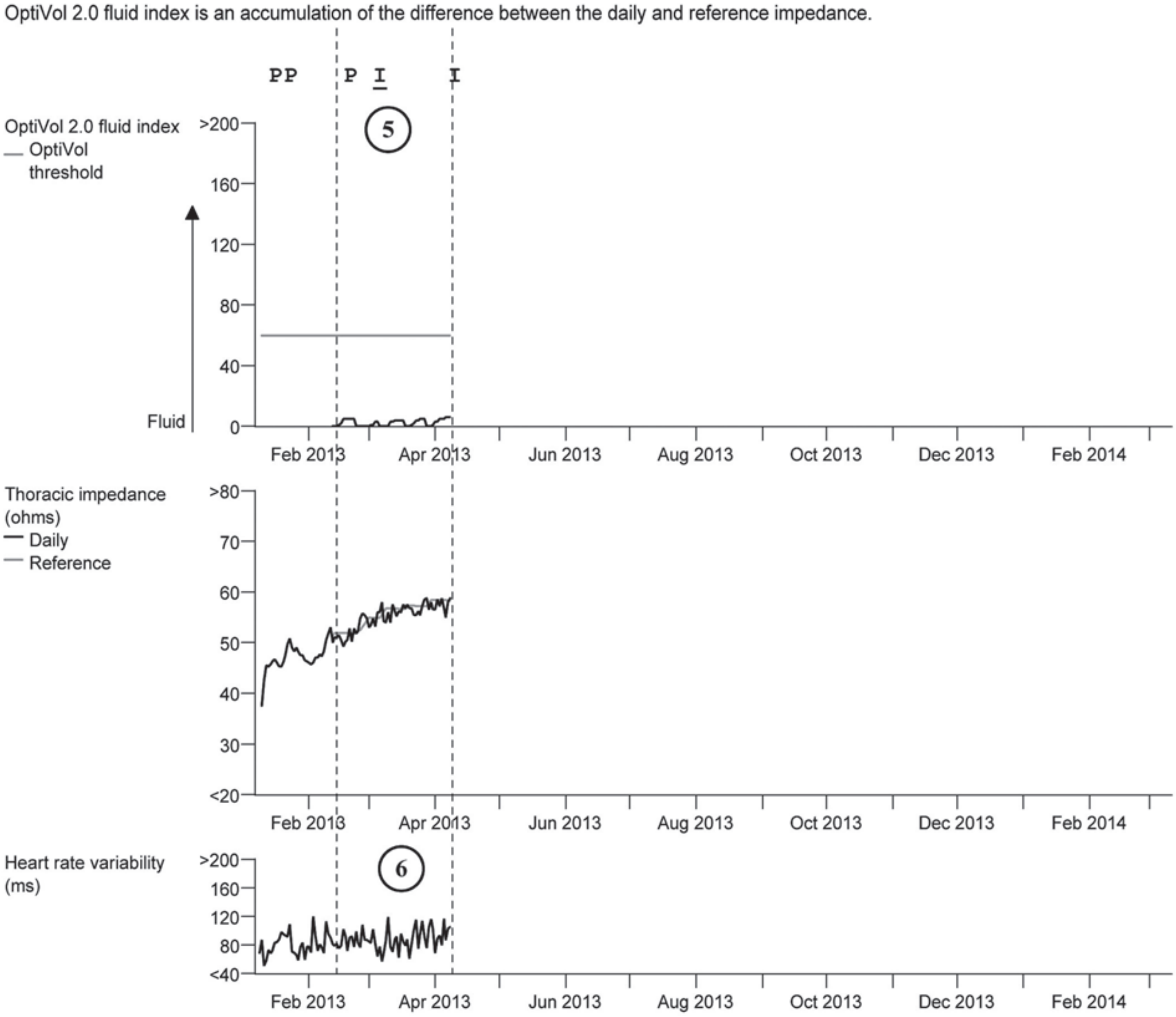
A decrease in HRV (sinus variability) may herald the development of cardiac decompensation. The device measures each atrial interval and calculates the median interval every 5 min. It then calculates and records a daily variability, expressed in ms.


Cardiac Compass Report
Device: Viva XT CRT-D DTBA2D1
Feb 2013
Apr 2013
Jun 2013
Aug 2013
Oct 2013
Dec 2013
Feb 2014
P = Program
I = Interrogate
_ = Remote
P P
P I
I
One or more shocks/day
A
V
1
Treated VT/VF episodes/day
>5
4
3
2
1
0
2
V. rate during VT/VF (bpm)
VF
FVT
VT
>250
200
150
<100
Non-sustained VT episodes/day
>10
8
6
4
2
0
AT/AF total minutes/day
60
50
40
30
20
10
0
V. rate during AT/AF (bpm)
max/day
avg/day
>200
150
100
<50
% Pacing/day
Atrial
Ventricular
100
75
50
25
0
3
Avg V. rate (bpm)
Day
Night
>120
100
80
60
<40
Patient activity hours/day
4
3
2
1
0
4

Cardiac Compass Report

Device: **Viva XT CRT-D DTBA2D1**

OptiVol 2.0 fluid index is an accumulation of the difference between the daily and reference impedance.



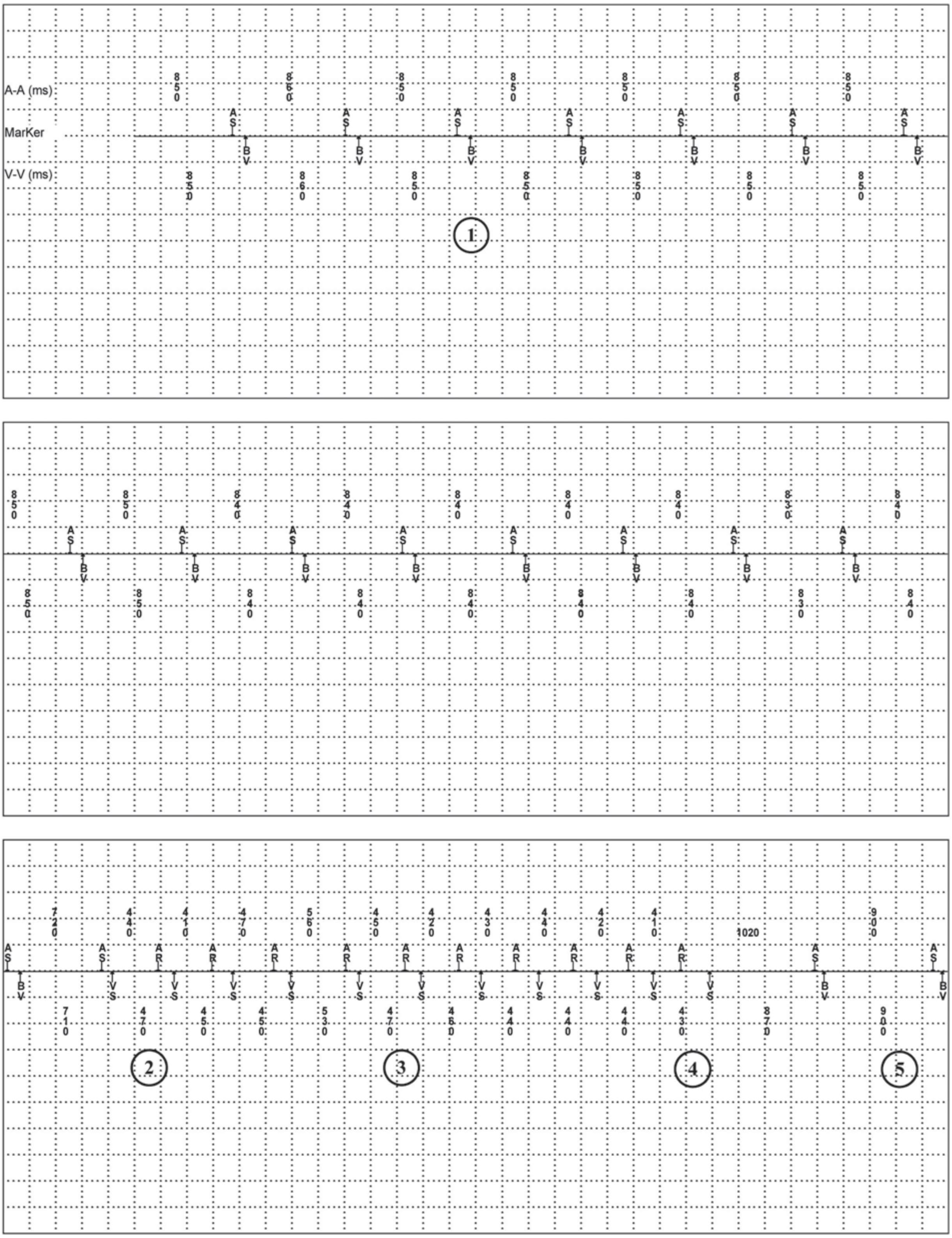
Episode of ventricular sensing

When BiV stimulation is not consistent, the source of spontaneous ventricular events must be ascertained. Episodes of ventricular sensing (absence of BiV stimulation) can be retrieved from the device memory during interrogation of the device. An episode of ventricular sensing is defined as a period during which ventricular stimulation is inhibited by spontaneous ventricular activity. The data collected with an episode of ventricular sensing include the date and time, the duration, the intervals and markers, the peak atrial and ventricular rates, and an indication of whether the episode participated in a tachyarrhythmia. The device begins the data collection for an episode of ventricular sensing after a programmable number of consecutive sensed ventricular events, and quits collecting the data after a programmable number of consecutive paced ventricular events.
In this patient, a few episodes of ventricular sensing were stored in memory; this type of episode includes the display of intervals and markers, without EGM.

1: atrial sensing and BiV stimulation.
2: onset of arrhythmia after an atrial extrasystole (AR);
3: 1:1 tachycardia followed by series of spontaneous atrial and ventricular events. The various VS are preceded by an AR (atrial event falling in the PVARP). The ventricular events were interpreted by the device as VES (VS non-preceded by AS). The PVARP was therefore extended to 400 ms, such that the next atrial event also fell in the PVARP. After 10 (programmable value) consecutive VS, the device recorded an episode of ventricular sensing.
4: end of arrhythmia with a ventricular event. Its onset and termination are consistent with an atrial tachycardia.
5: resumption of BiV stimulation. The end of sensing required 3 (programmable value) ventricular stimulated events.

Monitored VF Episode # 2

Device **Viva XT CRT-D DTBA2D1**



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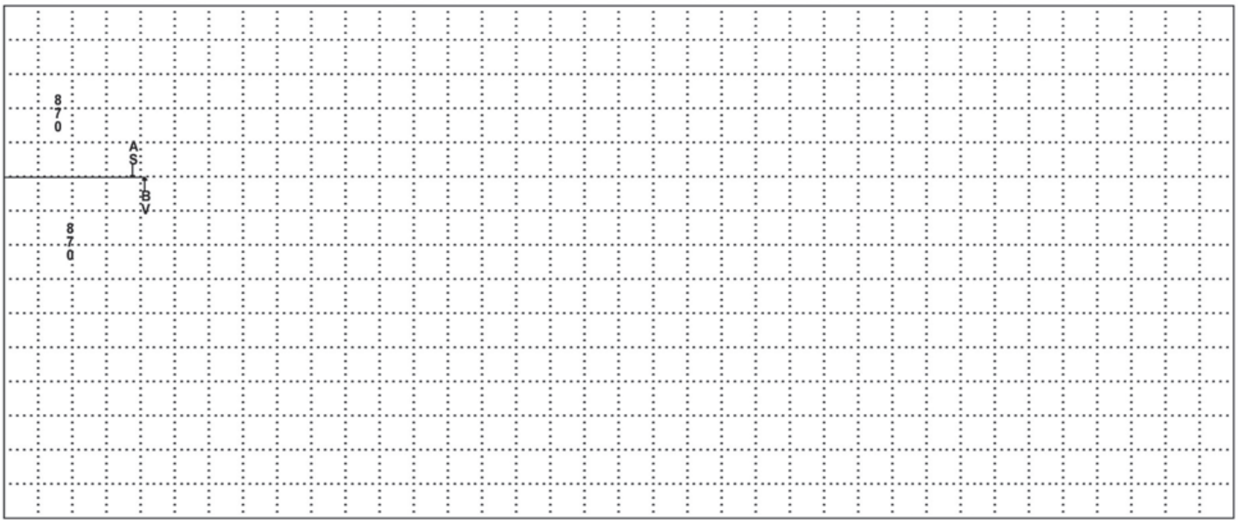
Monitored VF Episode # 2

Devcie: **Viva XT CRT-D DTBA2D1**



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Chapitre 2

Basic Parameters Programming

Basic parameters Programming

The first goals of the basic CRT programming are to maintain a permanent biventricular capture and to optimize the patient hemodynamic. CRT recipients may present various form of underlying disease. Therefore CRT optimization should be tailored to the patient characteristics. CRT programming should also take into account the need for detecting and treating ventricular arrhythmias.

Minimal rate and pacing mode

Tuning the pacing basic interval will impact the percentage of atrial pacing. The left atrium is the only cavity that cannot be stimulated directly with a conventional CRT; however, it plays a major role in the preload of the LV failing heart. It seems that the activation time of the left atrium is longer in a majority of patients during atrial stimulation (atrial latency + inter-atrial delay) as compared with the timing during sinus rhythm. As a consequence, the LV filling time may be reduced during atrial pacing.

In patients with no sinus node dysfunction, the basic heart rate should be kept low in order to reduce as much as possible the percentage of atrial pacing. This will allow for a more physiological activation of the left atrium but also for preserving the battery.
Both the VDD and DDD pacing mode can be programmed. In patients with no sinus node dysfunction, the DDI pacing mode should be avoided.
In patients with a sinus node dysfunction at rest, either intrinsic or induced by a drug (beat-blockers…), atrial pacing is mandatory. The DDD pacing mode with a rate response (in case of chronotropic incompetence) should be preferred and the VDD mode should be avoided.
There is no consensus on a minimal heart rate for all patients. At least, it is suggested that a basic pacing rate of 60bpm is associated with a better cardiac output without increasing the cardiac oxygen consumption when compared to a basic heart rate of 40bpm. Also, it can be said that higher resting heart rate (>70bpm) should be avoided. Still, in some patients with frequent ventricular extrasystole or slow VT, increasing the minimal heart rate may allow for reducing the burden of arrhythmias and increase the rate of biventricular pacing. However, these effects are usually temporarily observed or only partially useful. It is also possible to program some algorithm that may reduce the incidence of atrial fibrillation by increasing the heart rate and forcing the atrial stimulation. Potential benefits from these therapies in resynchronized patients remain to be demonstrated.

Upper tracking rate

We will see in the paragraph dedicated to the programing at exercise, some specific characteristics related to the upper tracking rate (UTR).
An important proportion of CRT patients present a sinus rhythm, a normal AV conduction and normal chronotropic capacities. Therefore, the UTR should be programed just above the maximal sinus rate achieved during exercise. Doing so, the biventricular stimulation is kept during the all exercise and Wenckebach behaviors are avoided. A classical mistake consists in programing a low UTR in CRT patients. In such situation, the biventricular pacing is lost at peak exercise, whereas it is probably the most needed. Current switch mode quality embedded in pacemaker is good enough to avoid a risk of rapid pacing during AF episodes. There is thus no risk to increase the UTR to 140, 150bpm, in particular if loss of biventricular pacing is demonstrated during exercise.

Rate responsive mode

Rate responsive algorithm principles are detailed in chapter 5, dedicated to the programing of CRT during exercise. Intrinsic and drug induced chronotropic insufficiency is frequently observed in HF patients. Programing a rate responsive function in this context clearly improves the patient's exercise capacity and quality of life. The DDDR pacing mode should be favored in patients presenting a peak exercise HR below 70% of the predicted maximal HR. In contrast, in patients with a normal chronotropic function, rate response algorithm should be avoided because it may result in unnecessary increase of the atrial pacing, that may interfere with the physiological acceleration, increase the myocardial consumption, and even alter the patient hemodynamic.

Switch mode

Heart failure patients are prone to present episodes of atrial fibrillation. Accordingly, the switch mode should be systematically programmed.
If the patient is in atrial fibrillation, a resting HR slightly increased (70bpm for example) in conjunction with a rate response, allows for increasing the percentage of biventricular pacing.

Atrial and ventricular sensing

Atrial leads are bipolar. Ventricular leads are programmable either in «true» bipolar (dedicated) or in tip to coil configuration (integrated bipolar). There are two types of right ventricular leads: the true bipolar (tip electrode + ring electrode) and the integrated bipolar leads (no ring, sensing being performed between the tip electrode and the defibrillation coil). With a true bipolar lead, it is possible to choose between a true bipolar (tip – ring) or an integrated - pseudo bipolar (tip – coil) configuration. The sensing vector is therefore programmable via the polarity configuration.
With an integrated bipolar lead, the sensing vector will occur only between the tip electrode and the defibrillation coil.
There is no left ventricular sensing on the Medtronic ICDs.
The primary goal of the CRT programing is to maintain the percentage of biventricular pacing around 100%. Therefore, ventricular oversensing and inappropriate inhibition should be minimized. The ventricular sensing should be programmed to avoid the detection of any P wave, T wave or ventricular double counting (frequently observed in patients with severe conduction delay), but also to detect ventricular EGM during ventricular arrhythmias (which is mandatory for the good functioning of the ICD).
Atrial undersensing may also cause a reduction in the rate of biventricular pacing.
Exercise and the increase in the amplitude of the respiratory movements are often associated with a decrease in the atrial sensing. Therefore, we recommend programming a relatively high sensitivity as compared with the sensing at rest.

Blanking periods

A blanking period follows a sensed or a paced event in the same cavity or a paced event in the other cavity. There is also a blanking period after a shock. Blanking periods following paced events are programmable with a value superior or equal to the blanking period following a sensed event.
After biventricular stimulation, the duration of the atrial blanking or the ventricular post stimulation blanking starts from the end of the second stimulus if a VV delay is programmed. The atrial detection is deactivated after an atrial-sensed event for the all duration of the atrial post atrial sensed blanking period. After a paced atrial event, the atrial detection is deactivated for the all duration of the atrial post atrial paced blanking period. The ventricular detection is deactivated after a sensed ventricular until the end of the ventricular post ventricular sensed blanking period. After a paced ventricular, the ventricular detection is deactivated for until the end of the ventricular post ventricular paced blanking period. The Atrial blanking period after a paced ventricular event (30 ms) and the Ventricular blanking period after an atrial paced event (30 ms) are not programmable.

Post ventricular atrial refractory period (PVARP)

Recurrent sequences AR-VS with loss of biventricular stimulation may occur when relatively long PVARP are programmed classically after a premature ventricular complex or an oversensing of the T-wave. The following P wave falls in the PVARP and do not launch a new AV delay. This results in a conducted, spontaneous QRS. If the PP interval is shorter than the sum AR-VS + PVARP, the following P waves fall also in the PVARP and the AR-VS cycles continue. The probability that the phenomenon continue by itself increases with the duration of the spontaneous PR interval (prolonged AR-VS intervals) and the duration of the PVARP. Some algorithms allowing for a transient prolongation of

the PVRAP (response to a VPB, interruption of PMT) can promote this phenomenon. Programing an automatic PVARP (adaptation of the PVARP duration to the heart rate: the slower is the HR, the longer is the PVRAP) can also facilitate this mechanism (PVARP auto).
Interrogating the device memory identifies repetitive cycles (AR-VS) in the ventricular sense episodes. With CRT patients, those algorithms should thus be carefully programed.

To interrupt this succession of AR-VS cycles, the atrial tracking recovery algorithm should be programmed. It allows for a quick recovery of the atrial synchronization in case of its loss due to several consecutive atrial events in the PVARP. The PVARP is temporarily shortened and the following P-wave (classified as AS instead of AR) launches an AV delay triggering biventricular stimulation.

Ventriculo-atrial crosstalk prevention

VA crosstalk (oversensing of the ventricular stimulus or depolarization by the atrial channel) may alter the quality of the discrimination of the arrhythmias but also trigger inappropriate switch mode commutation and result in the loss of biventricular pacing
Typically, crosstalk problems present themself with an alternating pattern of two different morphologies and two different atrial cycles (short – long sequence). To reduce the risk of crosstalk, the atrial sensitivity may be reduced, with the risk of undersensing episodes of atrial fibrillation.

Tracing 1: alternating atrial sensed and paced events

Patient

47 years old man, implanted with a triple chamber defibrillator Viva XT CRT-D for dilated cardiomyopathy with left bundle branch block; 3 months – routine - follow-up after implantation (DDD 70 bpm);

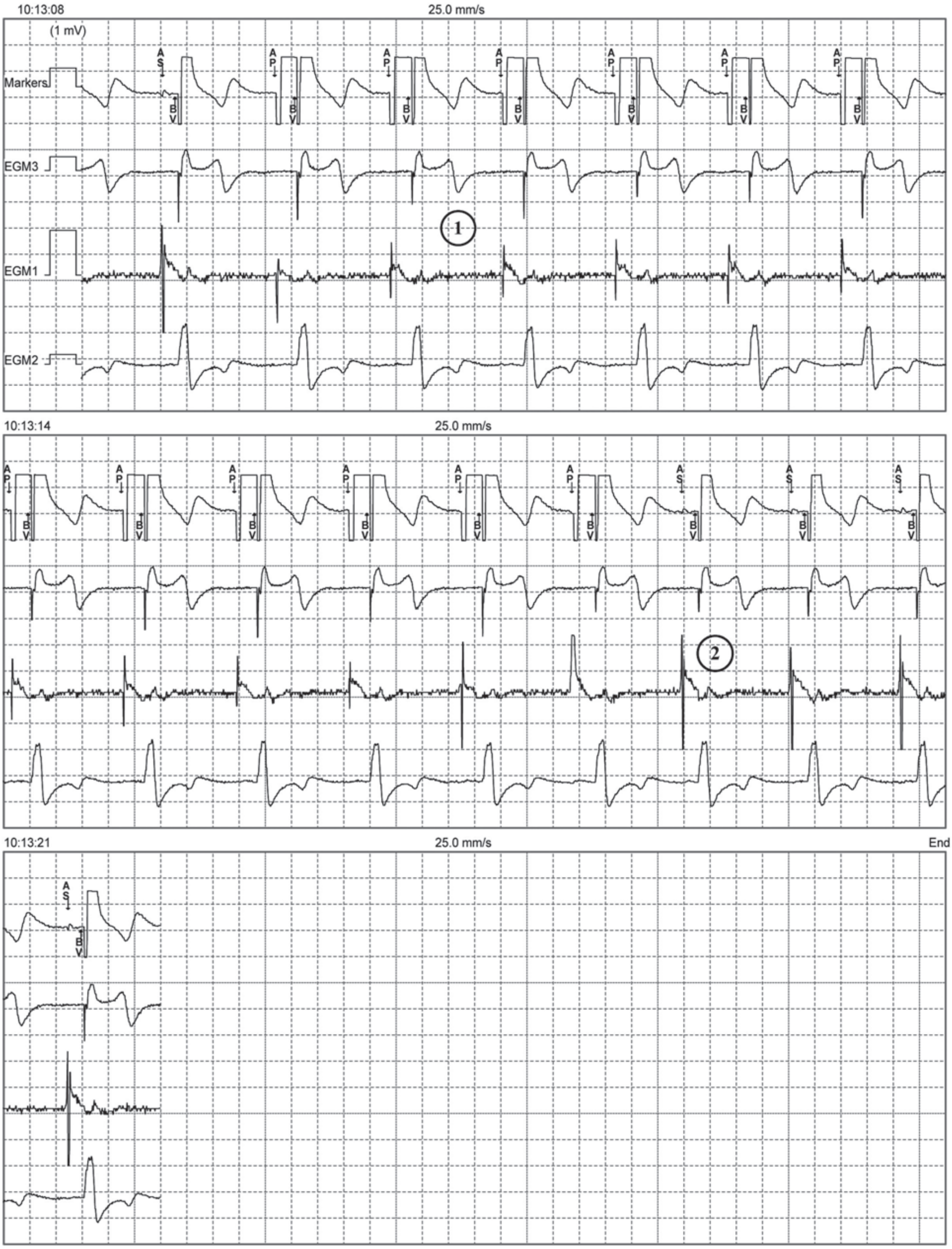
Tracing

1: atrial stimulation and biventricular stimulation (AP-BV);
2: atrial sensed event and biventricular stimulation (AS-BV);
3: persistent alternating atrial paced and sensed events;
Modification of the programing: DDD 60 bpm;
4: permanent atrial detection and biventricular stimulation;

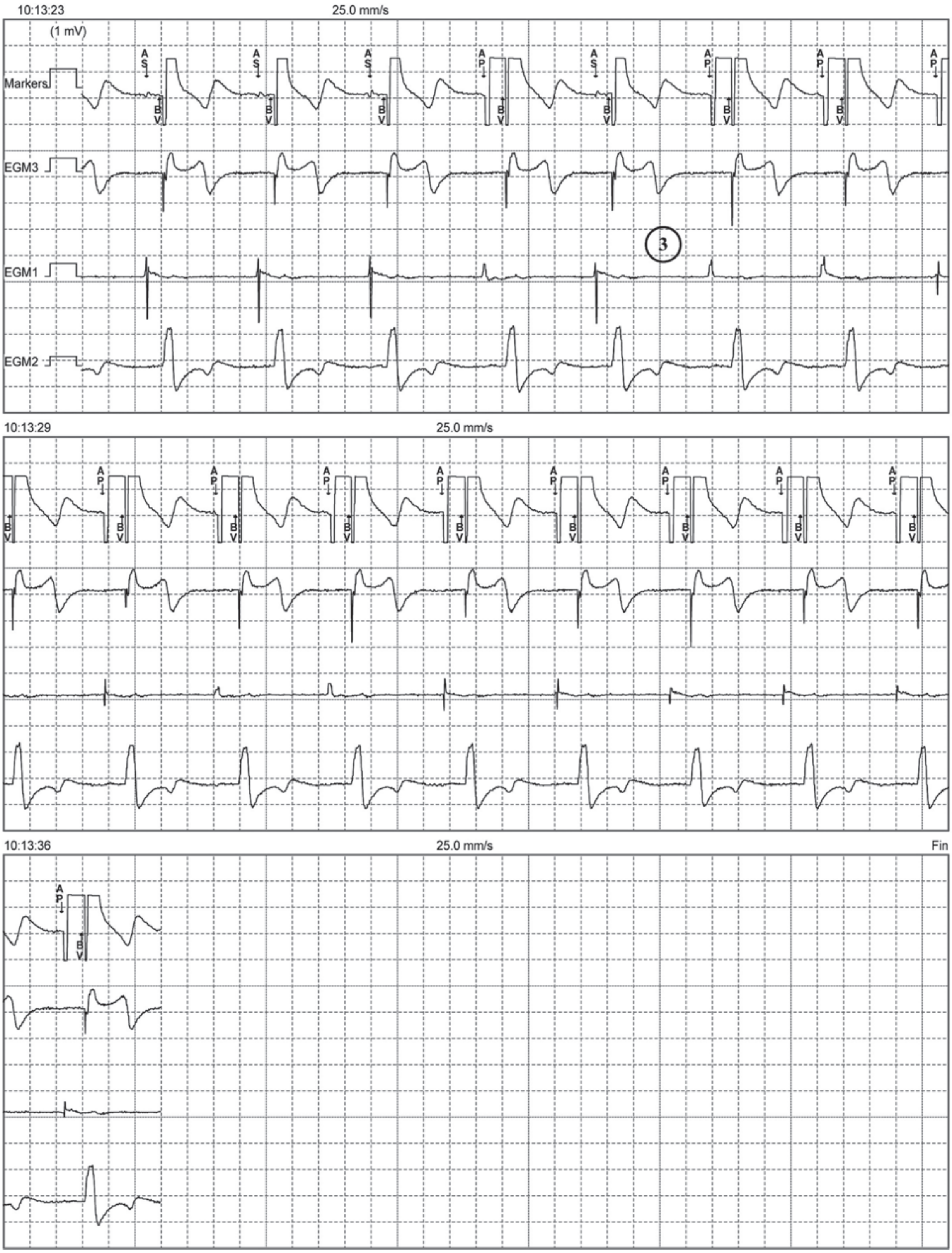
Comments

In the absence of manifest sinus node dysfunction, it is preferable to promote spontaneous atrial activity by programing a relatively low minimal heart rate. In this patient, programming the minimal heart rate at 70 bpm induced a competition and alternation between the spontaneous atrial rhythm and the atrial pacing. Slowing the minimum frequency yielded a permanent atrial sensing at rest as during exercise that allowed 1) to limit energy consumption and save battery 2) to maintain a physiological atrial activation and reduce the atrial activation time. However, the effect on the potential occurrence of an atrial arrhythmia remains more controversial.

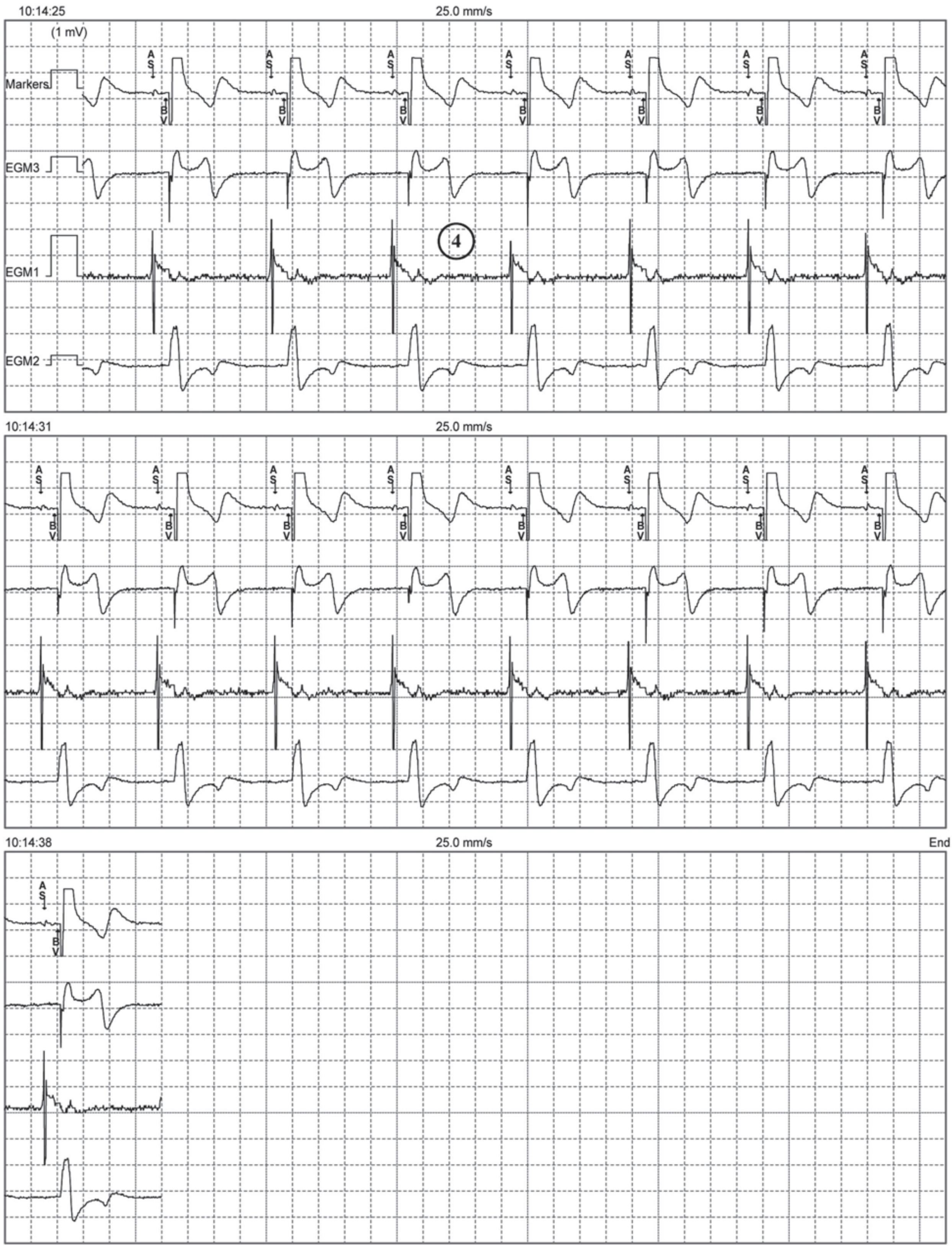
Device: **Viva XT CRT-D DTBA2D1**



Device : **Viva XT CRT-D DTBA2D1**



Device : **Viva XT CRT-D DTBA2D1**



Tracing 2: VA crosstalk and atrial undersensing

Patient

65 years old man, implanted with a triple chamber defibrillator Concerto II CRT-D for valvular cardiomyopathy with left bundle branch block; crosstalk and adjustment of the atrial sensitivity at 0.5 mV; interrogation of the device demonstrating ventricular sensed cycles.

Tracing

Ventricular sensed episode obtained during the initial interrogation of the device;

1: alternation of AS – BV – AR (the ventricular activity is sensed by the atrial channel but falls in the PVARP) cycles; possible crosstalk;

2: series of 6 consecutive VS cycles corresponding to an episode of atrial undersensing (no modification of the ventricular rate); loss of biventricular stimulation;

Tracing recorded during the interrogation of the device

3: atrial detection and biventricular pacing (AS-BV);

4: atrial undersensing and ventricular sensing;

5: crosstalk (AS-BV-AR cycles);

6: long lasting episode of atrial undersensing with the absence of biventricular pacing;

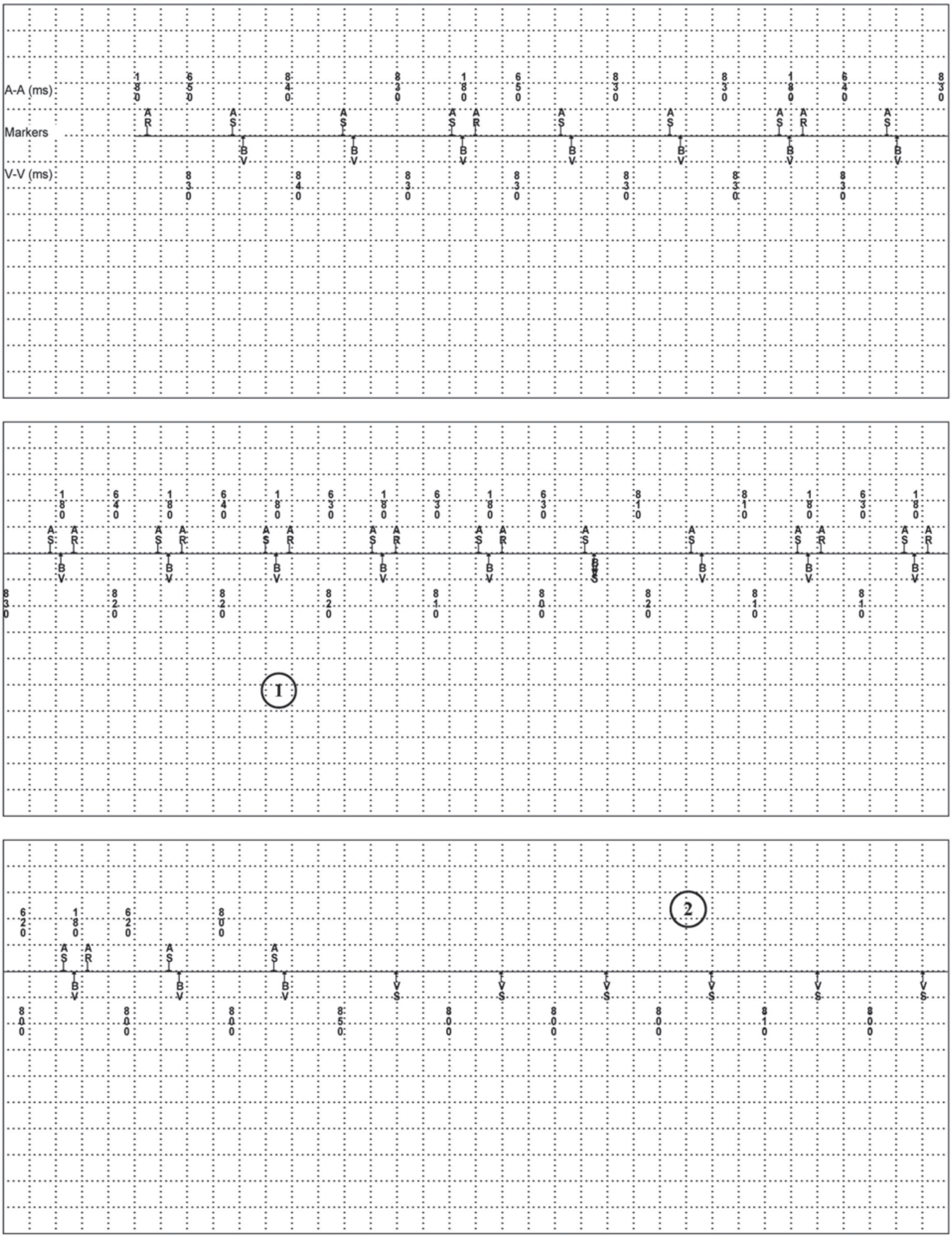
Comments

This tracing illustrates the difficulty of adjusting the atrial sensitivity in CRT patients. This patient has both a VA crosstalk justifying a decrease of the atrial sensitivity, and an atrial detection signal (in sinus rhythm) of small amplitude, warranting an increase of the atrial sensitivity. At rest, the atrial amplitude was measured at 0.8 mV. The crosstalk was permanent with the atrial sensitivity programmed at 0.5 mV. The quality of the atrial detection can be altered with the chest expansion. In patients with preserved atrioventricular conduction, the sudden loss of the atrial detection will result in an interruption of biventricular pacing. In patients with no AV conduction (dependent patients), the sudden loss of the atrial detection will result in a sharp drop of the heart rate. In this patient, the solution is probably not to try to find a compromise in programming the atrial sensitivity (avoid crosstalk and preserve detection) but to set a high sensitivity (0.3 mV) and try to avoid crosstalk by extending an absolute post-ventricular atrial blanking period. This may reduce the device capacity to detect episodes of atrial arrhythmia and to discriminate the origin of the arrhythmias.

Monitored VT/VF episode # 9659

Device: **Concerto II CRT-D D294TRK**

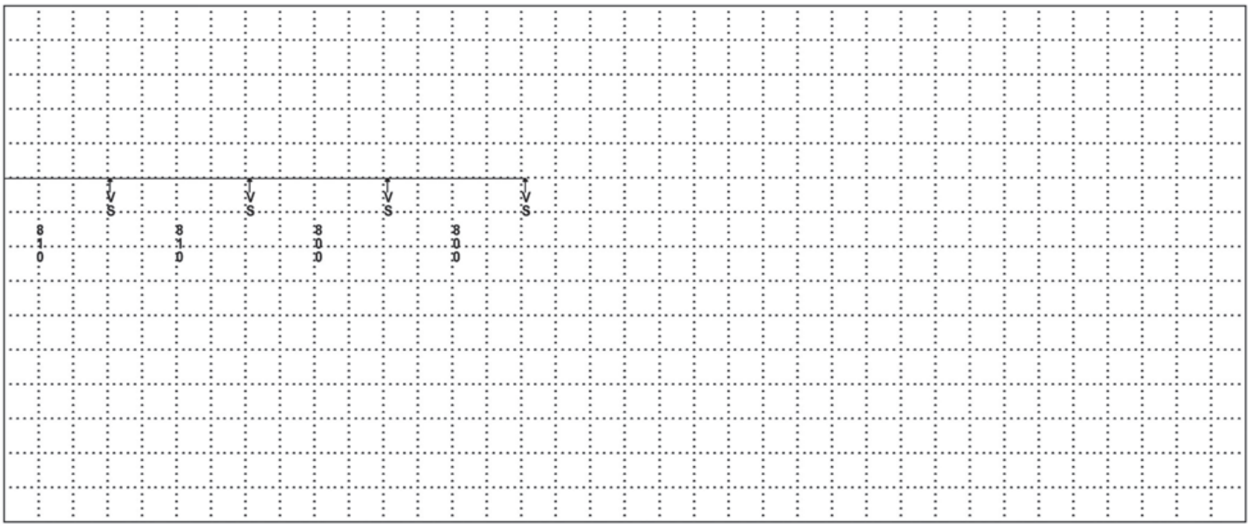
ID :



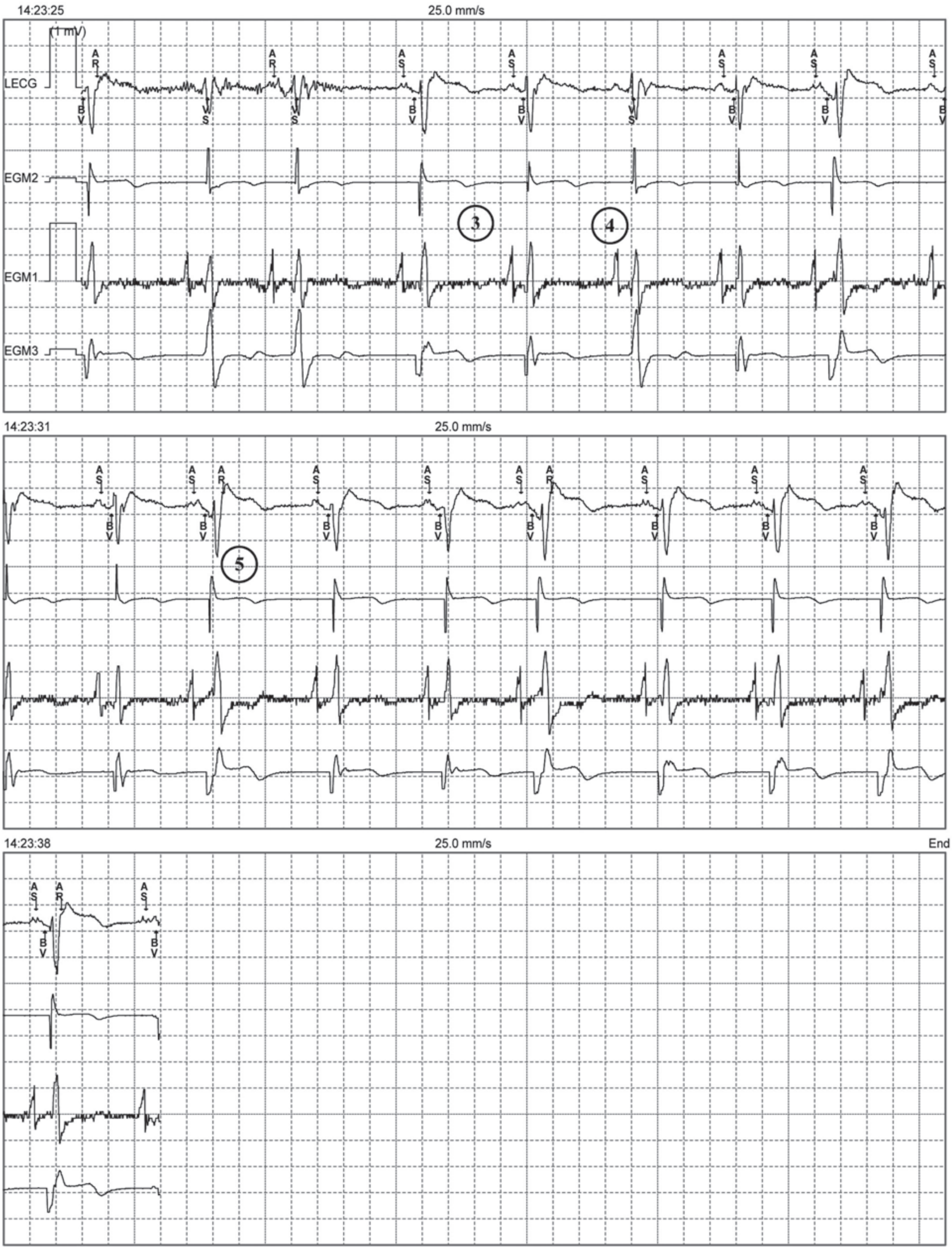
Monitored VT/VF episode # 9659

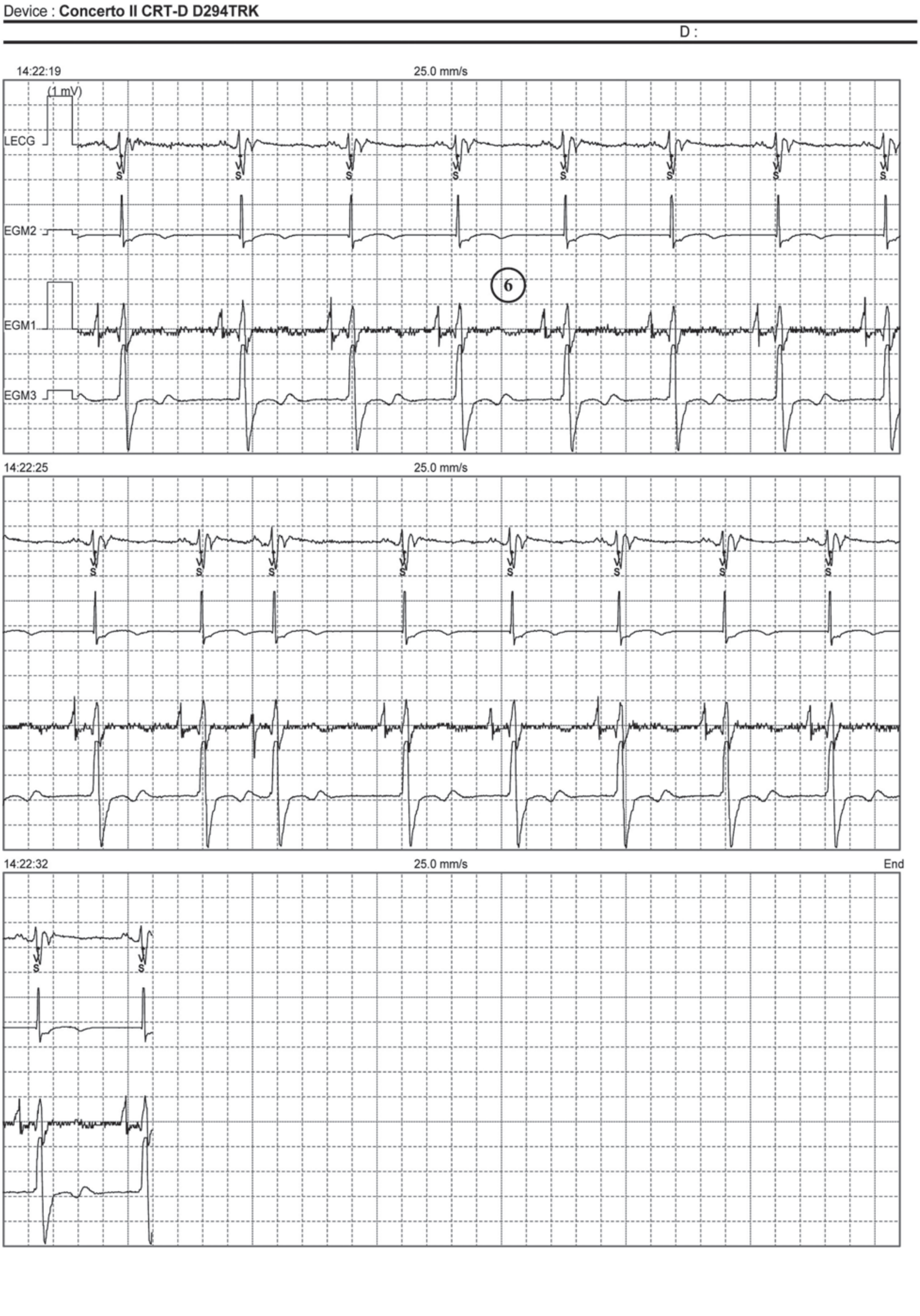
Device : **Concerto II CRT-D D294TRK**

D :



Device : **Concerto II CRT-D D294TRK**





Device : Concerto II CRT-D D294TRK
D :
14:22:19
25.0 mm/s
(1 mV)
LECG
EGM2
EGM1
EGM3
6
14:22:25
25.0 mm/s
14:22:32
25.0 mm/s
End

Tracing 3: crosstalk and ventricular oversensing

Patient

65 years old man, implanted with a triple chamber defibrillator Concerto II CRT-D for ischemic cardiomyopathy with complete AV bloc and episodes of atrial arrhythmias; implanted with a true (dedicated) bipolar ventricular lead in the inter-ventricular septum; several episodes of dizziness;

Tracing

Episodes of ventricular sensed event in the device memory

1: possible atrial arrhythmia and biventricular pacing;
2: spontaneous atrial and ventricular rhythm (with a 1/1 ratio and synchronous atrium and ventricle);
3: recovery of biventricular pacing;

Episodes of non-sustained VT in the device memory

4: diagnosis of non-sustained VT;
5: atrial arrhythmia and biventricular pacing; paced ventricular event are detected in the atrium (V/A crosstalk); we can also identify on the ventricular channel a small amplitude signal (non detected) preceding the atrial signals;
6: probable A/V crosstalk with detection of the atrial signal by the ventricular channel and inhibition of biventricular pacing resulting in a pause of 2 to 3 seconds; the atrial component that was present before but not detected at the ventricular level, is now detected; these are noted TS (in the VT zone);
7: recovery of biventricular pacing;

During this consultation, the complete interrogation of the device was performed with a programmed sensitivity of 0.5 mV

EGM1: atrial EGM, EGM2: ventricular EGM (bipolar channel), EGM3: ventricular EGM (far-field channel)

8: atrial arrhythmia and biventricular pacing;
9: modification of the programming (increase of the ventricular sensitivity at 0.3 mV);
10: A/V crosstalk; ventricular oversensing of the atrial activity during respiratory movements (breath); ventricular pause (false diagnosis of non-sustained VT);
11: biventricular pacing recovery;
12: programming of ventricular sensitivity at 0.5 mV;
13: atrial arrhythmia and biventricular pacing;
14: activation of the algorithm of response to sensed event (trigger pacing) and of a ventricular sensitivity of 0.3mV;
15: ventricular oversensing occurring during a deep breath but no pause because the biventricular pacing response to a detected ventricular event is activated (VVT); markers are difficult to see because they are superimposed (fusion of VS and BV); this type of particular stimulation is limited in frequency; however the device is less sensitive after a stimulation than after a sensed event. Accordingly, the first signals following the ventricular pacing are not detected (detection occurs at the end of the cycle when the sensitivity is maximal), which explain a limited frequency of intervention;
16: interruption of oversensing;
17: new episode of ventricular oversensing due to respiratory movements;

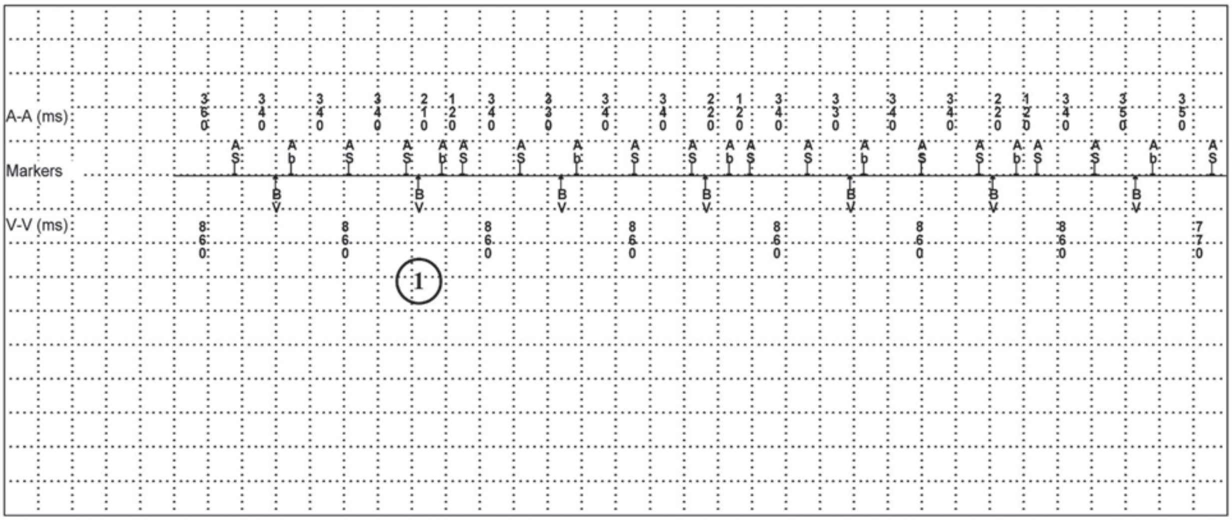
Comments

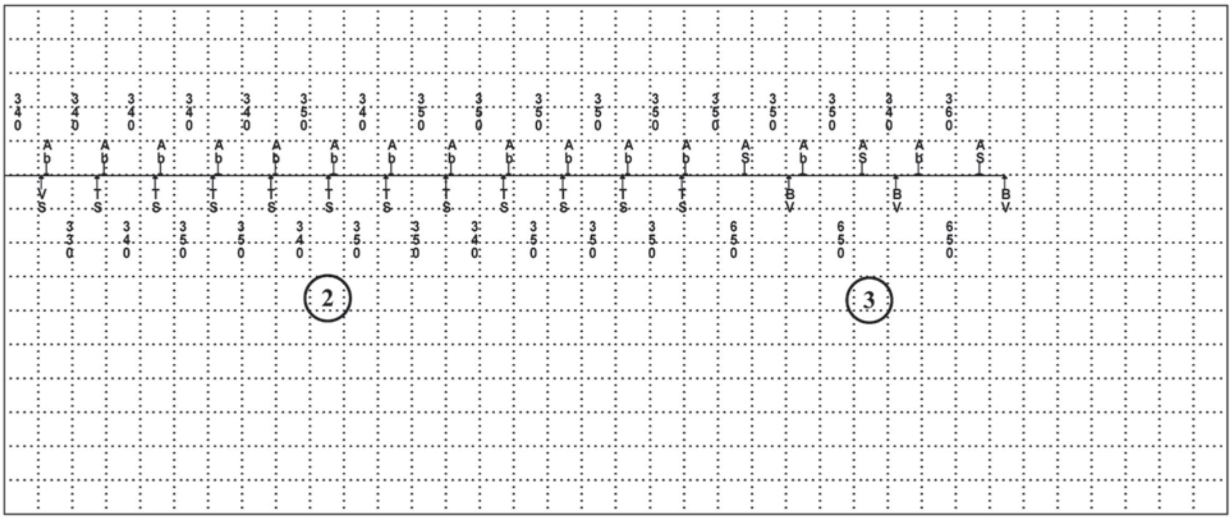
This pacemaker-dependent patient had multiple episodes of pre-syncope related to a crosstalk of an atrial arrhythmia to the ventricular channel, inducing inappropriate inhibition of the ventricular stimulation and prolonged asystole. This ventricular oversensing of the atrial signal varied with the respiratory cycles, appearing only during inspiration, which explained the brief duration of the pauses and the relatively modest symptoms.

There is no post atrial-sensed ventricular blanking period that can protect against this type of ventricular oversensing. In addition, the atrial signal was first seen by the ventricular channel then by the atrial channel, which precludes the effectiveness of such a blanking period.
Two options may be preferred in this context: 1) reposition the right ventricular lead; in this patient the lead was positioned on the high inter-ventricular septum (no lead displacement seen on the chest X-ray); 2) find a compromise for the device programming; the first option would be to reprogram the RV detection in integrated bipolar (ventricular sensing between the coil and the tip electrode); in this case, this option did not allow to suppress the atrial oversensing; a second option would be to program the response to a detected ventricular sensed event option. As demonstrated in this case, this option allowed to avoid pacing inhibition without suppressing the atrial oversensing; a third option would be to reduce ventricular sensitivity to avoid the atrial oversensing. However, this would be associated with an increased risk of undersensing true ventricular arrhythmias.
In this patient, reprogramming the ventricular sensitivity at 0.6 mV has eliminated these episodes of oversensing; induction of a FV was performed to verify the accurate detection of the ventricular arrhythmia despite the alteration of the ventricular sensitivity.

VT/VF Episode # 52

Device : **Concerto II CRT-D D294TRK**





non sustained VT/VF episode # 1 16799

Device: **Concerto II CRT-D D294TRK**

Episode #16799: 09:03:10

(4)

Episode Summary

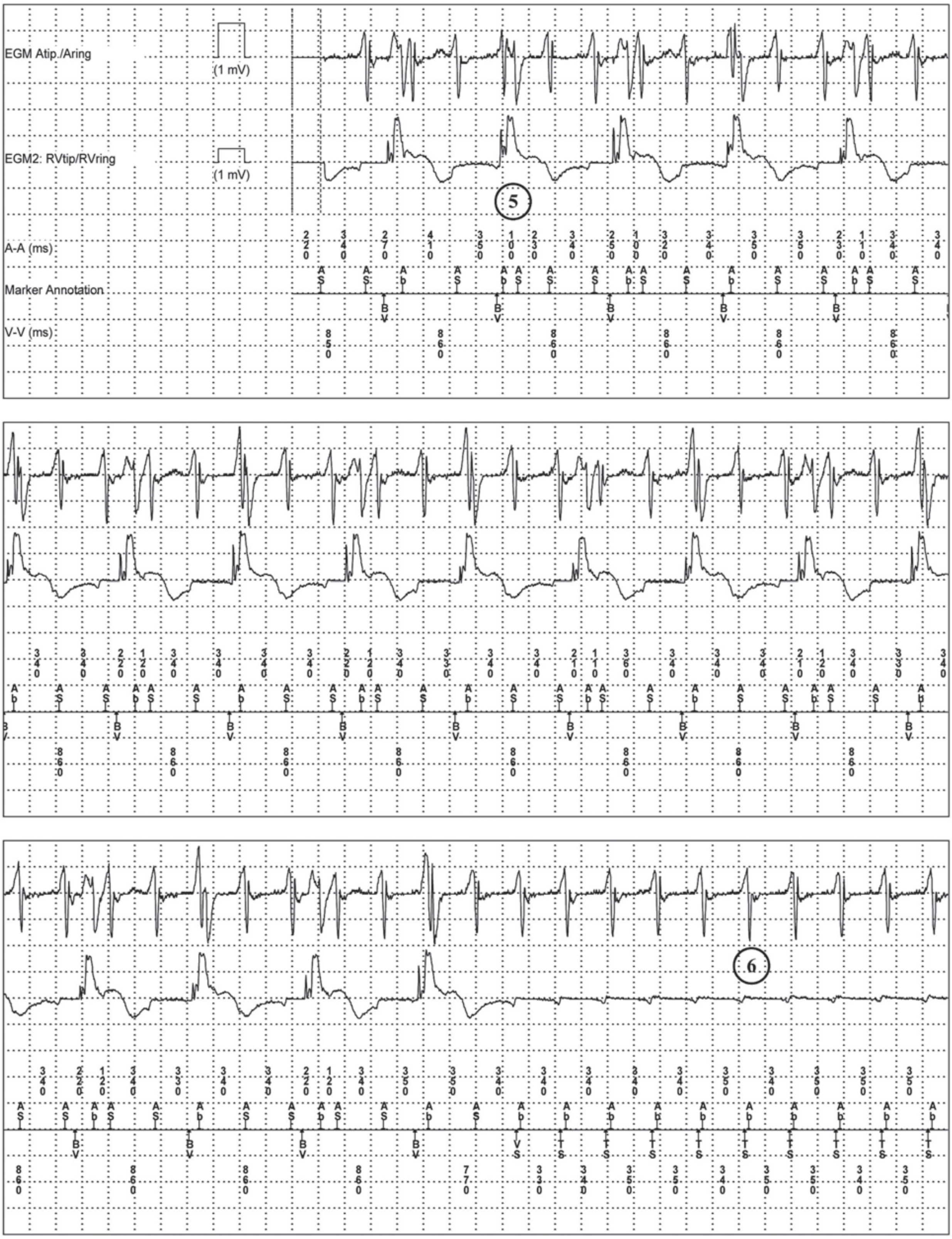
Initial type	VT non sustained (spontaneous)
Duration	1 s (11 beats)
V. médian	171 min^{-1} (350 ms)
Activity at onset	Off, Sensor = 74 bpm

Parameter Settings		Initial	Redetect	V. Interval (Rate)
VF	On	18/24	9/12	280 ms (214 bpm)
FVT	via VF			240 ms (250 bpm)
VT	On	16	12	430 ms (140 bpm)
Monitor	Off	20		

EGM	Source	Range	Sensitivity	
EGM1	Atip/Aring	+/- 8 mV	Atrial	0.3 mV
EGM2	RVtip/RVring	+/- 8 mV	RV	0.3 mV

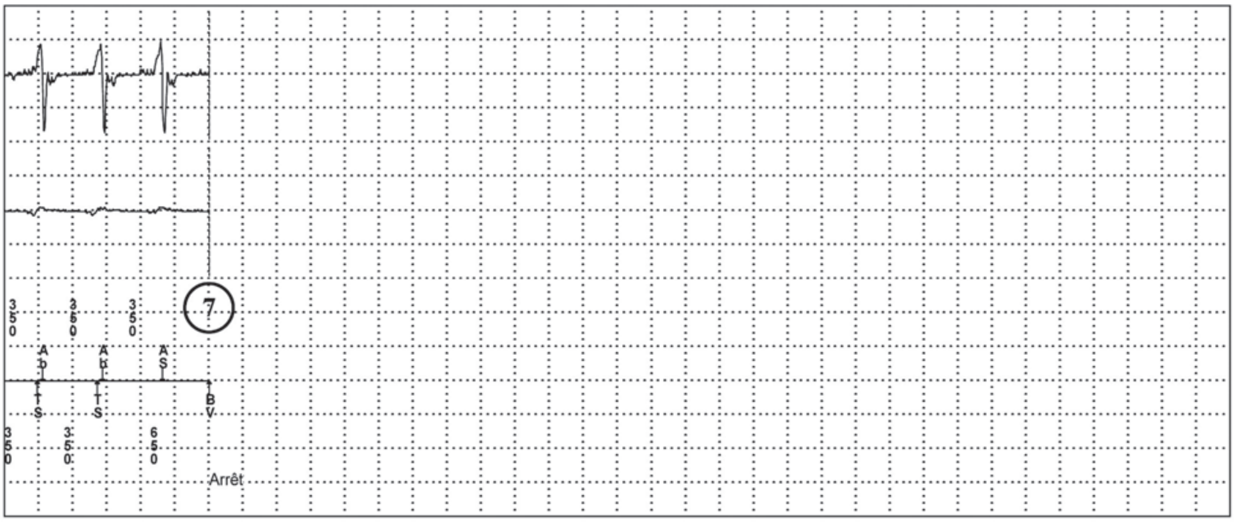
non sustained VT/VF episode # 1 16799

Device : **Concerto II CRT-D D294TRK**

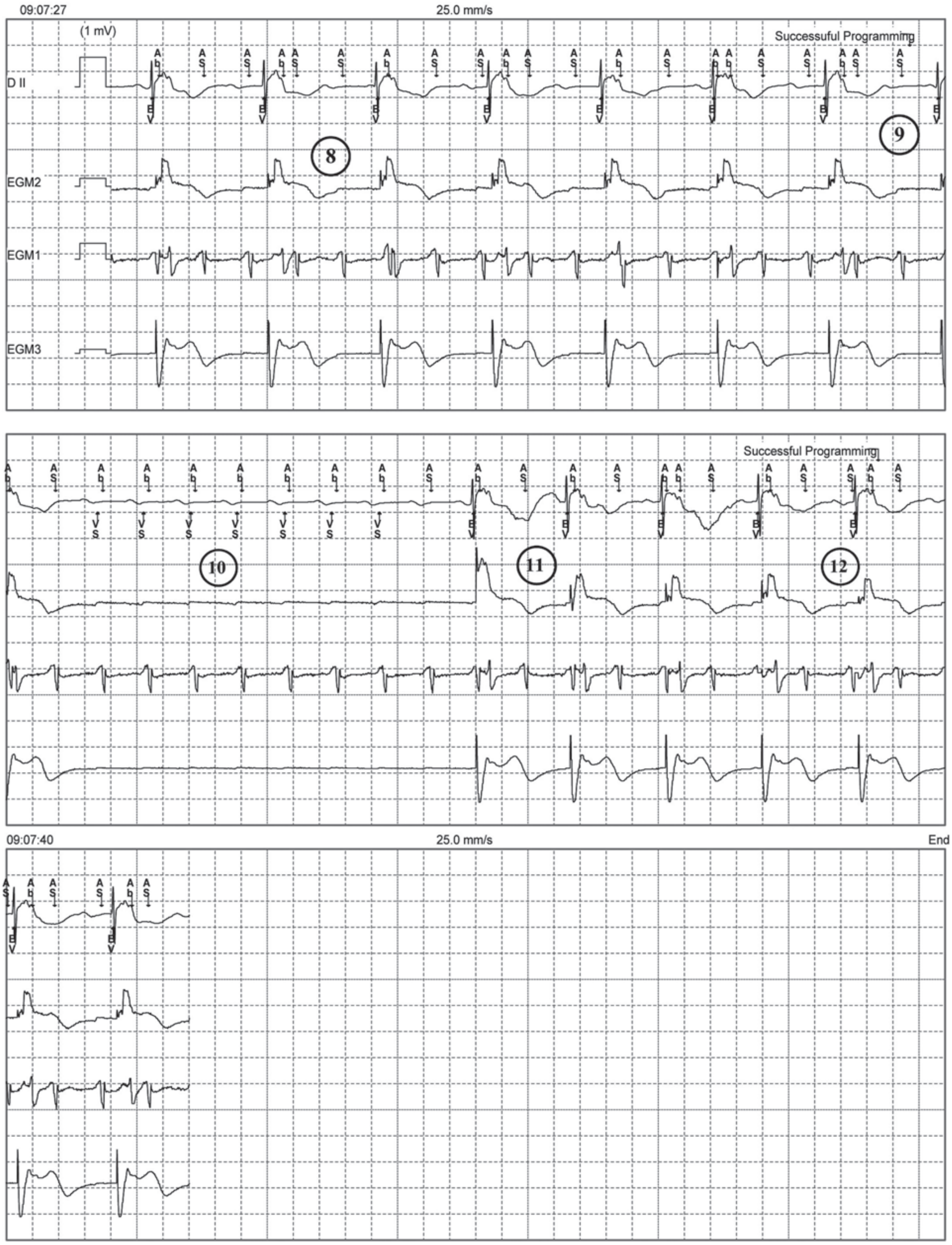


non sustained VT/VF episode # 1 16799

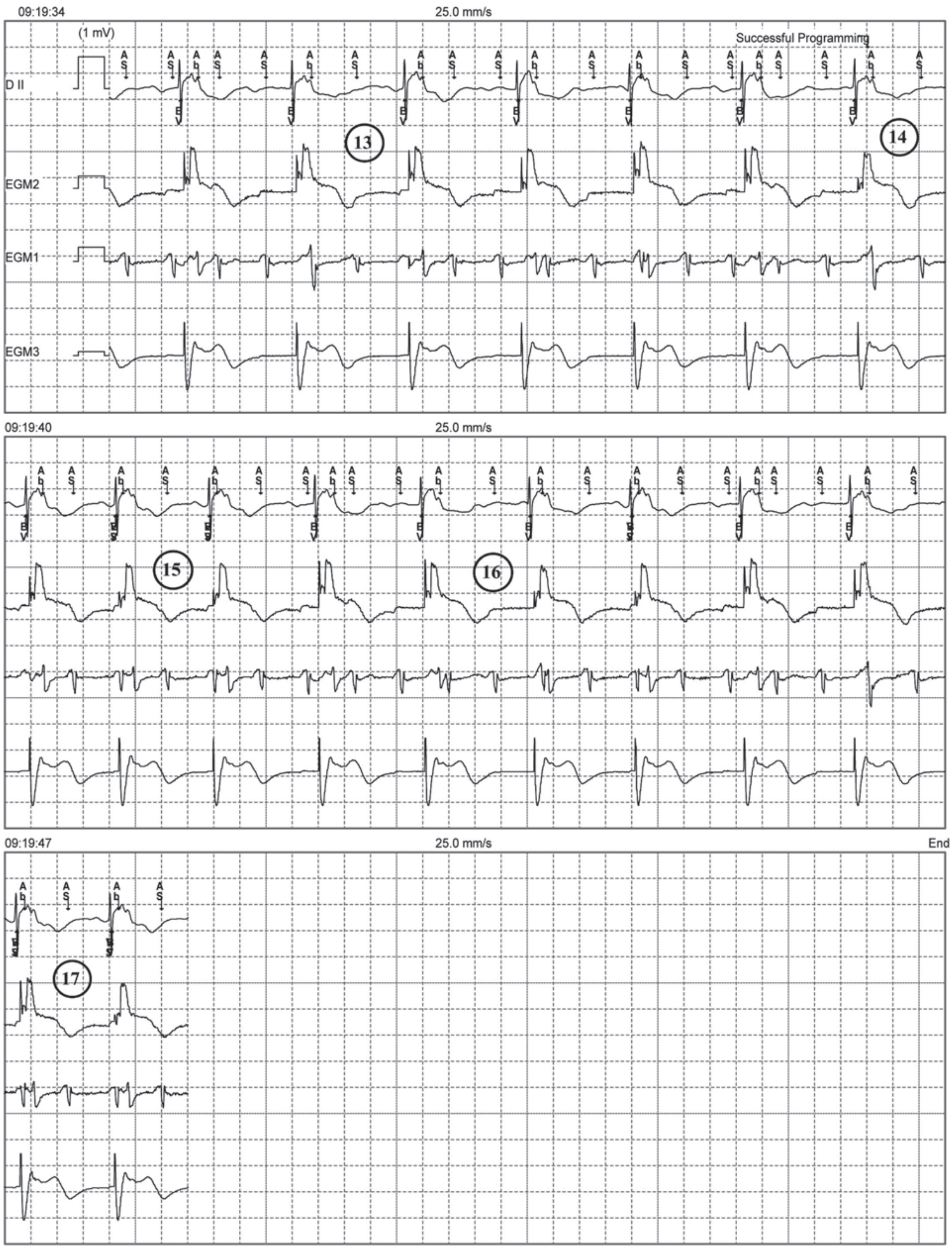
Device : **Concerto II CRT-D D294TRK**



Device : **Concerto II CRT-D D294TRK**



Device : **Concerto II CRT-D D294TRK**



Tracing 4: loss of biventricular stimulation due to A/V crosstalk

Patient

77 years old man, implanted with a triple chamber defibrillator Consulta CRT-D for mitral valvular cardiomyopathy with left bundle branch block and long PR interval; routine follow-up 3 months after implantation; episodes of ventricular detection are recorded; the right ventricular lead is implanted on the inter-ventricular septum and is not displaced on the chest X-ray.

Tracing

Episodes of ventricular sensed event in the device memory

1: atrial and biventricular pacing (AP-BV);

2: atrial stimulation and detection of two spontaneous ventricular events with a fixed coupling interval of 270-280ms; a ventricular premature beat with a short coupling interval is suspected.

Interrogation of the device and recording of the tracings; EGM1: Atrial EGM, EGM2: Ventricular EGM (bipolar channel), EGM3: Ventricular EGM (far-field channel);

3: atrial and biventricular pacing (AP-BV);

4: atrial stimulation and detection of two spontaneous ventricular events; probable crosstalk: the atrial depolarization is detected by the ventricular channel after the safety window (first VS marker); the second VS corresponds to the detection of the spontaneous ventricular depolarization;

5: decrease of the ventricular sensitivity (from 0.3 to 0.5 mV);

6: disappearance of the crosstalk;

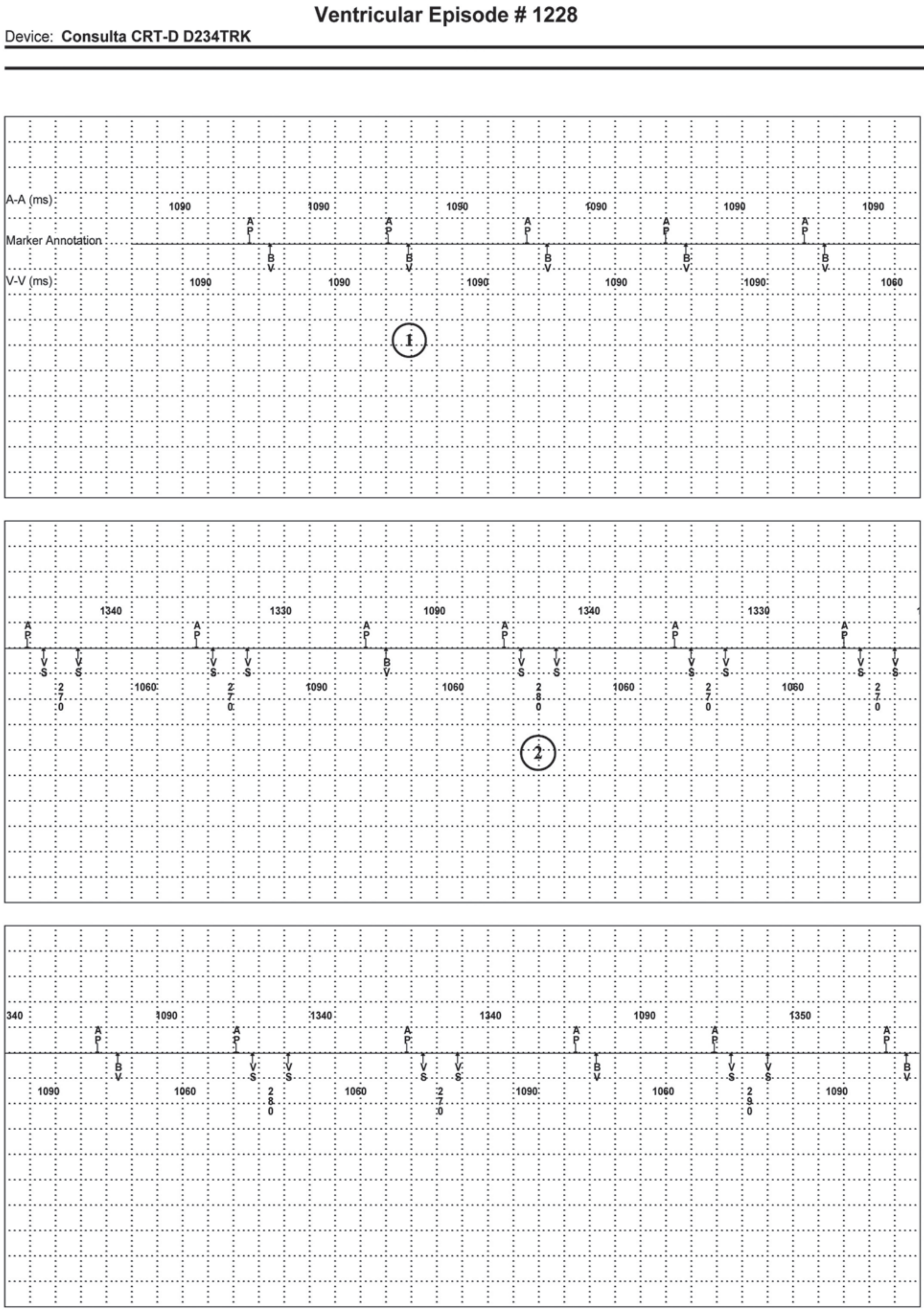
Comments

This tracing shows a relatively rare case of loss of biventricular pacing after A/V crosstalk following atrial pacing. Atrial pacing starts 2 periods of ventricular protection to avoid crosstalk: 1) A non-programmable post atrial paced ventricular blanking period (that last 30 ms on the new CRT-D platforms); during this period of time, no ventricular detection is possible 2) A safety window ending 110 ms after the atrial pacing; its duration is not programmable but it is possible to deprogram this parameter (programming off); this is not desirable because the deactivation of this safety window can lead to asystole in pacemaker-dependent patients or to the loss of the biventricular pacing in non-dependent patients in case of late A/V crosstalk (ventricular detection of the atrial stimulus or atrial depolarization).

This tracing is relatively rare because the crosstalk occurs after the safety window, which was turned on and programmed to run during the atrio-ventricular delay. In this particular patient, the post-stimulation atrial depolarization time is significantly prolonged and detected by the ventricular channel more than 110 msec after the atrial stimulus.

Possible solution options are relatively similar to the previous tracing: 1) reposition the right ventricular lead; 2) reprogram the polarity of ventricular sensing (ineffective in this patient); 3) alter the ventricular sensing;

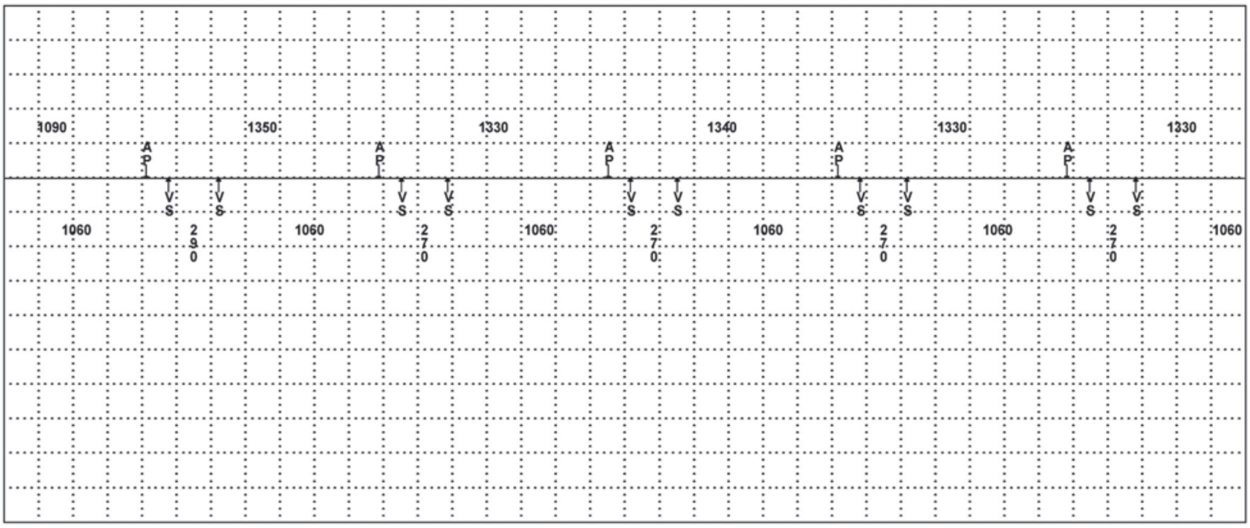
In this patient, reprogramming the sensitivity to 0.6 mV eliminated the oversensing; a VF induction was used to validate the correct detection of a ventricular arrhythmias.

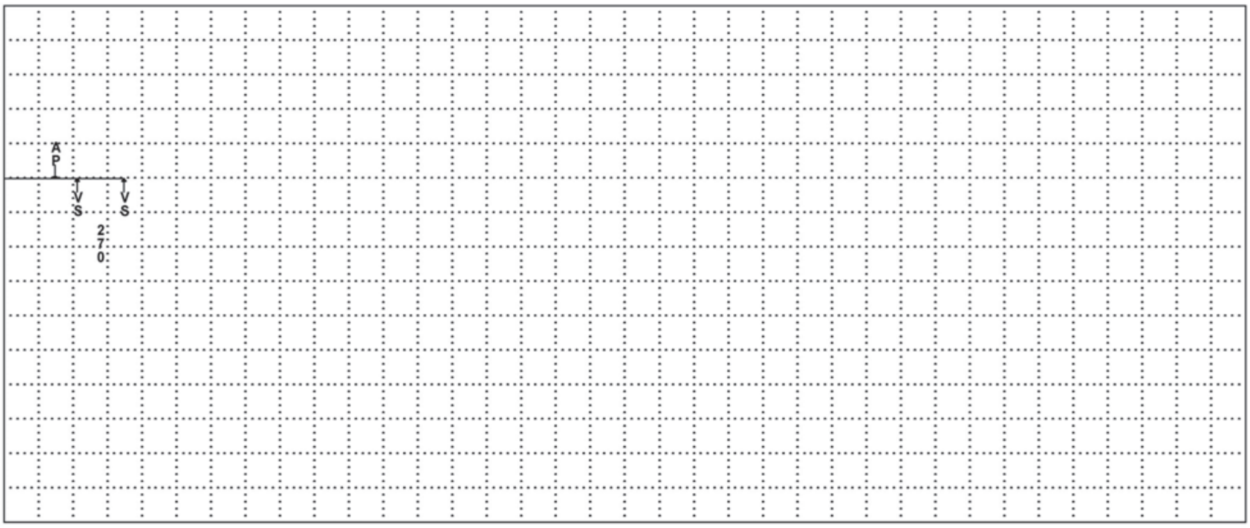

Ventricular Episode # 1228
Device: Consulta CRT-D D234TRK
A-A (ms)
Marker Annotation
V-V (ms)
1
2

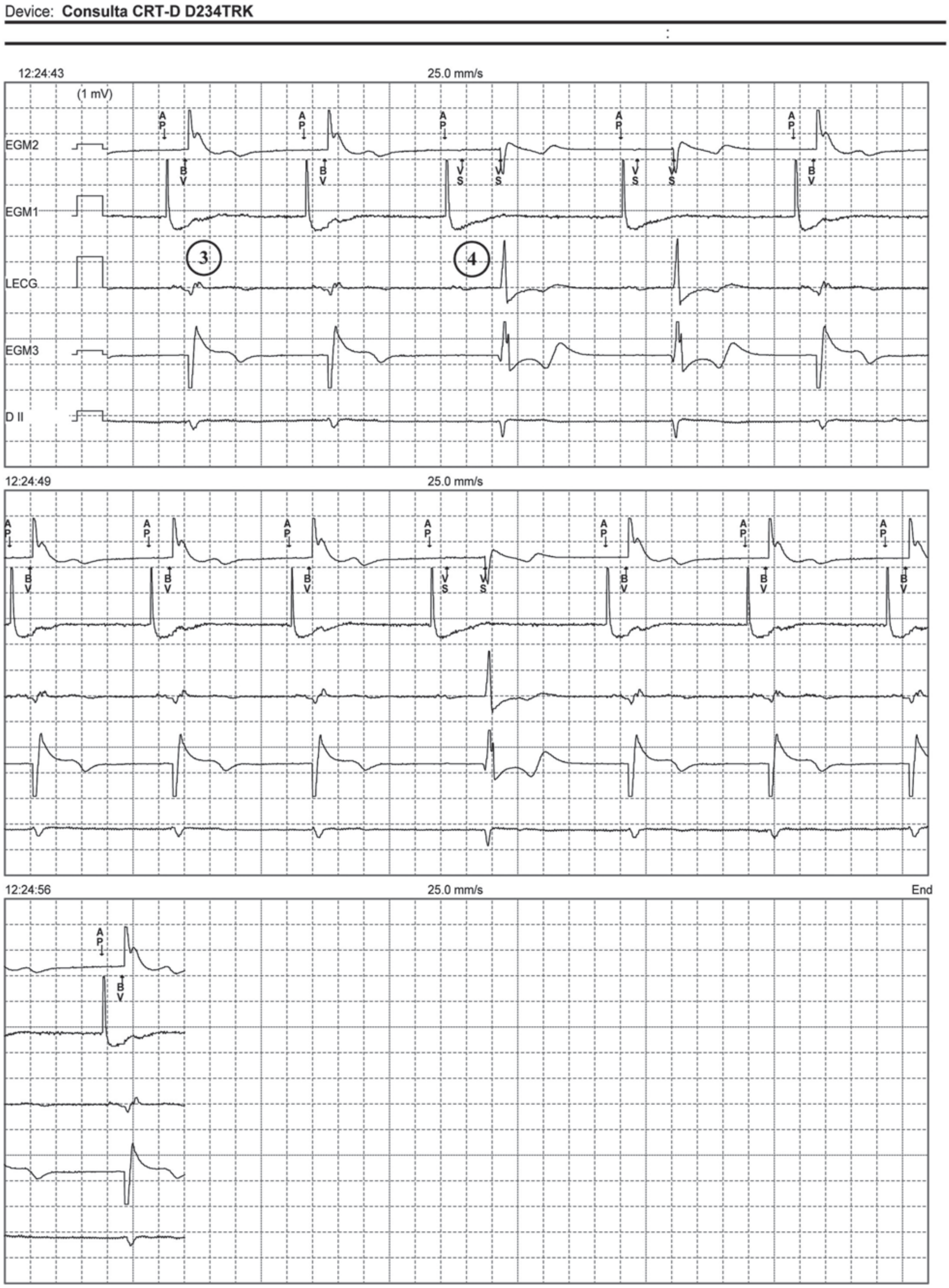
Ventricular Episode # 1228

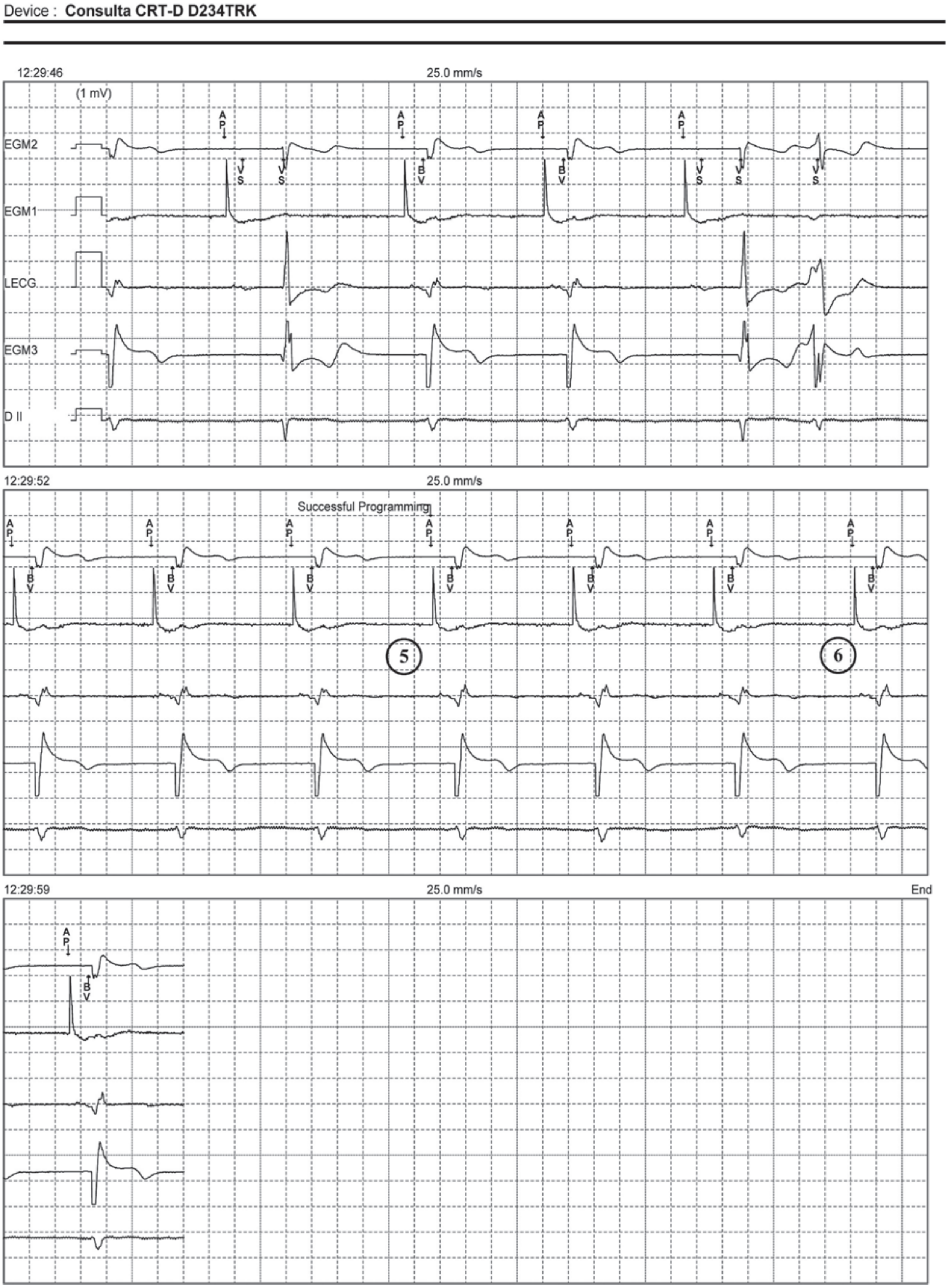
Device: **Consulta CRT-D D234TRK**

D :






Device: Consulta CRT-D D234TRK
12:24:43
25.0 mm/s
(1 mV)
EGM2
EGM1
LECG
EGM3
D II
AP
BV
VS
3
4
12:24:49
25.0 mm/s
12:24:56
25.0 mm/s
End


Device : Consulta CRT-D D234TRK
12:29:46
25.0 mm/s
(1 mV)
EGM2
EGM1
LECG
EGM3
D II
AP
VS
BV
12:29:52
25.0 mm/s
Successful Programming
5
6
12:29:59
25.0 mm/s
End

Tracing 5: loss of biventricular pacing due to long PR interval and P wave in the PVARP

Patient

65 years old man, implanted with a triple chamber defibrillator Protecta XT CRT-D for primary cardiomyopathy with sinus dysfunction, left bundle branch block and long PR interval; routine follow-up 6 months after implantation; recording of spontaneous ventricular sensed event.

Tracing

Episodes of ventricular sensed event in the device memory

1: atrial sense and biventricular pacing (AS-BV);
2: probable ventricular premature beat;
3: atrial activity falling in the PVARP, no AV delay and absence of biventricular pacing;
4: consecutive AR-VS cycles with prolonged loss of biventricular pacing;

RV threshold test in VDI mode at 90bpm

5: ventricular capture with dissociated atrial rhythm followed by conduction from the atrium to the ventricle: AS-VS cycles with long PR interval; interruption of the test;
6: during the last stimulation of the threshold test (VP), prolongation of the PRAPV; sinus activity falling in the PVARP;
7: successive AR-VS cycles with a long PR interval and sinus P wave in the PVARP;
8: moderate sinus pause allowing the P wave to fall outside the PVARP;
9: recovery of biventricular pacing;

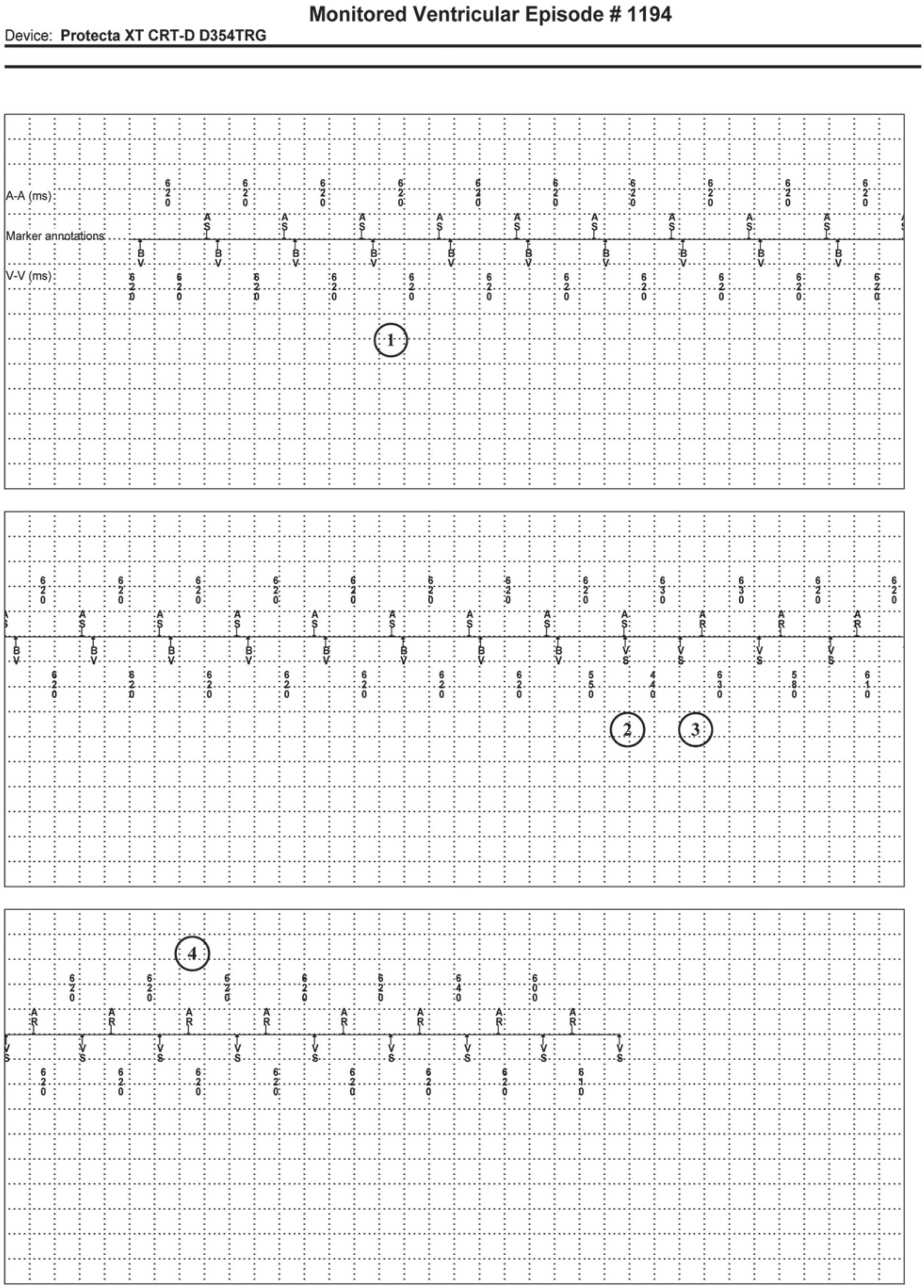
Modification of the device programming (atrial tracking recovery algorithm is turned ON); the patient is discharged

New episodes of ventricular detection recorded by the device

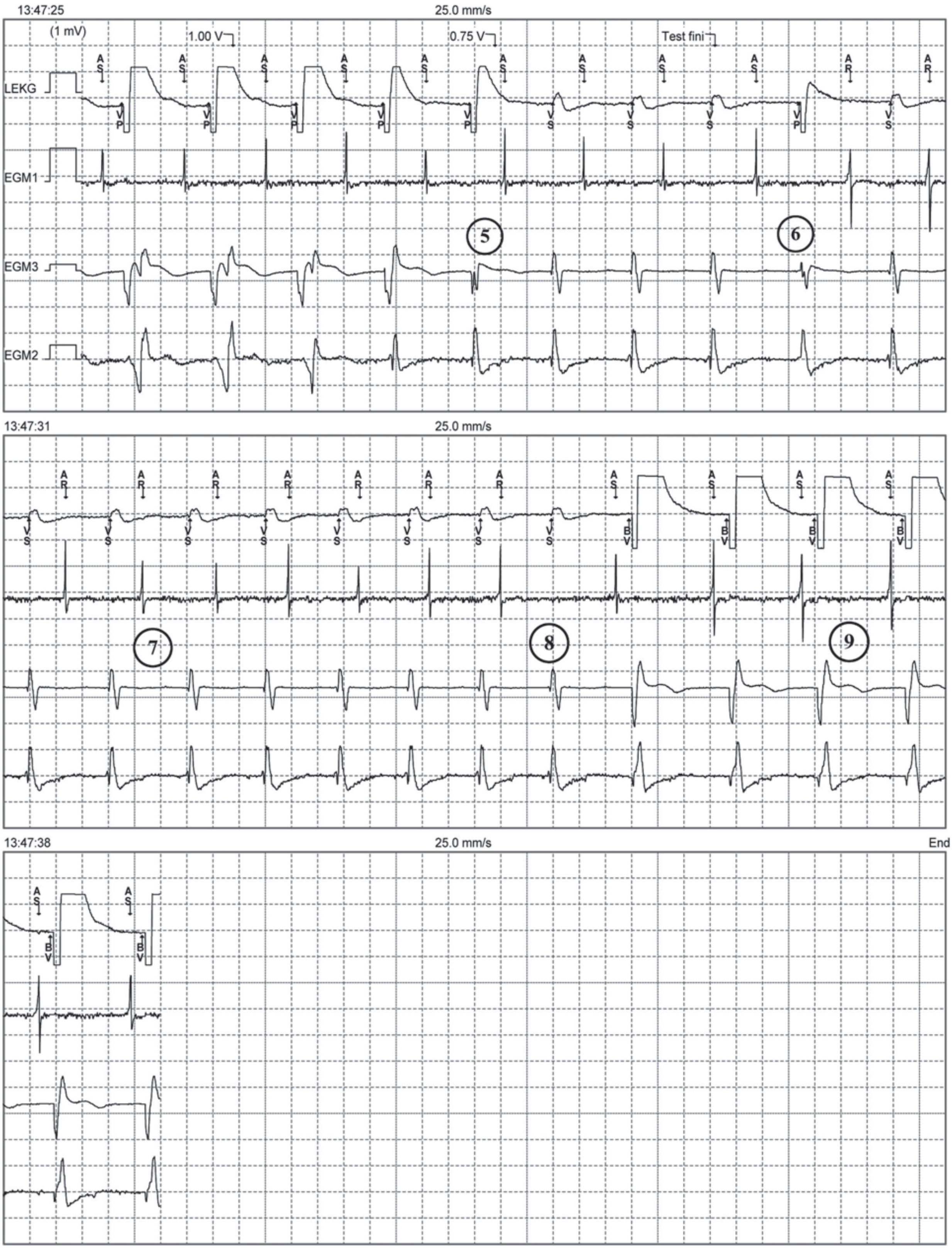
10: atrial sensed and biventricular pacing (AS-BV);
11: ventricular quadruplet;
12: atrial activity falling in the PRAPV, no AV delay and absence of biventricular stimulation; succession of AR-VS cycles with prolonged loss of biventricular pacing;
13: intervention of the atrial tracking recovery algorithm; shortening of the PRAPV; recovery of the biventricular pacing;

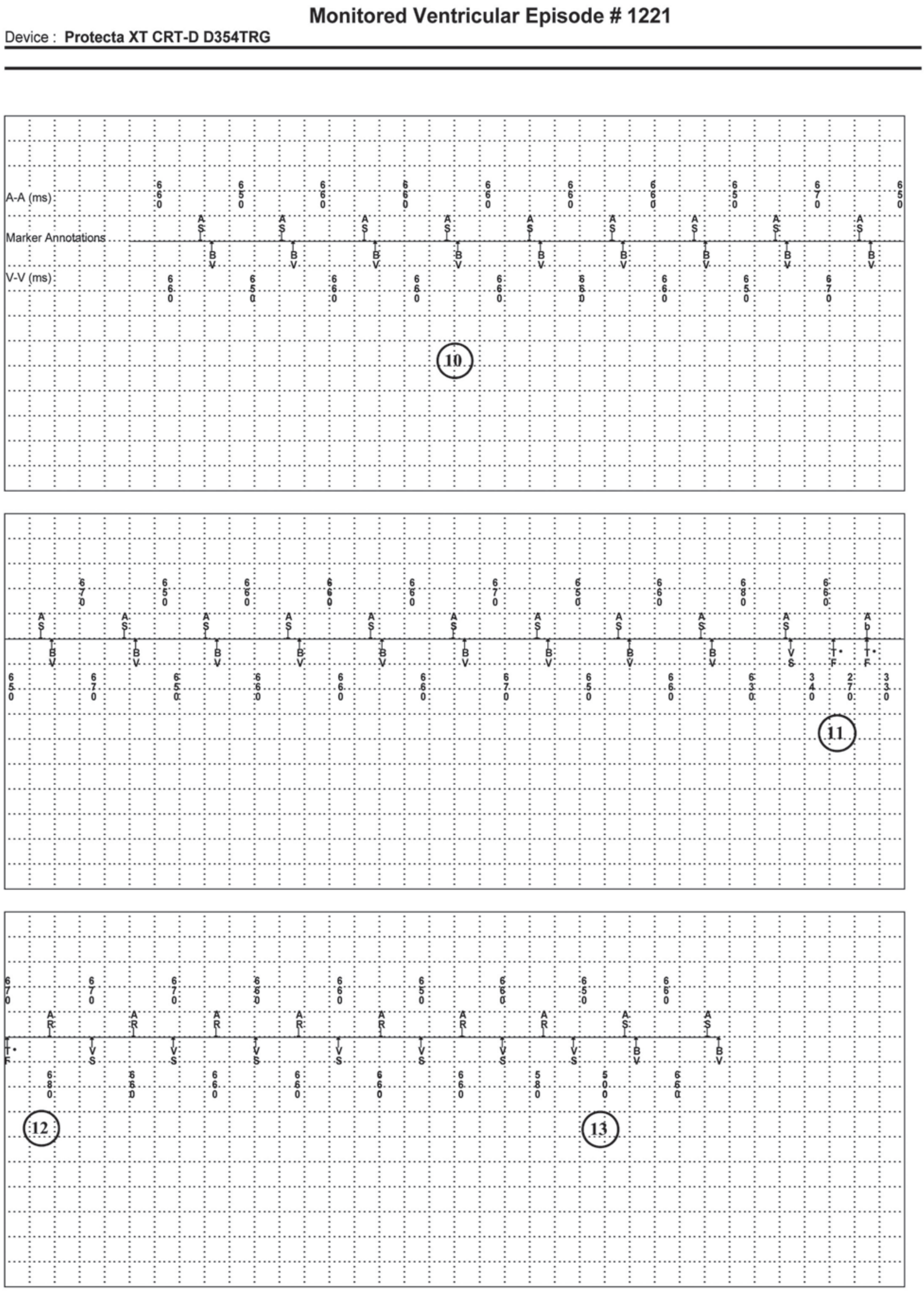
Comments

This example illustrates a relatively common cause of loss of biventricular pacing in patients with long PR interval. Following a loss of atrio-ventricular synchrony (ESV, pacing threshold...), a P wave falls in the PVARP, and does not launch a new AV delay. As a result, spontaneous conducted ventricular events appear. The probability that the P wave falls into the PVARP and maintains the phenomenon increases with the PR duration (the longest, the more important is the risk), the sinus rate (the fastest, the higher is the risk) and the programming of some algorithms (PVARP extension after VPB, auto-threshold procedure, automatic PVARP). The programming of these algorithms should be discussed case-by-case, particularly in CRT patients with long PR (higher risk of occurrence of this type of phenomenon with a theoretically lower risk of PMT in the presence of impaired AV conduction). Programming the atrial tracking recovery algorithm interrupts the repetition of these cycles. This algorithm must be systematically programmed ON.


Monitored Ventricular Episode # 1194
Device: Protecta XT CRT-D D354TRG
A-A (ms)
Marker annotations
V-V (ms)
1
2
3
4

Device : **Protecta XT CRT-D D354TRG**




Monitored Ventricular Episode # 1221
Device : Protecta XT CRT-D D354TRG
A-A (ms)
Marker Annotations
V-V (ms)
10
11
12
13

Tracing 6: oversensing of the T wave

Patient

53 years old woman implanted with a triple chamber defibrillator Protecta XT CRT-D for ischemic cardiomyopathy with left bundle branch block; routine follow-up;

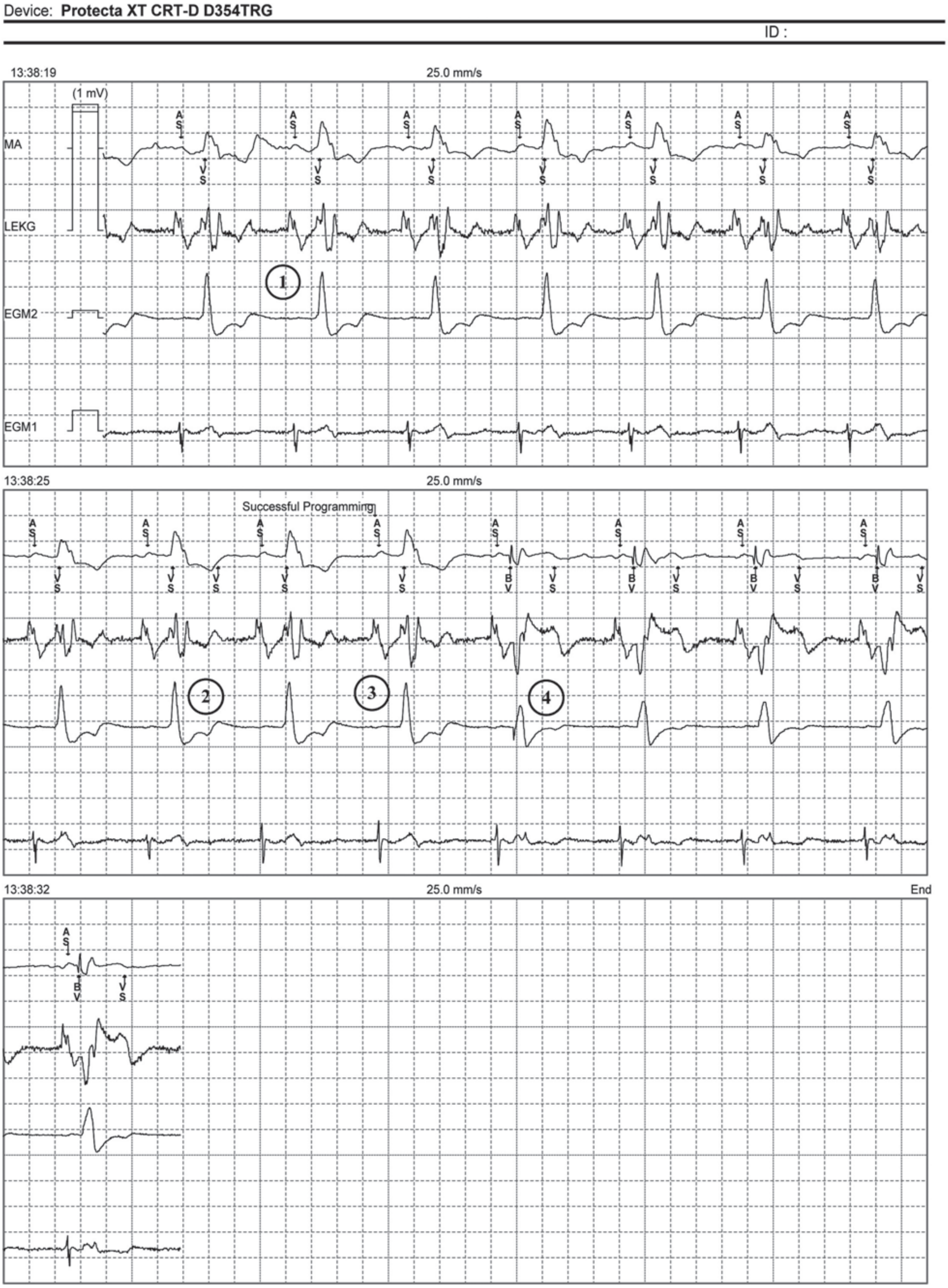
Tracing

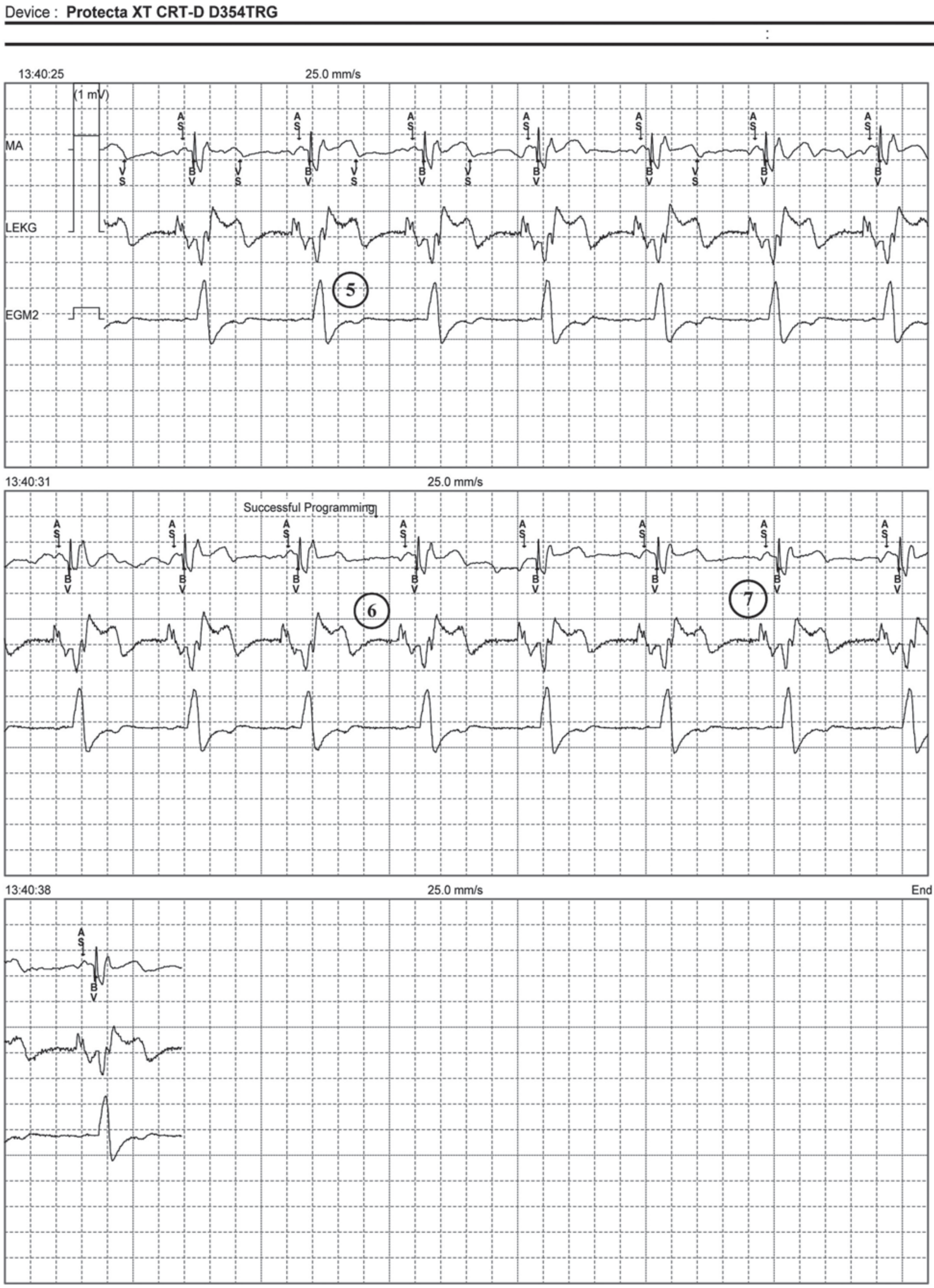
Temporary programming ODO;

1: atrial sense and biventricular pacing (AS-BV);
2: oversensing of the T-wave on a spontaneous ventricular event;
3: biventricular pacing is turned ON;
4: oversensing of the T-wave during biventricular pacing;
5: persistent T-wave oversensing;
6: modification of the programming; decrease of the ventricular sensing;
7: oversensing resumed;

Comments

In this patient, oversensing of the T wave was present after a spontaneous ventricular event but also after a paced ventricular event. It was not responsible for a significant drop in the percentage of biventricular pacing. The device recorded a large number of premature ventricular contractions corresponding to the T-wave oversensing episodes.
Oversensing of the T wave can in some cases promote the absence of biventricular pacing. The T wave is considered as a ventricular premature contraction, which causes a prolongation of the PVARP if the "response to a VPB" algorithm is turned ON. The next sinus P-wave falls into the PVARP, and therefore does not trigger a new AV delay, and the phenomenon perpetuates as shown in the previous case.


Device: Protecta XT CRT-D D354TRG
ID :
13:38:19
25.0 mm/s
(1 mV)
MA
LEKG
EGM2
EGM1
1
13:38:25
25.0 mm/s
Successful Programming
2
3
4
13:38:32
25.0 mm/s
End


Device : Protecta XT CRT-D D354TRG
13:40:25
25.0 mm/s
(1 mV)
MA
LEKG
EGM2
5
13:40:31
25.0 mm/s
Successful Programming
6
7
13:40:38
25.0 mm/s
End

Tracing 7: T-wave oversensing

Patient

78 years old woman, implanted with a triple chamber defibrillator Viva XT CRT-D for ischemic cardiomyopathy with a large QRS; routine follow-up and episode of T-wave oversensing;

Plot

1: alternation of different frequencies;
2: alternation between two ventricular cycles;

Tracing

3: biventricular stimulation;
4: T-wave oversensing (TS) following a paced ventricular event;
5: this ventricular sensed event (TS) is considered as a premature ventricular contraction and triggers a prolongation of the PVARP; the next spontaneous atrial event falls in the PVARP (AR) and conducts a spontaneous QRS (VS);
6: late T-wave oversensing following the spontaneous ventricular event; the next spontaneous atrial depolarization is even closer to this T-wave, and falls this time in the post ventricular atrial blanking, and is labeled Ab;
7: as a consequence, the next spontaneous ventricle is detected in the fast VT via VF zone (TF.);
8: similar sequence;
9: diagnosis of T-wave oversensing made by the device; therapies are withheld;

Text

10: diagnosis of T-wave oversensing made by the device;

Comments

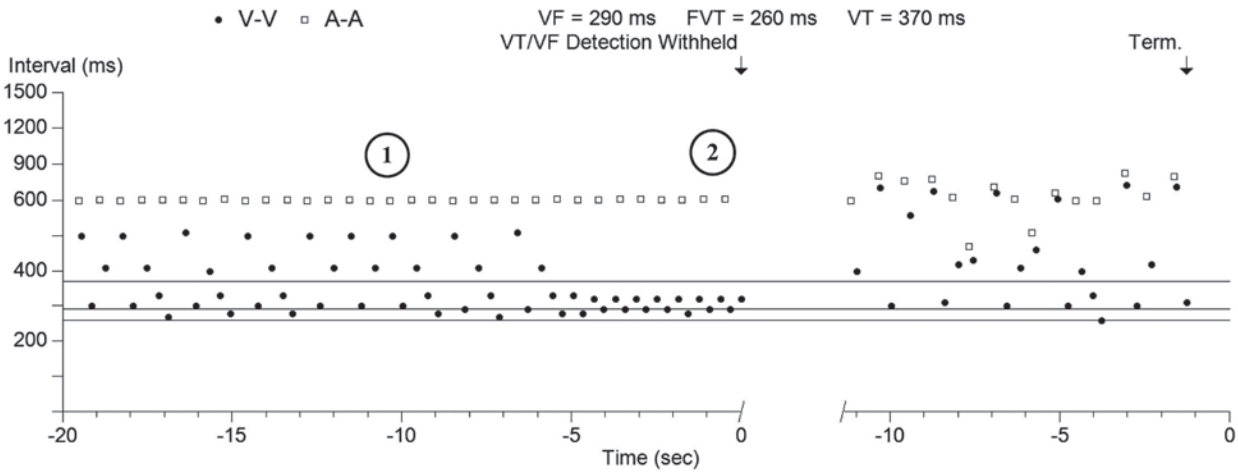
Programming the new algorithm for the discrimination of the T wave oversensing can inhibit and prevent the occurrence of inappropriate therapies. This algorithm identifies alternation between two different cycles and signals (R-waves and T waves) of different amplitudes.
In this patient, the T wave oversensing is responsible for a decrease in the percentage of biventricular pacing. To avoid this oversensing, it is possible to change the programming of the right ventricular sensing polarity (bipolar to integrated bipolar). In this patient, this change did not have a positive effect. In contrast, reducing the ventricular sensitivity from 0.3 to 0.6 mV eliminated the oversensing. However, to certify the accurate detection of ventricular signals during an episode of arrhythmia, a FV induction test can be performed with this new ventricular sensitivity.

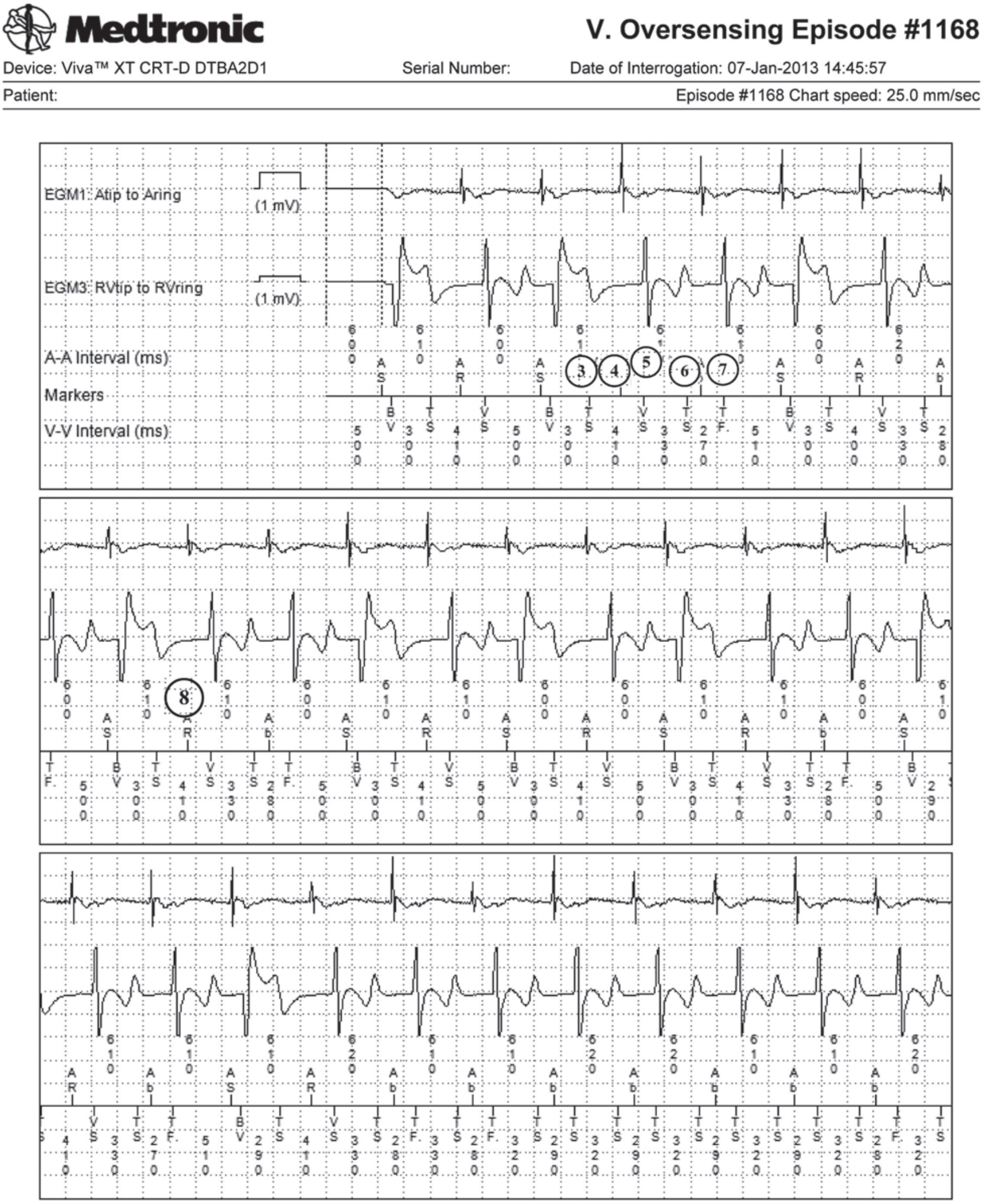
Medtronic **V. Oversensing Eisode #1168**

Device: Viva™ XT CRT-D DTBA2D1 Date of Interrogation: 07-Jan-2013 14:45:57

Patient: -

Type	ATP Seq	Shocks	Success	ID#	Date	Time hh:mm	Duration hh:mm:ss	Avg bpm A/V	Max bpm A/V	Activity at Onset
V. Oversensing-TWave				1168	06-Jan-2013	12:51	:06:41	98/200	102/---	Active



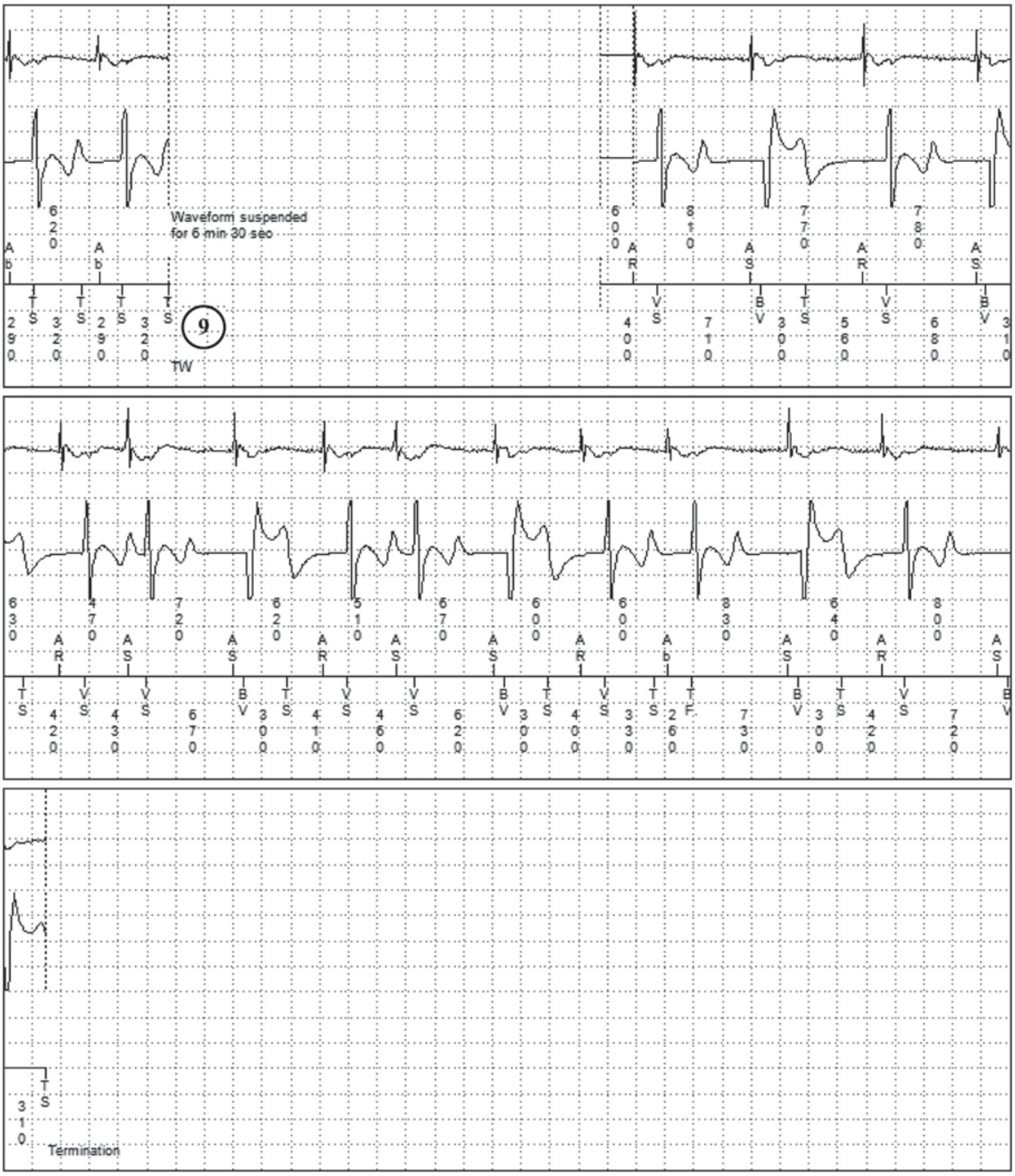

Medtronic
V. Oversensing Episode #1168
Device: Viva™ XT CRT-D DTBA2D1
Serial Number:
Date of Interrogation: 07-Jan-2013 14:45:57
Patient:
Episode #1168 Chart speed: 25.0 mm/sec
EGM1: Atip to Aring
(1 mV)
EGM3: RVtip to RVring
(1 mV)
A-A Interval (ms)
Markers
V-V Interval (ms)
3
4
5
6
7
8

Medtronic

V. Oversensing Episode #1168

Device: Viva™ XT CRT-D DTBA2D1 Serial Number: Date of Interrogation: 07-Jan-2013 14:45:57

Patient: Episode #1168 Chart speed: 25.0 mm/sec



Medtronic **V. Oversensing Episode #1168**

Device: Viva™ XT CRT-D DTBA2D1 Date of Interrogation: 07-Jan-2013 14:45:57

Episode #1168: 06-Jan-2013 12:51:43

Episode Summary		**Other Criteria Triggered**
Initial Type	V. Oversensing-TWave (spontaneous)	TWave
Duration	6.7 min	
A/V Max Rate	102 bpm/---	
V. Median	188 bpm (320 ms)	
Activity at onset	Active, Sensor = 88 bpm	

(10)

Wavelet Measurements Prior to Initial Withholding of Detection

Wavelet Result:	Wavelet not applied	
Template Status:	OK	
-8.	No Match	0 %
-7.	No Match	4 %
-6.	No Match	0 %
-5.	No Match	1 %
-4.	No Match	0 %
-3.	Match	94 %
-2.	No Match	0 %
-1.	Match	91 %

Parameter Settings		**Initial**	**Redetect**	**V. Interval (Rate)**
VF	On	24/32	12/16	290 ms (207 bpm)
FVT	via VF			260 ms (231 bpm)
VT	On	16	12	370 ms (162 bpm)
Monitor	Off	28		

PR Logic/Wavelet	
AF/Afl	On
Sinus Tach	On
Other 1:1 SVTs	On
Wavelet	Monitor, Match = 70%
Template	11-Dec-2012, Auto = On
SVT V. Limit	290 ms

Other Enhancements	
Stability	Off
Onset	Off
High Rate Timeout	
VF Zone Only	Off
All Zones	Off
TWave	On
RV Lead Noise	On+Timeout
Timeout	0.75 min

Polarity	**RV**
Pace Polarity	Bipolar
Sense Polarity	Bipolar

EGM	**Source**	**Range**
EGM1	Atip to Aring	+/- 8 mV
EGM3	RVtip to RVring	+/- 8 mV

Sensitivity	
Atrial	0.3 mV
RV	0.3 mV

Tracing 8: loss of biventricular pacing due to crosstalk

Patient

68 years old man implanted with a triple chamber defibrillator Viva XT CRT-D for dilated cardiomyopathy with atypical bundle branch block; routine follow-up; reduction of the percentage of biventricular pacing;

Tracing

Episodes of ventricular sensed event in the device memory

1: 3 consecutive cycles AR-VS;
2: commutation (MS: mode switch) to DDD mode with recovery of the atrial synchronism;
3: alternation of AS-BV-Ab cycles; probable V/A crosstalk;
4: commutation to DDIR (MS);
5: asynchronous mode (DDIR) with no AV delay after an atrial sensed event; spontaneous ventricular events (VS);

Recording of an episode of AT/AF in the device memories

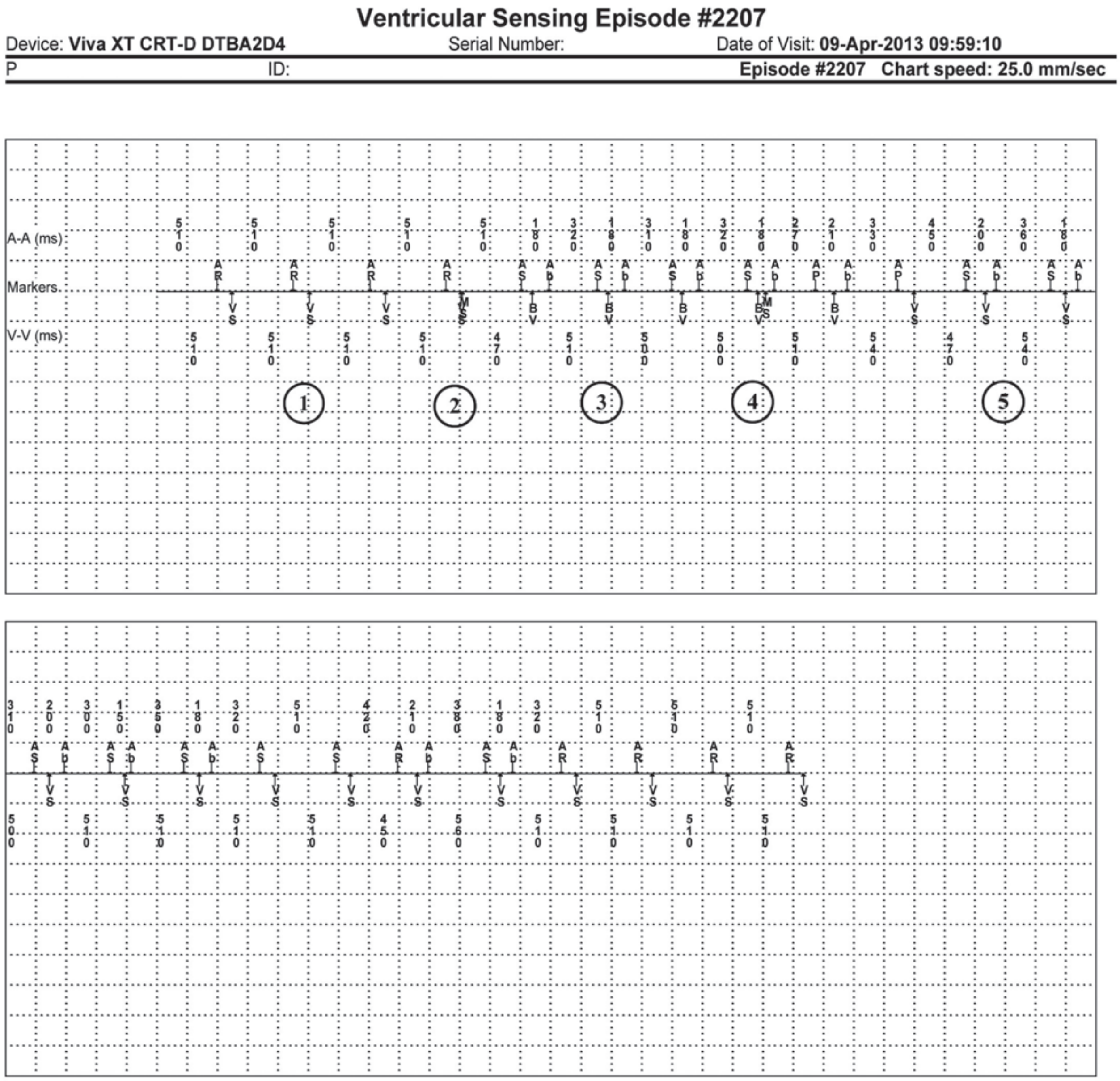
6: on the plot, typical aspect in rail (alternation of 2 different atrial frequencies) compatible with a crosstalk;
7: probable crosstalk following the spontaneous ventricular depolarization; fixed AR-VS-Ab sequence, except for some cycles with a very short VS-Ab interval;
8: intermittent interruption of the crosstalk;
9: commutation to a synchronous mode (MS);
10: crosstalk restarts;
11: diagnosis of AF and commutation to DDIR mode;
12: absence of biventricular stimulation (spontaneous ventricular events);
13: diagnosis of AF made by the device for a duration of 20 seconds;

Tracing recorded during the consultation

14: biventricular stimulation and crosstalk, the ventricular signal being detected by the atrial channel in the PVARP (AR);
15: decrease of the atrial sensitivity (from 0.3 to 0.6 mV);
16: crosstalk disappearing;

Comments

Defibrillator memories were saturated by short episodes of misdiagnosed atrial arrhythmias related to crosstalk. The atrial detection following a ventricular pacing has been changed in the new ICD platforms with 3 programming possibilities of post ventricular atrial blanking: the absolute blanking period corresponding to a traditional blanking (no marker), a partial blanking and a partial + blanking period (marker Ab). A signal detected in this blanking period does not trigger AV delay but is counted for the analysis of the atrial rhythm (for the discrimination process) and for the mode switch algorithm. This new blanking period is associated with an increased risk of inappropriate commutation of mode due to VA crosstalk. The recorded electrograms must be systematically analyzed to confirm the diagnosis made by the device. In this patient, repeated episodes of false AF were responsible for a significant decrease in the percentage of biventricular pacing. Programming a partial blanking + (with a reduction of the atrial sensitivity at the beginning of ventricular cycle) did not suppress the crosstalk. Reprogramming of the constant atrial sensitivity to 0.6 mV was effective.

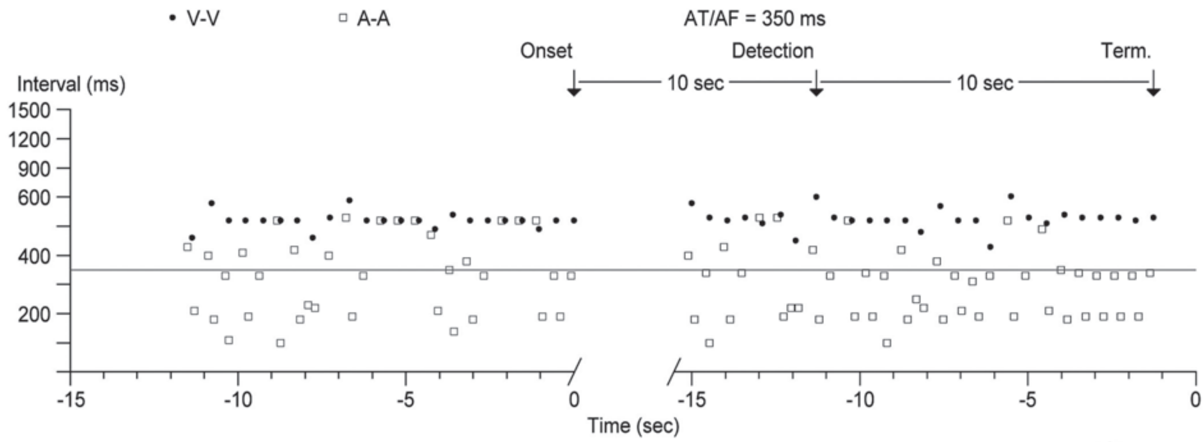

Ventricular Sensing Episode #2207
Device: Viva XT CRT-D DTBA2D4
Serial Number:
Date of Visit: 09-Apr-2013 09:59:10
P
ID:
Episode #2207 Chart speed: 25.0 mm/sec
A-A (ms)
Markers
V-V (ms)
1
2
3
4
5

Monitored AT/AF Episode #154

Device: **Viva XT CRT-D DTBA2D4** Serial Number: Date of Visit: **09-Apr-2013 09:59:10**

- -

Type	ATP Seq	Shocks	Success	ID#	Date	Time hh:mm	Duration hh:mm:ss	Avg bpm A/V	Max bpm A/V	Activity at Onset
AT/AF				154	09-Apr-2013	08:24	:20	213/114	240/115	Rest

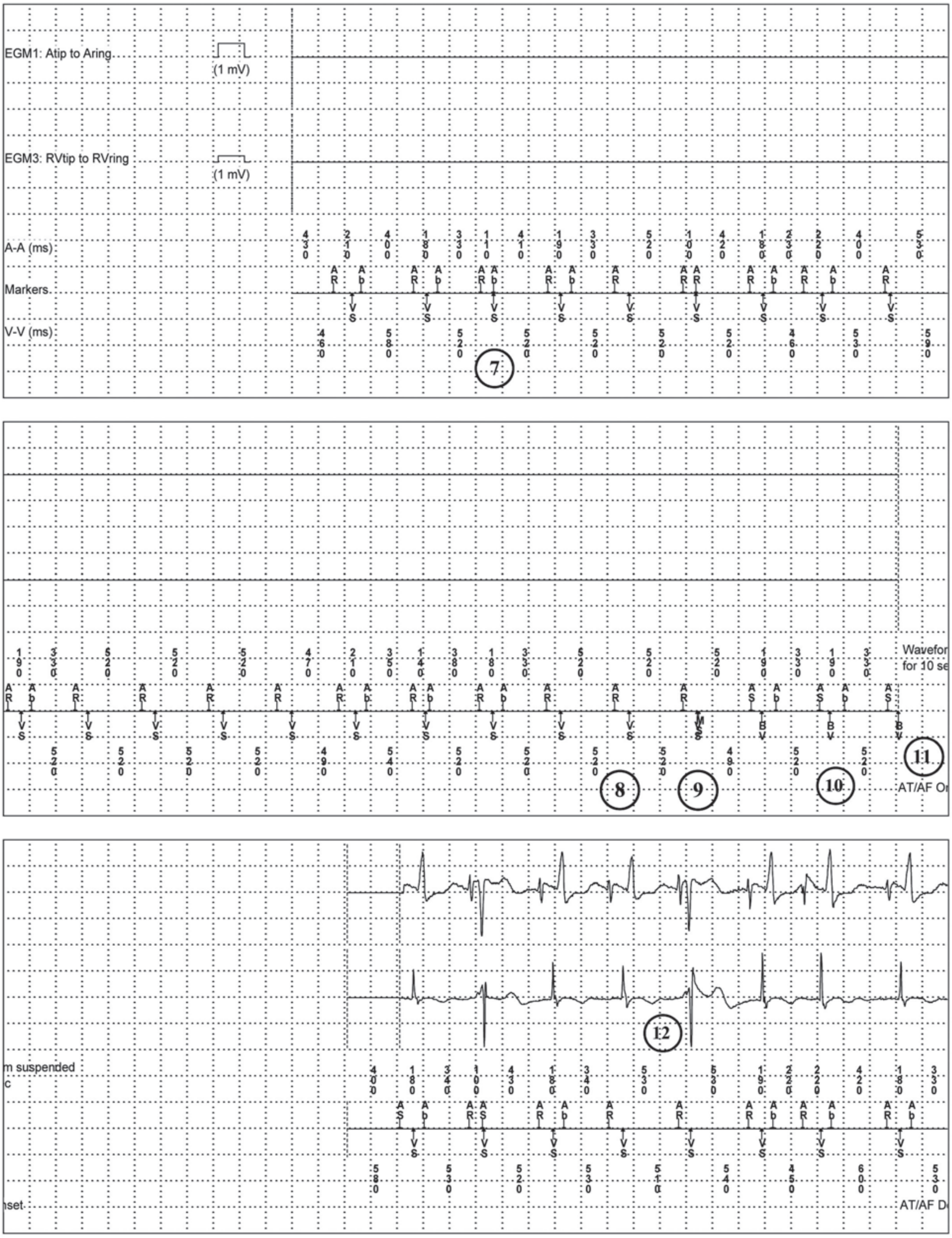


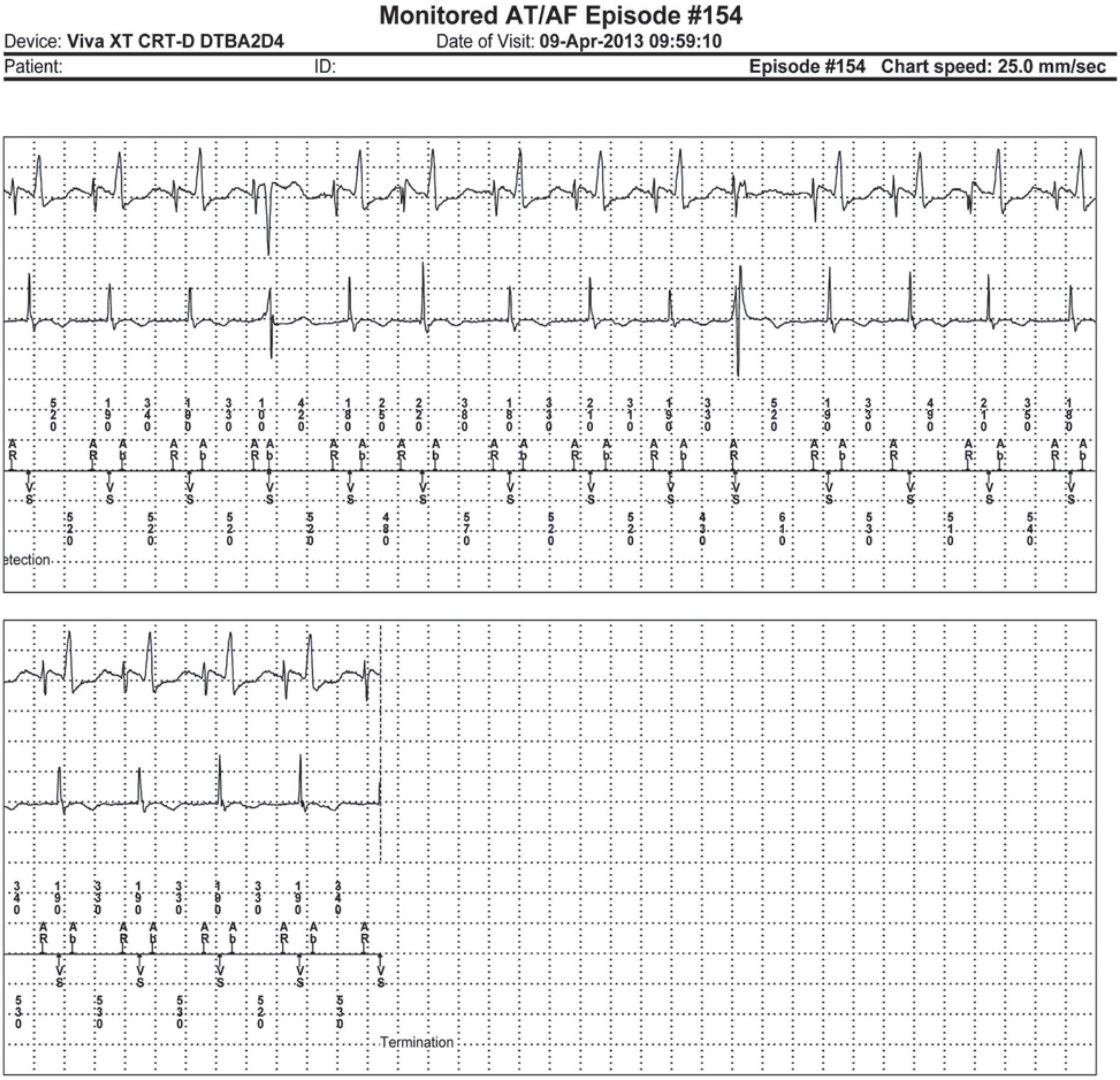
(6)

Monitored AT/AF Episode #154

Device: **Viva XT CRT-D DTBA2D4** Date of Visit: **09-Apr-2013 09:59:10**

ID:




Monitored AT/AF Episode #154
Device: Viva XT CRT-D DTBA2D4
Date of Visit: 09-Apr-2013 09:59:10
Patient:
ID:
Episode #154 Chart speed: 25.0 mm/sec
etection
Termination

Monitored AT/AF Episode #154

Device: **Viva XT CRT-D DTBA2D4** Serial Number Date of Visit: **09-Apr-2013 09:59:10**

Physician: - - -

Episode #154: 09-Apr-2013 08:24:19

(13)

Episode Summary

Initial Type	AT/AF Monitor (spontaneous)
Duration	20 sec
A/V Max Rate	240 bpm/115 bpm
A. Median	176 bpm (340 ms)
Activity at onset	Rest, Sensor = 38 bpm

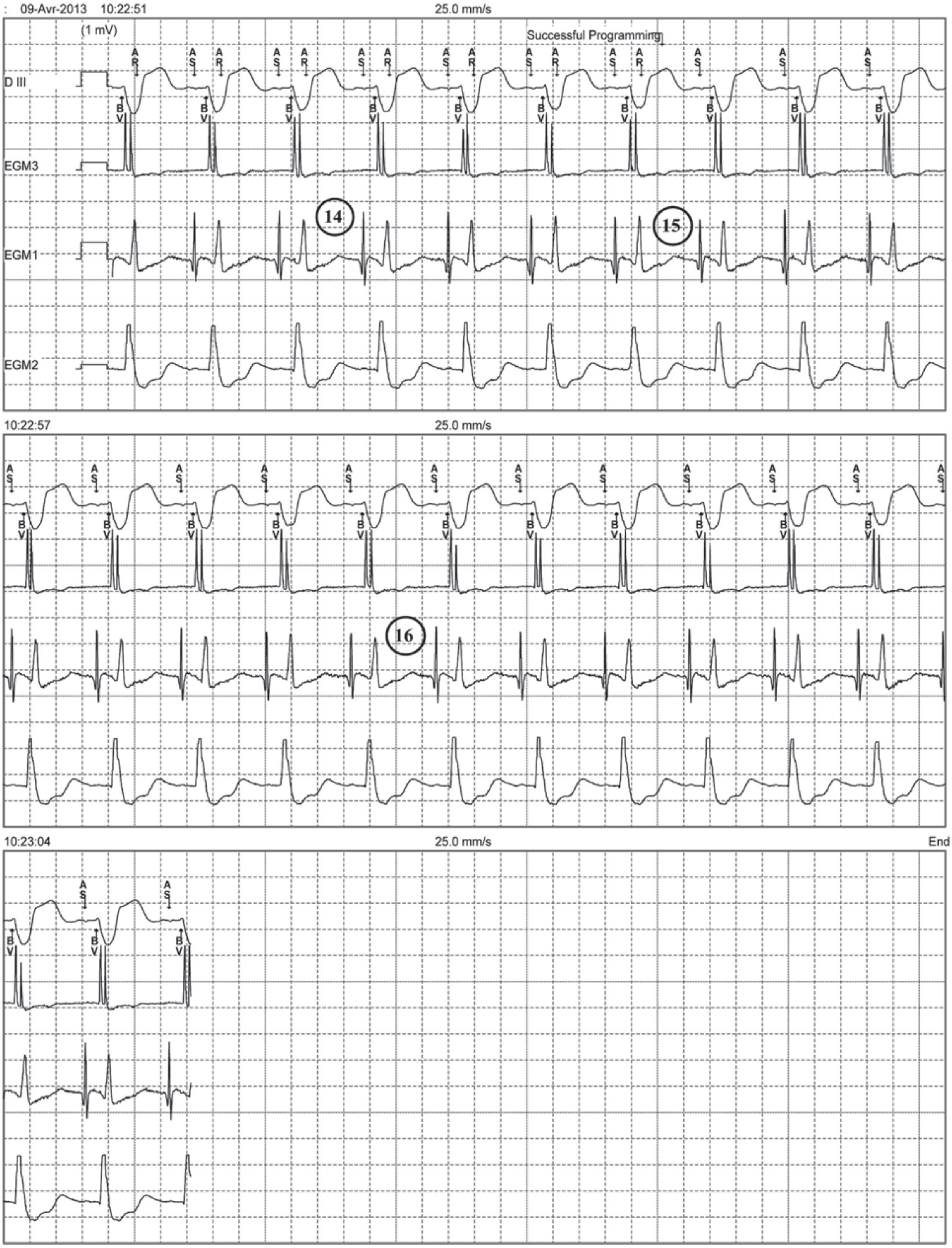
Parameter Settings		Zones		A. Interval (Rate)
AT/AF	Monitor	1	AT/AF	350 ms (171 bpm)

Polarity	RV
Pace Polarity	Bipolar
Sense Polarity	Bipolar

EGM	Source	Range	Sensitivity	
EGM1	Atip to Aring	+/- 8 mV	Atrial	0.3 mV
EGM3	RVtip to RVring	+/- 8 mV	RV	0.3 mV

S

Device : **Viva XT CRT-D DTBA2D4**



Chapitre 3

Left Ventricular Pacing

Left ventricular pacing

Four different approaches have been proposed to allow for left ventricular stimulation: epicardial stimulation with a trans-venous lead positioned in a branch of the coronary sinus, endocardial stimulation with a trans-septal lead, direct epicardial stimulation after surgical placement of the lead on the left ventricule, and finally the epicardial stimulation via a lead placed directly by percutaneaous puncture in the pericardial space. The trans-venous approach represents the reference method and the first-line approach in a majority of centers. The coronary sinus drains almost the entire left ventricle and also the atria. The length, orientation and diameter of the coronary sinus are highly variable and makes difficult to predict the feasibility of the procedure. Several valves can obtrude or reduce the caliber of the coronary sinus. The Thébésius valve is found just at the ostium, the valve of Vieussens at the ostium of the first postero-lateral vein. The phrenic nerve is located along the lateral veins, along a posterior side branches of the anterior vein and finally along the anterior veins emerging from the postero-lateral vein.

Schematically, the implantation procedure follows the next steps: venous access, introduction of a support sheath in the right atrium, cannulation of the coronary sinus, contrast media injection and selection of the target vein, positioning of the lead, sheath removal.
Recent years have been marked by the development of new leads of variable sizes and shapes. Once the contrast injection is completed, the operator can choose the best lead corresponding to the anatomical characteristics of the target vein. The size of the ostium of the target vein and the caliber of its main part are crucial for this choice. The operator must find a good match between lead diameter and size of the internal lumen of the vessel. Some other parameters that are difficult to predict will also influence the choice of the stimulation site and therefore the choice of the optimal lead: the presence of high thresholds and the presence of phrenic nerve stimulation.

Pacing configuration

The arsenal of left ventricular leads offered by Medtronic includes monopolar, bipolar and quadripolar leads. The pacing polarity is fully programmable in the left ventricle using various selections of bipoles and according to lead specificity: quadripolar (4-pole), bipolar or not (two or one electrodes). Quadripolar leads provide 16 pacing polarities, while unipolar leads and bipolar leads provide 1 or 4 pacing polarities respectively.

Unipolar leads

The single electrode of a unipolar lead is called «LV tip». If a unipolar left ventricular lead is implanted, only one programming configuration is available on the new generation of defibrillators: DistLV tip to RV coil. The ICD cannot be integrated in the stimulation circuit. In a three chamber pacemaker however, unipolar stimulation between the tip electrode and can is possible, the only electrode of the lead being the active electrode and the can being the neutral electrode.

Bipolar leads

The two electrodes are called «LV tip» and «LV ring or LV anode». If a bipolar left ventricular lead is implanted, four programming options are available with the new generation of defibrillators: LV tip to RV coil; LV ring to RV coil; LV tip to LV ring (LV bipolar) and LV ring to LV tip. LV Thresholds are often higher with the LV ring to RV coil configuration. The tip electrode (cathode) is generally used as the active electrode, the RV coil or ring VG (anode) being used as a neutral electrode.

Quadripolar leads

The 4 electrodes are called LV1, LV2, LV3 and LV4, LV1 being the most distal electrode. Sixteen different configurations can be proposed.

Automatic test «VectorExpress »: general concept

This test is available on the device compatible with a quadripolar leads and facilitates the choice of a stimulation configuration by automatically measuring the impedance and the stimulation thresholds for left ventricular pacing in all possible different polarities. The results include the threshold simulation, the relative impact of the results on the longevity of the device and lead impedance for each polarity of stimulation tested. The results of the phrenic nerve stimulation threshold test can also be included. The test results can be used to determine the most suitable LV stimulation polarity. They can also be used to set the amplitude and the pulse duration, to ensure the appropriate control of the threshold test, to reduce the energy used and therefore to optimize the device longevity.

Automatic test «VectorExpress »: practical modalities

The Automatic test «VectorExpress » determines the LV pacing threshold for each LV pacing polarity for the selected pulse duration. The test varies the amplitude of stimulation to find the lowest threshold that effectively entrains the left ventricle. The device estimates the LV threshold by observing the right ventricular-coupled event detected after a pacing in the LV. If a right ventricular event is detected during the threshold test, the result is «entrained». If no right ventricular response is detected, the result is a «loss of entrainment». If the results are inconclusive or too many intrinsic events occur, the test is aborted with the actual specific pacing polarity and the test progress to the next pacing polarity.

A stimulation threshold test is performed for each selected polarity LV pacing amplitude at an initial value of 2.5 V. The search process then varies depending on whether this test amplitude of 2.5 V is above or below the LV threshold.
If the test amplitude of 2.5 V is higher than the LV threshold, the device lowers the amplitude by increments of 0.25 V until the LV threshold value or the minimum amplitude test (0.25 V) is reached.
If the test amplitude of 2.5 V is lower than the LV threshold, the stimulus amplitude is increased to 6.0 V. If the test amplitude of 6.0 V remains lower than the stimulation threshold, the test indicates that the threshold is greater than 6.0 V for that polarity. Otherwise, the device lowers the amplitude by increments of 0.5 V until the test LV threshold or the minimum amplitude of 3 V is reached.
The last test amplitude test entraining the RV defines the threshold for that LV pacing polarity.
The test of the 16 possible vectors takes 2 to 3 minutes. It is possible to exclude the polarities known for causing phrenic nerve stimulation.

Amplitude of left ventricular pacing

The main goal when programming a CTR device is to ensure permanent biventricular capture. The adjustment of the stimulation amplitude is expected to optimize the device lifespan while maintaining an adequate safety margin. Epicardial left ventricular pacing thresholds are often higher and more variable than right ventricular pacing thresholds. A recent study found threshold values 2 times higher for left ventricular leads than for the right ventricular leads. However, it is not always necessary to select a high safety margin (corresponding to two times the threshold) because this is accompanied by premature use of the battery in case of threshold exceeding 2 volts. Moreover, in some patients it is necessary to adjust precisely the stimulation amplitude and pulse duration in order to obtain a left ventricular capture with no phrenic stimulation.

The amplitude of LV stimulation also affects the probability of anodal capture. The cathode located at the extremity of the left ventricular lead is generally smaller than the anode. The reduced size of the cathode creates a high current density. The existence of high amplitudes of stimulation can result in a current density sufficiently high to capture the tissue close to the anode. In a triple chamber stimulator, the RV ring electrode is often used as anode for LV pacing. A high amplitude of stimulation may result in right ventricular "anodal" capture and in a triple points stimulation: right ventricular cathode and left ventricular + right ventricular anode. The occurrence of anodal capture is more common when the LV pacing configuration includes a true bipolar right ventricular lead (ring electrode) rather than an integrated bipolar lead (the right anode being the RV coil), probably because the size of the ring is smaller and allows for higher current density. The electrocardiographic aspect is often slightly modified compared to the traditional biventricular appearance. A 12-lead electrocardiogram, rather than the single derivation ECG on the programmer is usually required to make the diagnosis. Although anodal capture can significantly alter the analysis of the left ventricular threshold test, the hemodynamic effects of this type of stimulation might be favorable (by increasing the number of stimulation sites). However, its clinical impact remains to be demonstrated. Anodal capture generally requires high amplitudes of stimulation, which has a negative effect on the device longevity.

Tracing 1: LV lead dislodgement

Patient

64 years old man implanted with a triple chamber defibrillator Viva XT CRT-D for idiopathic dilated cardiomyopathy with a left bundle branch block; follow-up 3 months post implant; non-responder patient with unchanged symptomatology (shortness of breath for the daily activities); the device interrogation reveals 100% of biventricular pacing;

Tracing

On the tracings, the first line corresponds to the surface ECG with the superimposed markers, the second one to the right ventricular bipolar EGM, the last one to the LV tip / RV coil EGM

1: spontaneous atrial rhythm and biventricular pacing (AS-BV);
2: modification of the programming (RV pacing only);
3: in right ventricular pacing configuration, the aspect of the surface and endocardial ECGs are identical to that observed during biventricular pacing suggesting an absence of left ventricular capture;

Measurement of left ventricular pacing threshold (VDI 90 bpm)

4: ineffective LV pacing;
5: LV pacing captures the left atrium; the atrial depolarization is detected by the right atrial channel after the conduction delay between the right atrium and left atrium;
6: the atrial activation is conducted to the ventricle; there is no ventricular marker as this signal falls within the post-ventricular stimulation ventricular blanking period; the timing between the signals detected in the right atrium and the right ventricle is relatively short, but the delay between the left atrium and right ventricle is longer and corresponds to the conduction time between atrium and ventricle;
7: loss of atrial capture by the LV lead;
8: ineffective left ventricular pacing;
9: the spontaneous RV activity is detected by the RV lead because it falls after the blanking period;

The left ventricular lead of this patient had dislodged and fallen into the coronary sinus; he underwent a repositioning of the LV lead in a lateral vein;

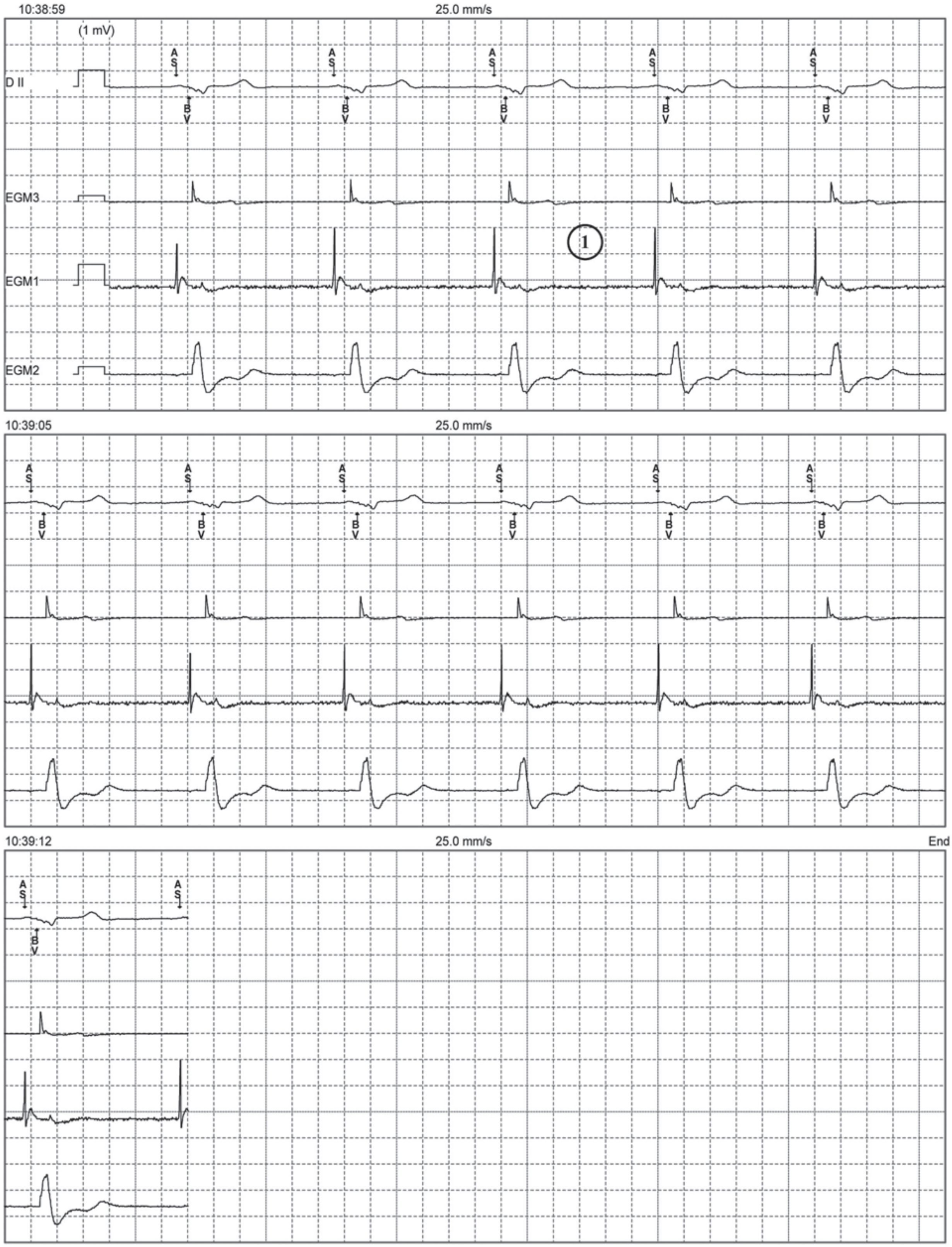
New ICD interrogation

10: RV pacing;
11: modification of the device programming (biventricular pacing);
12: clear modification of the surface ECG suggesting a left ventricular capture;

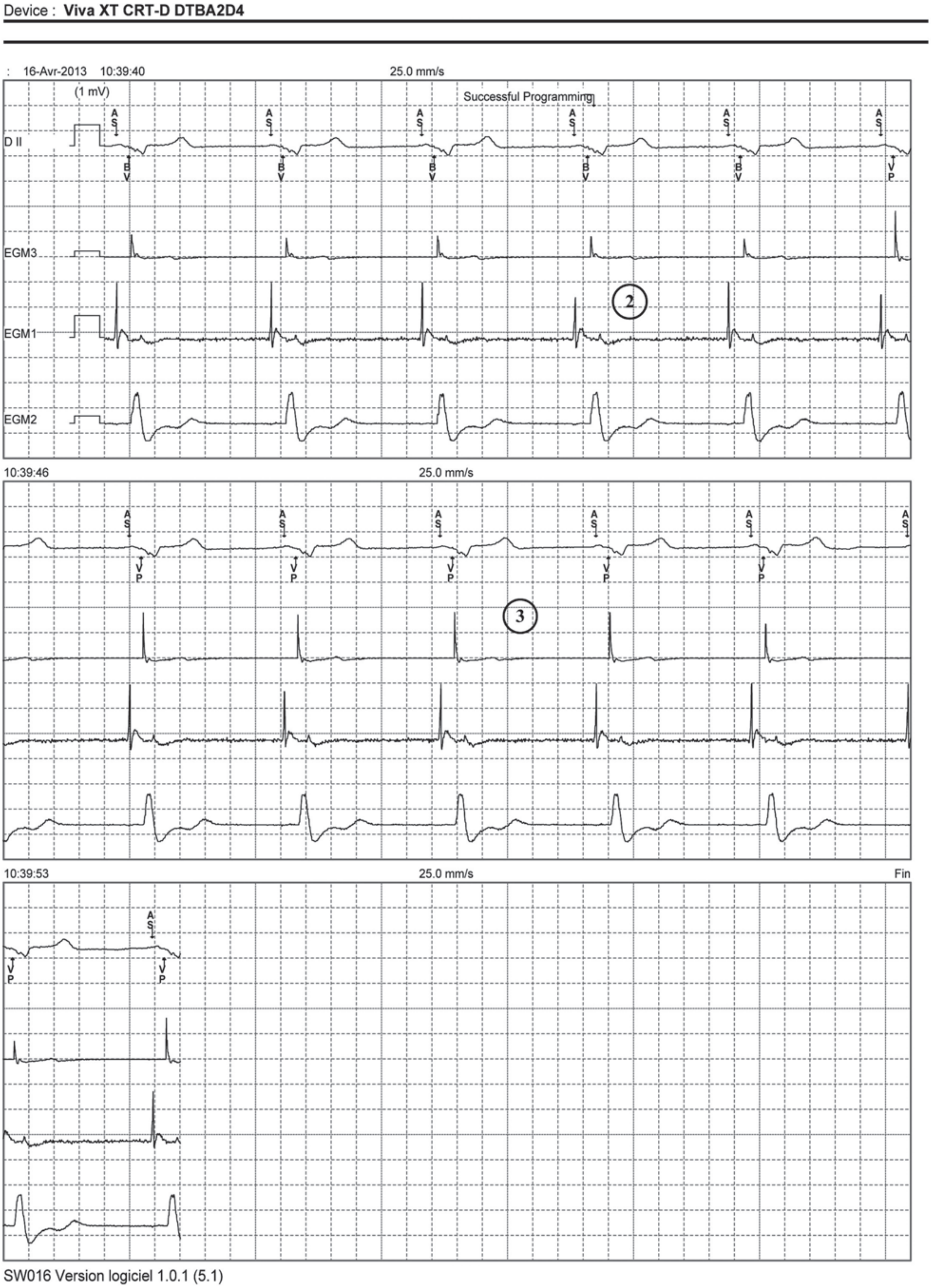
Comments

This tracing demonstrates one of the specificities of the monitoring of CRT patients. A percentage of biventricular pacing close to 100% is a necessary prerequisite but not sufficient for a good response to resynchronization. Indeed, biventricular pacing does not mean effective biventricular capture. In this patient, the interrogation of the device memories found a permanent biventricular pacing, but the surface electrocardiogram demonstrated a typical right ventricular apical pacing aspect with negative QRS in DII, DIII, aVF, and V1, and a wide positive QRS in DI. In this patient, the left ventricular lead had moved and had fallen in a position near the left atrial vein explaining the particular aspect of the threshold test. The vast majority of implantation procedures of CRT ends with the positioning of a left ventricular epicardial lead in a side branch of the coronary sinus. The risk of displacement of this type of lead is important because they are not equipped with an active fixation. LV leads are simply placed into the CS veins and blocked distally in small collaterals, or maintained in position by the curvatures of the lead in the vein meanderings.

Device : **Viva XT CRT-D DTBA2D4**



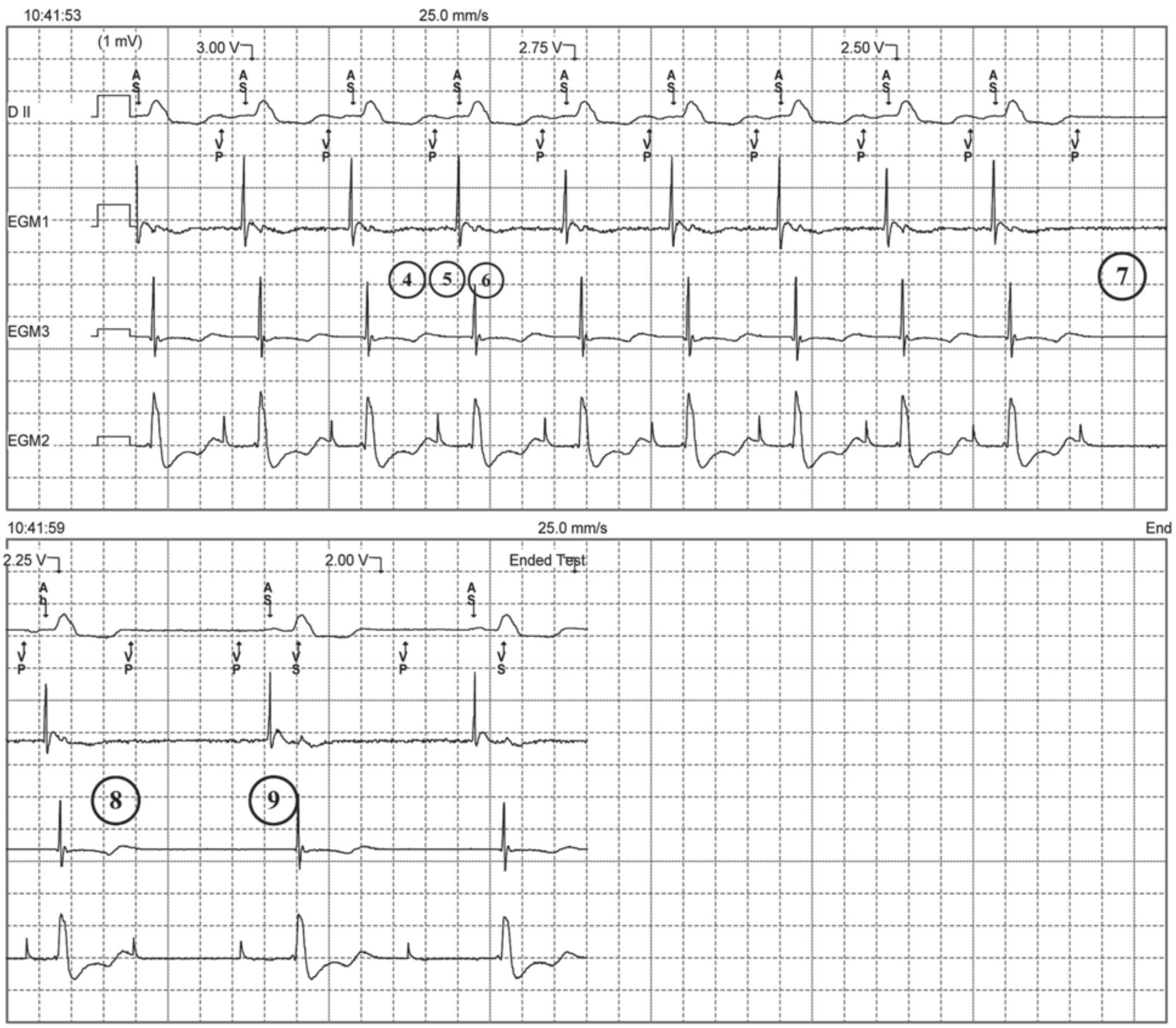
SW016 Version logiciel 1.0.1 (5.1)


Device : Viva XT CRT-D DTBA2D4
: 16-Avr-2013 10:39:40
25.0 mm/s
(1 mV)
Successful Programming
D II
EGM3
EGM1
EGM2
AS
BV
VP
2
10:39:46
25.0 mm/s
3
10:39:53
25.0 mm/s
Fin
SW016 Version logiciel 1.0.1 (5.1)

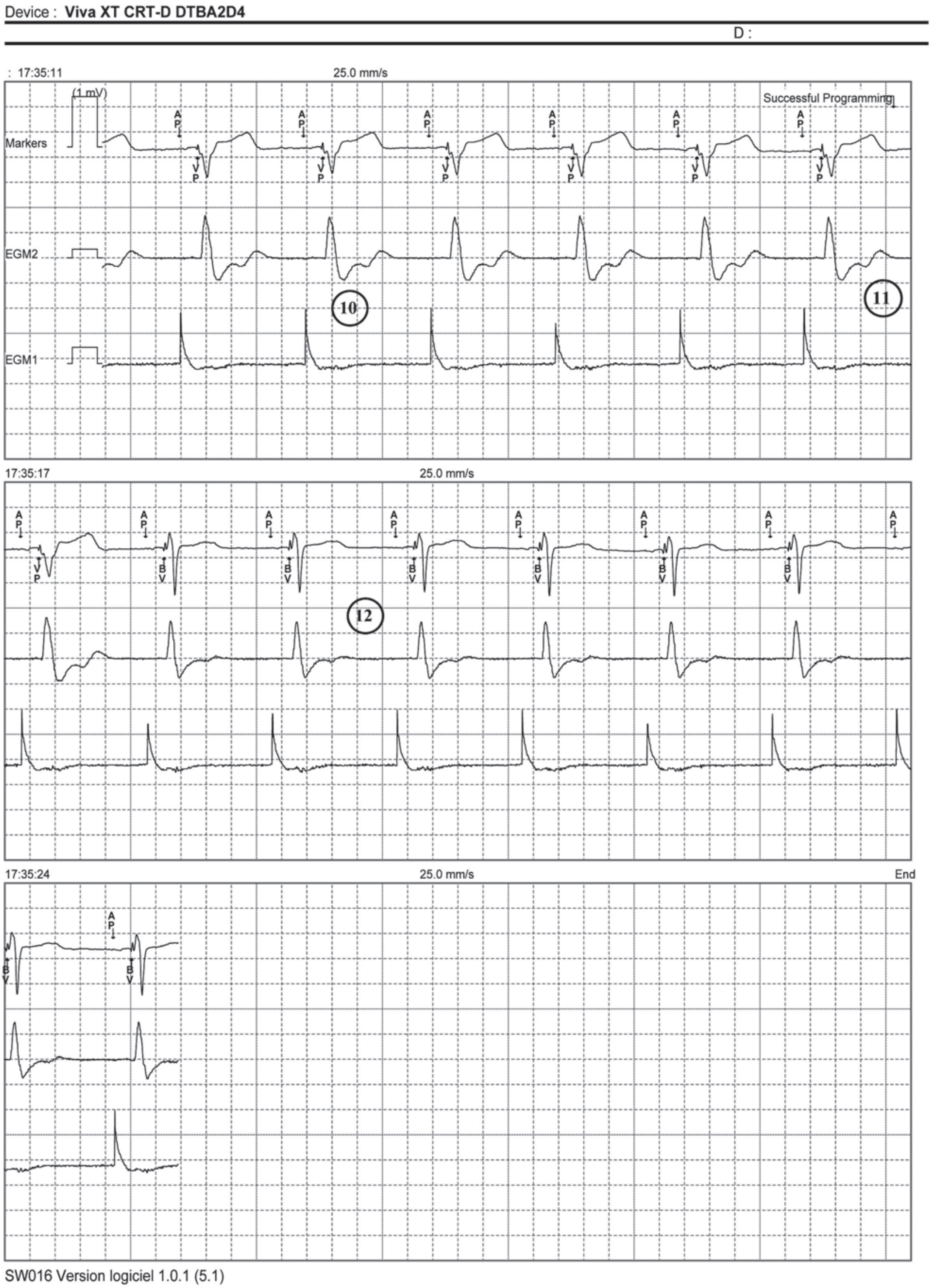
Amplitude Threshold Test - LV

Device : **Viva XT CRT-D DTBA2D4**

D :



SW016 Version logiciel 1.0.1 (5.1)


Device : Viva XT CRT-D DTBA2D4
D :
: 17:35:11
25.0 mm/s
(1 mV)
Successful Programming
Markers
EGM2
EGM1
10
11
17:35:17
25.0 mm/s
12
17:35:24
25.0 mm/s
End
SW016 Version logiciel 1.0.1 (5.1)

Tracing 2: unipolar LV lead threshold test

Patient

64 years old man implanted with a triple chamber defibrillator Concerto II CRT-D with positioning of a LV lead Medtronic 4195 in a small lateral vein; complex implantation due to the small caliber of the veins + high threshold values + several stimulation sites with a phrenic nerve capture;

Tracing

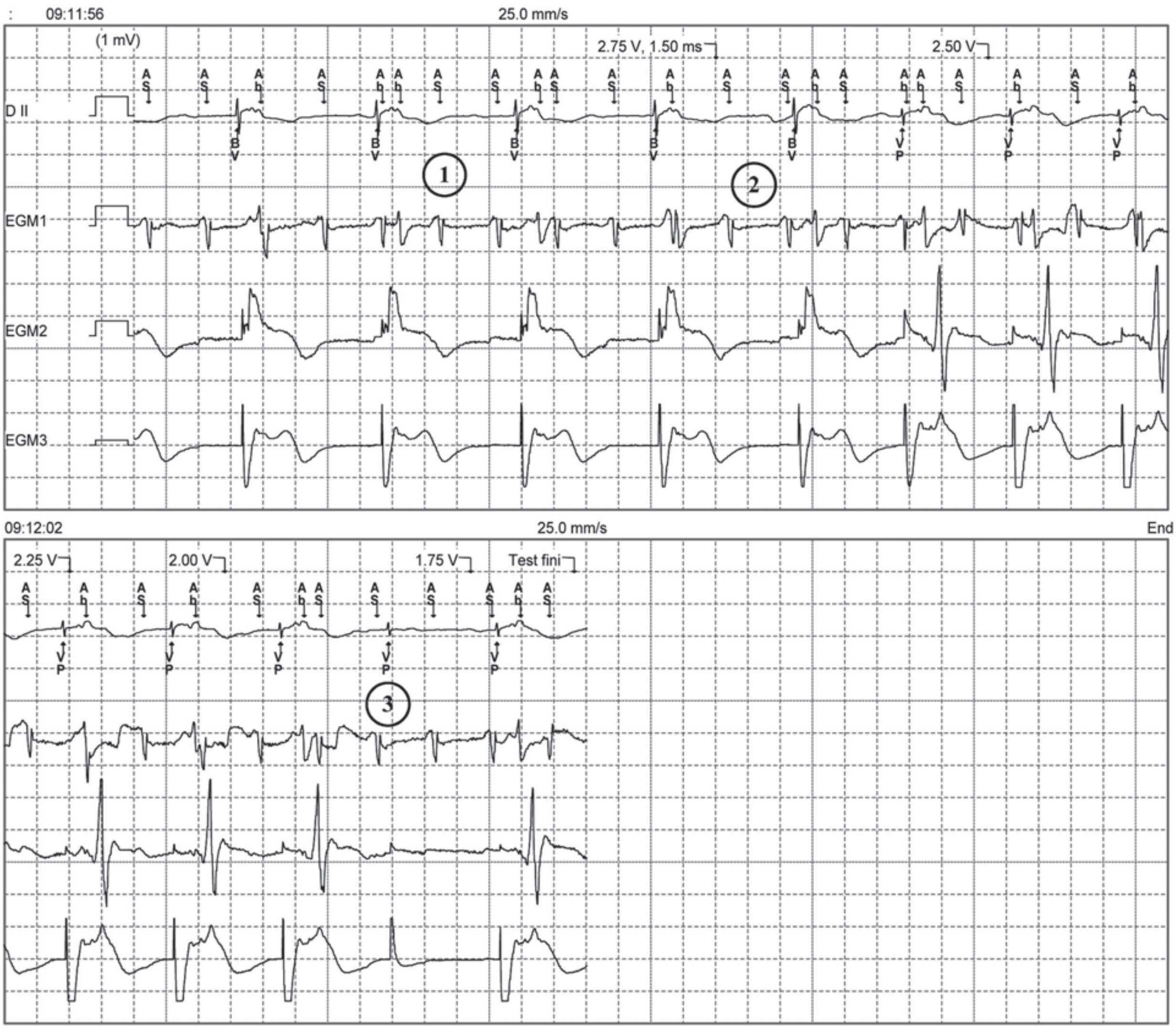
1: AF with biventricular pacing;
2: LV thresholds (EGM3), LV tip – RV coil configuration;
3: loss of LV capture (threshold 2.25 V/ 1.5 ms);
4: LV threshold test in LV tip – LV ring (LV anode) configuration;
5: absence of LV capture at maximal output (8 V/1.5 ms);

Comments

During the interrogation of the device, it is essential to know the characteristics of the implanted material. Information about the patient and the implanted material (age, cardiologist, indication for implantation, models implanted leads...) are normally entered into the device at the time of implantation, but can be changed at any time. The Medtronic 4195 lead is unipolar. It is preferably used when the target vein is of very small caliber. On a triple chamber defibrillator, the only acceptable configuration is LV tip – RV coil but it is possible to test the lead in a LV tip – LV ring configuration. In this dependent patient, the stimulation is obviously inefficient because the lead is not bipolar but unipolar. As a result, this causes a temporary asystole during the test. On a triple-chamber pacemaker, it is possible to program unipolar LV stimulation between the tip electrode and the can of the device (in a defibrillator, the box can cannot be part of the stimulation circuit).

Amplitude Threshold Test - LV

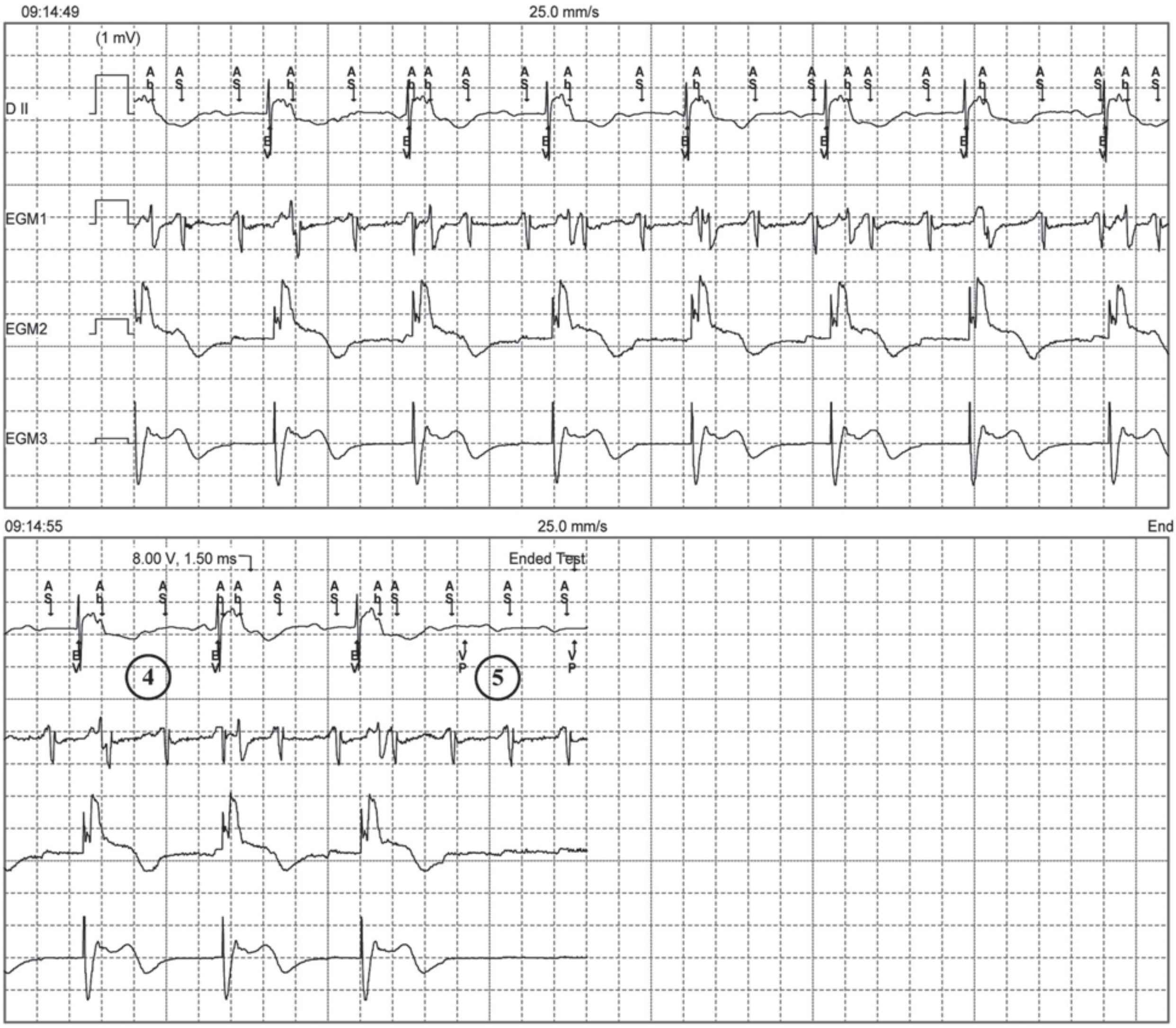
Device: **Concerto II CRT-D D294TRK**



9995 Version logiciel 7.4

Amplitude Threshold Test - LV

Device: **Concerto II CRT-D D294TRK**



9995 Version logiciel 7.4

Tracing 3: bipolar LV lead threshold test

Patient

70 years old man implanted with a triple chamber defibrillator Viva XT CRT-D and a Medtronic 4194 LV lead for ischemic cardiomyopathy with a left bundle branch block; follow-up 3 days after the implant; LV threshold performed in different stimulation configurations (stimulation DDD 90 bpm, amplitude decrement, fixed pulse width of 0.4 ms);

Tracing

1: LV threshold in LV tip – RV coil configuration;
2: loss of LV capture at 0,5 V (threshold 0.75 V/0.4 ms); absence of phrenic nerve stimulation;
3: LV threshold in LV tip – LV ring (anode) configuration;
4: loss of LV capture at 0,5 V (threshold 0.75 V/0.4 ms); absence of phrenic nerve stimulation;
5: LV threshold in LV ring – LV tip configuration;
6: loss of LV capture at 2V (threshold 2.25 V/0.4 ms); absence of phrenic nerve stimulation;
7: LV threshold in LV ring – RV coil configuration;
8: loss of LV capture at 3V (threshold 3.25 V/0.4 ms); absence of phrenic nerve stimulation;

Comments

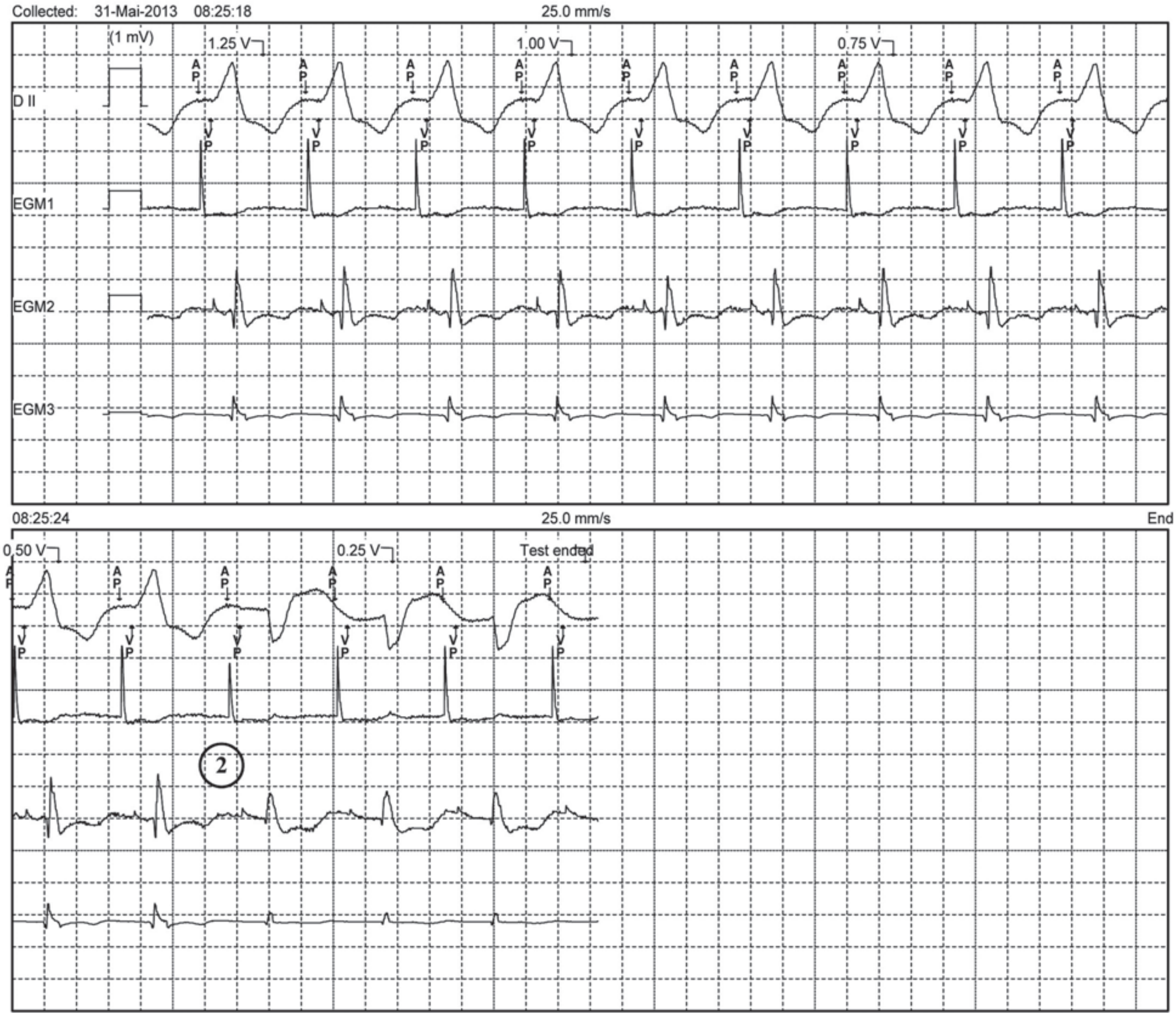
In a patient implanted with a triple chamber defibrillator and a bipolar left ventricular lead, 4 pacing configurations are programmable. Four factors can influence the choice of a pacing configuration: the presence of a diaphragmatic stimulation, the hemodynamic impact, the pacing threshold and the impedance. In this patient, the left ventricular lead was positioned in an anterolateral vein and no pacing configuration was associated with a phrenic stimulation, even for high amplitudes. With this type of bipolar left ventricular lead, the 2 electrodes are close, and will provide nearly identical electrocardiographic appearance (confirmed on a 12-lead ECG) whatever the chosen configuration is. Therefore, it seems logical to assume that the chosen pacing configuration will have only little influence on the hemodynamic impact. The third parameter of comparison between the four configurations seems however decisive in this patient. When the distal electrode is active (LV tip - RV coil LV tip – RV ring), the stimulation threshold is lower than 1 volt at 0.4 ms. When the LV anode is active (LV ring – LV tip, LV ring - RV coil), the threshold is higher (> 2 volts to 0.4 ms). Indeed, the 4194 lead has a large anodal ring surface area that reduces the current density at the electrode edges and therefore increases the threshold. The choice of pacing configuration will have a significant influence on the pacing amplitude necessary to obtain a sufficient margin and therefore a major influence on consumption and on the device longevity. The fourth parameter is the impedance of stimulation. All things being equal, it is preferable to program the pacing configuration that provides the higher impedance, since the drain of the battery is inversely proportional to the value of the impedance. When the LV threshold is high, this is an important parameter to consider.

Device : **Viva XT CRT-D DTBA2D1**

Bipolar LV lead threshold test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	DistaleLV/SpireRV		DistaleLV/SpireRV
Mode	DDD		DDD
Lower rate	90 min-¹		60 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	0.25 V	0.75 V	2.50 V
LV Capture	0.40 ms	0.40 ms	0.40 ms
Management			Arrêt
V Pace Blanking	300 ms		230 ms
A Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

1



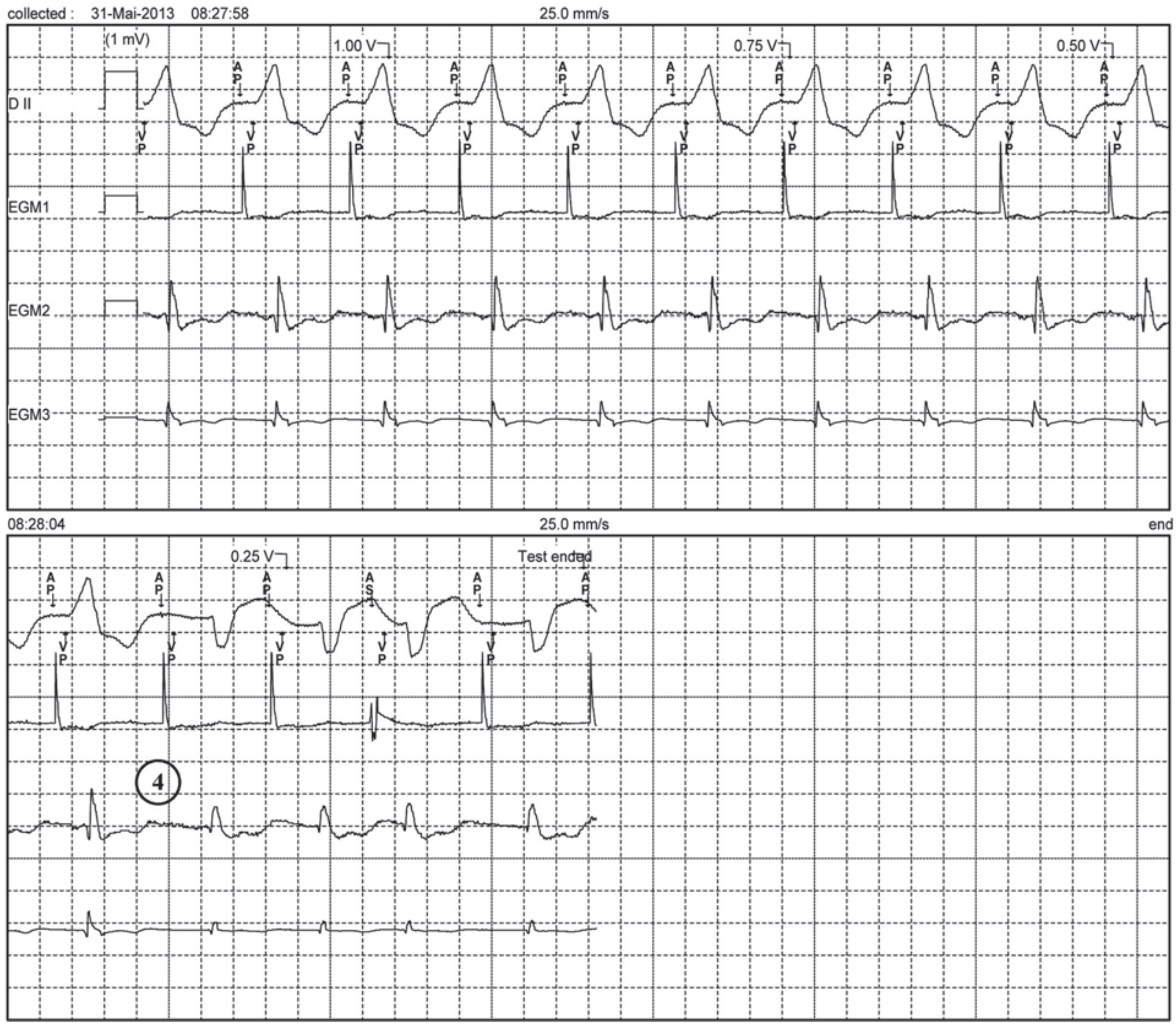
Device: **Viva XT CRT-D DTBA2D1**

ID :

Bipolar LV lead threshold test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	DistaleLV/AnodeLV		DistaleLVSpireRV
Mode	DDD		DDD
Lower rate	90 min-¹		60 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	0.25 V	0.75 V	2.50 V
LV Capture	0.40 ms	0.40 ms	0.40 ms
Management			Arrêt
V Pace Blanking	300 ms		230 ms
A Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

3



Device : **Viva XT CRT-D DTBA2D1**

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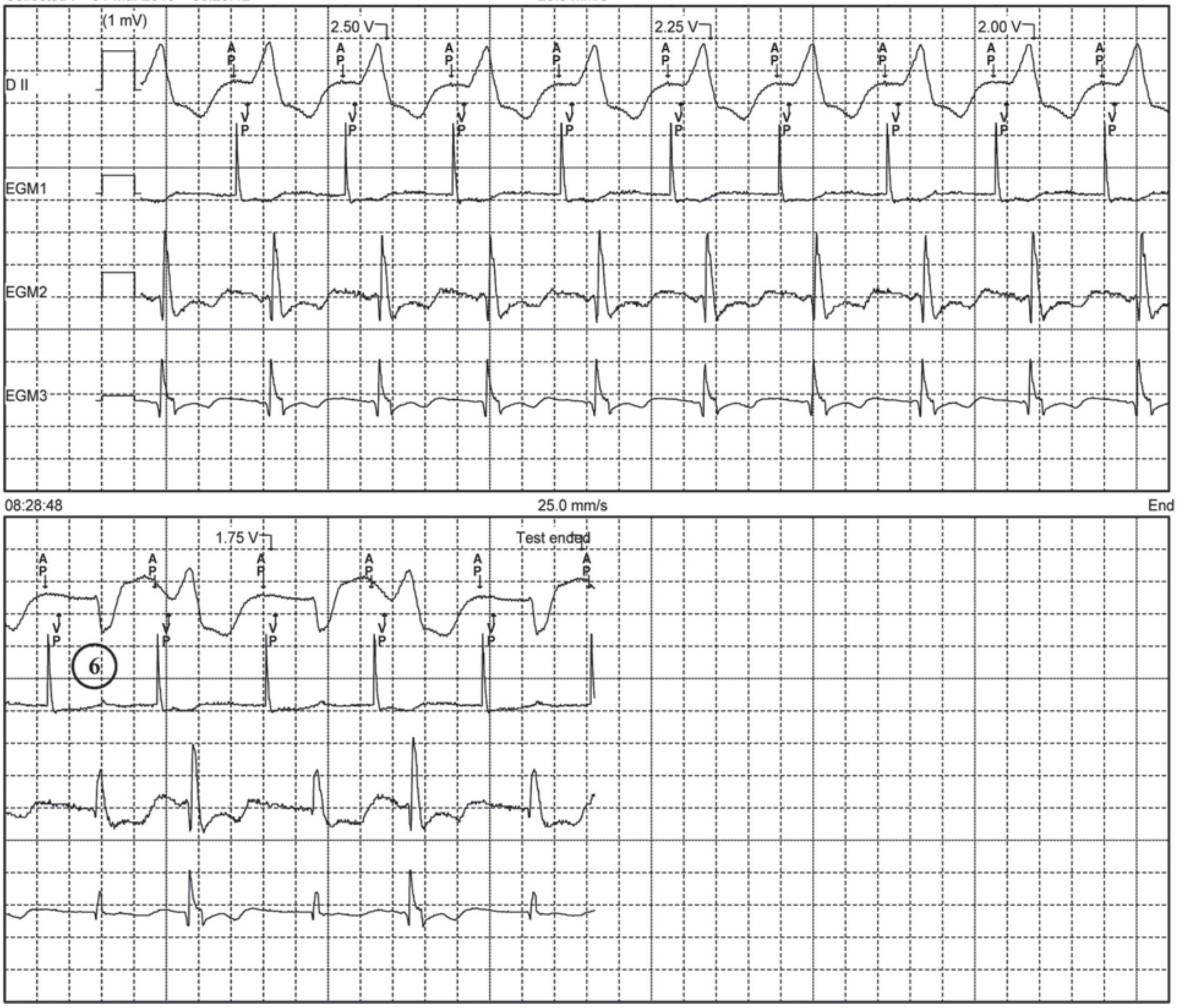
Bipolar LV lead threshold test

	Ending Value	Threshold	Permanent
LV Pace Polarity	AnodeLV/DistaleLV		DistaleLV/SpireRV
Mode	DDD		DDD
Lower rate	90 min-¹		60 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	1.75 V	2.25 V	2.50 V
LV Capture	0.40 ms	0.40 ms	0.40 ms
Management			Arrêt
V Pace Blanking	300 ms	5	230 ms
A Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

Collected : 31-Mai-2013 08:28:42 25.0 mm/s

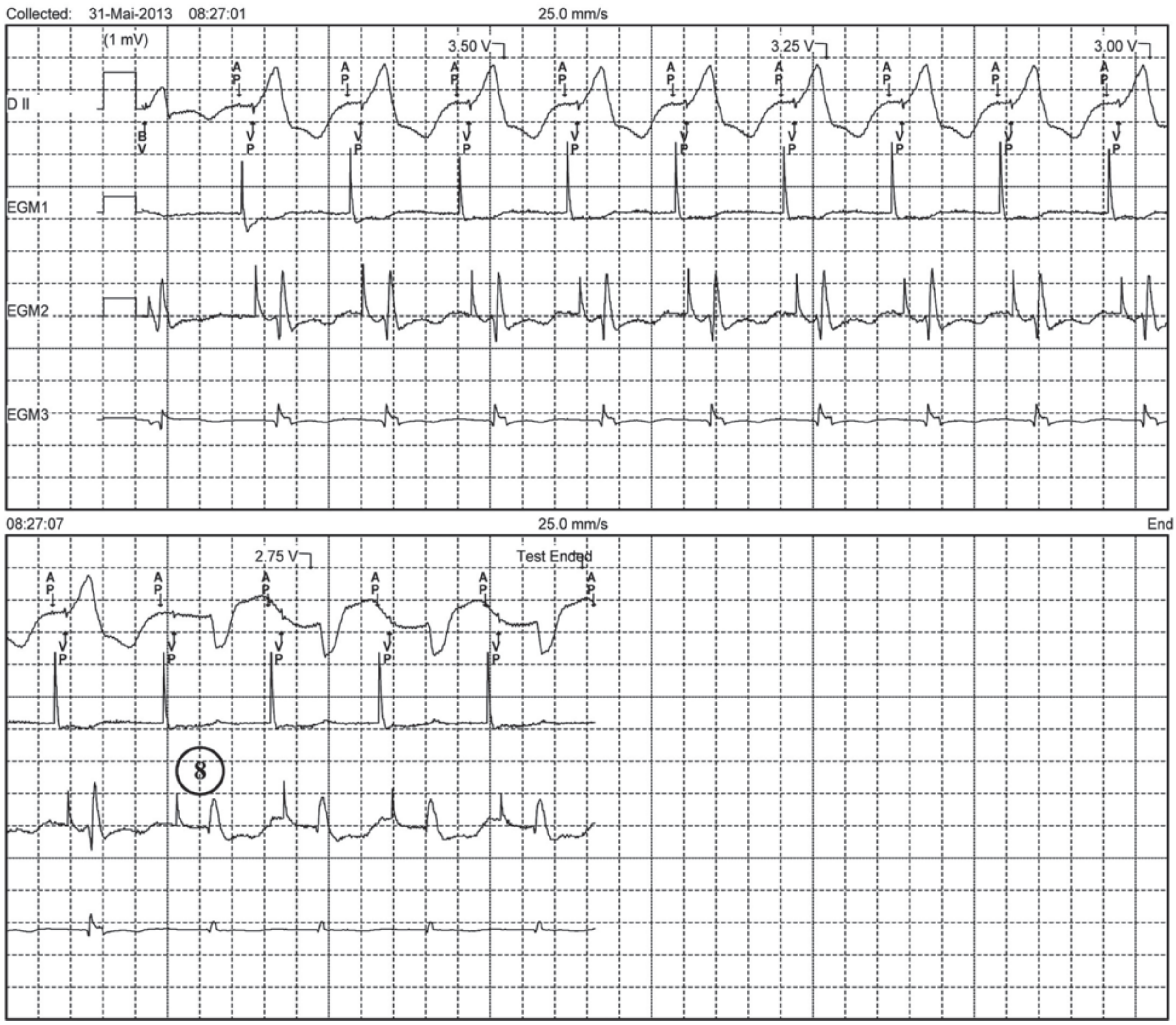


Device : **Viva XT CRT-D DTBA2D1**

Bipolar LV lead threshold test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	AnodeLV/SpireRV		DistaleLV/SpireRV
Mode	DDD		DDD
Lower rate	90 min-¹		60 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	2.75 V	3.25 V	2.50 V
LV Capture	0.40 ms	0.40 ms	0.40 ms
Management			Arrêt
V Pace Blanking	300 ms		230 ms
A Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

7



Tracing 4: quadripolar LV lead threshold test

Patient

62 years old man implanted with a triple chamber defibrillator Viva Quad XT CRT-D connected to a quadripolar Medtronic 4298 LV lead for ischemic cardiomyopathy with left bundle branch block; the implantation procedure was difficult with few lateral veins of small caliber and a large inferior vein draining the lateral wall; presence of high threshold values in the apical part of the lateral wall and phrenic nerve stimulation; positioning of a quadripolar lead; LV threshold performed with the different pacing configuration (mode DDD 90 bpm, amplitude decrement, pulse width 0.4 ms);

Tracing

1: LV threshold in LV1 – RV coil configuration;
2: loss of LV capture (threshold 0.5 V/0.4 ms); absence of phrenic nerve stimulation;
3: LV threshold in LV1 – LV2 configuration;
4: loss of LV capture (threshold 0.75 V/0.4 ms); absence of phrenic nerve stimulation;
5: LV threshold in LV1 – LV3 configuration;
6: loss of LV capture (threshold 0.5 V/0.4 ms); absence of phrenic nerve stimulation;
7: LV threshold in LV1 – LV4 configuration;
8: loss of LV capture (threshold 1 V/0.4 ms); presence of phrenic nerve stimulation (phrenic nerve threshold 2 V/0.4 ms);
9: LV threshold in LV2 – RV coil configuration;
10: loss of LV capture (threshold 2.25 V/0.4 ms); absence of phrenic nerve stimulation;
11: LV threshold in LV2 – LV1 configuration;
12: loss of LV capture (threshold 2.75 V/0.4 ms); absence of phrenic nerve stimulation;
13: LV threshold in LV2 – LV3 configuration;
14: loss of LV capture (threshold 6 V/0.4 ms); absence of phrenic nerve stimulation;
15: LV threshold in LV2 – LV4 configuration;
16: loss of LV capture (threshold 6 V/0.4 ms); presence of phrenic nerve stimulation up to the threshold value;
17: LV threshold in LV3 – RV coil configuration;
18: loss of LV capture (threshold 4.75 V/0.4 ms); absence of phrenic nerve stimulation;
19: LV threshold in LV3 – LV1 configuration;
20: loss of LV capture (threshold 2.75 V/0.4 ms); absence of phrenic nerve stimulation;
21: LV threshold in LV3 – LV2 configuration;
22: loss of LV capture (threshold 6 V/1.5ms); absence of phrenic nerve stimulation;
23: LV threshold in LV3 – LV4 configuration;
24: loss of LV capture (threshold 6 V/1.5 ms); presence of phrenic nerve stimulation up to the threshold value;
25: LV threshold in LV4 – RV coil configuration;
26: loss of LV capture (threshold 8 V/0.4 ms); presence of phrenic nerve stimulation up to the threshold value;
27: LV threshold in LV4 – LV1 configuration;
28: loss of LV capture (threshold 2.75 V/0.4 ms); presence of phrenic nerve stimulation up to the threshold value;
29: LV threshold in LV4 – LV2 configuration;
30: loss of LV capture (threshold 8 V/1.5 ms); presence of phrenic nerve stimulation up to the threshold value;
31: LV threshold in LV4 – LV3 configuration;
32: loss of LV capture (threshold 8 V/1.5 ms); presence of phrenic nerve stimulation up to the threshold value;

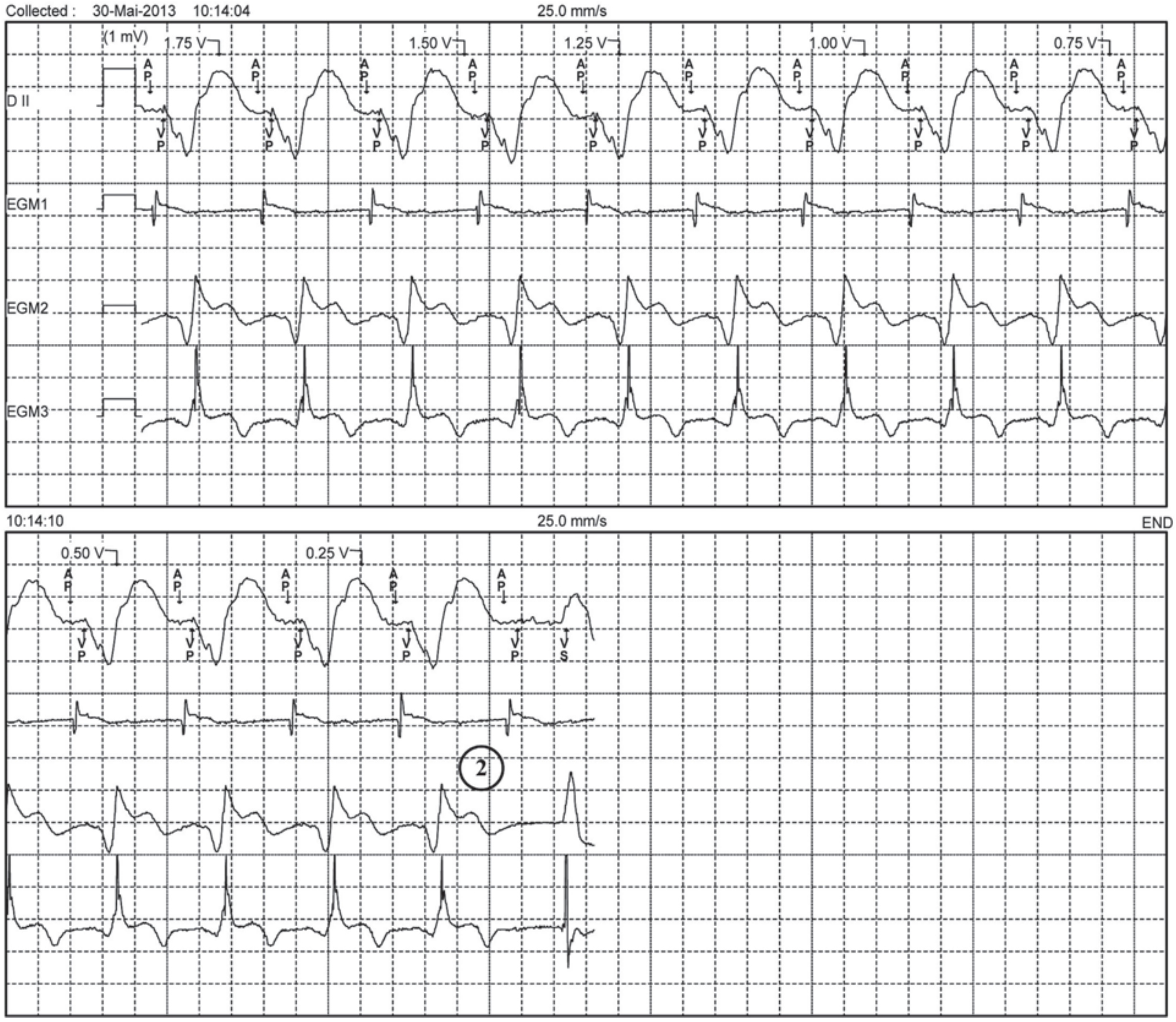
Comments

These tracings demonstrate the different potential benefits of implanting a quadripolar LV lead. Indeed, in this patient, the implantation procedure was difficult since the targeted veins were of small caliber, the stimulation thresholds were variable, and a phrenic stimulation was present at the apico-lateral region. It seems essential to avoid the configurations associated with phrenic nerve stimulation (often poorly tolerated by the patient). Pacing thresholds ranged from a very satisfying value (<1Volt at 0.4 ms) to thresholds close to the maximal capacity of the device. It seems clear that the impact on the battery longevity will be highly variable depending on the chosen configuration. The third criterion is the optimal site of pacing for hemodynamic and clinical benefits. The four electrodes on quadripolar leads are relatively spaced: in this patient, the distal tip electrode (LV1) was positioned in an apico-lateral region while the proximal electrode (LV4) was positioned in the baso-lateral region. Electrocardiographic changes from one configuration to another are only slightly visible on the derivation used for the evaluation of the pacing threshold. In contrast, the 12-lead electrocardiogram found significant changes in the appearance of the paced QRS depending on the chosen configuration. The electrical activation being different, it seems plausible that the degree of response may differ according to the chosen configuration. This reflects the difficulties found today to define what is an optimal site of pacing. In the absence of validated tool for defining a site as optimal, this criterion is rarely the criterion of choice between the different configurations.
In this patient, the selected configuration was LV1 / RV coil which allowed obtaining a satisfactory threshold value with no phrenic nerve stimulation. In case of no response to resynchronization, the choice of an alternative configuration to promote a better response remains empirical today.

Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

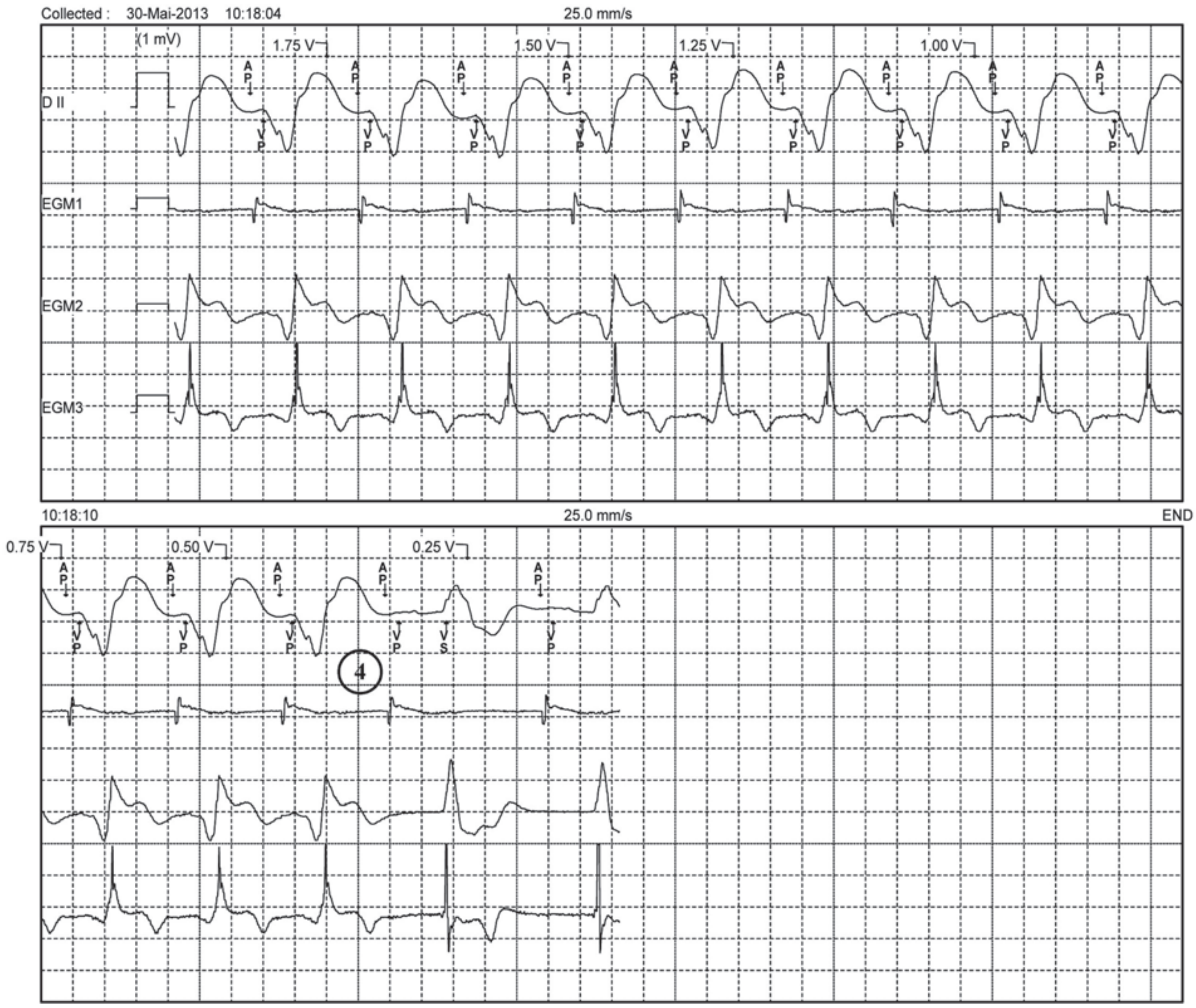
Valeurs	Ending Value	Threshold	Permanent
LV Pace Polarity	LV1/SpireRV		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	0.25 V	0.50 V	2.50 V
LV Pulse Width	0.40 ms	0.40 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude		(1)	6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto



Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

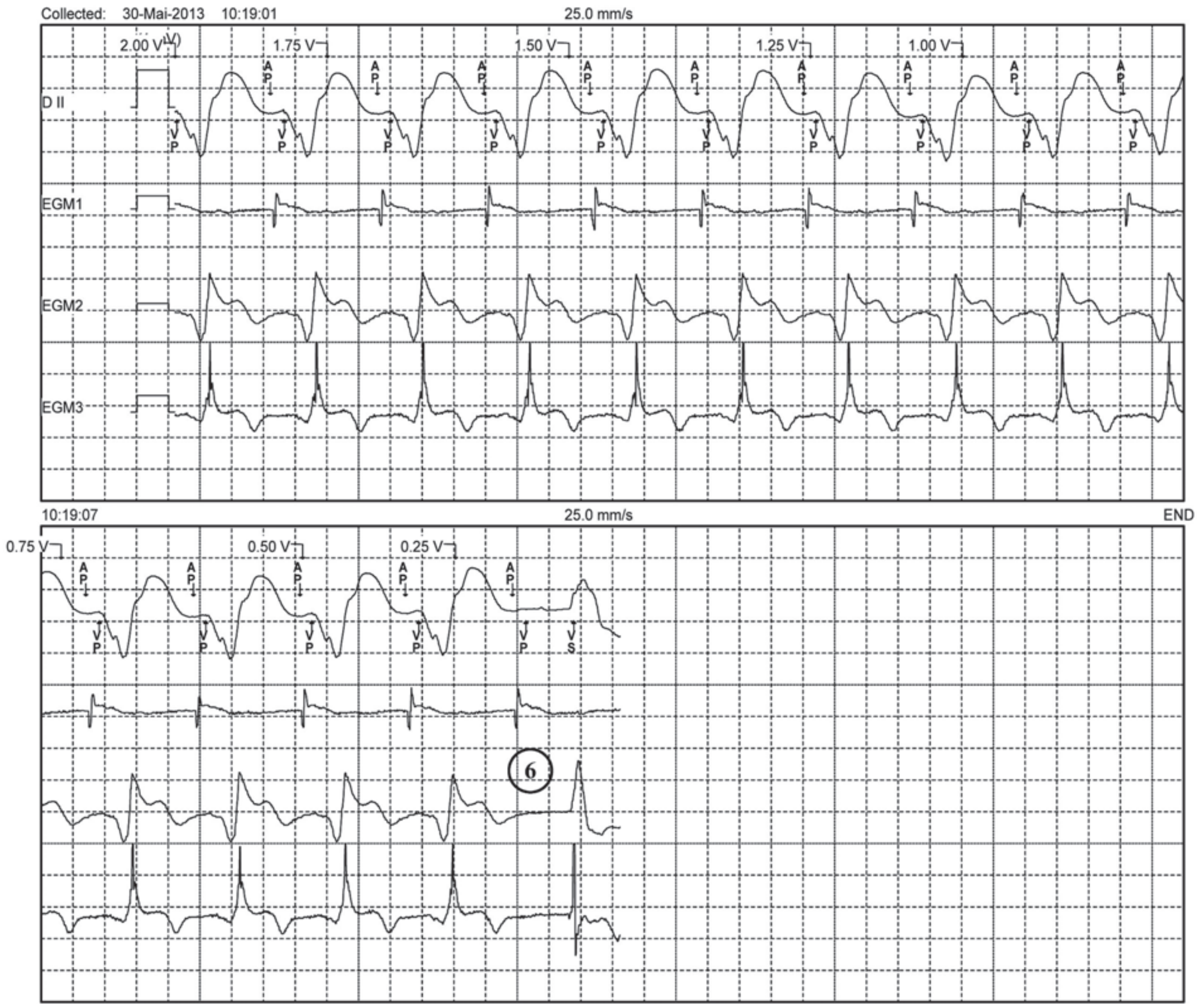
Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV1/LV2		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	0.25 V	0.75 V	2.50 V
LV Pulse Width	0.40 ms	0.40 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin	300 ms		+ 1.5 V
Max. Adapted Amplitude	200 ms	③	6.00 V
V. Pace Blanking			200 ms
A. Pace Blanking	340 ms		200 ms
PVARP			Auto



Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

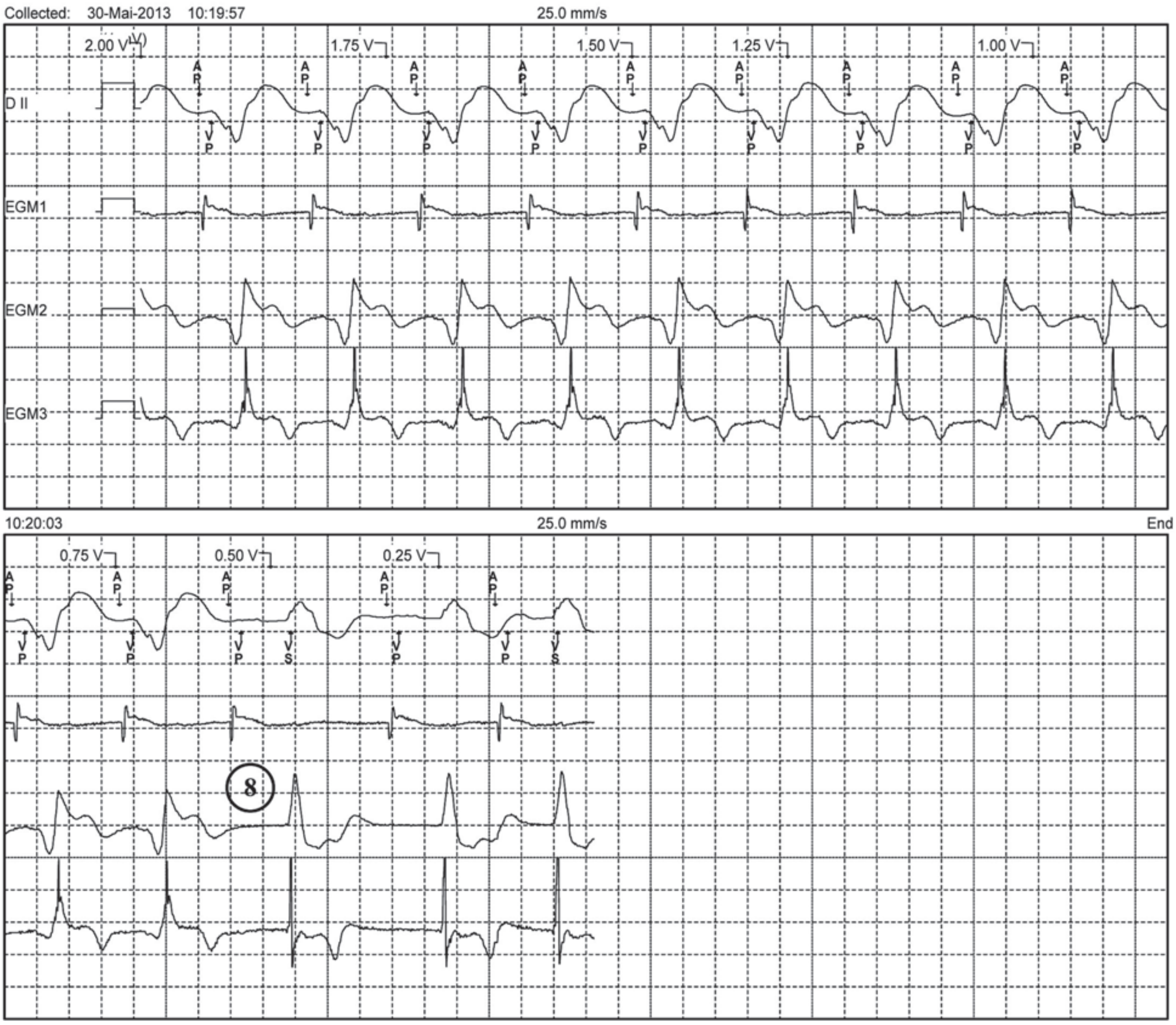
Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV1/LV3		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	0.25 V	0.50 V	2.50 V
LV Pulse Width	0.40 ms	0.40 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude		(5)	6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto



Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV1/LV4		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	0.25 V	1.00 V	2.50 V
LV Pulse Width	0.40 ms	0.40 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude		(7)	6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

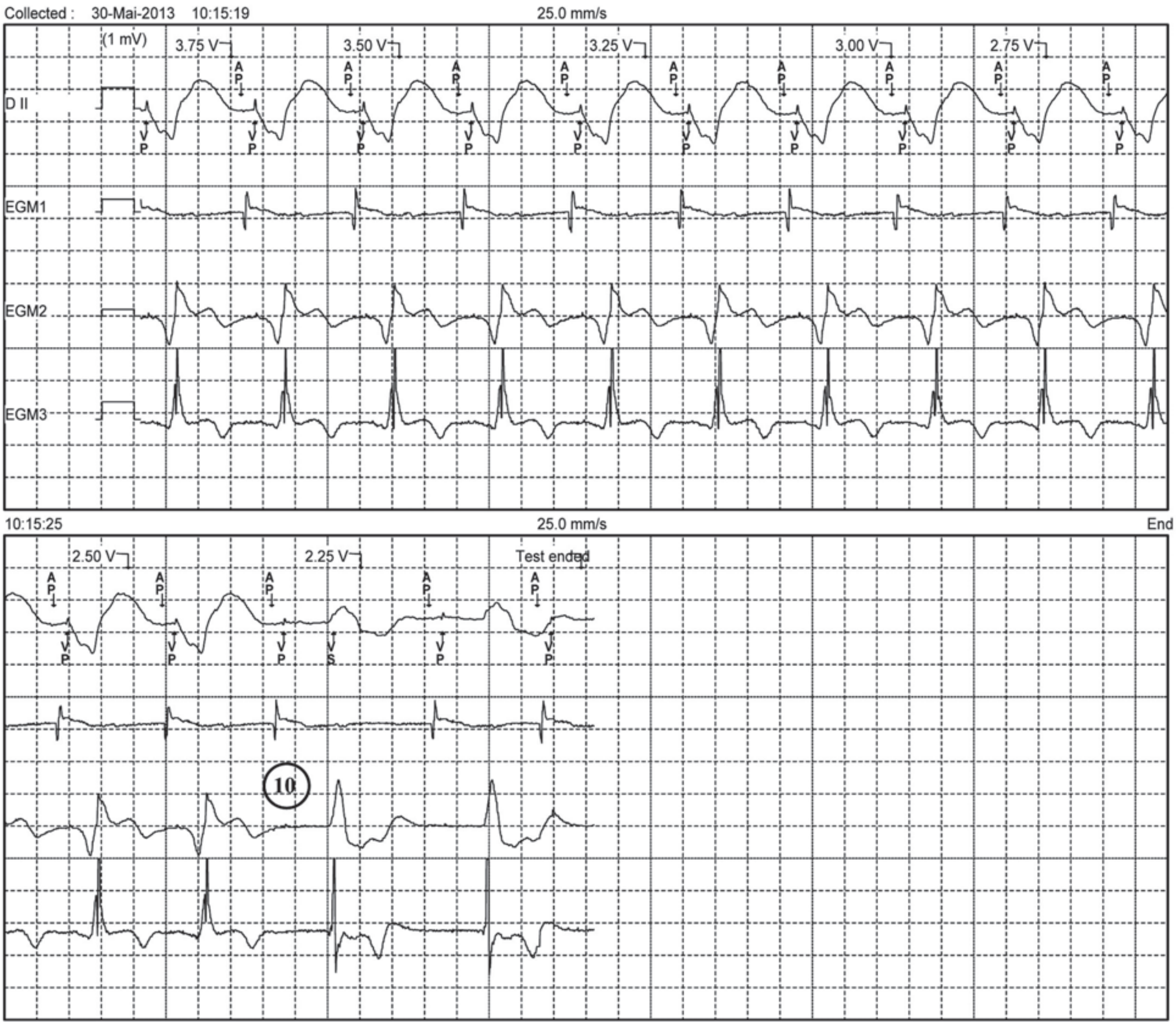


Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV2/SpireRV		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	2.25 V	2.75 V	2.50 V
LV Pulse Width	0.40 ms	0.40 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude			6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

9



Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV2/LV1		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	2.00 V	2.75 V	2.50 V
LV Pulse Width	0.40 ms	0.40 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude			6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

(11)

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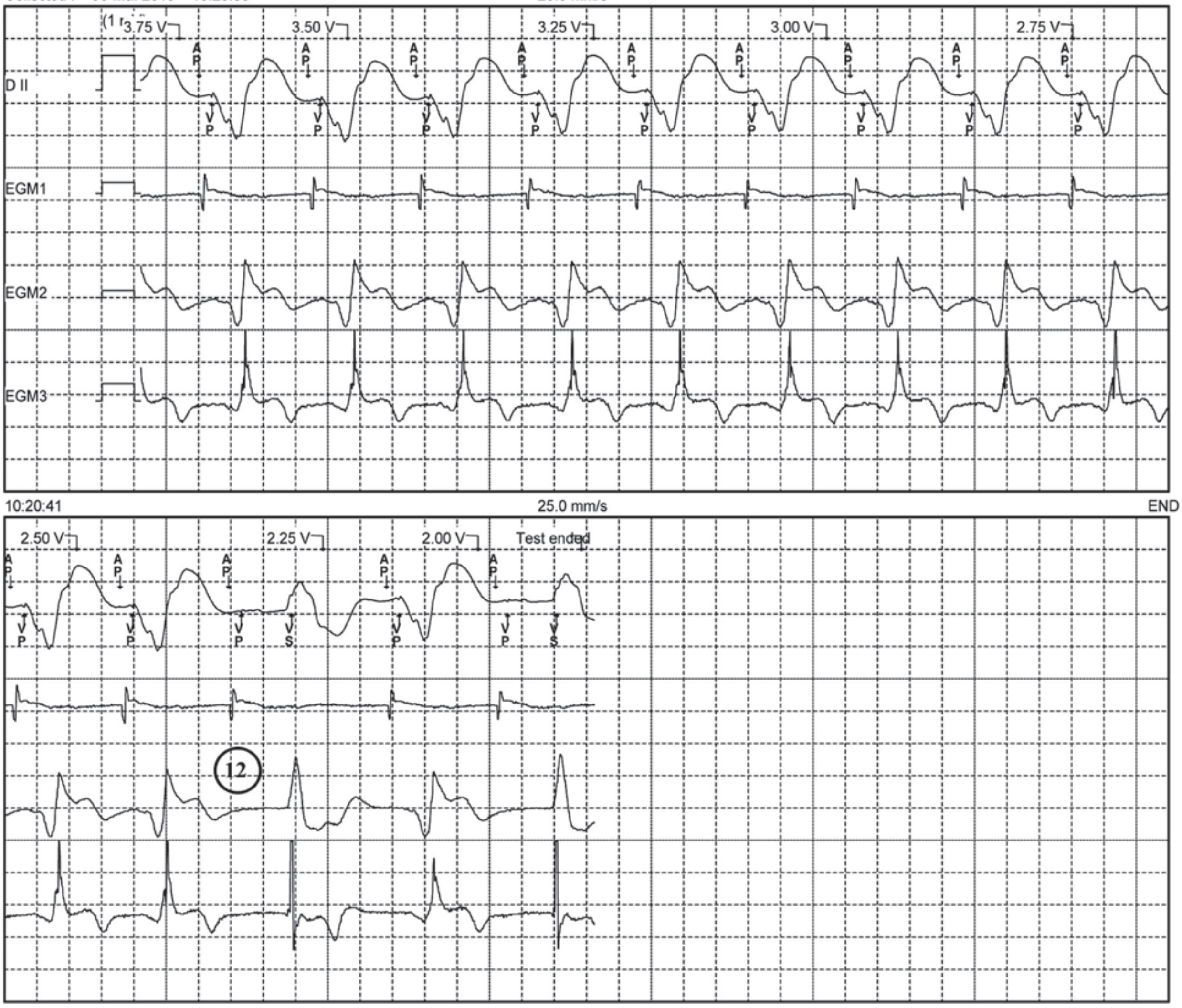
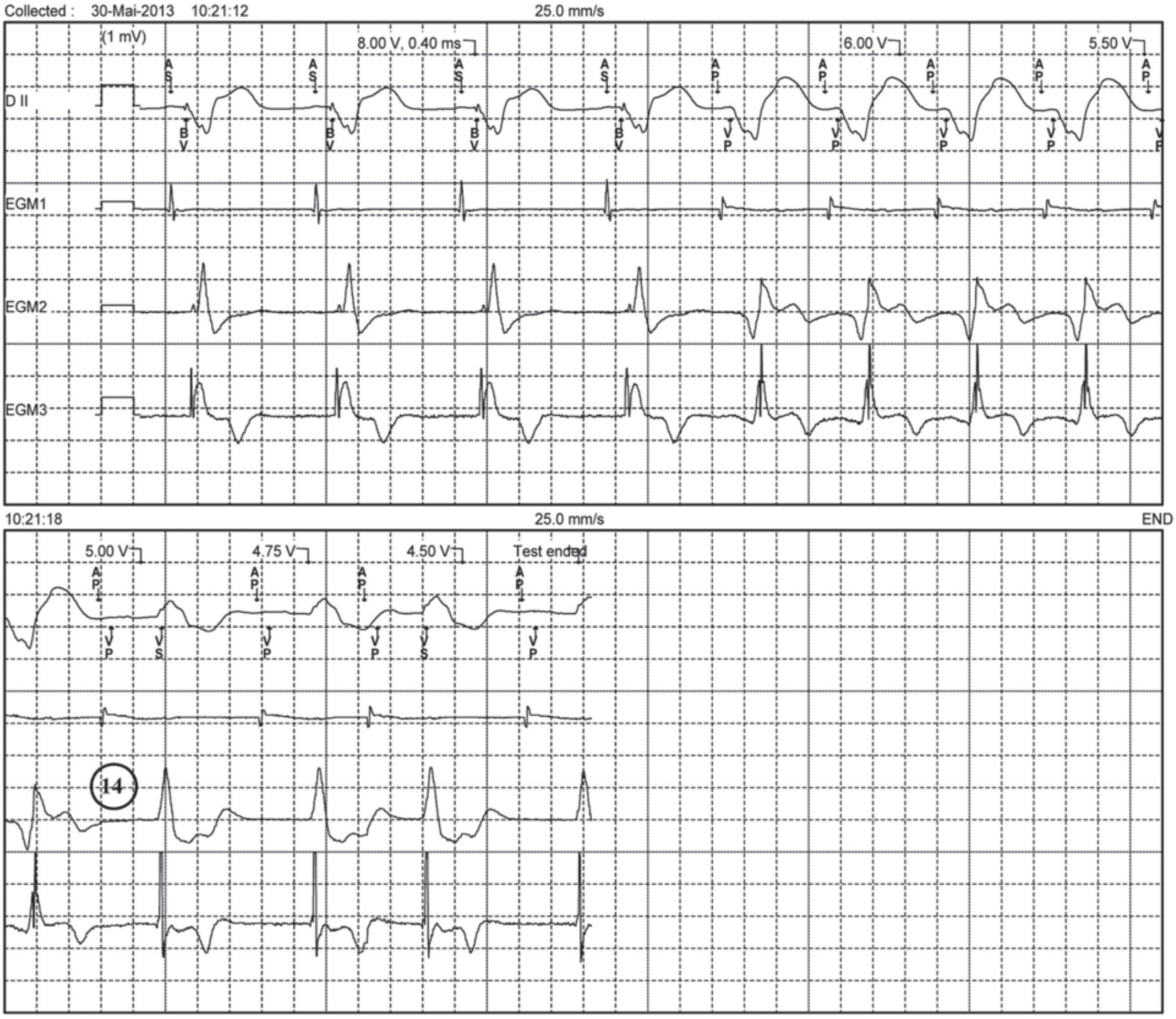


Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV2/LV3		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	4.50 V	6.00 V	2.50 V
LV Pulse Width	0.40 ms	0.40 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude			6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

(13)



Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV2/LV4		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	4.75 V	6.00 V	2.50 V
LV Pulse Width	0.40 ms	0.40 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude			6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

(15)

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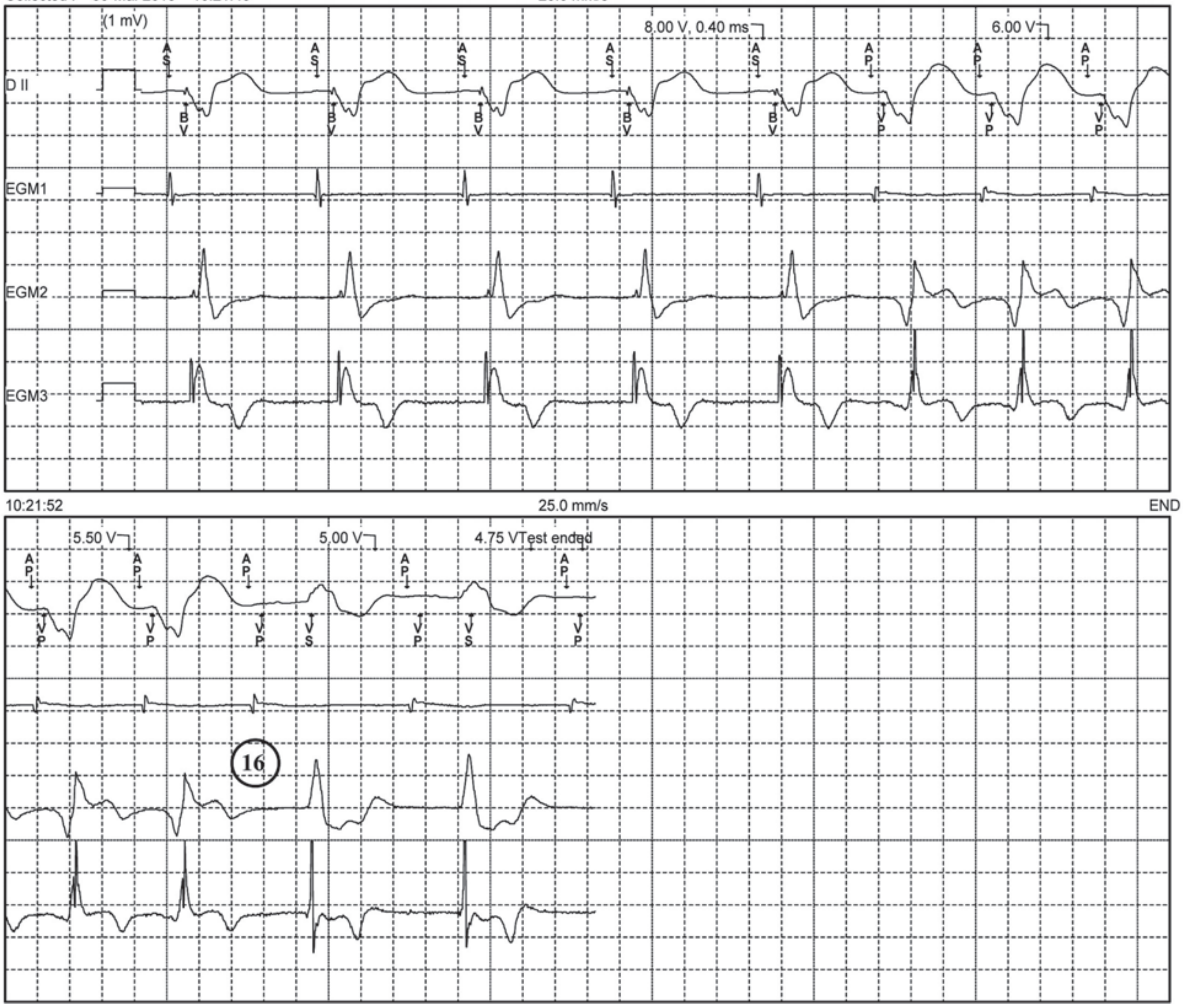
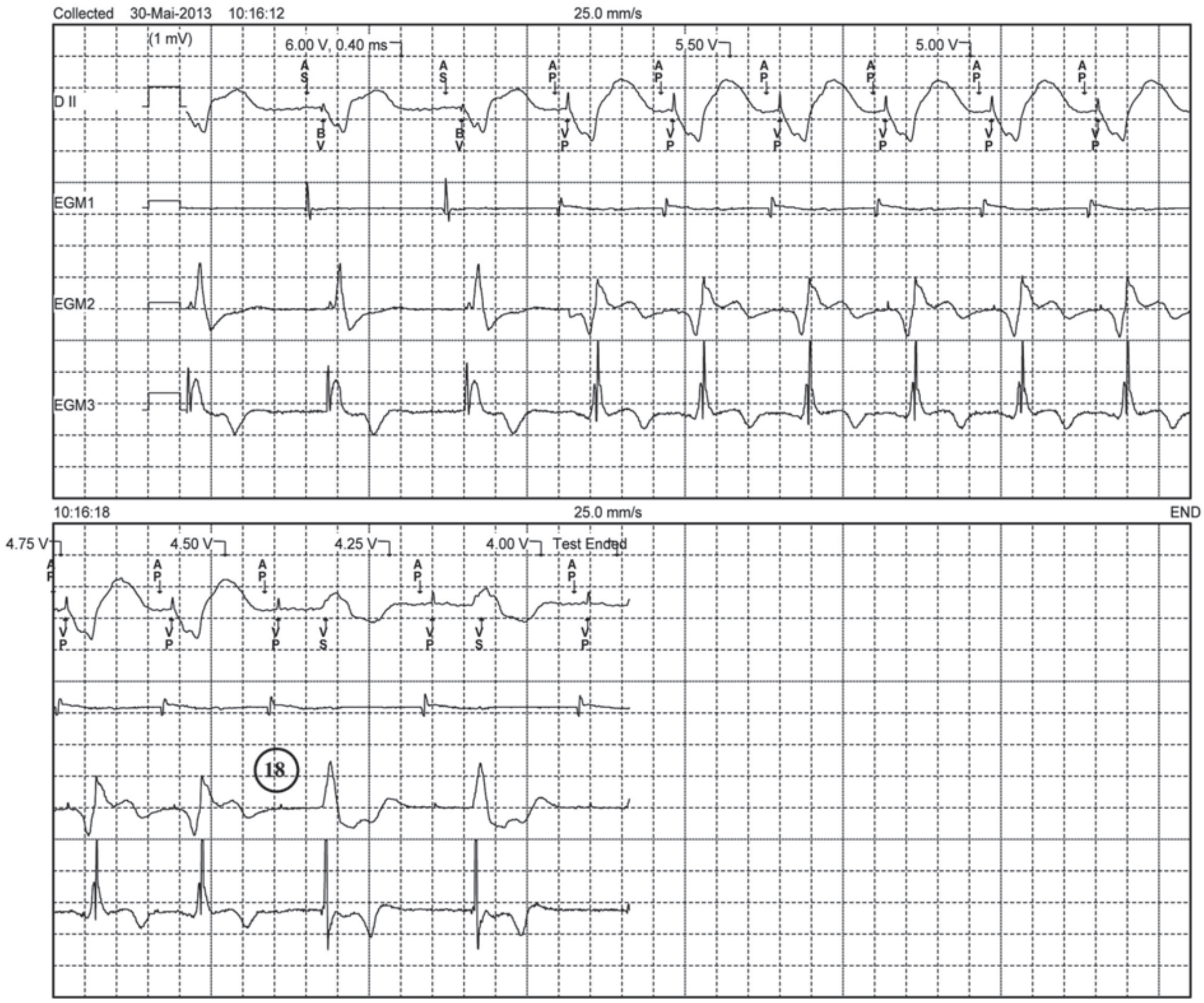


Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV3/SpireRV		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	4.00 V	4.75 V	2.50 V
LV Pulse Width	0.40 ms	0.40 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude			6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

17

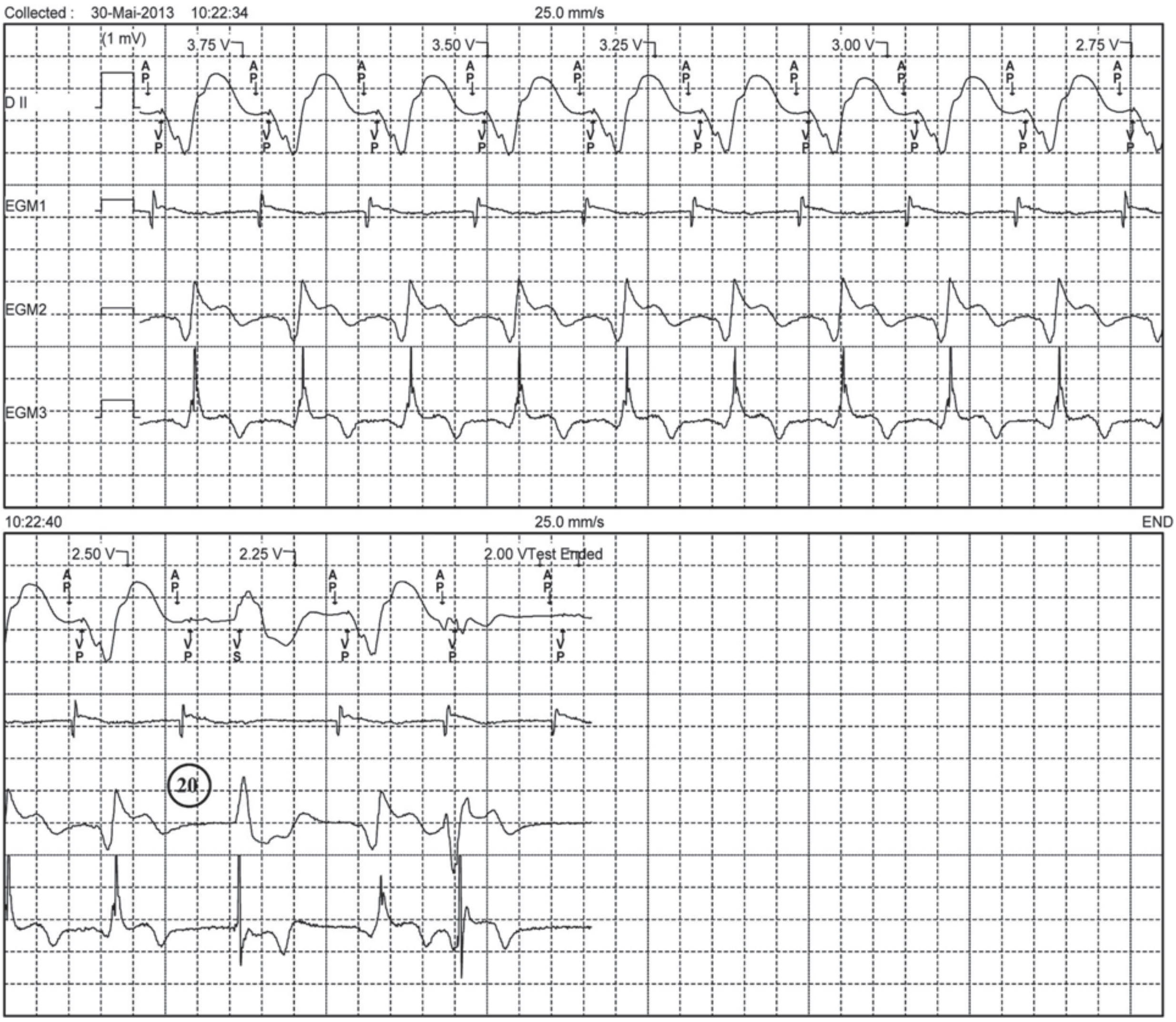


Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV3/LV1		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-1		50 min-1
AV Delay	80 ms		130 ms
LV Amplitude	2.00 V	2.75 V	2.50 V
LV Pulse Width	0.40 ms	0.40 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude			6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

19

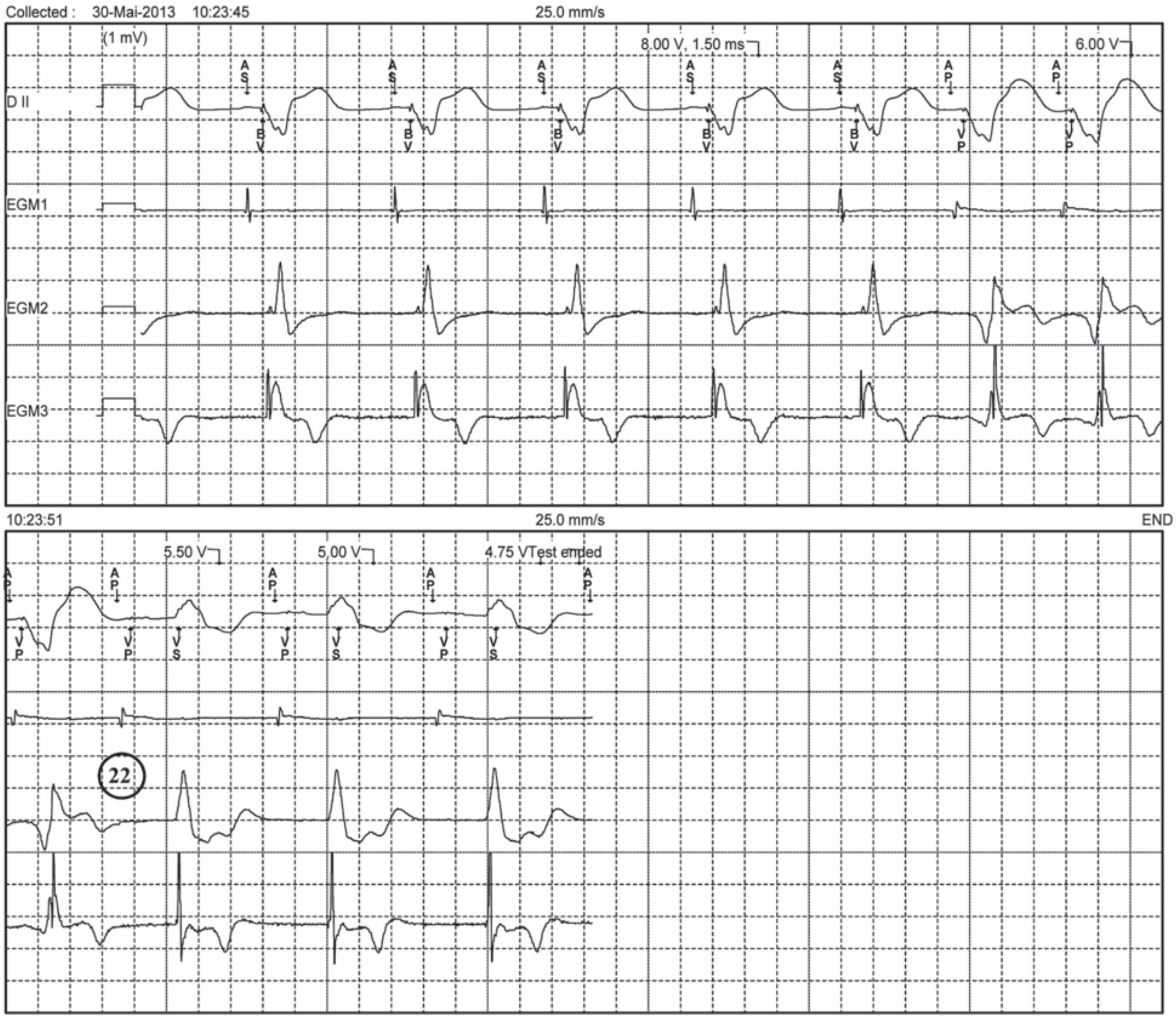


Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV3/LV2		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	4.75 V	8.00 V	2.50 V
LV Pulse Width	1.50 ms	1.50 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude			6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

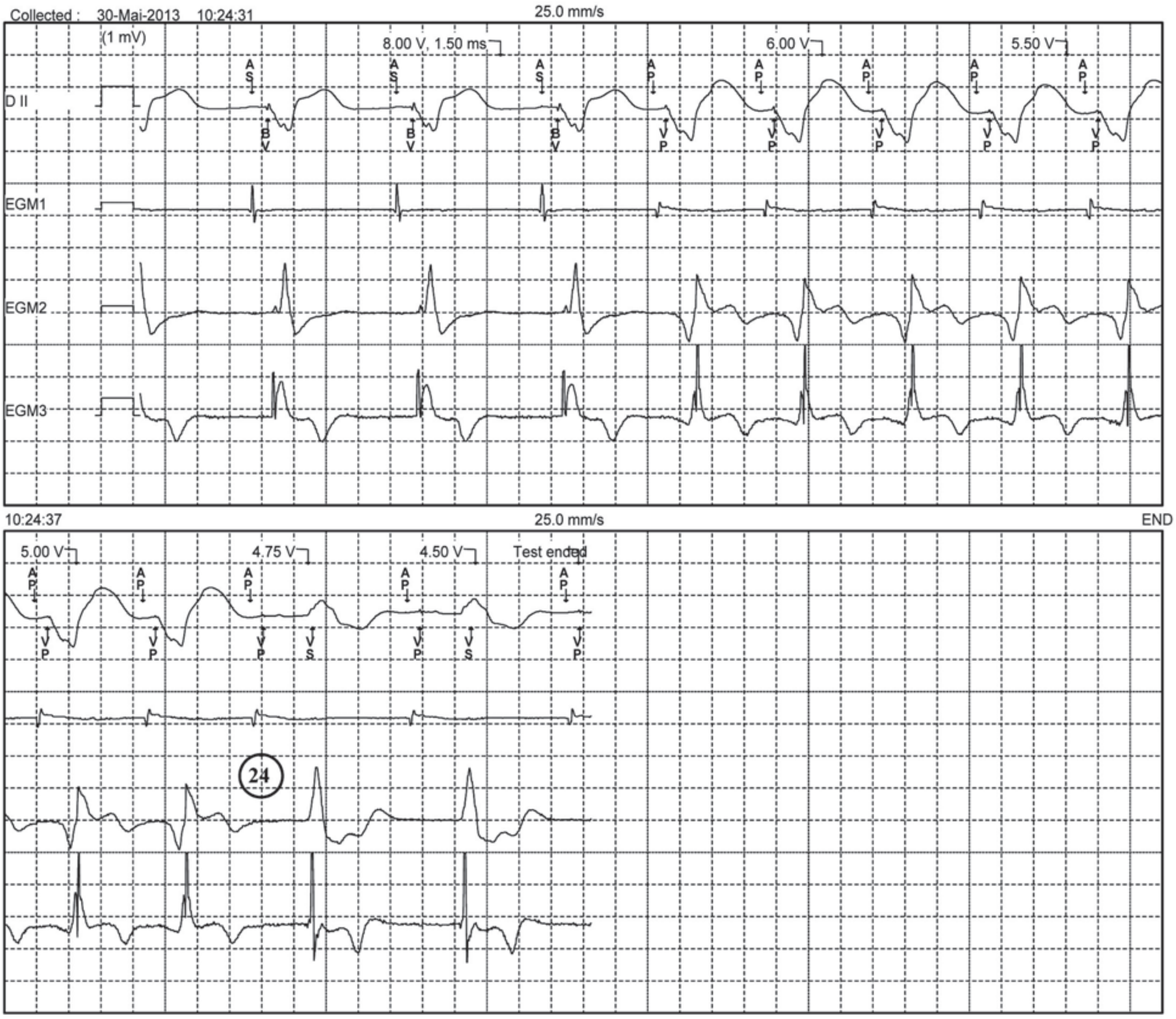
(21)



Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV3/LV4		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	4.50 V	5.50 V	2.50 V
LV Pulse Width	1.50 ms	1.50 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin		(23)	+ 1.5 V
Max. Adapted Amplitude			6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

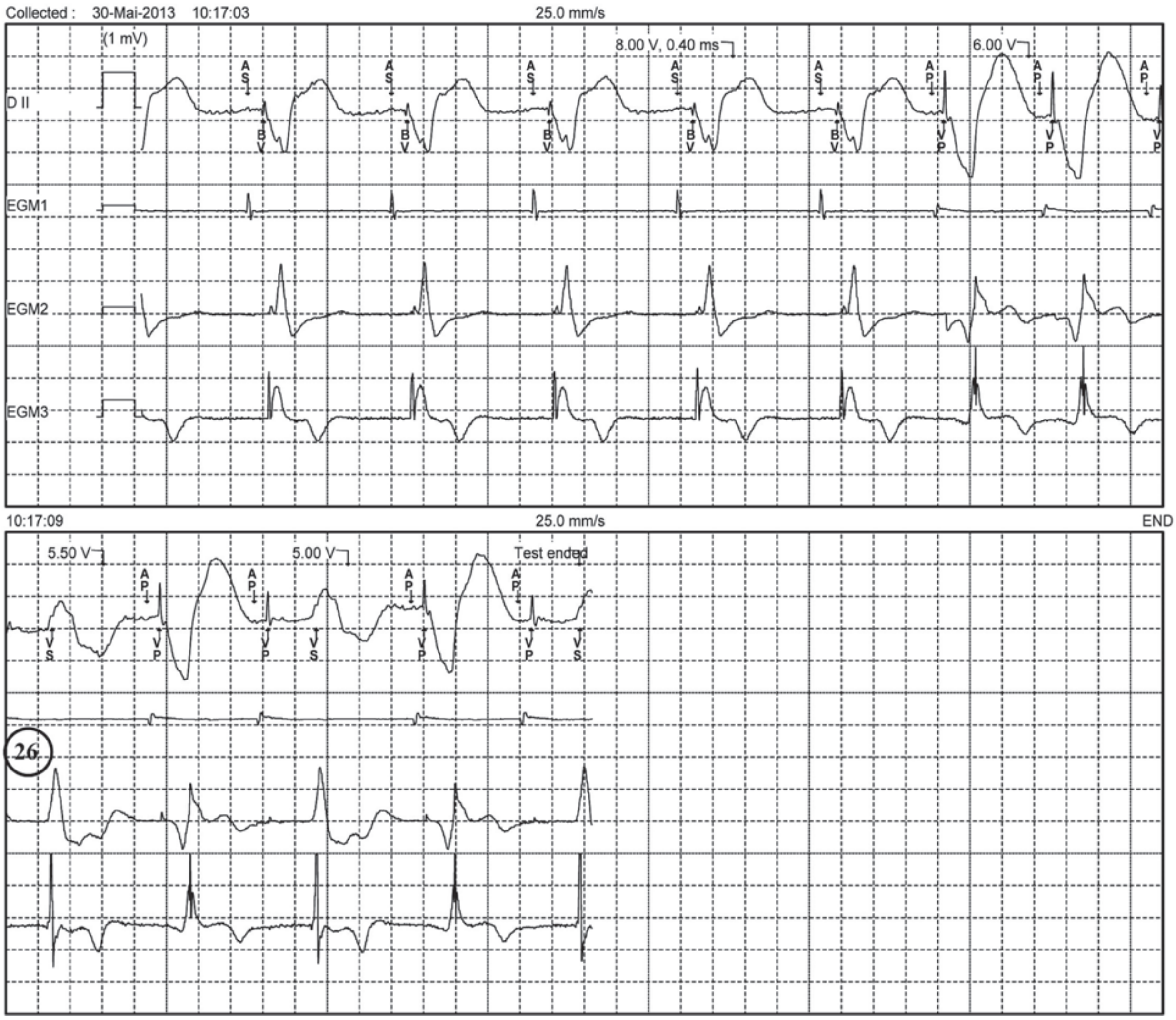


Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV4/SpireRV		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	5.00 V	8.00 V	2.50 V
LV Pulse Width	0.40 ms	0.40 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude			6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

25

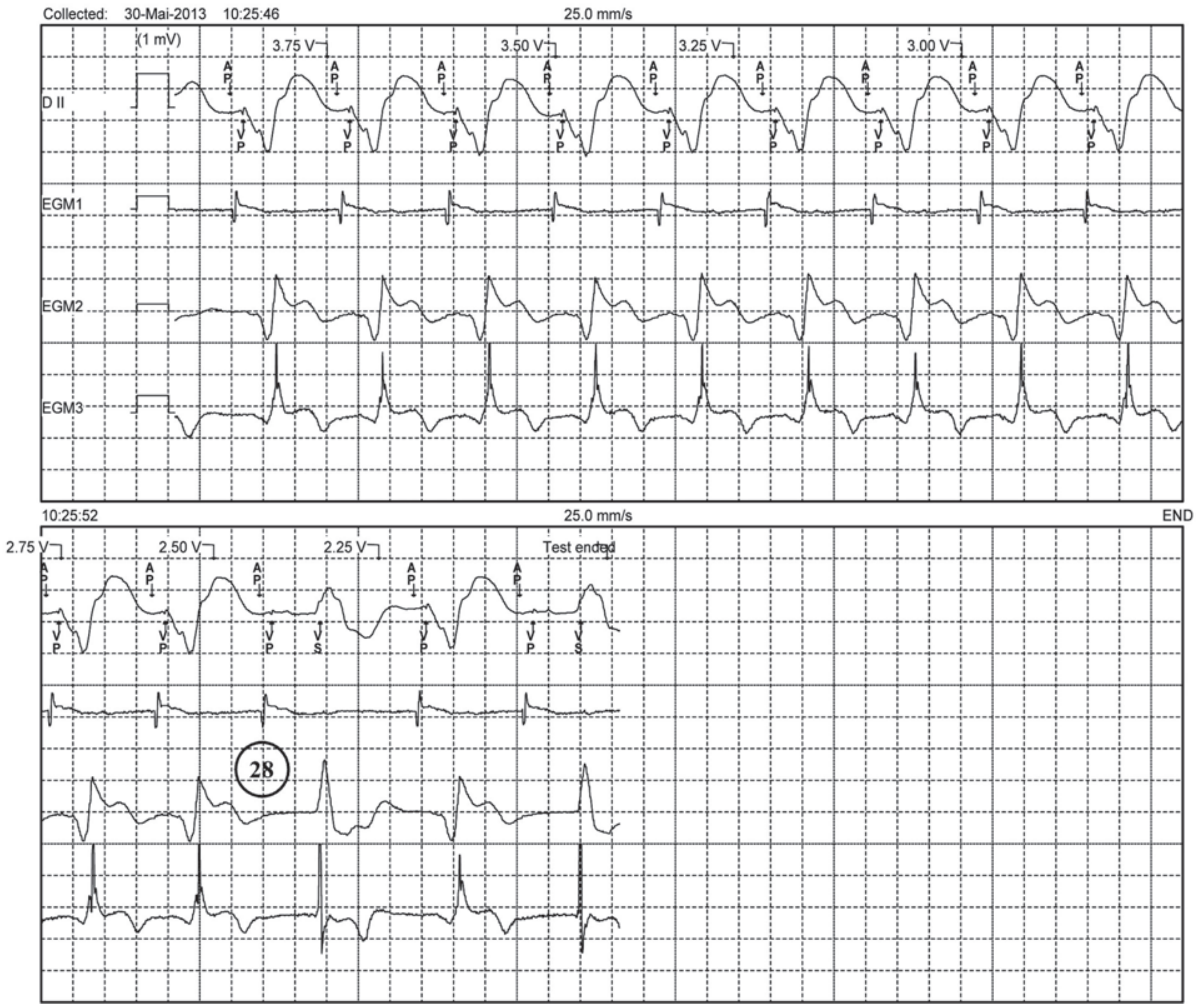


Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV4/LV1		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	2.25 V	2.75 V	2.50 V
LV Pulse Width	0.40 ms	0.40 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude			6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

27

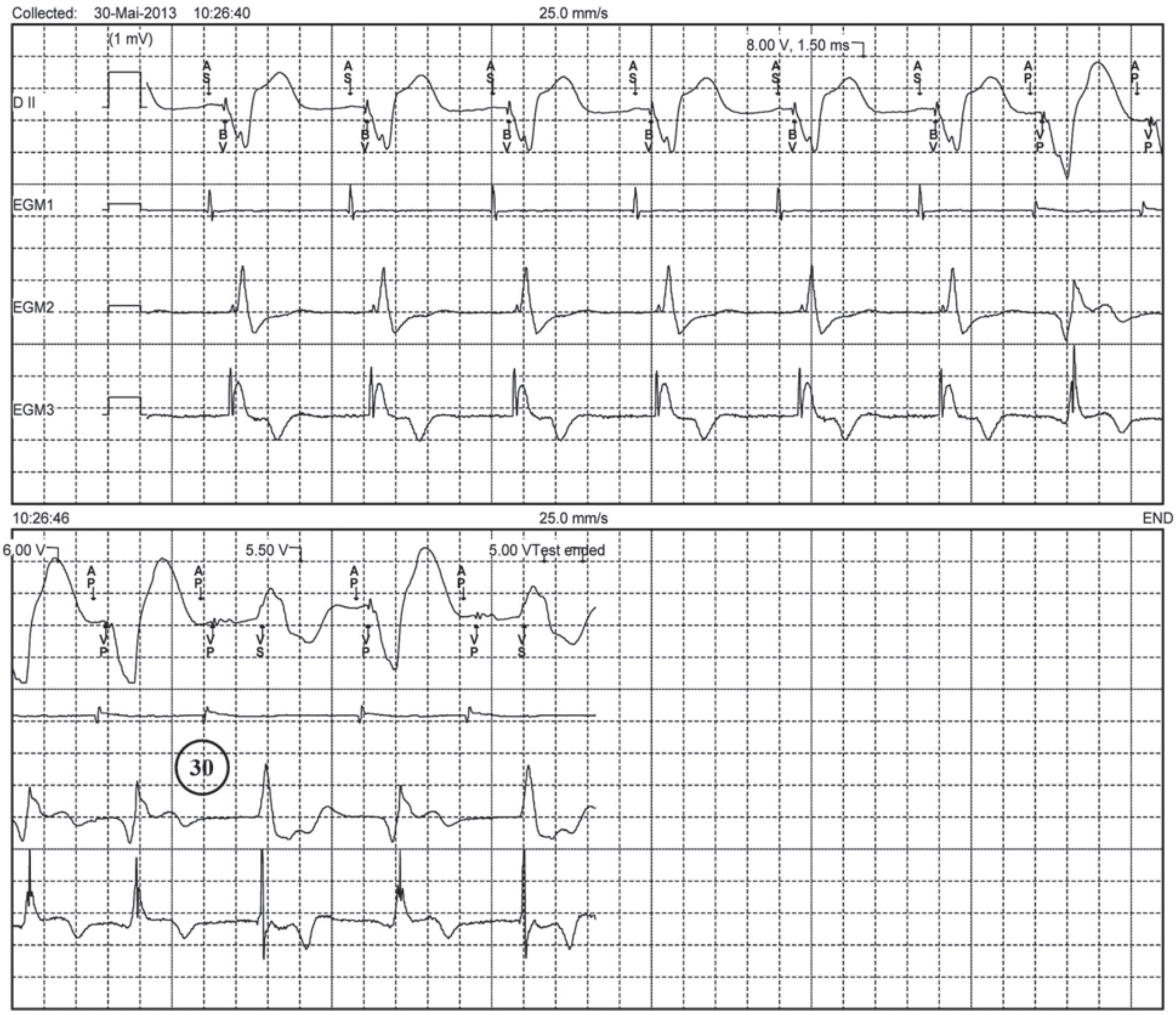


Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV4/LV2		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	5.00 V	8.00 V	2.50 V
LV Pulse Width	1.50 ms	1.50 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude			6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

29

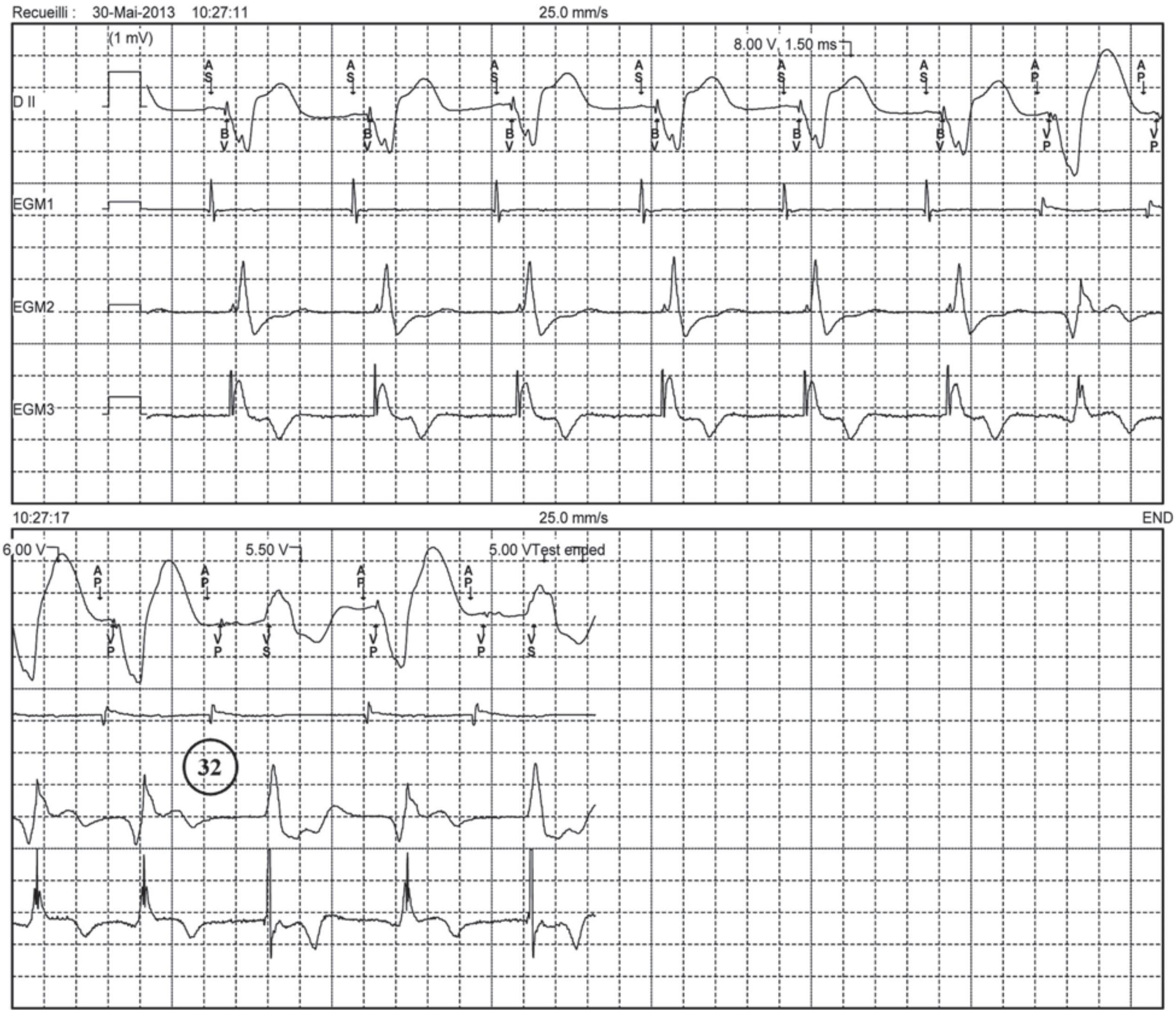


Device : **Viva Quad XT CRT-D DTBA2QQ**

LV Amplitude Threshold Test

Values	Ending Value	Threshold	Permanent
LV Pace Polarity	LV4/LV3		LV1/SpireRV
Mode	DDD		DDD
Lower Rate	90 min-¹		50 min-¹
AV Delay	80 ms		130 ms
LV Amplitude	5.00 V	8.00 V	2.50 V
LV Pulse Width	1.50 ms	1.50 ms	0.40 ms
LV Capture Management			Auto
Amplitude Margin			+ 1.5 V
Max. Adapted Amplitude			6.00 V
V. Pace Blanking	300 ms		200 ms
A. Pace Blanking	200 ms		200 ms
PVARP	340 ms		Auto

31



Tracing 5: anodal capture

Patient

81 years old man implanted with a triple chamber pacemaker Consulta CRT-P with bipolar RV and LV leads for severe ischemic cardiomyopathy with right bundle branch block; routine follow-up; the ECG shows two slightly different aspect of the paced QRS; LV pacing amplitude is set at 3.5 V/0.4 ms in a (distal) tip LV – ring (anode) RV;

Tracing

LV pacing Threshold test realized in LV bipolar configuration (LV tip – LV ring / anode);

1: this tracing allows for visualizing the left ventricular bipolar electrocardiographic appearance;

A second LV pacing threshold test is realized in LV tip – RV ring (anode) configuration;

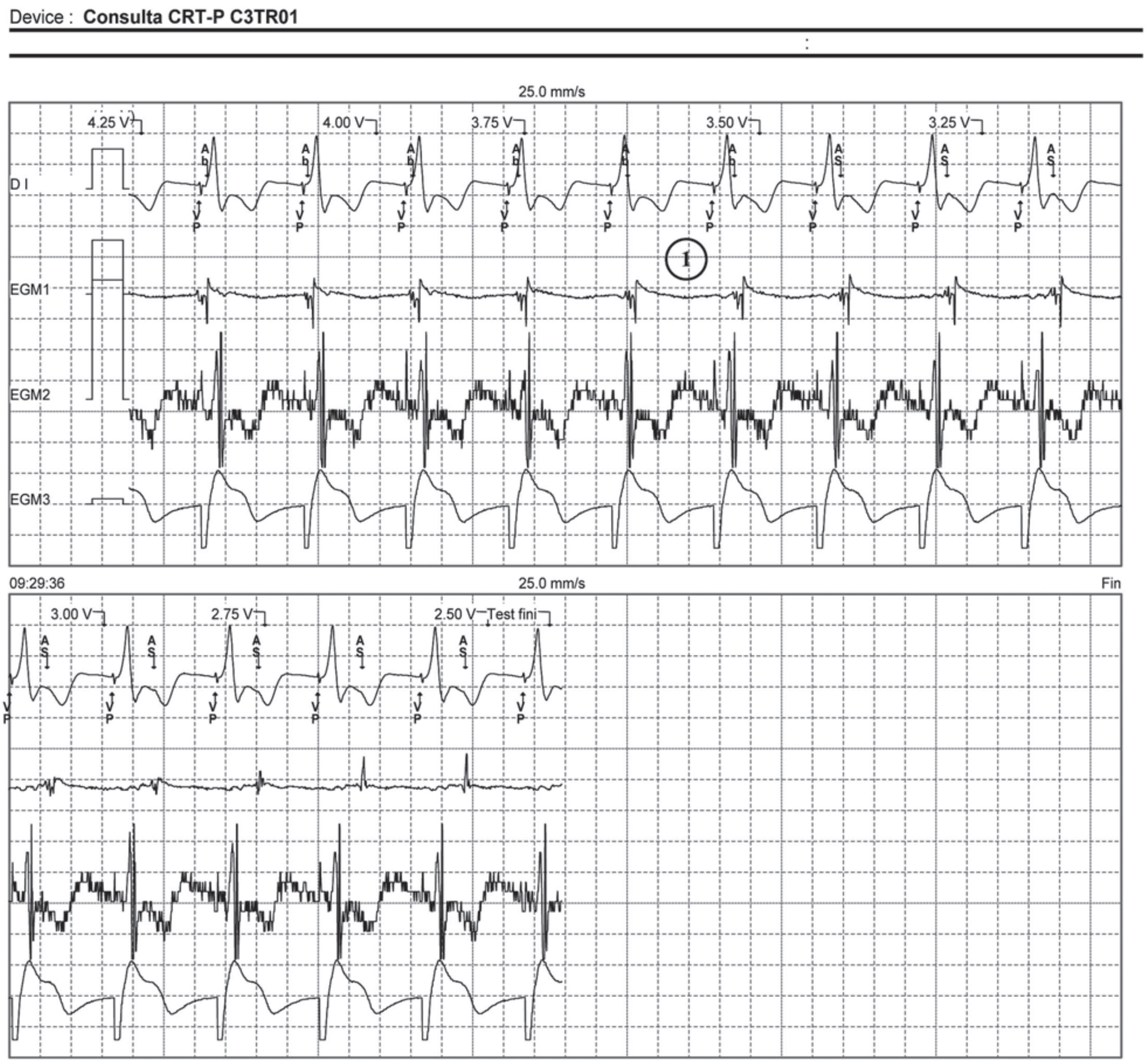
2: a different electrocardiographic aspect is obtained;

3: from 3.25 Volts, modification of the electrocardiographic appearance which becomes similar to the one observed during LV bipolar configuration (RV anodal capture threshold);

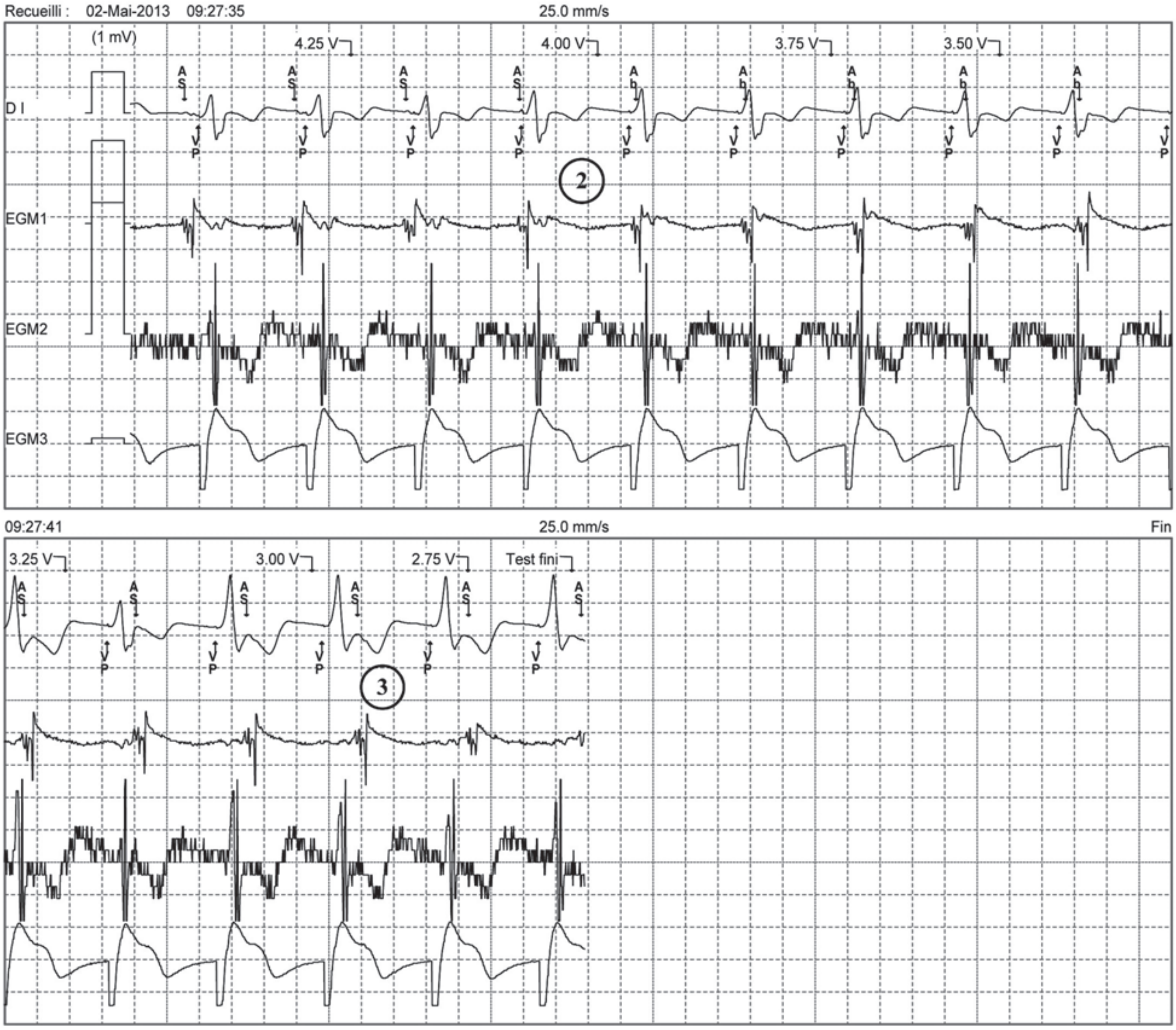
In this patient the loss of LV capture occurs at an amplitude below 1 Volt / 0.4 ms (not shown on this tracing) which corresponds to the threshold value of the LV;

Comments

This patient presents with an anodal RV capture when the pacing configuration is set to LV tip – RV ring configuration. The modification of the electrocardiogram is clear during the LV threshold test where the QRS appearance varies from a biventricular pattern (in LV tip – RV ring configuration) to a pure LV paced pattern for amplitudes below 3.5 Volts. It is more difficult to differentiate anodal capture during biventricular pacing (actually pseudo-triventricular: anode and cathode RV + distal LV) compared to a traditional biventricular pacing (cathode RV + distal LV). In this patient, the ECG pattern was slightly different on the distal portion of the QRS in leads V2, V3 and V4. The real threshold of LV stimulation was less than 1 Volt / 0.4 ms. In the absence of demonstration of any hemodynamic superiority of a configuration with anodal capture, given the very small change in the electrocardiographic pattern, and to save the battery energy, an output amplitude of 2.5 volts / 0.4 ms (without anodal capture) was selected.


Device : Consulta CRT-P C3TR01
25.0 mm/s
4.25 V
4.00 V
3.75 V
3.50 V
3.25 V
D I
EGM1
EGM2
EGM3
1
09:29:36
25.0 mm/s
Fin
3.00 V
2.75 V
2.50 V
Test fini
Page 1

Device : **Consulta CRT-P C3TR01**



Page 1

Tracing 6: loss of LV capture diagnosed by remote monitoring

Patient

64 years old man implanted with a triple chamber defibrillator Concerto II CRT-D for ischemic cardiomyopathy with left bundle branch block; symptomatic phrenic nerve stimulation; pacing output set at 1.5 Volts/0.4 ms with a minimal margin on the pacing threshold but with no phrenic nerve stimulation; follow-up by remote monitoring; reception of an EGM tracing in the context of an Optivol alert, statistical report indicating a permanent biventricular pacing;

Tracing

In the absence of any alert, a remote consultation is performed every 3 months; asymptomatic patient
Succession of AS-BV cycles;

1: probable biventricular capture;

2: probable intermittent loss of LV capture; the EGM aspect remains unchanged on the bipolar RV channel; clear modification of the LV tip – RV coil EGM appearance with manifest activation from the RV;

The physician missed the diagnosis; a few days later, an Optivol alert triggered a new remote consultation:

3: permanent loss of LV capture;

4: the percentage of LV pacing remains 100%;

5: Optivol alert triggered by the pulmonary overload index out of the limits;

Comments

This tracing demonstrates the interest but also the difficulty of the remote monitoring in CRT patients. The programming of this patient was initially very precise and allowed for an effective and permanent LV capture (with only a small margin over the threshold of 1.25 V / 0.5 ms) without any phrenic stimulation (phrenic stimulation threshold 2 V / 0.5 ms). The first tracing was received during a programmed remote consultation where data and electrograms were transmitted. Rapid analysis of tracing did not recognize the intermittent loss of left ventricular capture. A few days later, the loss of LV capture became permanent and was associated with the occurrence of congestive signs and an increase in the pulmonary overload index. A second tracing was transmitted as a part of the Optivol alert. The analysis of this second tracing shows the persistent loss of LV capture despite a permanent biventricular pacing. This patient was convened before the onset of major symptoms and received a diuretic therapy. LV tests confirmed the diagnosis. A change in the left ventricular pacing configuration allowed for recovering an effective LV capture with no phrenic stimulation and with normalization of thoracic impedance.

This case illustrates the importance of early diagnosis of loss of LV capture. It also illustrates the importance of analyzing, in details, the information transmitted.

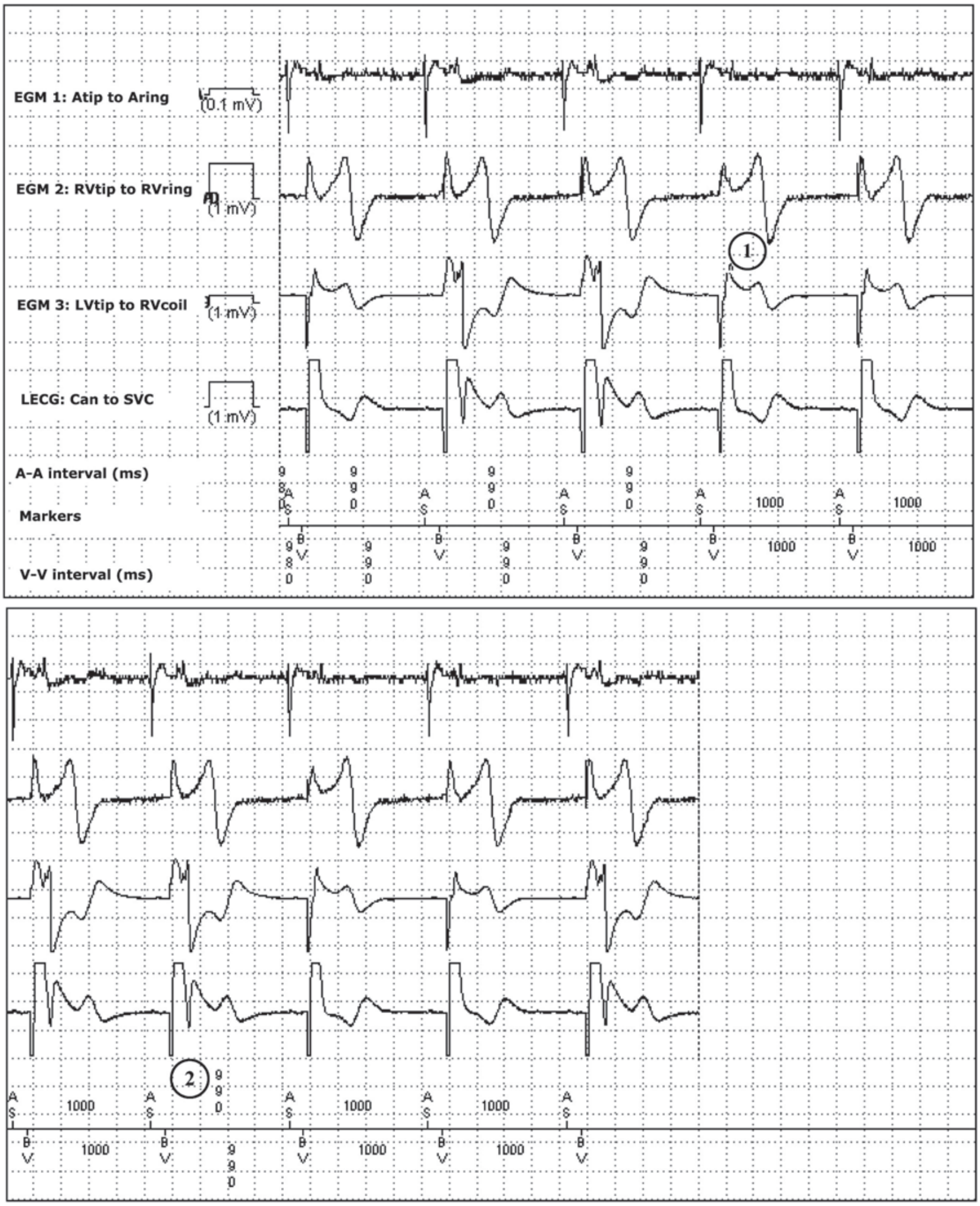
Medtronic

Current EGM

Device: Concerto™ II CRT-D D294TRK

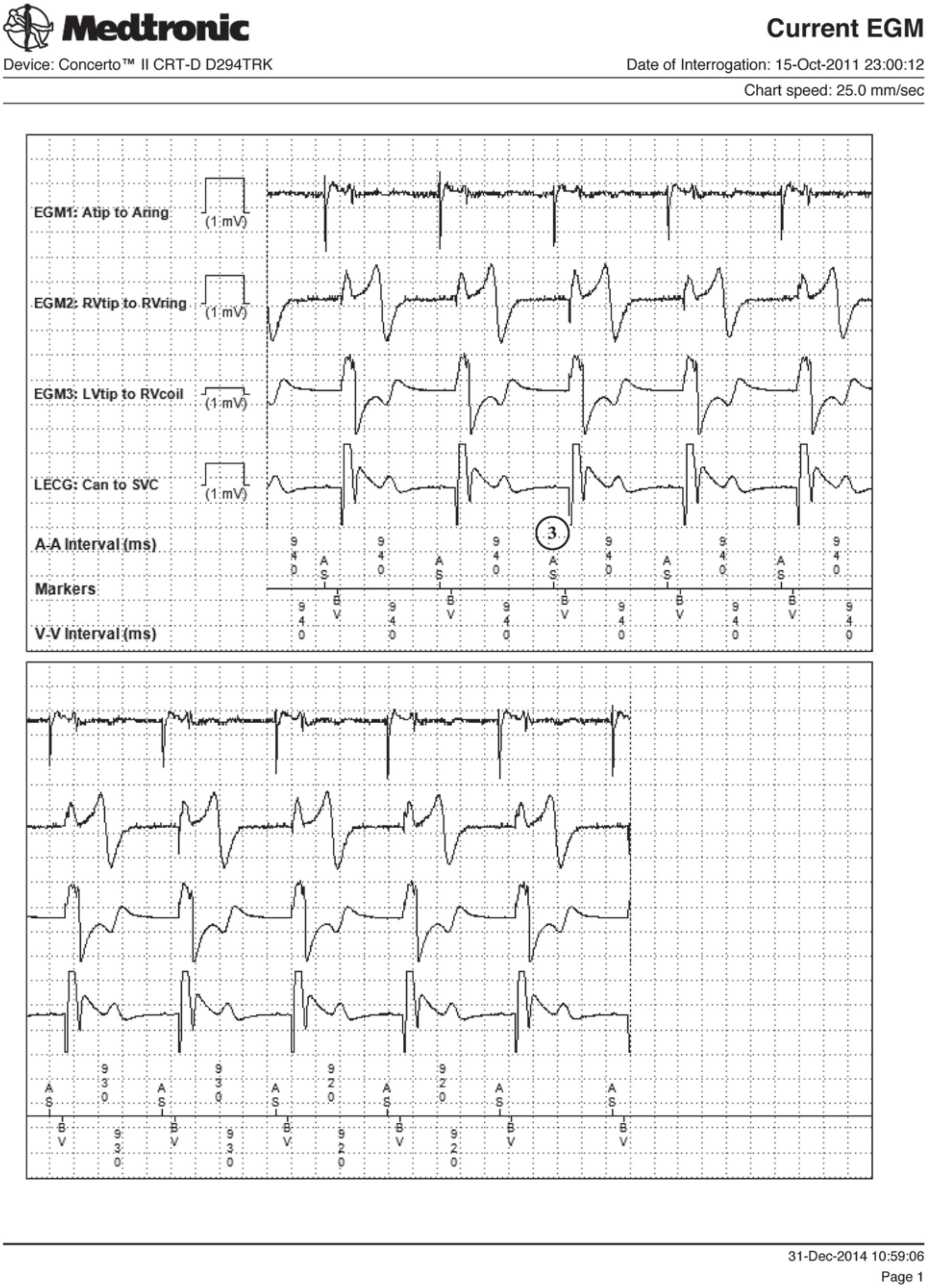
Date of Interrogation: 15-Oct-2011 23:00:12

Chart speed: 25.0 mm/sec



31-Dec-2014 10:59:06

Page 1


Medtronic
Current EGM
Device: Concerto™ II CRT-D D294TRK
Date of Interrogation: 15-Oct-2011 23:00:12
Chart speed: 25.0 mm/sec
EGM1: Atip to Aring
(1 mV)
EGM2: RVtip to RVring
(1 mV)
EGM3: LVtip to RVcoil
(1 mV)
LECG: Can to SVC
(1 mV)
A-A Interval (ms)
Markers
V-V Interval (ms)
3
31-Dec-2014 10:59:06
Page 1

Medtronic **Quick Look II**

Device: Concerto™ II CRT-D D294TRK — Date of Interrogation: 15-Oct-2011 23:00:12

Device Status (Implanted: 08-Dec-2009)

Battery Voltage (RRT=2.63V)	3.13 V	(15-Oct-2011)	
Last Full Charge	9.2 sec	(09-Jun-2011)	
	Atrial(1888tc)	**RV**	**LV**
Pacing Impedance	475 ohms	494 ohms	494 ohms
Defibrillation Impedance		RV=80 ohms	
Capture Threshold			Off
Measured On			
Programmed Amplitude/Pulse Width	2.50 V / 0.40 ms	2.50 V / 0.40 ms	1.50 V / 0.50 ms
Measured P/ R Wave	1.1 mV	>20 mV	
Programmed Sensitivity	0.60 mV	0.30 mV	

Parameter Summary

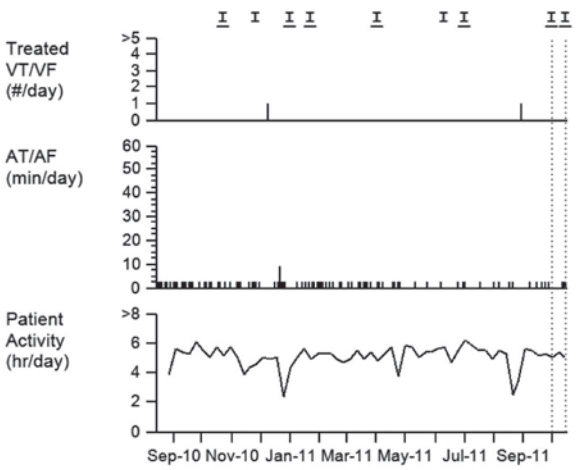
Mode	DDD	Lower Rate	50 bpm	Paced AV	130 ms
Mode Switch	171 bpm	Upper Track	150 bpm	Sensed AV	100 ms
V. Pacing	LV->RV	Upper Sensor	120 bpm		

Detection		**Rates**	**Therapies**
AT/AF	Monitor	>171 bpm	All Rx Off
VF	On	>222 bpm	ATP During Charging, 35J x 6
FVT	OFF		All Rx Off
VT	On	171-222 bpm	Burst(3), Ramp(3), 20J, 25J, 35J x 2

Enhancements On: AF/Afl, Sinus Tach

Clinical Status	**Since 01-Oct-2011**
Treated	
VF	0
FVT (Off)	
VT	0
AT/AF(Monitor)	
Monitored	
VT (Off)	
VT-NS (>4 beats, >171 bpm)	0
SVT: VT/VF Rx Withheld	0
AT/AF	0
Time in AT/AF	<0.1 hr/day (<0.1%)
Functional	**Last Week**
Patient Activity	5.2 hr/day

Cardiac Compass Trends (Aug-2010 to Oct-2011)



Therapy Summary	**VT/VF**	**AT/AF**	**Pacing**	**(% of Time Since 01-Oct-2011)**
Pace-Terminated Episodes	0	0	AS-VS	< 0.1%
Shock-Terminated Episodes	0	0	AS-VP	99.8%
Total Shocks	0	0	AP-VS	0.0%
Aborted Charges	0	0	AP-VP	0.2%

(4)

OBSERVATIONS (2)

· Alert: Possible fluid accumulation: exceeded OptiVol Threshold, 15-Oct-2011 -- ongoing.
· VF detection may be delayed: VF Detection Interval is faster than 300 ms (200 bpm).

31-Dec-2014 11:00:08
Page 1

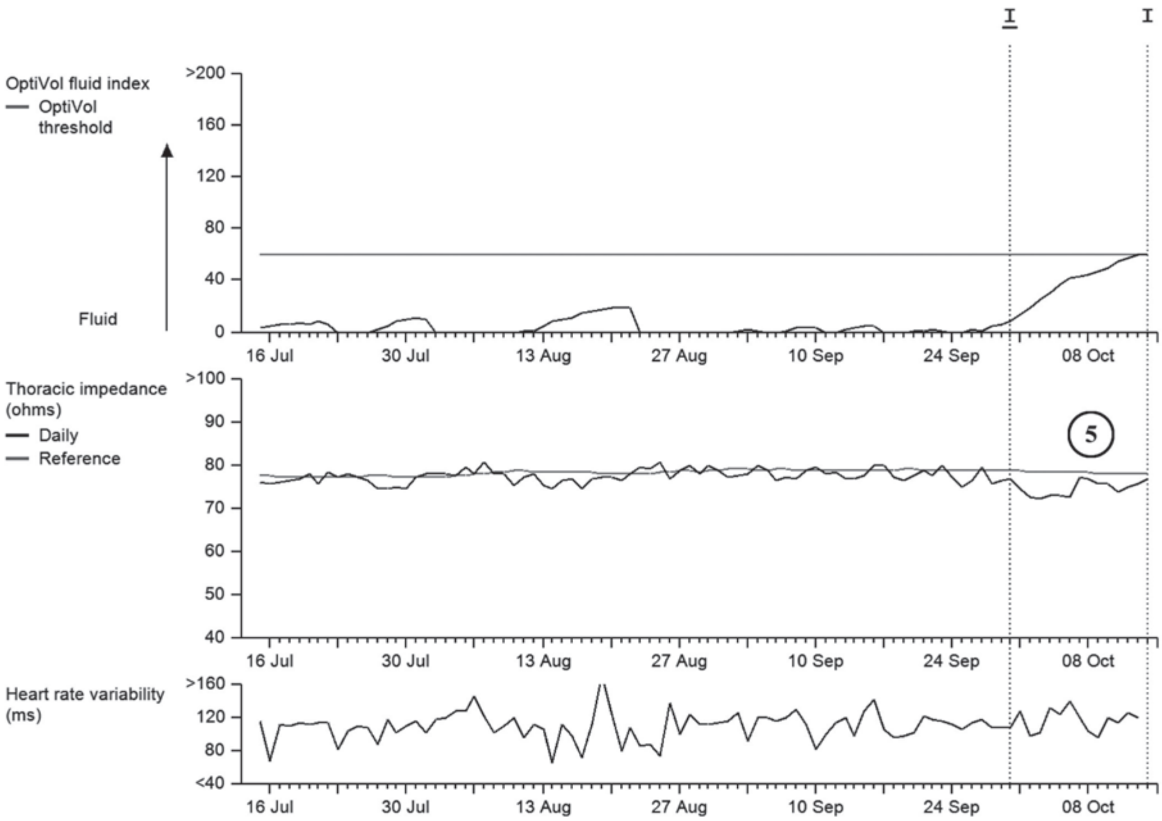
Medtronic — **Cardiac Compass - Last 90 Day Zoom**

Device: Concerto™ II CRT-D D294TRK

Date of Interrogation: 15-Oct-2011 23:00:12

Last 90 Day Zoom (Jul 17, 2011 - Oct 15, 2011)

OptiVol fluid index is an accumulation of the difference between the daily and reference impedance.



Tracing 7: loss of RV capture

Patient

70 years old man implanted with a triple chamber defibrillator Viva XT CRT-D for severe ischemic cardiomyopathy and left bundle branch block; good response to the resynchronization therapy; two endocarditis required the complete removal of the system (first implanted on the left side, then on the right side); complete surgical re-implantation of a defibrillator with 2 coils, a bipolar atrial and RV lead and a bipolar LV lead; routine follow-up;

Tracing

1: atrial and biventricular stimulation (AP-BV);
2: double counting of the paced QRS (BV-FS);

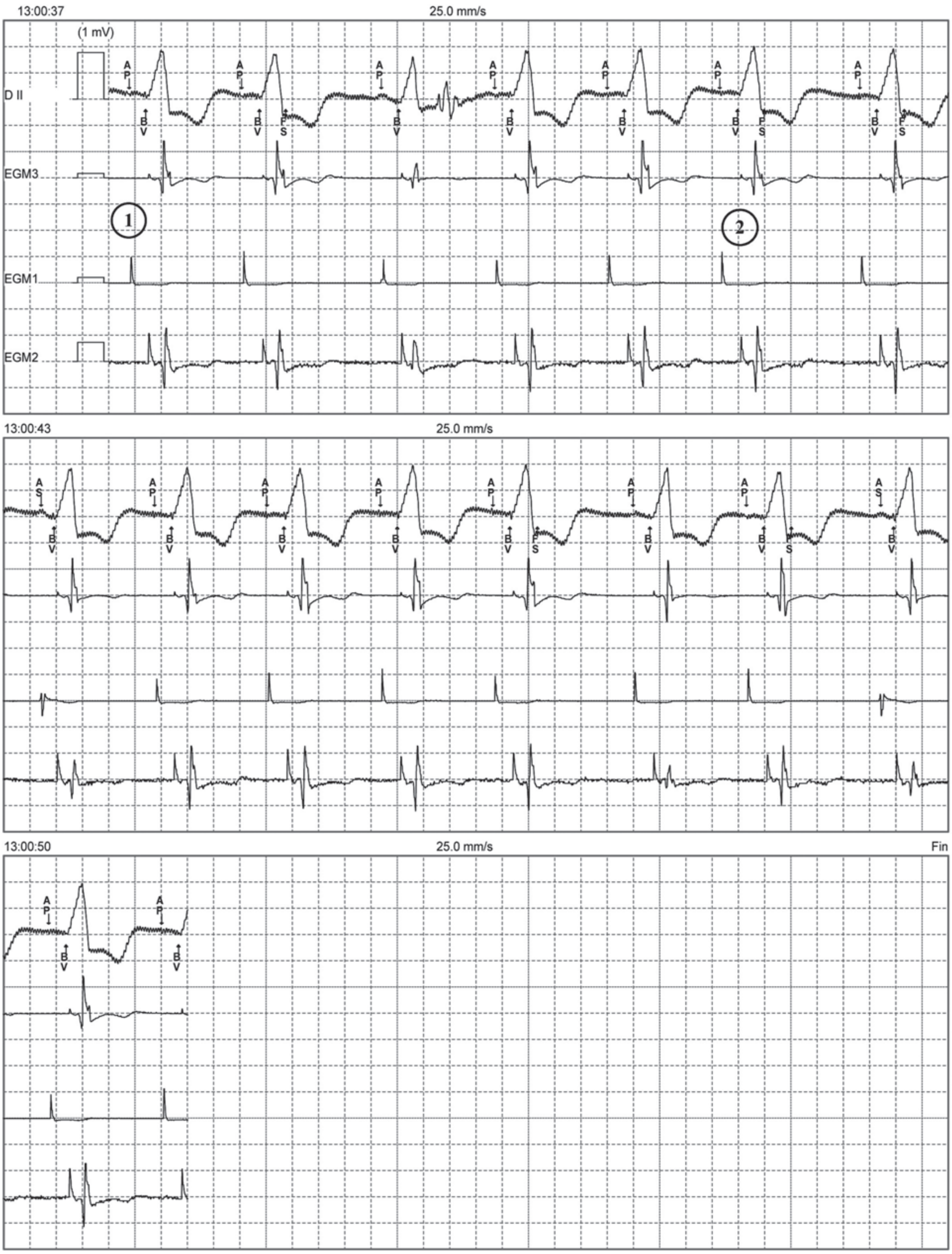
RV pacing threshold test performed in bipolar configuration (DDD mode, 90 bpm)

3: first aspect in RV pacing (probable double anodal and cathodal capture of the right cavity);
4: change in the paced QRS pattern (pure cathodal capture);
5: loss of RV capture (threshold 5.5 Volts/0.7 ms);
6: biventricular stimulation with an amplitude of 5 Volts/0.7 ms;
7: modification of the programming with an increase of the amplitude to 8 Volts (superior to the RV threshold);
8: clear modification of the ARS appearance with a narrowing of the QRS and biventricular capture;

Comments

The loss of the right ventricular capture due to a lead dislodgement or the elevation of the RV threshold is uncommon, because the right ventricular lead is screwed into the endocardium. In this patient, the right ventricular lead was implanted surgically. The two electrodes were sewn on the epicardium and were relatively distant from each other, which explains the increase in threshold (epicardial thresholds are often higher) but also the double aspect of QRS. The thresholds are usually high immediately after a surgical epicardial implantation, however they tend to quickly improve during the first 3 months, a phenomenon encouraged by the elution of steroids (4968 leads).
The right ventricular loss of capture is accompanied by a pure left ventricular capture without any changes in the refractory periods and without any adaptation of the post-ventricular pacing ventricular blanking period. A pure left ventricular pacing is often associated with an increased QRS width and the double counting of the paced QRS (detected by the right ventricular lead).

Device: **Viva XT CRT-D DTBA2D1**



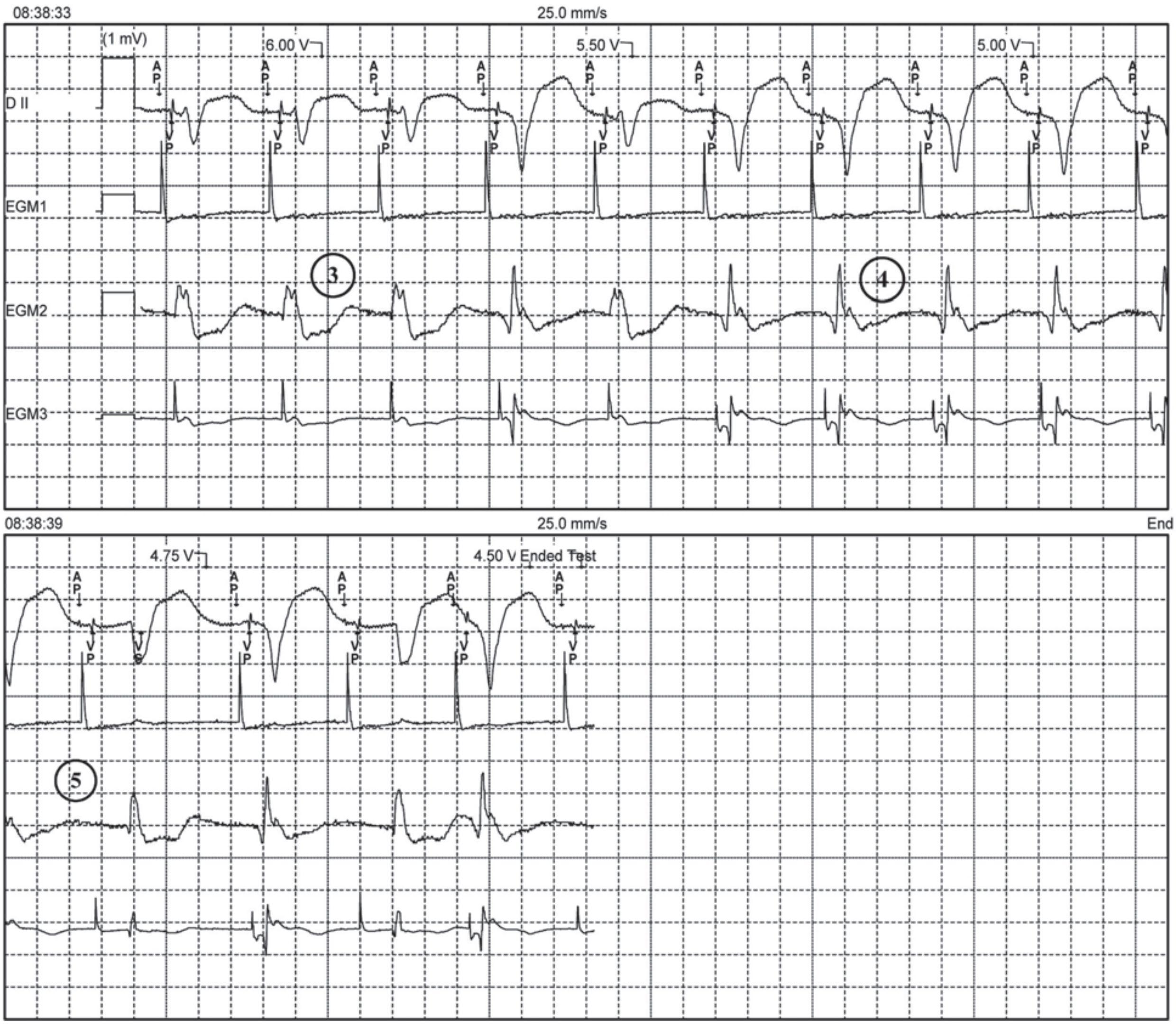
Pacing Threshold Test Report.

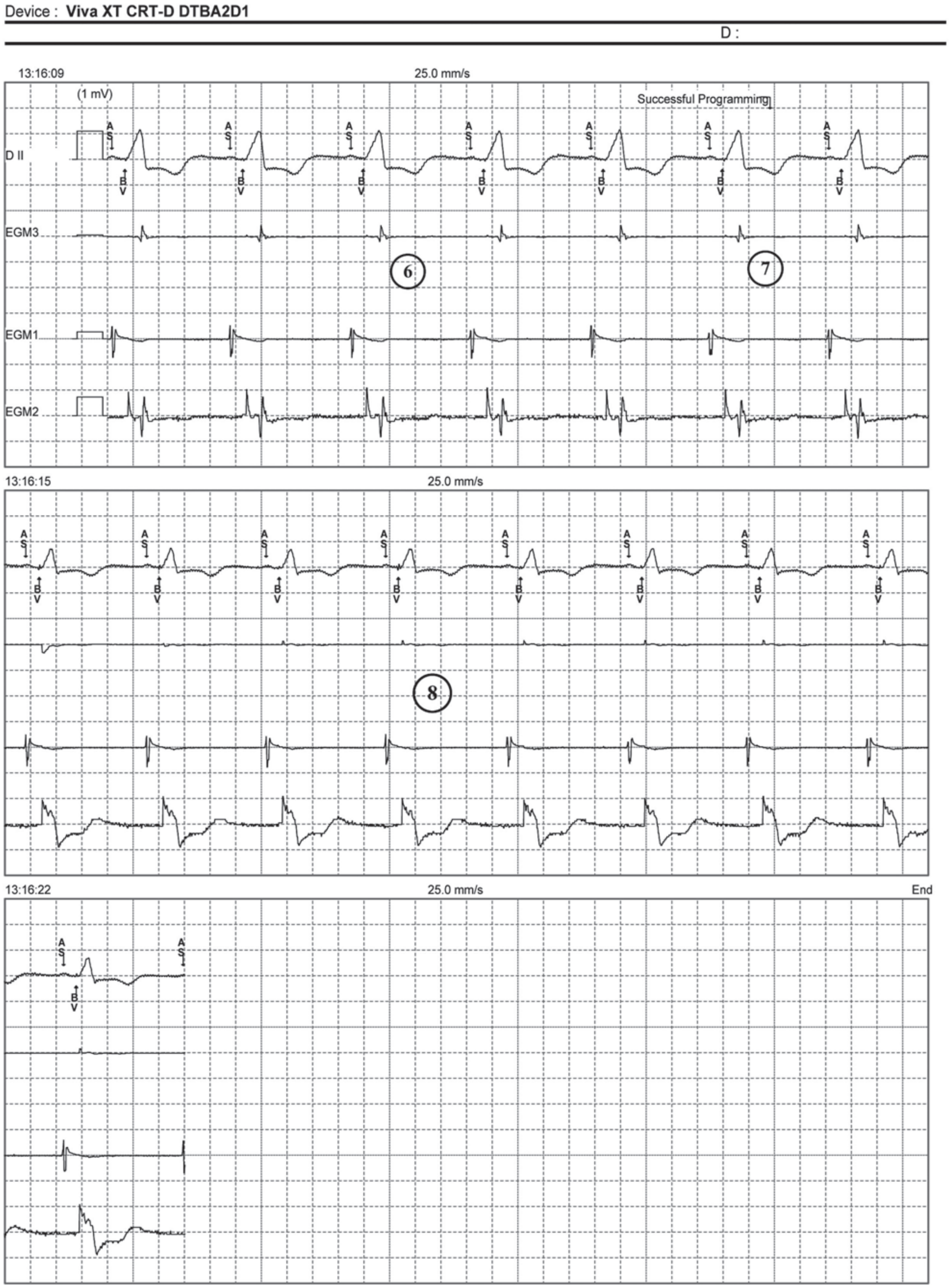
Device : **Viva XT CRT-D DTBA2D1**

:

Ventricular Threshold

		Threshold	programmed
RV Pace polarity	Bipolar		Bipolar
Mode	DDD		DDD
Lower Rate	90 bpm		60 bpm¹
AV Delay	80 ms		130 ms
VD Amplitude	4.50 V	5.50 V	8.00 V
Pulse With	0.70 ms	0.70 ms	0.70 ms
RV capture management			off
V Blanking	300 ms		230 ms
A Blanking	200 ms		200 ms
PVARP	340 ms		Auto





Device : Viva XT CRT-D DTBA2D1
D :
13:16:09
25.0 mm/s
(1 mV)
Successful Programming
D II
EGM3
6
7
EGM1
EGM2
13:16:15
25.0 mm/s
8
13:16:22
25.0 mm/s
End

Chapitre 4

AV delay and VV delay Optimization

AV delay and VV delay Optimization

Biventricular resynchronization provides significant clinical benefit, a reverse remodeling with reduction of the cardiac volume, and a decrease in morbidity and mortality in heart failure patients with wide QRS. The main limitation of this therapy is that all studies found a significant percentage of patients that do not respond favorably to the resynchronization therapy. Different approaches have been proposed to reduce the percentage of non-responders. Once the patient is implanted, a sub-optimal adjustment of the CRT device can contribute to alter the quality of the response. The principle of the CRT is to change the sequence of activation in a patient with electrical conduction disorder by adjusting the activation delays between a right atrial lead, a right ventricular lead and a left ventricular lead. Two programmable parameters are accessible in this context: 1) the AV delay that determines the activation timing between the right atrium and the right ventricle, with independent programming of a detected AV delay (after the detection of a spontaneous atrial (AS cycle -BV)) and a paced AV delay following an atrial pace (AP-cycle BV). It is possible to program a variable AV delay with a linear reduction of the AV delay paralleling the increase in heart rate; 2) The VV delay regulates the activation delay between the right ventricle and left ventricle; simultaneous activation (VV delay to 0), a right pre-activation (RV LV, X ms) or a left pre-activation (LV RV, X ms) are programmable; it is not possible to program a variable VV delay with different values at rest and during exercise. Acute hemodynamic studies have clearly demonstrated a significant benefit provided by the optimization of the AV and / or VV delay. The clinical demonstration of this benefit is much less convincing.

AV delay optimization

The atrial contraction contributes to 20-30% of the cardiac output at rest in heart failure patients with systolic dysfunction, this contribution increasing during exercise. Heart failure patients with electrical conduction disorder often displays atrioventricular asynchrony with a shortening of the filling time, a merging of the E and A waves and diastolic mitral regurgitation.

In resynchronized patients, programming a short AV delay allows for anticipating the E wave, a dissociation of E and A waves and prolongation of the filling time. The AV delay should not be set too short because this would result in the amputation of the A wave by mitral closure. Adjusting the AV delay is recommended after implantation of a CRT pacemaker or defibrillator even if the level of clinical evidence is modest.

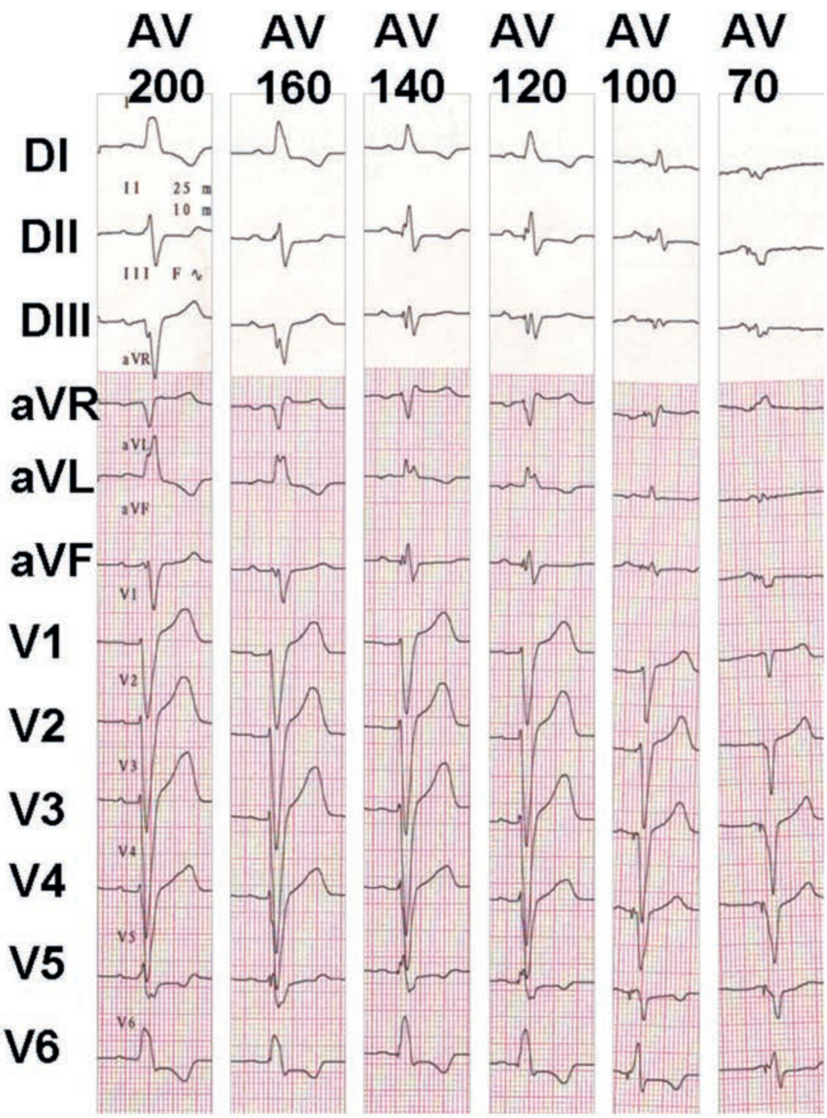
There are large inter-individual variations in the intra-atrial conduction and intra-ventricular disorders generating marked differences in terms of optimal AV delay justifying theoretically a tailored approach for each patient. The sensed and paced AV delays are independently programmable and must also be optimized independently. A limitation of the optimization of the AV delay is that it is usually performed at rest in supine position and for a given heart rate. These conditions differ significantly from those observed in everyday life. During exercise, unlike patients with healthy heart where the optimal AV delay shortens with increasing heart rate, it seems that resynchronized patients response to stress is not stereotypical. In some patients the optimal AV delay during exercise is longer than at rest, in others it is shorter. The systematic use of the automatic AV delay algorithm probably ensures continuous capture during exercise but is not necessarily associated with an additional hemodynamic benefit. Therefore its programming should be discussed for each patient. Biventricular resynchronization allows for reverse remodeling with a progressive reduction over time of the tele-systolic and end-diastolic volume sand pressures. Therefore, the optimization of the AV delay should be ideally repeated periodically.

The optimal AV delay allows for a maximum contribution of the left atrial contraction to left ventricular filling, prolongs the filling time, improves the cardiac output in the absence of diastolic mitral regurgitation.

If the AV delay is set too long, the atrial contraction occurs too early in diastole, limiting the atrial contribution to the ventricular filling. The atrial contraction is superimposed with the initial diastolic phase. The cardiac echocardiography finds a fusion between E wave and A wave and a short filling time with a persistent diastolic mitral regurgitation.

If the AV delay is set too short, the ventricular contraction occurs too early resulting in premature mitral closure interrupting the current filling and limits atrial contribution to ventricular filling. The echocardiography finds a premature E wave, a long filling time and split E and A waves with a truncated A wave by the mitral closure. The decrease in end-diastolic pressure and the decreased preload lead to a reduction in the dP / dt max and the cardiac output.

Before starting the AV delay optimization, some elements must be known. In patients with complete atrioventricular block and high grade AV block or with a very long PR interval, changes in AV delay will have no direct effect on the degree of ventricular capture and fusion. In contrast, in patients with preserved atrioventricular conduction, prolonging the AV delay will cause a progressive fusion with spontaneous activation. Adjusting the AV delay must be performed under electrocardiographic control by integrating the idea that in the group of patients with no complete AV block, which represents the majority of the patients, tuning the AV delay will vary the delay between the atrial systole and the ventricular systole but also will directly interfere with the ventricular activation sequence and the degree of ventricular fusion. To overcome this difficulty, the AV delay is often systematically programmed short (between 90 and 120 ms after a sensed atrial activity and between 130 and 150 ms after atrial pacing).



Example of progressive AV delay adjustment in a resynchronized patient with preserved AV conduction; progressive fusion appears with the prolongation of the AV delay.

Various techniques have been proposed to optimize the AV delay:

Echocardiography

Different echocardiographic methods have been proposed to optimize the AV delay: the Ritter's method (that has not been validated in a population of patients with heart failure), the search for a maximum aortic or mitral VTI, a maximum dP / dt max, and the iterative method. The latter is widely used in clinical practice, the goal being to obtain the longest filling time with no amputation of the A wave based on trans-mitral flow analysis.

Other methods

Various estimates of the cardiac contractility or cardiac output can be used: wave pulse, blood pressure, dP / dt max, electrocardiographic appearance ... The clinical applicability in daily practice is often limited.

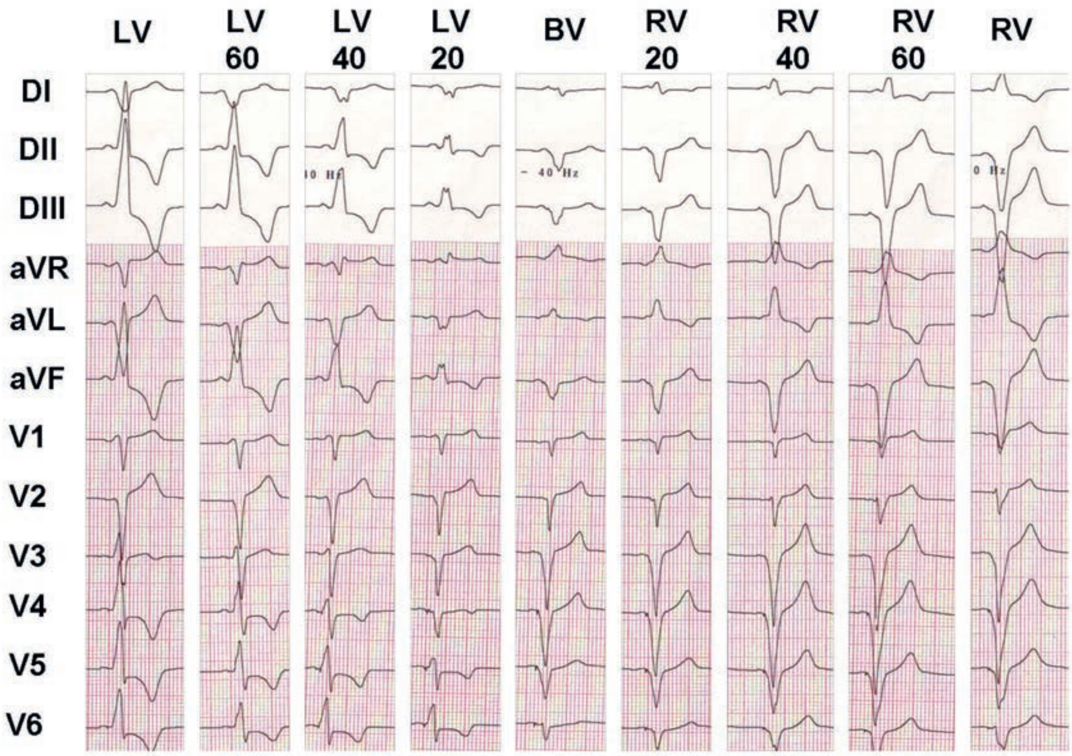
Automatic optimization algorithm embedded in the device

If repeated optimizations of AV delay are necessary and must be done in various conditions of pre load, the ideal solution would be that the pacemaker realizes it itself. The AdpativCRT function is available in the latest generation of Medtronic defibrillators; the operating principles of this new algorithm will be discussed at the end of the present chapter.

VV delay Optimization

Some patients do not respond to CRT and continue to display a significant mechanical ventricular dyssynchrony after implantation. Adjusting the VV delay results in sequential biventricular pacing and has a direct impact on the sequence of ventricular activation. Modifying the VV delay may be proposed to reduce the persistent asynchrony in non-responding patients. This parameter appears interesting in theory in patients with a suboptimal position of the LV lead, or a latency and a prolonged conduction time at the stimulation site. If the optimization of VV delay allows for significant acute hemodynamic benefit, the question of the clinical relevance of this parameter remains debated and not confirmed by clinical studies. As for setting the AV delay, it is likely that the remodeling process directly affects the optimization of VV delay and that the optimization of this parameter must be repeated over time and in various pre-load conditions.

The same tools can be used to optimize AV and VV delay. Cardiac echocardiography is often used in clinical practice. The aortic VTI reflecting the cardiac output, the dP/dt max reflecting the cardiac contractility or the measurement of the degree of ventricular asynchrony are mostly used. Once again, the AdaptivCRT function also proposes to automatically optimize the VV delay. In the light of the practical limits of the VV optimization, the repeated automatic adjustment of this parameter by the device itself looks promising. However, it is still necessary to demonstrate its clinical relevance.



This example shows the effect of VV delay on the ventricular electrical activation; if it is easy to show that the electrocardiographic appearance is actually different from one configuration to another, it is much more difficult to determine what configuration will provide the best clinical response.

LV pacing alone or biventricular pacing?

One of operating principle of the AdaptivCRT algorithm consists in choosing between left ventricular with fusion and biventricular pacing.

No study has ever demonstrated superiority of biventricular pacing on a pure left ventricular stimulation. In contrast, acute hemodynamic studies have consistently found significant benefit with isolated left ventricular pacing. Similarly, clinical studies found a benefit more or less identical in terms of NYHA class, exercise capacity and ventricular remodeling to those observed with biventricular pacing. Nevertheless, large studies demonstrating the benefits provided by resynchronization were all performed with biventricular stimulation and not with left ventricular stimulation.

In LV pacing configuration, the resynchronization of the two ventricles can be obtained by the fusion between left ventricular paced activation of the right ventricle intrinsic activation. If it seems that the optimal acute hemodynamic benefit may be obtained with a certain degree of fusion (limited data on a very limited number of patients), this optimal degree of fusion is difficult to define and to maintain during exercise (changes in the heart rate and PR interval).

Isolated left ventricular pacing is an attractive option, particularly if the implanted device is a CRT pacemaker. Indeed, it may be performed by using a conventional dual chamber pacemaker without implantation of right ventricular lead which increases the cost / effectiveness ratio and reduces the risk of complication. However, in AV block pacemaker dependent patients, implanting only a left ventricular lead seems risky given the higher percentage of lead dislodgement and high pacing threshold. In patients implanted with a CRT defibrillator, the implantation of a right ventricular lead is essential. However, programming the device in a « LV stimulation only » configuration avoids the consumption associated with right ventricular pacing.

AdaptivCRT algorithm

As seen previously, the ideal for repeated optimizations of the pacing configuration would be that the device itself performs this automatically. This optimization procedure has no additional costs, and is «effortless» for the physician and the different clinical departments (echocardiography, electrophysiology...). Moreover, the majority of measurements made by the device are reproducible. The optimization algorithm AdaptivCRT was developed with this goal. The demonstration of its favorable clinical impact on resynchronized patients remains, however, unproved.

Operating principles

The AdaptivCRT algorithm is only available in DDD or DDDR mode and can be programmed on by selecting either: 1) the "Adaptive Bi-V" setting - the device automatically optimizes the pacing parameters (AV and VV delays) – or 2) the "Adaptive Bi-V and LV" setting – the device will choose between a pure LV pacing configuration with fusion and a regular biventricular pacing with optimization of the AV and VV delays. This algorithm can also be turned off by programming 3) "Nonadaptive CRT".

This algorithm never leads to the use of extreme values of AV or VV delays. For AdaptivCRT function, possible sensed AV delays range between 80 ms and 140 ms. Possible paced AV delays range between 100 ms and 180 ms. The range of timing for the intraventricular VV delays varies from 0 ms to 40 ms (left or right pre-excitation).

AdaptivCRT operating function relies on the regular evaluation of 1) the atrio-ventricular conduction time, which corresponds to the delay between the EGM recorded by the right atrial lead and the EGM recorded by the right ventricular lead; 2) the width of the P-wave, which corresponds to the delay between the atrial EGM recorded on the bipolar channel of the right atrial lead and the end of the atrial EGM recorded by the shock channel; 3) the width of the QRS complex that corresponds to the delay between the EGM detected by the right ventricular bipole and the end of the EGM recorded on the shock channel.

The algorithm assesses the patient's intrinsic atrio-ventricular conduction every minute and determines if the patient's AV interval is normal or prolonged. The AV interval measurement is performed by extending the sensed and paced AV delay to 300 ms to allow for intrinsic conduction. In the absence of spontaneous conducted ventricular event for more than 3 consecutive cycles, a prolonged AV conduction is diagnosed and the time interval between AV interval measurements doubles (for example, 2 min, 4 min, 8 min… and so on until a max of 16 hours is reached).

The P-wave and QRS width measurements are scheduled every 16 hours. This interval warrants a sampling at various time of the day. During the measurement, the device will switch the recording channel EGM 1 to RV coil (HVA)/ SVC coil (HVB) (or HVA/atrial anode in the absence of SVC coil). After 5 beats, the delay between the atrial and the ventricular EGMs, the width of the P wave and the width of the QRS are measured.
The first measurement of the P-wave and the QRS width is scheduled 30 minutes after the implant. After implantation, the P-wave and the QRS width can be measured anytime by programming the parameter AdaptivCRT.

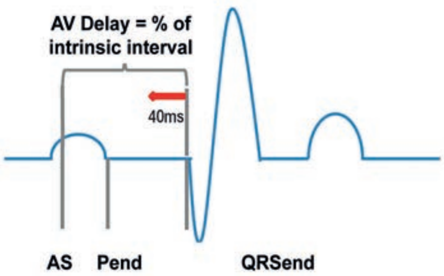
If the AdaptivCRT parameter is set to « Adaptive Bi-V and LV", it can switch automatically between the auto BIV and LV mode. The patient will be stimulated in pure LV mode, if the following conditions are respected: 1) the patient's heart rate must be less than or equal to 100 bpm; 2) the conduction delay between the spontaneous atrial EGM and the spontaneous ventricular EGM must be less than or equal to 200 ms; 3) the conduction delay between the paced atrial EGM and the spontaneous ventricular EGM must be less than or equal to 250 ms.
If one of these criteria is not found, the patient is stimulated in a biventricular mode.

Details of the algorithm operating function

The exact functioning of this algorithm is relatively confidential.

In a first step, the device assesses intrinsic conduction to determine if a patient's AV interval is normal or prolonged. Normal AV intervals are defined as less than 200 ms for atrial-sensed intervals and less than 250 ms for atrial-paced intervals.

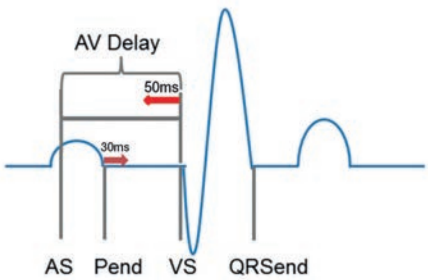
In the presence of a normal AV conduction time and if the patient's heart rate is below 100bpm, the device will use the Adaptative LV pacing mode (LV pace only). The timing of the LV pace is automatically adjusted based on the intrinsic AV interval measurement that occurs every minute.
If the patient AV conduction time exceeds 133.3ms, the LV pacing occurs at about 70% of the intrinsic AV interval.
If the AV conduction time is inferior to 133.3ms, the LV pacing will be delivered 40 ms prior to the intrinsic QRS (calculated AV delay - 40ms).



When intrinsic AV intervals are prolonged, or when the patient's heart rate is above 100 bpm, or if a loss of LV capture is confirmed by LV capture management (LVCM), the Adaptive BiV mode will operate.

The AV delay will then be calculated as follows:

- After a sensed atrial event, the AV delay is adjusted to pace 40 ms after the end of the P wave (measured on the shock channel) but at least 50 ms before the onset of the intrinsic QRS.
- After a paced atrial event, the AV delay is adjusted to pace 30 ms after the end of the P wave (measured on the shock channel) but at least 50 ms before the onset of the intrinsic QRS during atrial pacing (timing between the atrial stimulus and the bipolar right ventricular EGM).



During Adaptive BiV pacing, the optimal VV delay will be deducted from the QRS width.
If the QRS duration (timing between the bipolar RV EGM and the end of the QRS EGM on the shock channel) is included between 50 ms and 150 ms, the LV will be pre-excited. If the QRS width is included between 150 and 180 ms, a right ventricular pre-excitation is set. If the QRS width is not included between 50 and 180 ms, a LV or RV pre-excitation of 10 ms will be used.
The AV conduction times and the P wave width will also be used to optimize the VV delay. If the AV conduction time during spontaneous atrial rhythm is longer than the P wave width, then the VV delay will be set to 0 ms.

Tracing 1: optimization of the AV delay in a patient with complete AV block

Patient

74 years old man implanted with a triple chamber pacemaker Consulta CRT-P for idiopathic dilated cardiomyopathy with complete AV block; pacemaker interrogation 3 days post implant;

Tracing

The first line corresponds to an electrocardiographic derivation with superimposed markers (MA), the second line to the bipolar atrial recording (EGM1), the third line to the bipolar right ventricular EGM (EGM3) and the fourth line to the distal (tip) LV / RV coil derivation (EGM2)

1: the programmed paced AV delay is short (100ms); atrial paced rhythm and biventricular pacing (AP-BV cycles); on the atrial EGM, we see that the ventricular depolarization occurs just in the middle of the atrial depolarization;

2: identical AV delay;

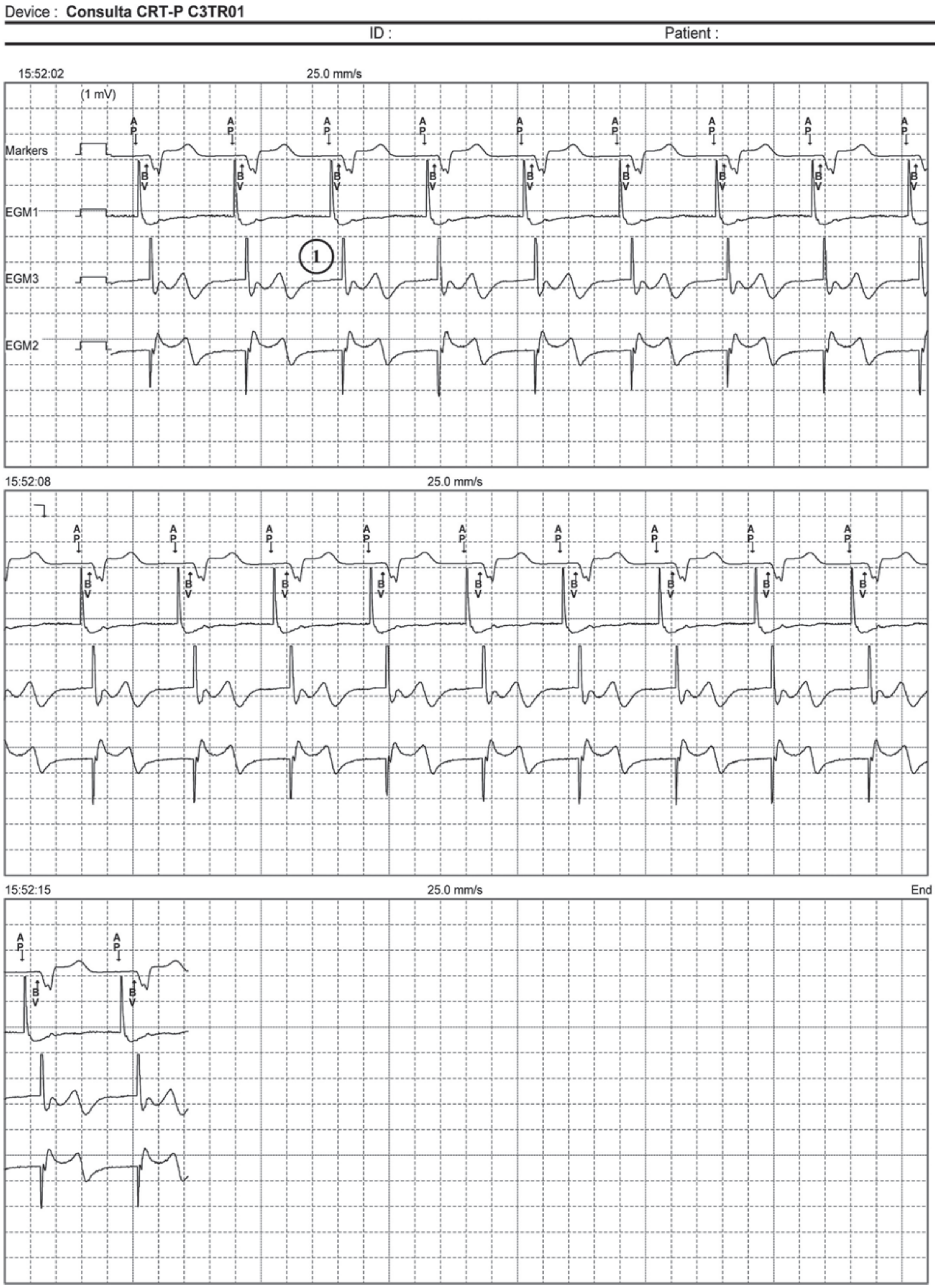
3: extension of the paced AV delay to 180 ms;

4: the appearance of the ventricular EGM is not impacted by the change of programming; the ventricular depolarization occurs now at the end of the atrial depolarization;

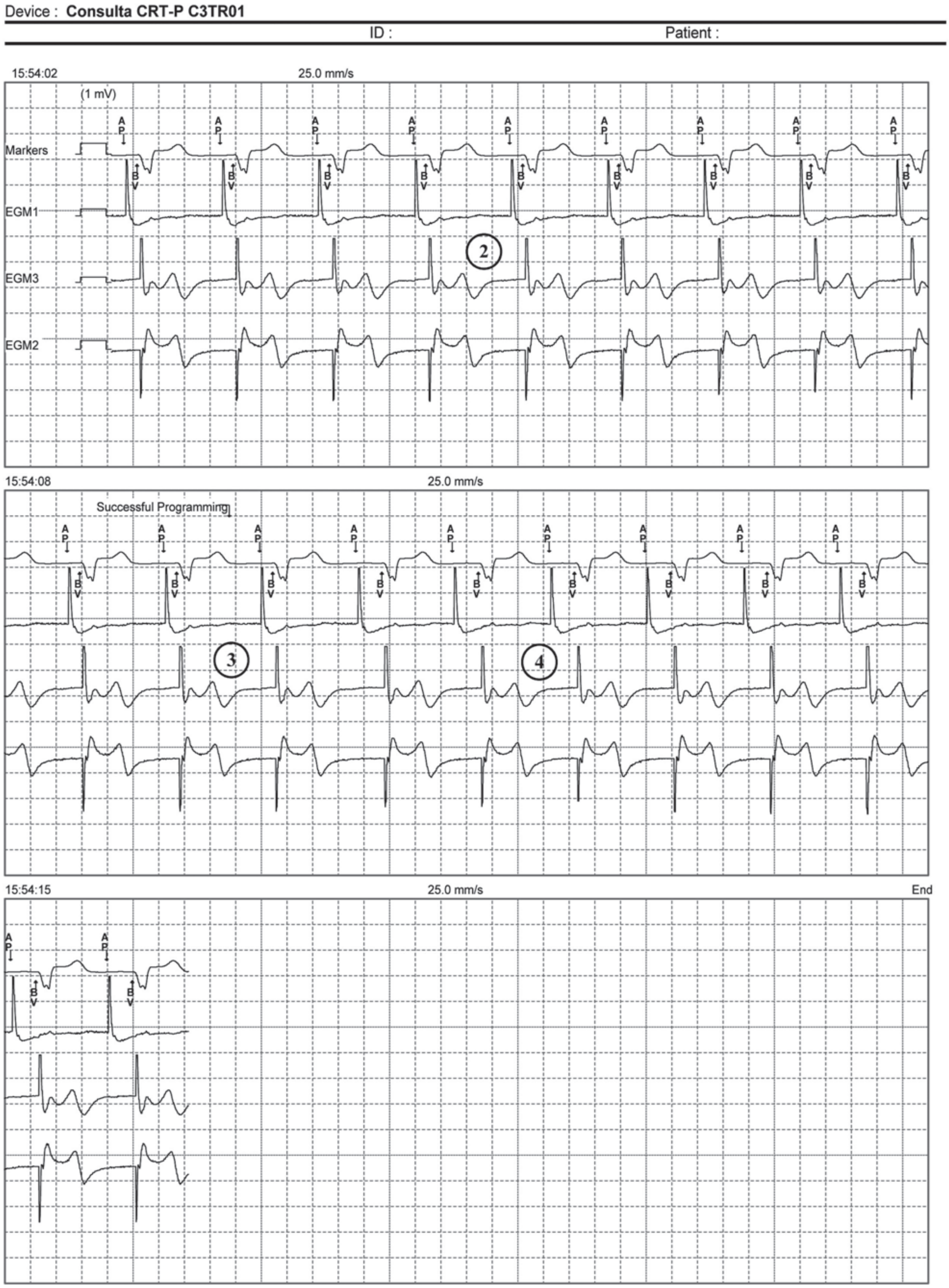
Comments

These tracings illustrate the specificity of the AV delay programming in a pacemaker dependent patient (complete AV block). For this type of patient, regardless of the programmed AV delay, the appearance of the stimulated QRS remains unchanged since no fusion with a potential spontaneous QRS occurs. This allows you to concentrate only on the chosen optimization parameter: the longest filling time with no abbreviation of the A wave, the importance of mitral regurgitation, the dP / dt max, the cardiac output ... Ideally, the optimal AV delay corresponds to the value that allows the best compromise between all these parameters. The analysis of the depolarization time is probably insufficient.

In this patient, the echocardiography showed a sharp amputation of the A-wave by a premature mitral valve closure at the first illustrated paced AV delay (100 ms). With the second and longer AV delay (180 ms), the filling time was prolonged with a dissociation of the A and the E-wave and the absence of truncated A-wave. The quality of the mitral filling pattern seemed reproducible. In contrast, high variations from cycle to cycle of the sub-aortic VTI signals were observed, making them not reproducible and therefore not interpretable.



Device : Consulta CRT-P C3TR01
ID :
Patient :
15:52:02
25.0 mm/s
(1 mV)
Markers
EGM1
EGM3
EGM2
AP
BV
1
15:52:08
25.0 mm/s
15:52:15
25.0 mm/s
End


Device : Consulta CRT-P C3TR01
ID :
Patient :
15:54:02
25.0 mm/s
(1 mV)
Markers
EGM1
EGM3
EGM2
AP
BV
2
15:54:08
25.0 mm/s
Successful Programming
3
4
15:54:15
25.0 mm/s
End

Tracing 2: optimization of the AV delay in a non-dependent patient

Patient

74 years old man implanted with a triple chamber defibrillator Viva XT CRT-D for idiopathic dilated cardiomyopathy with complete AV block; pacemaker interrogation 3 days post implant;

Tracing

The first line correspond to an electrocardiographic derivation with superimposed markers (MA), the second line to the bipolar right ventricular EGM (EGM3) and the third one to the bipolar atrial recording (EGM1);

1: the programmed paced AV delay is short (100ms); atrial paced rhythm and biventricular pacing (AP-BV cycles); on the atrial EGM, we see that the ventricular depolarization occurs just in the middle of the atrial depolarization; probable complete biventricular capture;

2: the paced AV delay is extended to 130 ms; the ventricular stimulus is less premature as compared with the previous atrial EGM; modified aspect of the ventricular EGM corresponding to a fusion (appearance close to the complete biventricular capture);

3: the paced AV delay is extended to 160 ms; the ventricular stimulus occurs now at the end of the atrial depolarization; modified aspect of the ventricular EGM which is completely different from the pattern during the complete biventricular capture;

4: the pattern of the QRS is variable depending on the degree of fusion that varies from cycle to cycle according to the degree of spontaneous atrio-ventricular conduction;

5: the paced AV delay is extended to 200 ms; the device detects a spontaneous ventricular event and paces accordingly (VVT mode corresponding to the programmed response to a sensed ventricular event); markers indicating a fusion between the VS and BV;

6: programming in AAI mode;

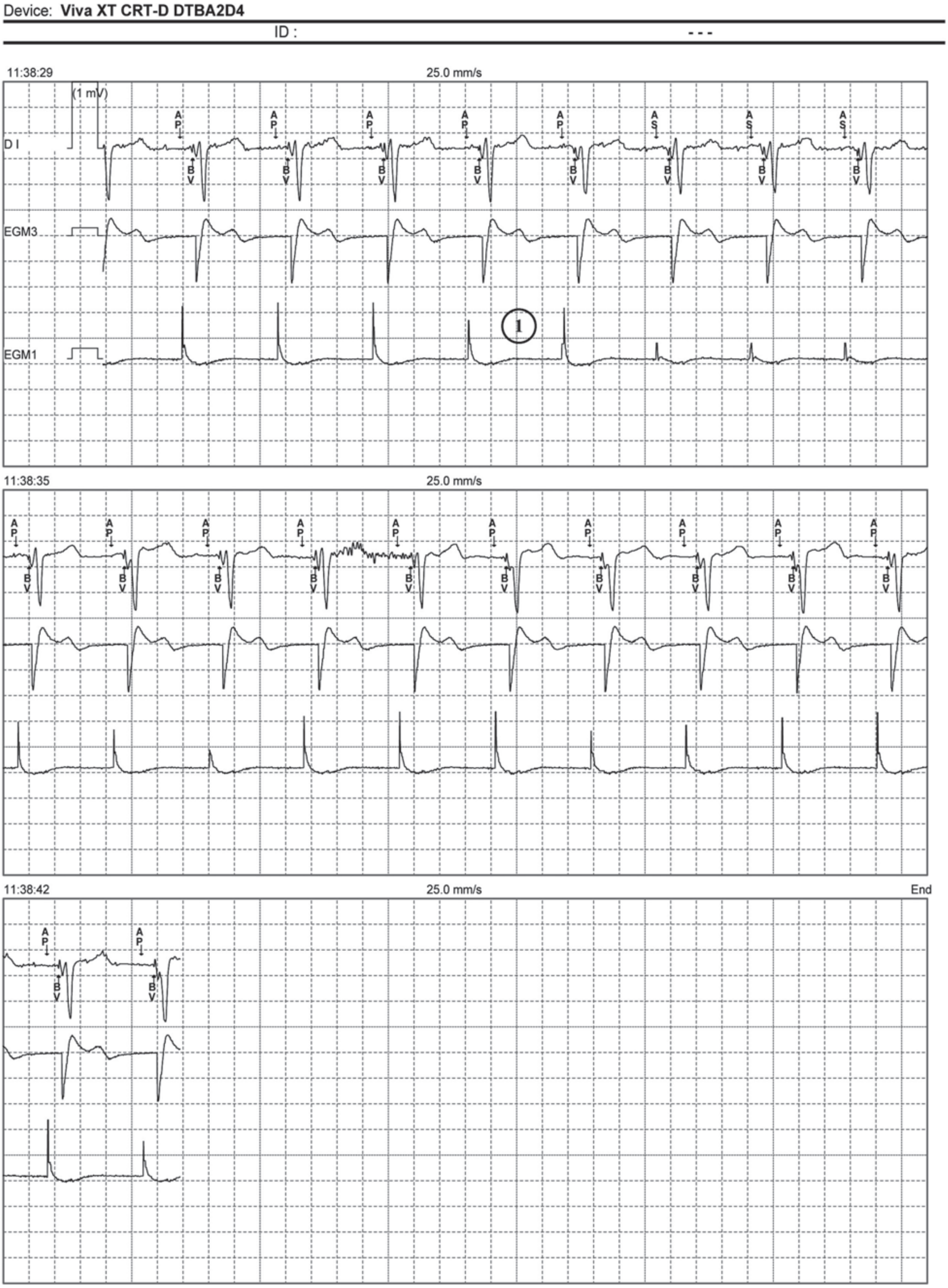
7: spontaneous QRS aspect very close to the one obtained in VVT mode; this demonstrates that despite this algorithm (response to a detected ventricular event), the degree of biventricular capture remains often only modest;

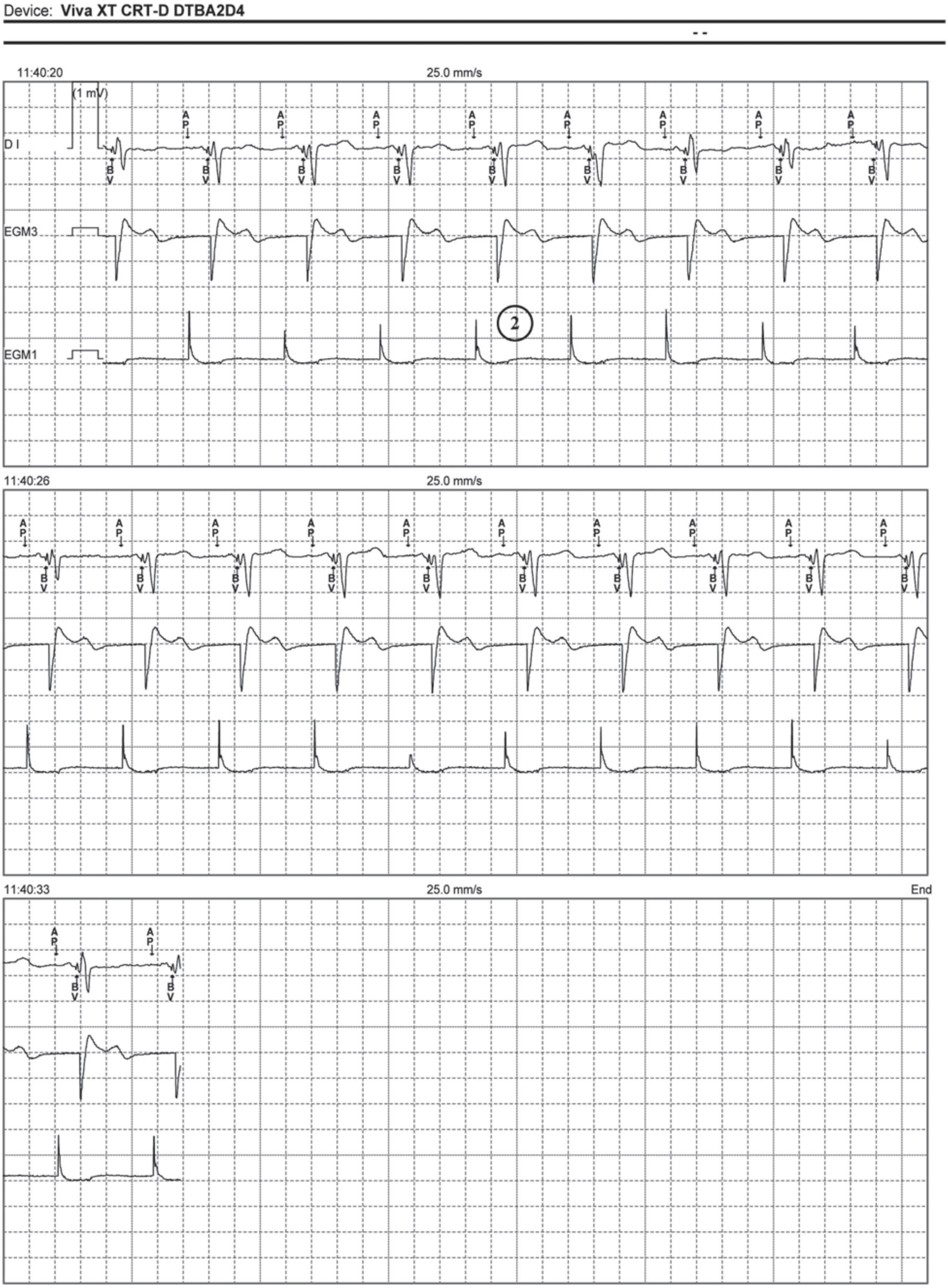
Comments

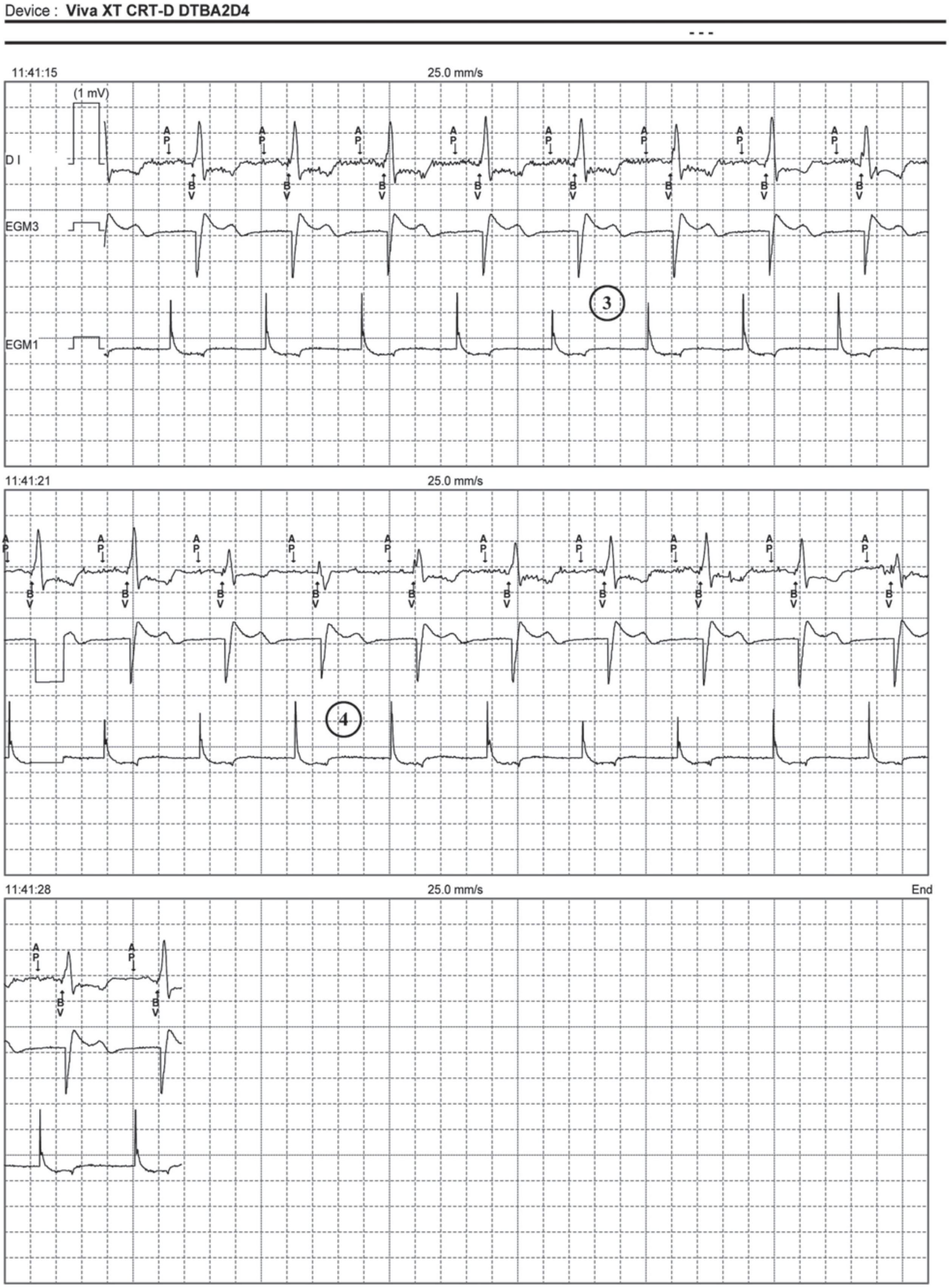
These tracings demonstrate the specificity of programming of the AV delay in a non-dependent patient: changes in the AV delay interferes with the quality of LV filling but also with the degree of biventricular capture and fusion with the intrinsic activation. As in the previous patient, the shortest AV delay was associated with a truncated A wave. However, it was the longest AV delay associated with a complete biventricular capture. Lengthening the AV delay allowed to improve the quality of filling but was also associated with a gradual fusion with the conducted QRS (ECG aspect approaching the spontaneous QRS appearance). The difficulty in optimizing the AV delay in this kind patient relates to the potential benefits of the fusion. Certainly, the device has been implanted in order to modify the spontaneous activation sequence, which was considered deleterious to cardiac function. Although it is difficult to determine which activation sequence is optimal, it seems essential that it significantly differs from that observed before implant. In other words, an excessive degree of fusion does not seem desirable. A paced AV delay of 130 ms was selected in this patient without any certainty that this value would match the optimal AV delay.

Even if it would be possible to program an AV delay generating an optimal degree of fusion, this would be true only in the specific condition of the consultation … and not anymore for example during exercise. The time of detection of the atrial activities varies notably with the breathing and the changes in P-wave amplitude. The AV conduction also tends to shorten variably depending on the type of effort. Providing the same degree of fusion as during the consultation, or simply providing any ventricular fusion at all, is almost impossible in practice.

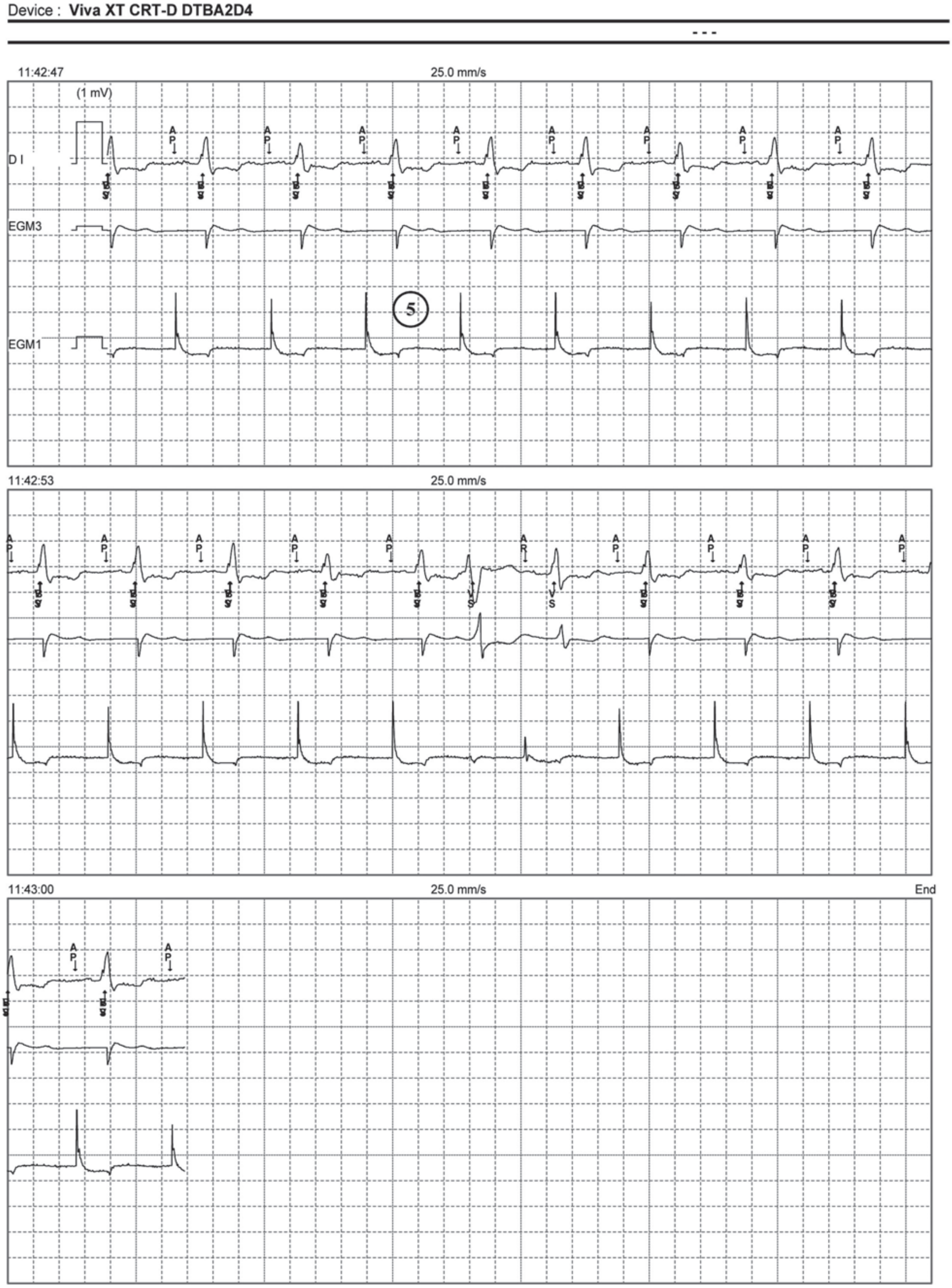
This tracing also illustrates the limits of the algorithms forcing the biventricular pacing (trigger mode). These algorithms may sometimes artificially increase the percentage of stimulation without allowing for a real resynchronization.

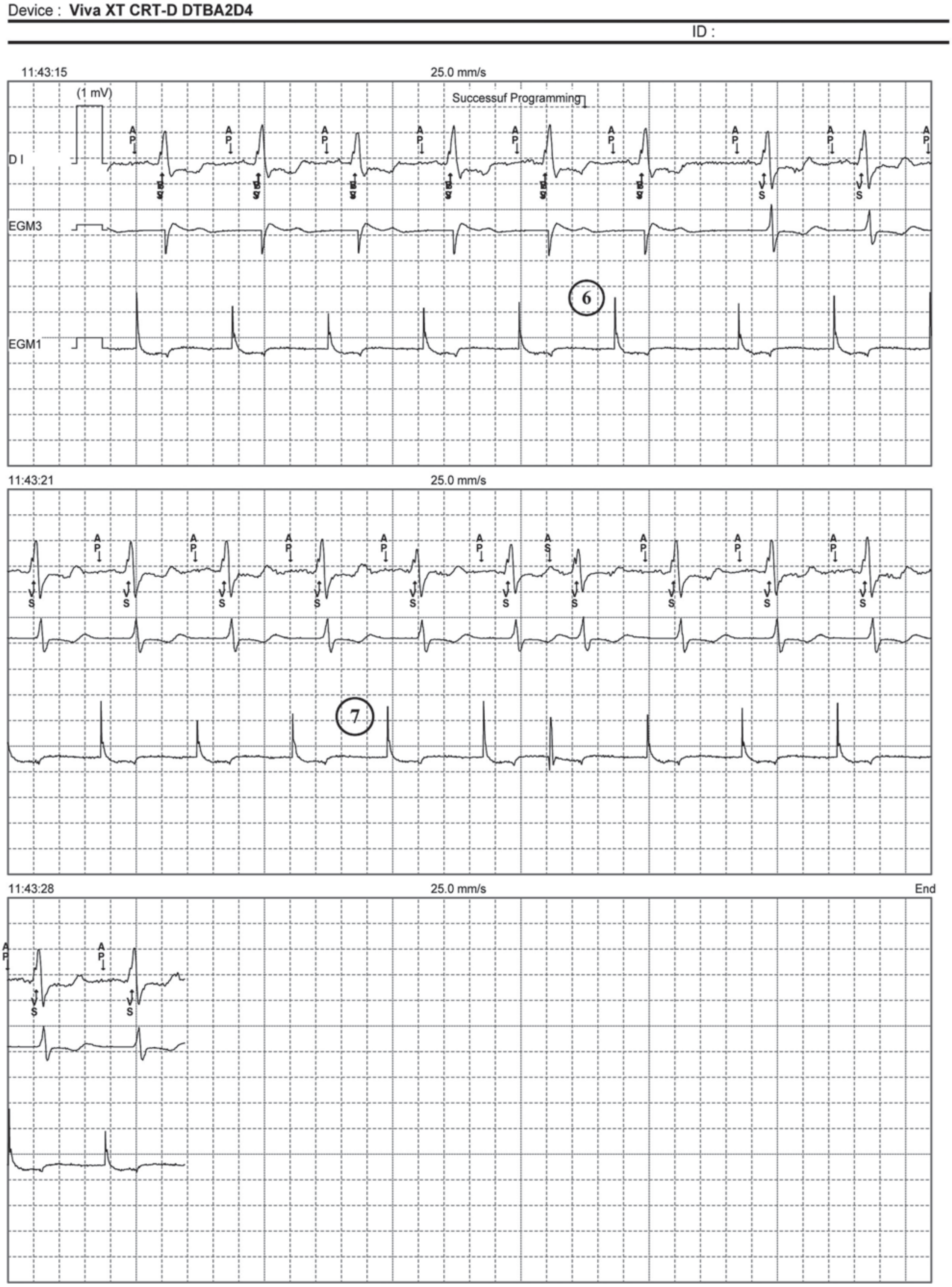

Device: Viva XT CRT-D DTBA2D4
ID :
- - -
11:38:29
25.0 mm/s
(1 mV)
D I
EGM3
EGM1
AP
BV
AS
1
11:38:35
25.0 mm/s
11:38:42
25.0 mm/s
End


Device: Viva XT CRT-D DTBA2D4
11:40:20
25.0 mm/s
(1 mV)
D I
EGM3
EGM1
2
11:40:26
25.0 mm/s
11:40:33
25.0 mm/s
End



Device : Viva XT CRT-D DTBA2D4
- - -
11:41:15
25.0 mm/s
(1 mV)
D I
EGM3
EGM1
3
11:41:21
25.0 mm/s
4
11:41:28
25.0 mm/s
End


Device : Viva XT CRT-D DTBA2D4
11:42:47
25.0 mm/s
(1 mV)
D I
EGM3
EGM1
5
11:42:53
25.0 mm/s
11:43:00
25.0 mm/s
End


Device : Viva XT CRT-D DTBA2D4
ID :
11:43:15
25.0 mm/s
(1 mV)
Successuf Programming
D I
EGM3
EGM1
6
11:43:21
25.0 mm/s
7
11:43:28
25.0 mm/s
End

Tracing 3: AdaptivCRT algorithm in a patient with a long PR interval

Patient

76 years old man implanted with a triple chamber defibrillator Viva Quad XT CRT-D for ischemic cardiomyopathy with a left bundle branch block and a long PR interval; follow-up 6 months after implant;

Tracing

The first line corresponds to an electrocardiographic derivation with superimposed markers (MA), the second line to the bipolar right ventricular EGM (EGM3) and the third one to the bipolar atrial recording (EGM1);

1: sinus rhythm and biventricular pacing (AS-BV) without AdaptivCRT function;
2: programming of the AdaptivCRT algorithm in Auto BiV and LV mode;
3: temporary prolongation of the AV delay to 300 ms; 5 AS-VS cycles with a LBBB morphology and a long PR interval; the delay between bipolar atrial EGM and the right ventricular bipolar EGM exceeds 200 ms but last less than 300 ms;
4: biventricular stimulation;

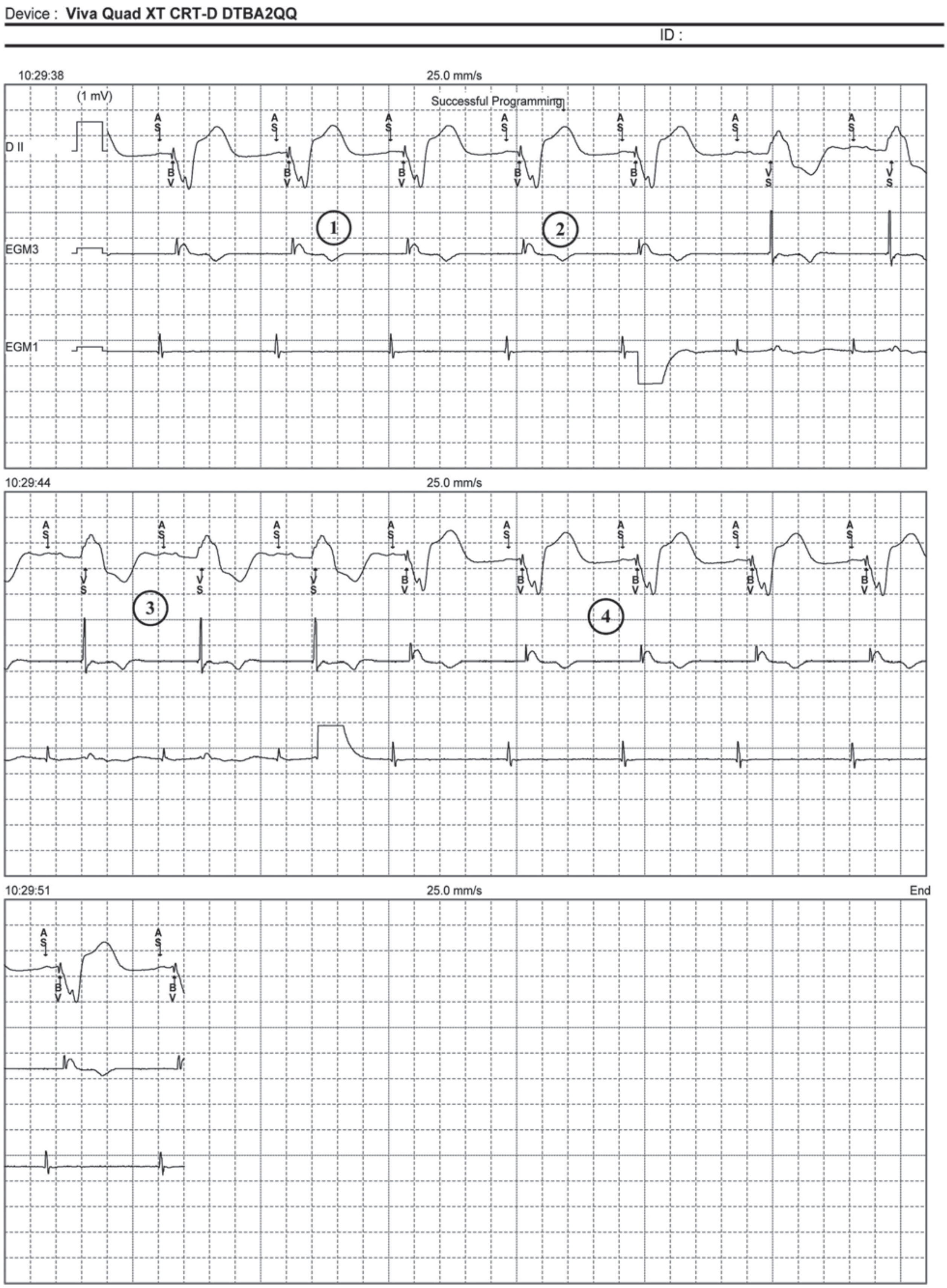
Deprogramming of the AdaptivCRT and reprogramming to the Auto BiV mode;

5: sinus rhythm and biventricular pacing (AS-BV) without the AdaptivCRT function;
6: programming of the AdaptivCRT algorithm in Auto BiV mode;
7: temporary prolongation of the AV delay to 300 ms, 5 consecutive AS-VS cycles with a LBBB pattern and a long PR interval; the delay between the bipolar atrial EGM and the right ventricular bipolar EGM exceeds 200 ms but lasts less than 300 ms ;
8: biventricular pacing;

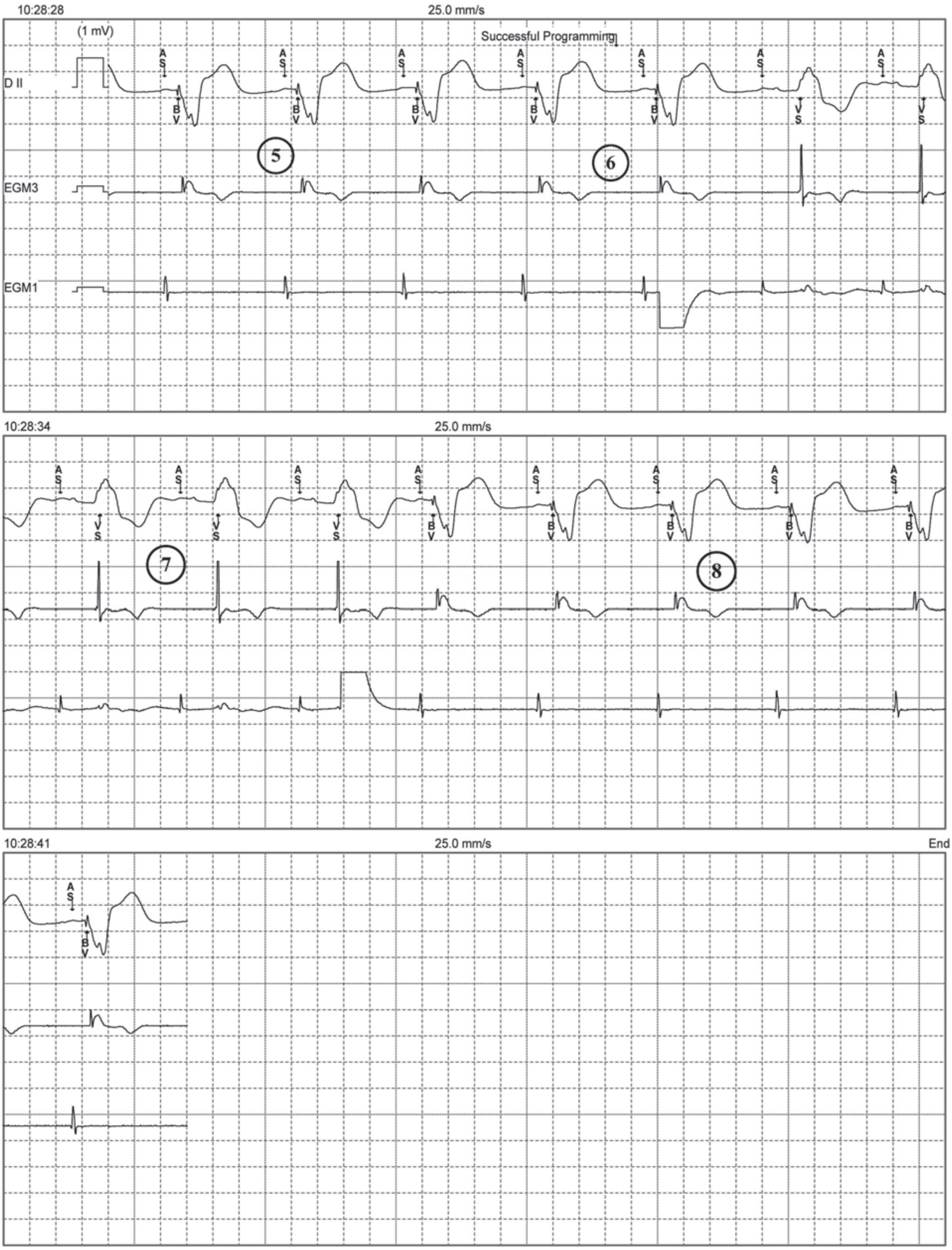
Comments

This tracing demonstrates some aspects of the operating function of the AdaptivCRT algorithm. After programming, the AV delay is extended to 300 ms to allow for intrinsic AV conduction. The device then measures the atrioventricular conduction time and the width of the P wave and the QRS complex. The AV delay is measured by analyzing the timing between the bipolar atrial EGM and the bipolar ventricular EGM that are displayed on this tracing. The analysis of the P-wave and the QRS width includes the HV shock channel (not displayed on this tracing).

The first step of the optimization process consists in the assessment of the atrio-ventricular conduction. In this patient, the time between spontaneous atrial and spontaneous right ventricular EGMs is greater than 200 ms which is defined as prolonged by the device. The patient is therefore stimulated in biventricular with both the programming AdaptivCRT Auto BiV and LV or AdaptivCRT Auto BiV. The rationale for this choice is that left ventricular pacing alone is probably more risky in a patient with AV conduction disorders. It is probably better to choose a biventricular pacing in this context, the right ventricular stimulation being effective if the left lead moves or presents an increased threshold. The « response to a detected ventricular event » algorithm is disabled during the 5 cycles used for the analysis. The periodic detection required for this measure can reduce the percentage of total biventricular stimulation by 1 to 2%. If the recording of the episodes of ventricular sensing is programmed from 5 consecutive cycles, the episodes of ventricular sensing related to the use of the AdaptivCRT will be recorded every 16 hours (5 cycles are required for measuring the width of the P wave and the QRS).


Device : Viva Quad XT CRT-D DTBA2QQ
ID :
10:29:38
25.0 mm/s
(1 mV)
Successful Programming
D II
EGM3
EGM1
AS
BV
VS
1
2
10:29:44
3
4
10:29:51
End

Device : **Viva Quad XT CRT-D DTBA2QQ**



Tracing 4: AdaptivCRT programming in a patient with a long PR interval

Patient

76 years old man implanted with a triple chamber defibrillator Viva Quad XT CRT-D for dilated cardiomyopathy with an atypical bundle branch block and a long PR interval; follow-up 3 months after implant;

Tracing

The first line corresponds to an electrocardiographic derivation with superimposed markers (MA), the second line to the bipolar atrial recording (EGM1), the third one to the bipolar right ventricular EGM (EGM3) and the fourth one to the distal (tip) LV / RV coil derivation (EGM2);

1: sinus rhythm and biventricular pacing (AS-BV) without AdaptivCRT function;
2: programming of the AdaptivCRT algorithm in Auto BiV and LV mode;
3: temporary prolongation of the AV delay to 300 ms; 5 consecutive AS-VS cycles with a LBBB morphology and a long PR interval; the delay between bipolar atrial EGM and the right ventricular bipolar EGM exceeds 250 ms but lasts less than 300 ms;
4: biventricular pacing;

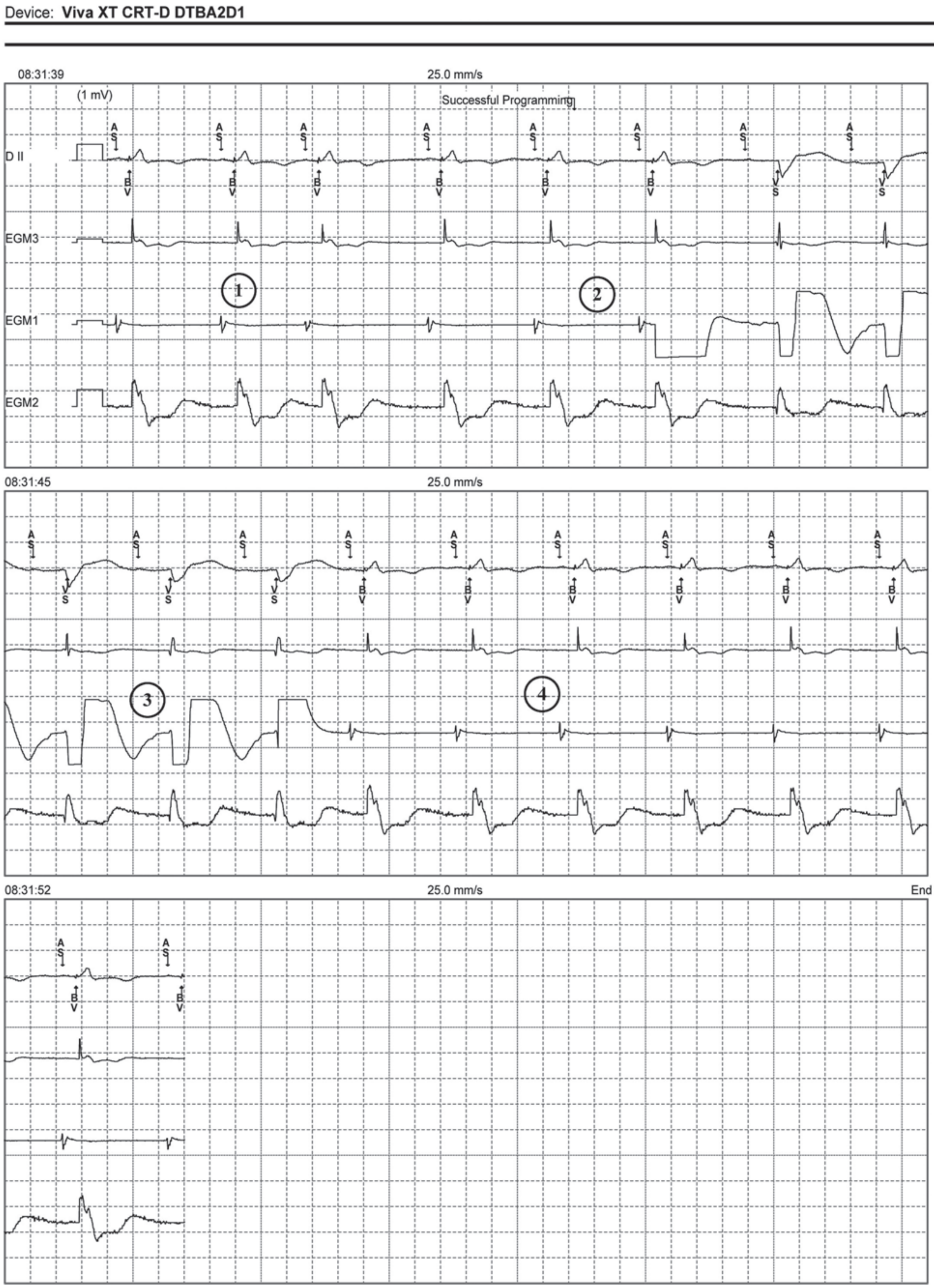
Deprogramming of the AdaptivCRT function and increase of the minimal HR to 75 bpm;

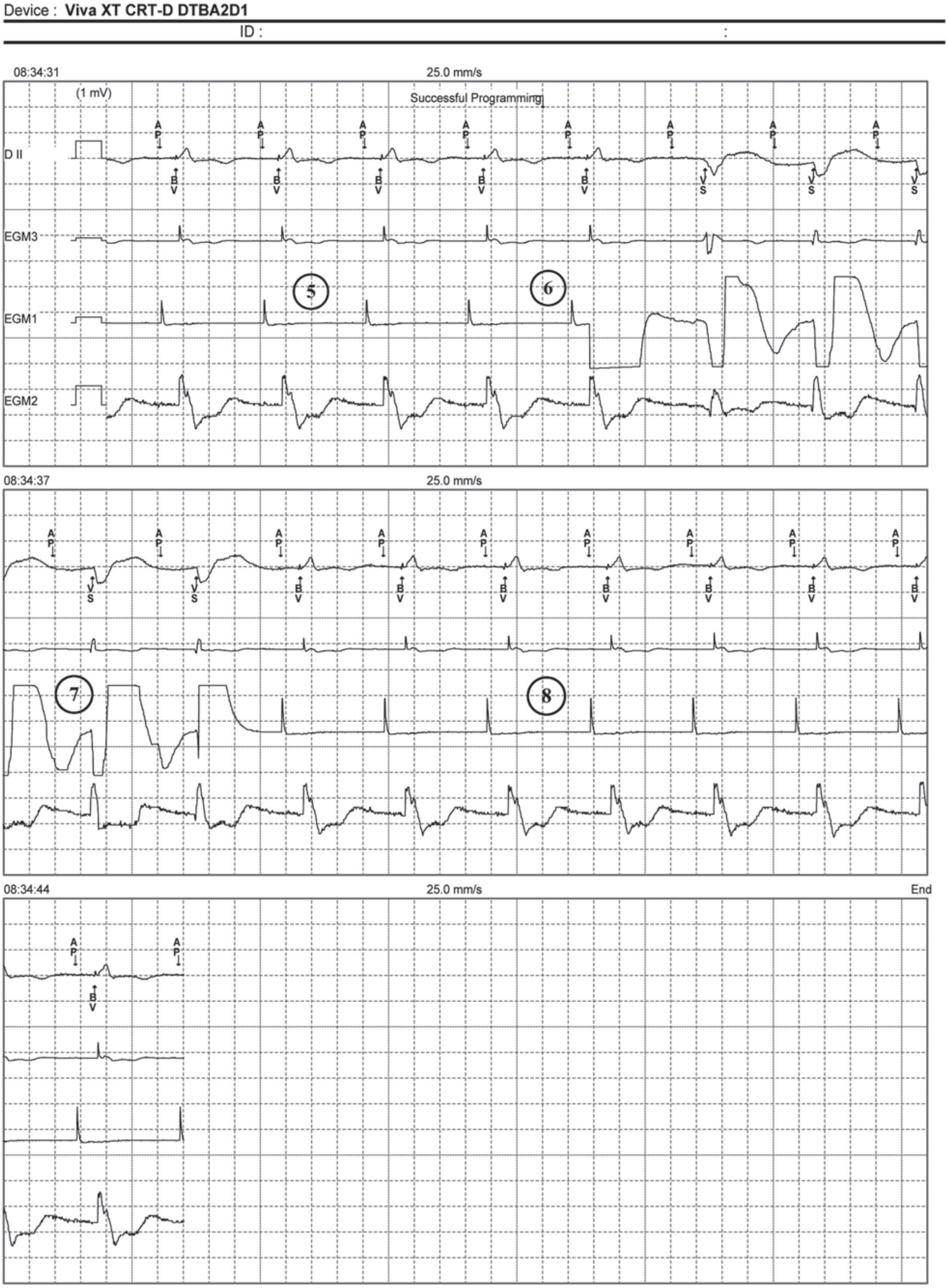
5: atrial stimulation and biventricular pacing (AP-BV) without the AdaptivCRT function;
6: programming of the adaptivCRT algorithm in Auto BiV and LV mode;
7: temporary prolongation of the AV delay to 300 ms; 5 consecutive AP-VS cycles with a LBBB morphology and a long PR interval; the delay between the atrial stimulus and the bipolar right ventricular EGM exceeds 250 ms but lasts less than 300 ms;
8: biventricular pacing;

Comments

This tracing illustrates other characteristics of this algorithm. The operating functions are very close during atrial sensed or paced rhythm. The threshold used to define a normal and abnormal AV conduction is 200 ms in spontaneous atrial rhythm and 250 ms when the atrium is paced. In this patient with long PR interval, these two AV delay are considered abnormal. However, none of them exceeds 300 ms. If the AV conduction time after a spontaneous or stimulated atrial event exceeds 300 ms, a biventricular stimulation is delivered. The device makes the diagnosis of atrioventricular block and the time interval between AV interval measurements doubles.

Heart rate histograms indicate the percentage of total ventricular detection and stimulation. They also provide the percentage of the stimulation delivered in a biventricular pacing mode and in a left ventricular pacing mode.


Device: Viva XT CRT-D DTBA2D1
08:31:39
25.0 mm/s
(1 mV)
Successful Programming
D II
EGM3
EGM1
EGM2
1
2
08:31:45
25.0 mm/s
3
4
08:31:52
25.0 mm/s
End


Device : Viva XT CRT-D DTBA2D1
ID :
08:34:31
25.0 mm/s
(1 mV)
Successful Programming
D II
EGM3
EGM1
EGM2
5
6
08:34:37
25.0 mm/s
7
8
08:34:44
25.0 mm/s
End

Tracing 5: AdaptivCRT programming in a patient with a normal PR interval

Patient

65 years old man implanted with a triple chamber defibrillator Viva XT CRT-D for idiopathic dilated cardiomyopathy with left bundle branch block; 3 months post implant interrogation;

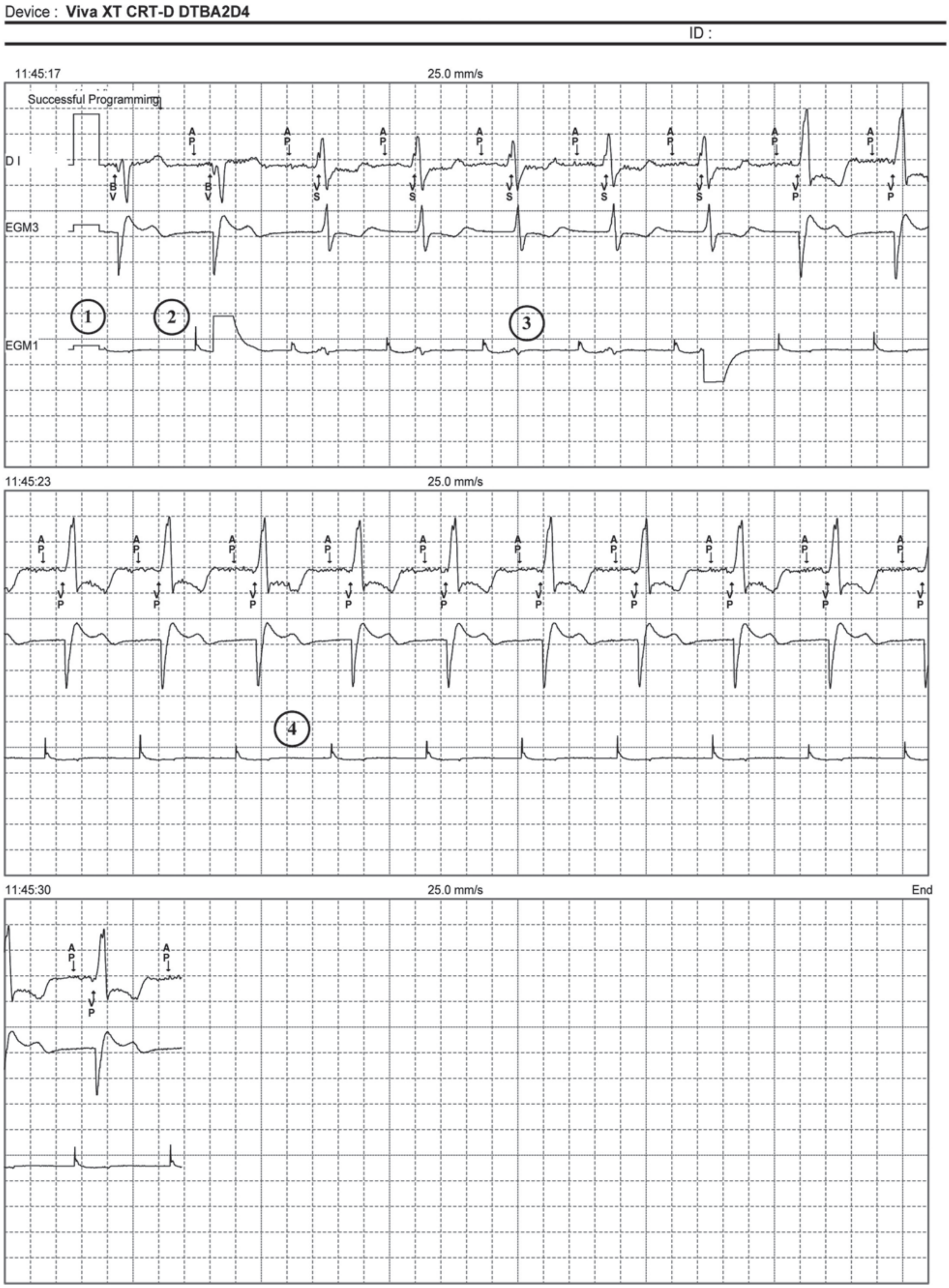
Tracing

The first line correspond to an electrocardiographic derivation with superimposed markers, the second line to the bipolar right ventricular EGM (EGM3) and the third one to the bipolar atrial recording (EGM1);

1: atrial and biventricular pacing (AP-BV) without AdaptivCRT function;
2: programming of the AdaptivCRT algorithm in Auto BiV and LV mode;
3: temporary prolongation of the AV delay to 300 ms; 5 consecutive AP-VS cycles with a LBBB morphology; the delay between the atrial stimulus and the bipolar right ventricular EGM is less than 250 ms;
4: LV pacing with fusion;

Comments

This tracing shows the operating function of this algorithm when the atrioventricular conduction is considered normal (delay between the spontaneous atrial EGM or the atrial stimulus and the spontaneous right ventricular EGM <200 ms and <250 ms respectively) and the heart rate is < 100 bpm. An isolated left ventricular pacing mode (with fusion with the intrinsic activation) is programmed in these conditions (auto LV mode). This prevents the right ventricular stimulation, reduces the energy consumption of the device and possibly extends the batteries lifespan. The post-ventricular pacing ventricular blanking period has to be programmed long enough (> 200 ms) in a unique left ventricular pacing configuration to minimize the risk of double counting the paced ventriculogram.


Device : Viva XT CRT-D DTBA2D4
ID :
11:45:17
25.0 mm/s
Successful Programming
D I
EGM3
EGM1
1
2
3
11:45:23
25.0 mm/s
4
11:45:30
25.0 mm/s
End

Chapitre 5

CRT Programming at Exercise

CRT programming at exercise

In a resynchronized patient, the main objectives of the programming during exercise are: 1) to maintain a permanent and effective biventricular capture for high heart rates, 2) to ensure a good contribution of atrial systole to cardiac output, and 3) to allow for appropriate heart rate acceleration which is the fundamental adaptive mechanism of the cardiac output during exercise, in particular in heart failure patients.
Checking for the maintenance of a permanent biventricular capture during exercise must be part of the standard CRT patient assessment. The recording of episodes of ventricular sensing occurring at high sinus rate in the device memories suggests the loss of LV capture at exercise. There are various causes that can lead to a loss of biventricular pacing during exercise: 1) atrial undersensing, 2) frequent ventricular extrasystoles, 3) atrial or ventricular arrhythmias, 4) a shortening of the intrinsic PR interval below the programmed AV delay, 5) a maximum tracking rate programmed too low for the patient's capacity. In patients with permanent atrial fibrillation and no His bundle ablation, the presence of an effective capture at rest does not guarantee the presence of a LV capture during exercise, when a competition between the improvement of the intrinsic atrioventricular conduction and the acceleration of the pacing rate dictated by the rate response algorithm may occur.

Different kinds of stress test can be performed in a resynchronized patient. The ideal is to have a simultaneous recording of the surface electrocardiogram and intracardiac electrograms (with the programmer) to detect in real time any dysfunction and correct it appropriately. The real-time analysis of the tracings during exercise is now facilitated by the development of the wireless technology and the possibility of remote telemetric interrogation of the device.

Traditional stress tests: they allow for evaluating the overall behavior of the device and the sensor during exercise. It seems that the adaptation of heart rate during exercise is more harmonious and close to that observed in real life with a treadmill than with a cycle ergometer. Indeed, the bicycle mobilizes essentially the muscles of the lower limbs, far from the implantation site of the device. Therefore, the activation of the sensor is delayed. At equal workload, the heart rate acceleration is greater on a treadmill as compared with the cycle ergometer.

Standardized tests in daily life: a large number of resynchronized patients are relatively old and present a limited capacity for the everyday life efforts (walking, toilet, cooking, household...). In these patients, it is essential to ensure the good function of the device during these everyday life stresses. The stress test type used to evaluate the device function must be adapted to these specificities. Different types of exercise under electrocardiographic monitoring can be performed: walking, climbing stairs, steps…

Rate-Responsive Pacing

Some patients present a chronotropic incompetence characterized by a heart rate that does not adapt to their level of physical activity. This inability to increase their heart rate during exercise may be associated with various symptoms like a shortness of breath, a fatigue or a reduced exercise capacity… In resynchronized patients with chronotropic incompetence (defined by the inability to achieve 85% of the theoretical maximum heart rate), programming a rate responsive pacing aims to ensure an increase of the cardiac output according to the metabolic need imposed by the ongoing effort. Programming a rate adaptive pacing must be systematic in the presence of severe chronotropic incompetence (inability to achieve 70% of the theoretical maximum heart rate).

The rate responsive algorithm available in the Medtronic devices uses an activity sensor measuring the patients' movement, a tool for converting the level of physical activity of the patient in a given pacing rate, a rate profile optimization algorithm based on the rate histogram to automatically adjust the rate response slope and finally a rate smoothing function for the acceleration and deceleration phases. The algorithm allows for a double slope acceleration, which can be automatically or manually customized.

The activity sensor is an accelerometer located in the device, which detects body movements of the patient. Since the detection of activity varies from one patient to another, the sensitivity of the accelerometer must be adjusted by reprogramming the activity threshold parameter. If the threshold is reduced, smaller body movements will influence the pacing rate. If the threshold is increased, major body movements will be required to influence the frequency of stimulation.

The Activities of Daily Living rate (ADL) is the average target rate that the patient achieves for moderate activities (nominally 95 bpm) and defines a level that helps him to maintain a stable pacing heart rate for moderate activities such as walking or household tasks, etc. The Upper Sensor Rate (USR) corresponds to the fastest rate at which the heart will be paced in response to signals from the rate-response sensor (nominally 130 bpm). An Independent control of the both the ADL and the upper sensor rate should be performed.

Maximal tracking rate

The operating function of the device when the heart rate exceeds the maximal tracking rate depends on the quality of the atrio-ventricular conduction.

In resynchronized patient with a complete AV block and a preserved chronotropic function, when the sinus rate accelerates and exceeds the maximal tracking rate, a ventricular stimulation at the end of the programmed AV Delay would be associated with a heart rate above the maximum value programmed, which is impossible. The ventricular rate can no longer follow the atrial rate in a 1/1 ratio. To overcome this limitation, the device extends the AV delay and a Wenckebach phenomenon occurs. As the sinus rate increases beyond the maximal tracking rate, the ventricular pacing rate remains at the maximal tracking value and the sensed AV delay is prolonged at each cycle of stimulation. After several pacing cycles, an atrial sensed event falls in the PVARP and is not coupled with a ventricular pacing, resulting in a missing ventricle. The next P-wave falls out the refractory period and initiates a programmed AV delay. This pattern repeats itself as long as the sinus rate remains higher than the maximum maximal tracking rate programmed. Missing beats occurs less frequently when the sinus rate is only slightly higher than the maximal tracking rate and more frequently when the sinus rate exceeds largely the maximal tracking rate. When the sinus rate falls below the maximum frequency, the AV synchronicity (1:1 ratio) is restored. The Wenckebach behavior can be characterized by the rate at which the first missing beat will occur and by the ratio of detected atrial beats and paced ventricular beats (for example 8:7, 7:6, 6:5 or 3:2). If the increase in the heart rate reaches the 2:1 block point, an important drop of heart rate occurs with a Atrium / Ventricle ratio of 2:1.
In a resynchronized patient with a good chronotropic function and a preserved AV conduction, when the sinus rate accelerates and exceeds the maximal tracking rate, the programmed AV delay lengthens progressively favoring the appearance of a fusion with the spontaneously conducted ventricles. At higher rates, the ventricular sensing inhibits the biventricular pacing. Four elements characterize this operation: 1) the intervals between 2 VS are shorter than those corresponding to the maximal tracking rate; 2) for a given cycle, the PR interval (AS-VS) is shorter than the theoretical AS-VP; 3) there is no P-wave undersensing or P-wave falling in the PVARP as in a typical Wenckebach period in a patient with atrioventricular block; 4) biventricular pacing restarts only when the atrial rate falls below the maximal tracking rate.

Therefore, it seems logical to program a high maximal tracking rate to avoid a Wenckebach behavior or the loss of biventricular pacing. In order to limit the increase in heart rate during exercise, it does not seem logical to limit the maximal tracking rate but rather to optimize the medical therapy with rate control agents. Programming a maximal tracking rate too low in coronary patient probably does not have any protective value… In contrast it may rather favor the loss of biventricular capture or the occurrence of intermittent blocked P waves that can promote disabling symptoms by increasing myocardial oxygen consumption and inducing a fall in cardiac output.

AV-delay optimization during exercise

It is possible to program different AV delay at rest and during exercise. This programming presents three goals: 1) hemodynamic optimization with the research of the AV delay at exercise allowing for the best exercise capacity 2) maintenance of a biventricular pacing at exertion (programmed AV delay shorter than the PR) 3) maintaining a regular atrioventricular synchronicity for high sinus rates (avoid to exceed the point of 2:1).
The requirements differ depending on the quality of the atrioventricular conduction. In a patient with a permanent complete atrioventricular block, there is no risk of resumption of the atrioventricular conduction at exercise and therefore no risk of loss of biventricular pacing. In contrast, the AV delay must be programmed short during exercise to enable a 1/1 synchronicity with the atrial activity (and avoid a sudden drop in heart rate when the atrial rate exceeds the 2:1 block point) and to allow for an optimal hemodynamic response. In a patient with a preserved atrioventricular conduction, there is no risk of rate drop after the occurrence of the 2:1 block point. However, the improvement of the intrinsic atrio-ventricular conduction can promote the loss of biventricular capture.

Optimizing the AV delay in order to improve the patient hemodynamic is difficult at rest… It is even more difficult during exercise. There is currently no method of reference for this optimization and the results in the literature are contrasted and conflicting. In a patient with a healthy heart but conduction disorders, the positive effect of shortening the AV delay during the effort has clearly been demonstrated. Various studies have analyzed the dynamics of the optimal AV delay in resynchronized patients with sometimes different results leading to conflicting recommendations: based on the patients and the studies, the optimal AV delay could be shorter, identical but also sometimes longer during exercise than at rest. Considering the physiological characteristics of the atrioventricular node in healthy patients, these disparate results are unexpected. Some methodological limitations may have contributed to these conflicting results. However, patients with heart failure and left bundle branch block represents an heterogeneous group of patient, which could have lead to a variable impact of the stress test on the intra-atrial conduction, atrioventricular or intraventricular times. In patients with ischemic heart disease particularly, the impact of the exercise on the heart rate, the load conditions and neuro-vegetative state may have a variable effects from patient to patient on the conductive and contractile tissue.

It seems therefore difficult to establish firm and final recommendations for the hemodynamic optimization of the AV delay at exercise. From a practical point of view, it seems inconceivable to consider an individualized dynamic optimization based on the echocardiographic pattern or other invasive or non-invasive technique. An automatic optimization at rest and during exercise of the AV delay by the device itself may be the solution but requires the development of specific algorithms and their clinical validation with the demonstration of clinical benefit provided in terms of response to the CRT and / or effort capacity.

In practice, what are the possibilities with current devices? The first point is that it is not possible to set a longer AV delay during exercise than at rest with a triple chamber Medtronic defibrillator. Two options are possible: maintaining a fixed AV (sensed or paced) delay both at rest and during exercise, or programming an adaptive AV delay which allows for a linear shortening of the AV delay with the increasing heart rate. Even if the demonstration of the hemodynamic benefit of dynamic AV delay remains controversial in resynchronized patients, programming a dynamic AV delay has certain advantages and is frequently proposed in clinical practice: 1) among the non-dependent patients with a shortening of the PR interval at exercise, a dynamic AV delay will maintain the biventricular pacing and avoid the PR interval to become shorter than the AV delay; 2) among pacemaker dependent patients, programming a dynamic AV delay and a PVARP Auto allows to postpone the occurrence of 2:1 block point beyond the maximum capacity of the patient.

Atrial sensitivity

Maintenance of a synchronous 1:1 atrioventricular relationship during exercise requires a perfect detection of the atrial activity. The exertion and the increased respiratory movements are often associated with an alteration of the atrial detection. The diagnosis relies on the absence of AR signals (2:1 block) and the absence of a marker despite the presence of an atrial signal. It is therefore necessary in these patients to increase the sensitivity and the margin as compared with the detection threshold measured at rest.

Ventricular extrasystole in patients with a long PR interval

At exercise, the acceleration of the sinus rate in combination with the occurrence of PVC in a patient with long PR interval may result in prolonged loss of biventricular pacing. Indeed, the P-wave following a PVC can fall into the PVARP which is extended to 400 ms (marker AR); no AV delay will thus be triggered and explain the absence of biventricular pacing; the following spontaneous ventricle will also be considered as a PVC and the PVARP will be extended. The longer is the PR interval, the faster is the atrial rate, the more important are the chances to see this phenomenon maintained (succession of cycles AR-VS). The atrial tracking recovery (ATR) algorithm aims to restore the atrio-ventricular synchronization and to restore delivery of cardiac pacing therapy upon identification of an atrial refractory sense-ventricular sense (AR-VS) pattern of cardiac activity. Once the AR-VS pattern is identified, the PVARP is temporarily shortened to allow the sensing of the atrial event, which previously was refractory and unable to initiate a sensed atrioventricular interval.

Tracing 1: ventricular detection during exercise

Patient

47 year old man implanted with a triple chamber defibrillator Viva XT in the context of an idiopathic dilated cardiomyopathy with left bundle branch block; 3 months post implant, good clinical response; device interrogation and identification of episodes of sensed ventricles;

Tracing

On the recorded tracings of consecutive sensed ventricles in the device memories, we find the atrial and ventricular markers but no electrograms

1: fast sinus rhythm at the upper tracking rate (460 ms, 130 bpm) biventricular stimulation (AS-BV);

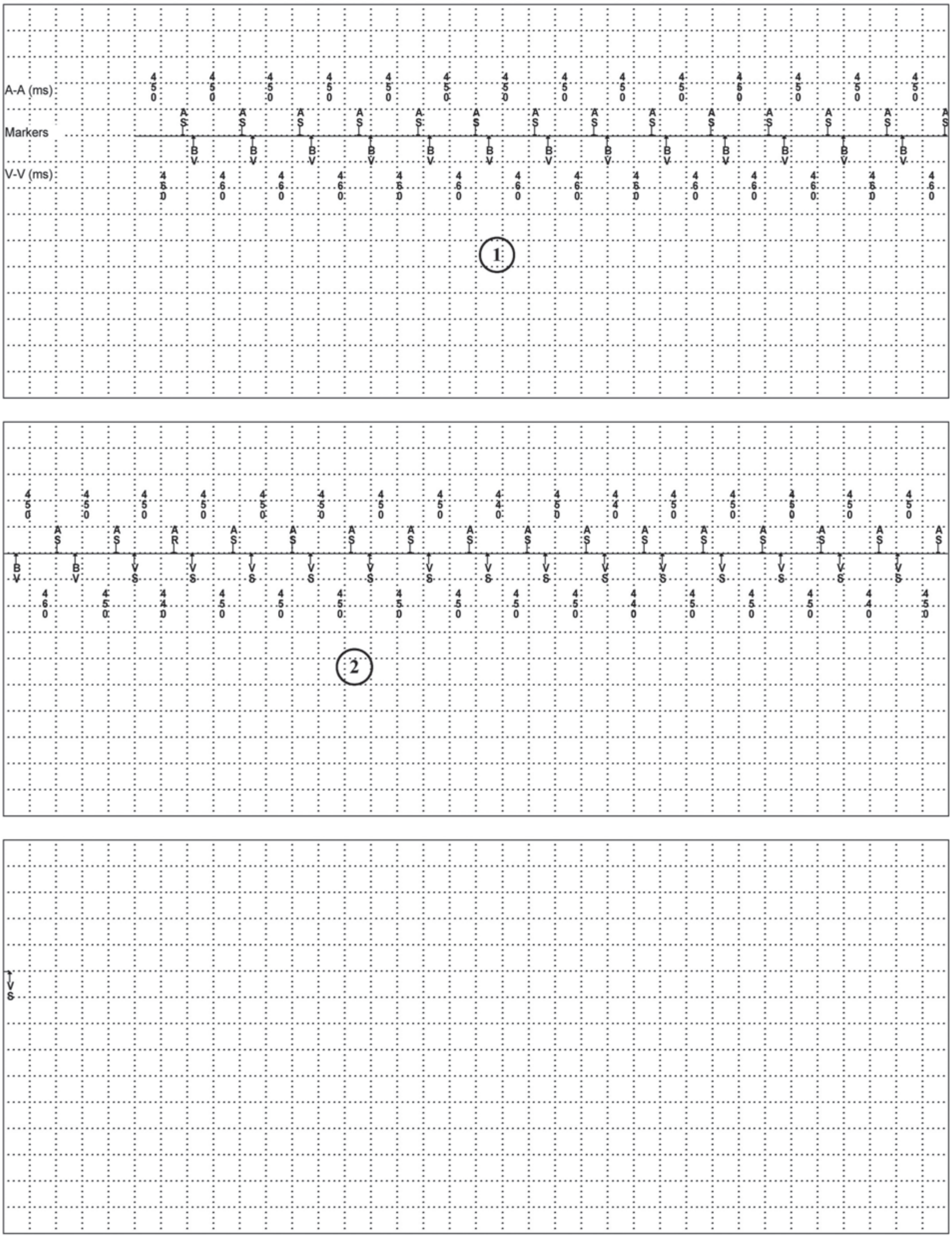
2: atrial rate above the upper tracking rate, spontaneous conducted ventricle (AS-VS) and loss of biventricular stimulation;

Comments

This tracing demonstrates the interest to analyze carefully the episodes of ventricular sensing stored in the device memory. This patient has a left bundle branch block but does not present a major atrioventricular conduction disorder (PR interval of 190 ms at rest and 170 ms at peak exercise). Programming a spontaneous AV delay at 150 ms at rest with rate adaptive AV delay of 110 ms at peak exercise ensures a complete biventricular capture up to the upper tracking rate. The tracing shows that the recorded rate displayed by the patient exceeds the upper tracking rate (sinus tachycardia). In a patient in complete atrioventricular block, this would result in a Wenckebach pattern. In this patient with a preserved atrioventricular conduction, no ventricular pacing being possible beyond the upper tracking rate, the AV delay gradually lengthens before the spontaneous conduction reappears with the loss of biventricular pacing at peak exercise. An increase of the upper tracking rate to 140 bpm has eliminated this type of episodes.

Monitored Ventricular Episode # 101

Device: **Viva XT CRT-D DTBA2Ds**



Tracing 2: ventricular detection during exercise

Patient

51 year old man implanted with a triple chamber defibrillator Consulta CRT-P in the context of an ischemic cardiomyopathy with left bundle branch block; excellent clinical response to resynchronization, a stress test (steps) is performed with the telemetry wand of the programmer placed onto the device;

Tracing

The first line corresponds to an electrocardiographic recording with superimposed markers, the second line correspond to the bipolar RV EGM, the third line correspond to the atrial EGM, the fourth line correspond to the far field EGM LV tip / RV ring - anode;

1: sinus rhythm and biventricular stimulation at rest (AS-BV);

2: EGM recording obtained during the stress test, which explains the poor quality of the tracing; atrial rate at the upper tracking rate; persistence of AS-BV cycles;

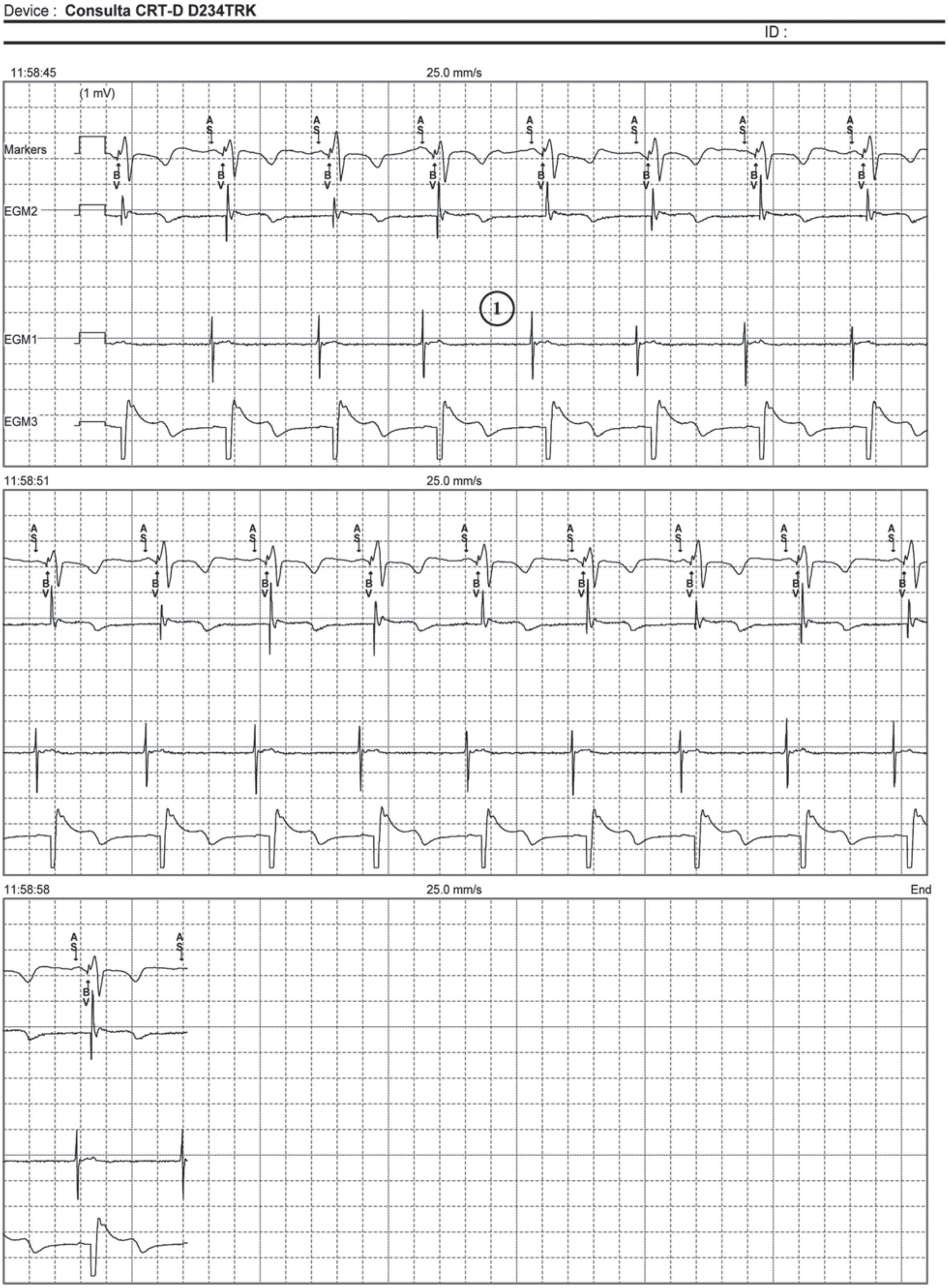
3: acceleration of the atrial rate above the UTR; discrete prolongation of the AV delay followed by a recovery of a spontaneous conduction and the loss of biventricular pacing (AS-VS cycles);

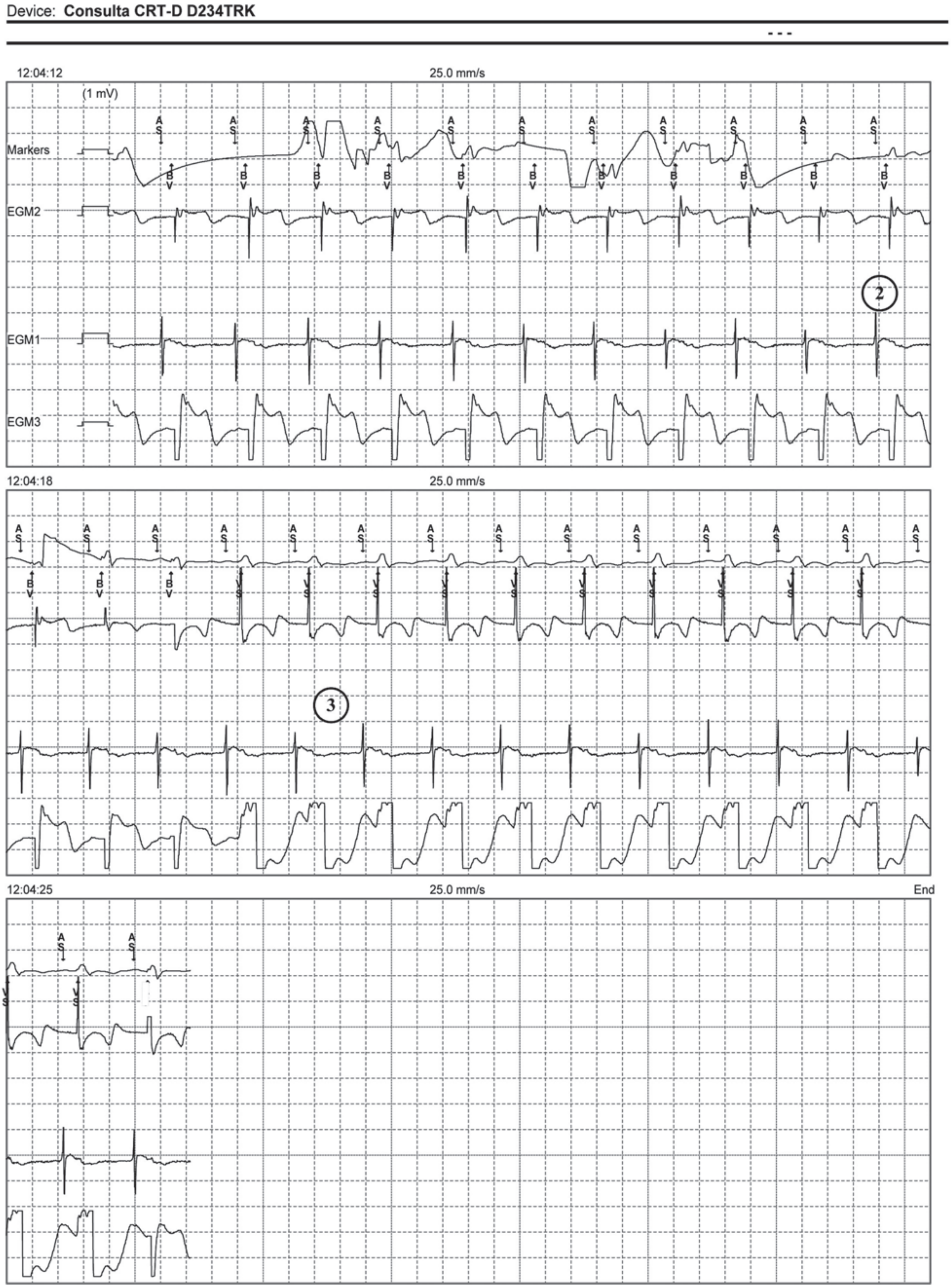
4: stress test is stopped; persistence of AS-VS cycles;

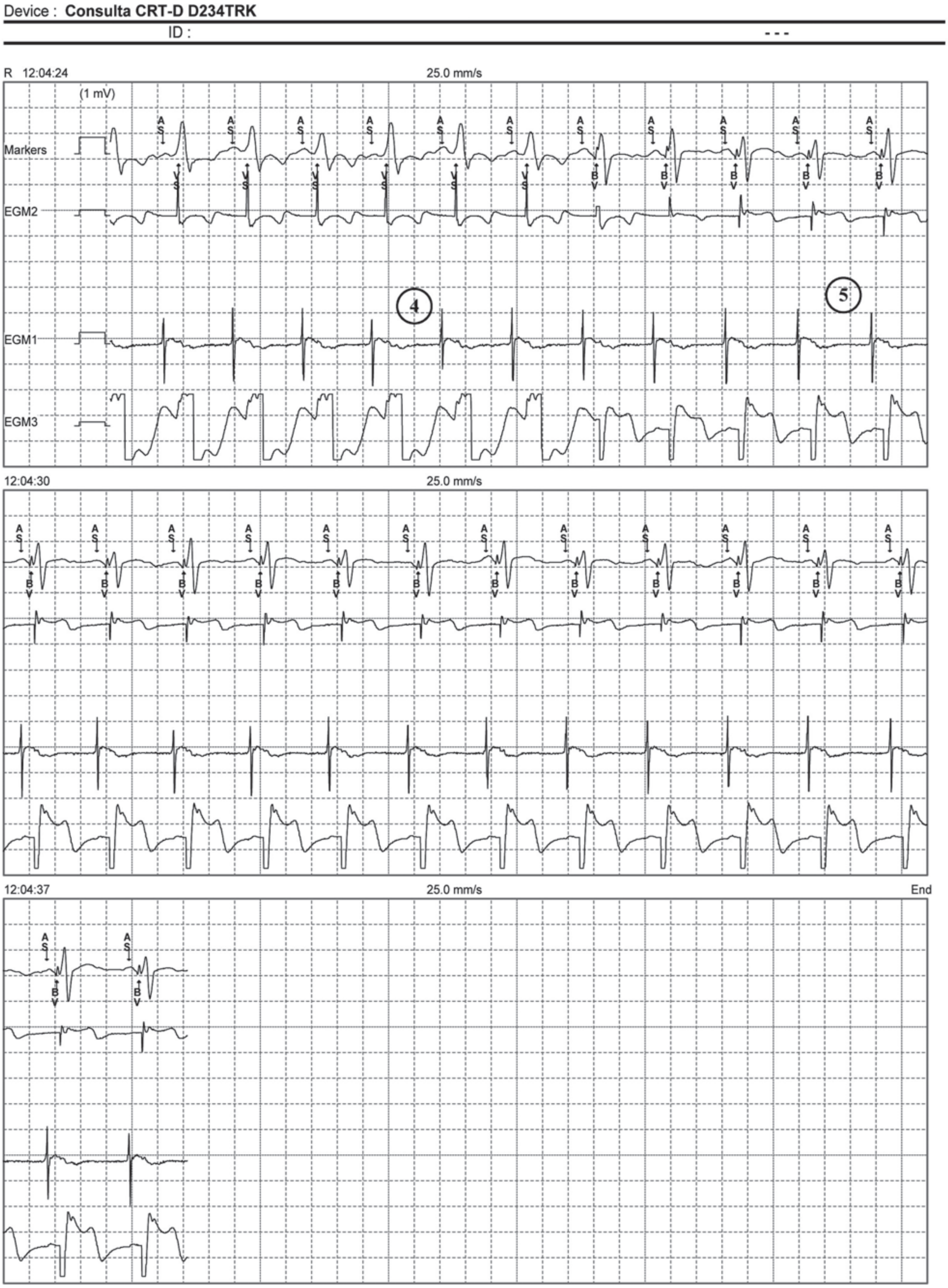
5: decrease of the heart rate below the UTR and recovery of a biventricular stimulation;

Comments

This tracing illustrates with electrograms the same problem as the previous tracing. There is no reason to limit the upper tracking rate below the patients' maximal capacity. However, this type of episode is rarely symptomatic because it is not associated with a sudden drop in the heart rate. This causes the loss of biventricular pacing at peak exercise. In this patient an increase of the UTR to 140 bpm solved the problem. This setting has been validated during a new stress test, which confirmed the persistence of biventricular pacing and capture up to the he maximal capacity of the patient. Conducting a stress test in CRT patient allows to confirm the proper functioning of the device at exercise and to ensure: 1) a good atrial sensing in patients without chronotropic incompetence, 2) a suitable adaptive rate response for patients with chronotropic incompetence, 3) that the 2 / 1 point is not reached during the exercise (rate adaptive AV delay and PVARP Auto), 4) the appropriate programming of the upper tracking rate and / or the maximum sensor rate, 5) the absence of arrhythmias during exercise (supraventricular arrhythmia, many VPCs, ventricular arrhythmia, pace maker mediated tachycardia…).


Device : Consulta CRT-D D234TRK
ID :
11:58:45
25.0 mm/s
(1 mV)
Markers
EGM2
EGM1
EGM3
1
11:58:51
25.0 mm/s
11:58:58
25.0 mm/s
End
AS
BV


Device: Consulta CRT-D D234TRK
12:04:12
25.0 mm/s
(1 mV)
Markers
EGM2
EGM1
EGM3
2
12:04:18
25.0 mm/s
3
12:04:25
25.0 mm/s
End



Device : Consulta CRT-D D234TRK
ID :
- - -
R 12:04:24
25.0 mm/s
(1 mV)
Markers
EGM2
EGM1
EGM3
4
5
12:04:30
25.0 mm/s
12:04:37
25.0 mm/s
End

Tracing 3: 2:1 block and Wenckebach behavior during exercise

Patient

Young patient (24 years old) implanted with a triple chamber pacemaker Consulta CRT-P for a complete congenital AV block; dizziness during exercise; stress test performed on an ergometer with the telemetry wand placed onto the device;

Tracing

The first line corresponds to an electrocardiographic recording with superimposed markers, the second line to the bipolar RA EGM, the third line to the LV tip / RV ring (anode) EGM and the fourth one to a second electrocardiographic lead with the RR intervals; significant effort and dizziness with major dyspnea;

- 1: atrial rhythm detected outside any refractory period (AS) and biventricular pacing;
- 2: atrial rhythm detected falling in the PVARP (AR) and not followed by a AV delay or a biventricular stimulation;
- 3: alternation AS-BV-AR cycles; 2:1 block point is reached (one P-wave on two falls in the PVARP and is not followed); sudden drop in the heart rate that explains the patients' symptoms;

Modification of the programming (rate adaptive AV delay and PRAPV auto)

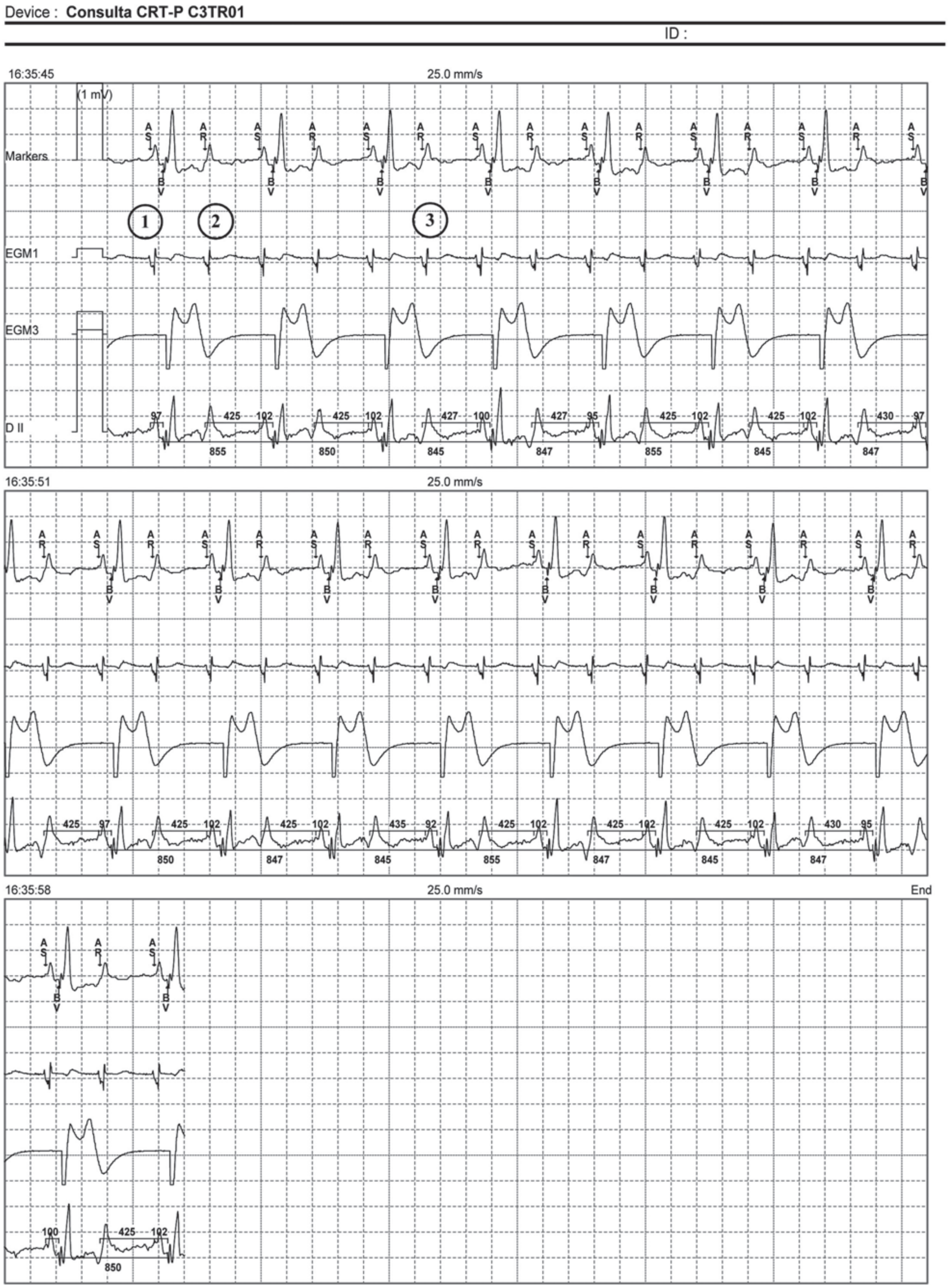
- 4: P-wave tracked with the prescribed AV delay (70 ms at peak exercise);
- 5: progressive lengthening of the AV delay to maintain the HR at the upper rate limit;
- 6: marked prolongation of the AV delay; the BV-AS interval is relatively short but the atrial signal is not detected in the PVARP; when programming a PRAPV auto mode in young adults, it is important to select a short minimal PVARP (180 ms in this case);
- 7: the P-wave falls in the post ventricular atrial blanking (Ab) and is therefore not followed by a AV delay or a biventricular stimulation; blocked P-wave;
- 8: Wenckebach behavior 8/7 (8 P-waves for 7 BV stimulation) with a progressive lengthening of the AV delay and 1 blocked P-wave every 8 P-waves;

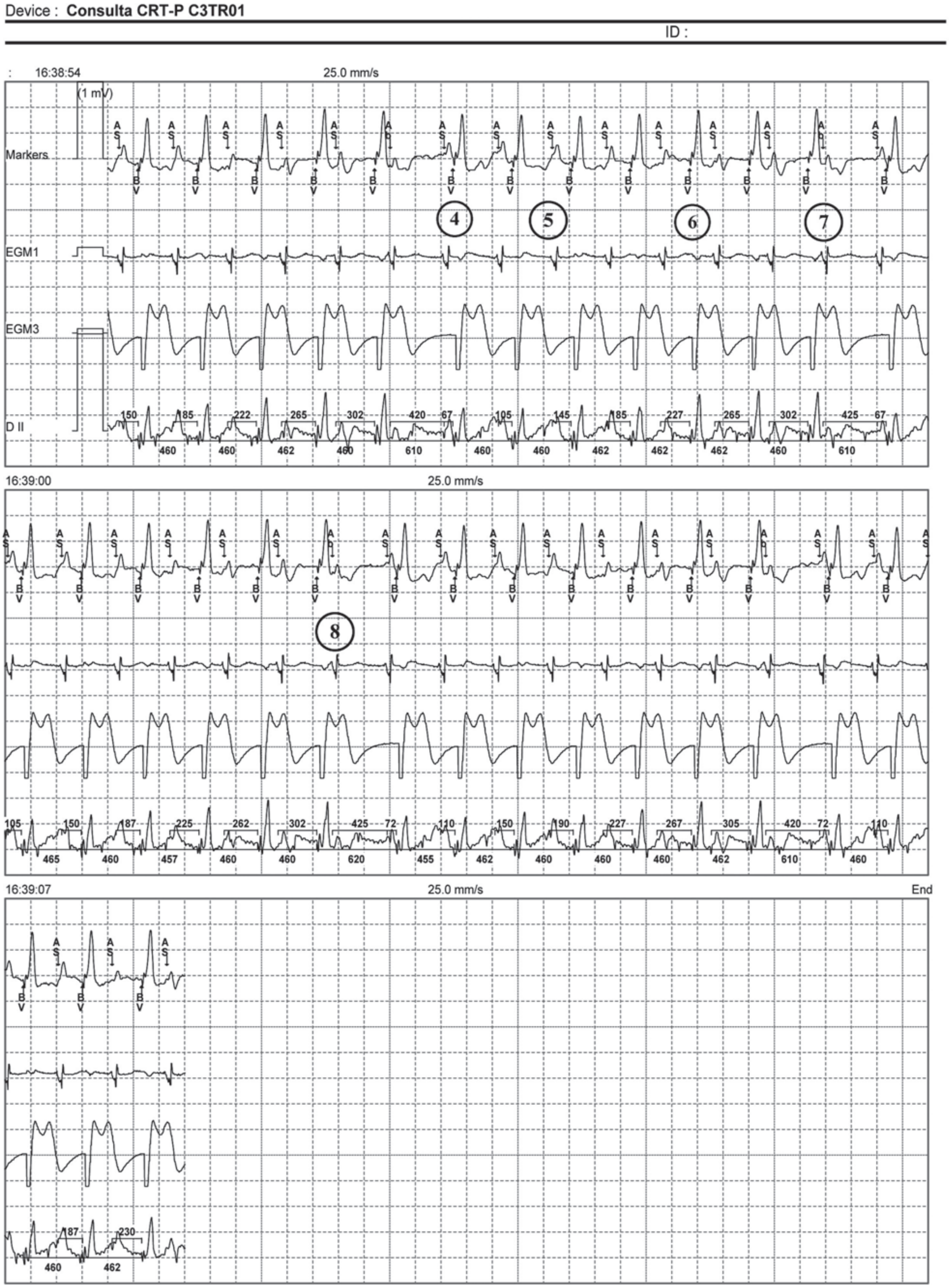
Modification of the programming (UTR is set at 180 bpm)

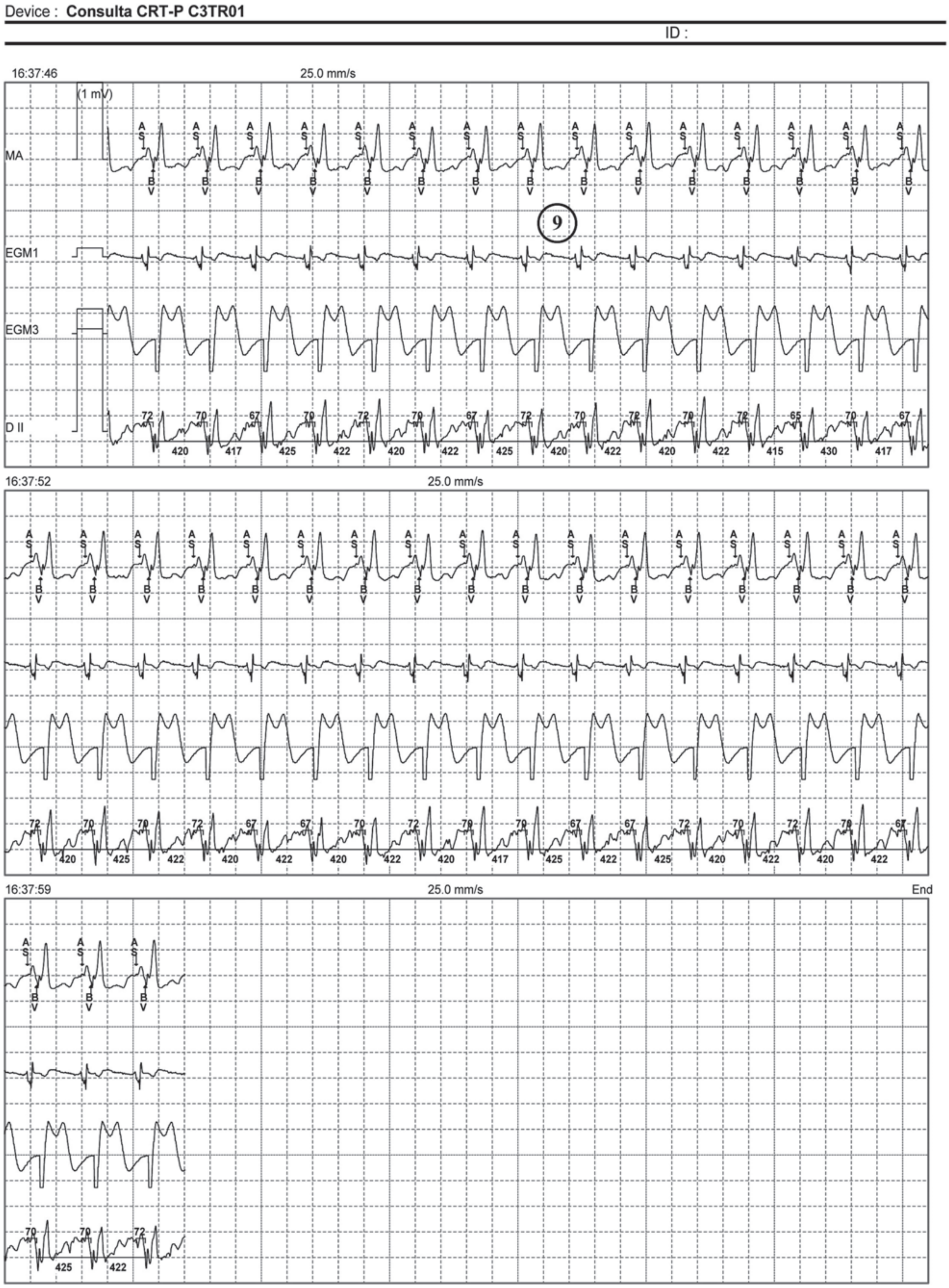
- 9: atrio-ventricular synchronization AS-BV 1/1;

Comments

This tracing focuses on the specific settings in young CRT patients with a complete atrioventricular block. A suitable setting of the device should 1) prevent the occurrence of the 2:1 block point, which is often associated with disabling symptoms. In this patient, the 2:1 block point was set too low. The total atrial refractory period (TARP) which defines the 2:1 block point is the sum AV delay + PVARP. In young patients, it is essential to push this 2:1 block point beyond the capacities of sinus acceleration. To do this, it is often necessary to 1) program a rate adaptive AV delay and an auto PVARP that adapts to the heart rate; 2) synchronize the biventricular pacing until the actual maximum heart rate reached by the patient. The Wenckebach behavior is most often less symptomatic than the 2:1 behavior but must be avoided by setting a sufficiently high upper tracking rate.


Device : Consulta CRT-P C3TR01
ID :
16:35:45
25.0 mm/s
(1 mV)
Markers
EGM1
EGM3
D II
1
2
3
16:35:51
25.0 mm/s
16:35:58
25.0 mm/s
End


Device : Consulta CRT-P C3TR01
ID :
16:38:54
25.0 mm/s
(1 mV)
Markers
EGM1
EGM3
D II
4
5
6
7
16:39:00
25.0 mm/s
8
16:39:07
25.0 mm/s
End


Device : Consulta CRT-P C3TR01
ID :
16:37:46
25.0 mm/s
(1 mV)
MA
EGM1
EGM3
D II
9
16:37:52
25.0 mm/s
16:37:59
25.0 mm/s
End

Tracing 4: undersensing during exercise

Patient

64-year-old man implanted with a triple chamber defibrillator Consulta CRT-D in the context of an ischemic cardiomyopathy with complete AV block; shortness of breath during exercise;

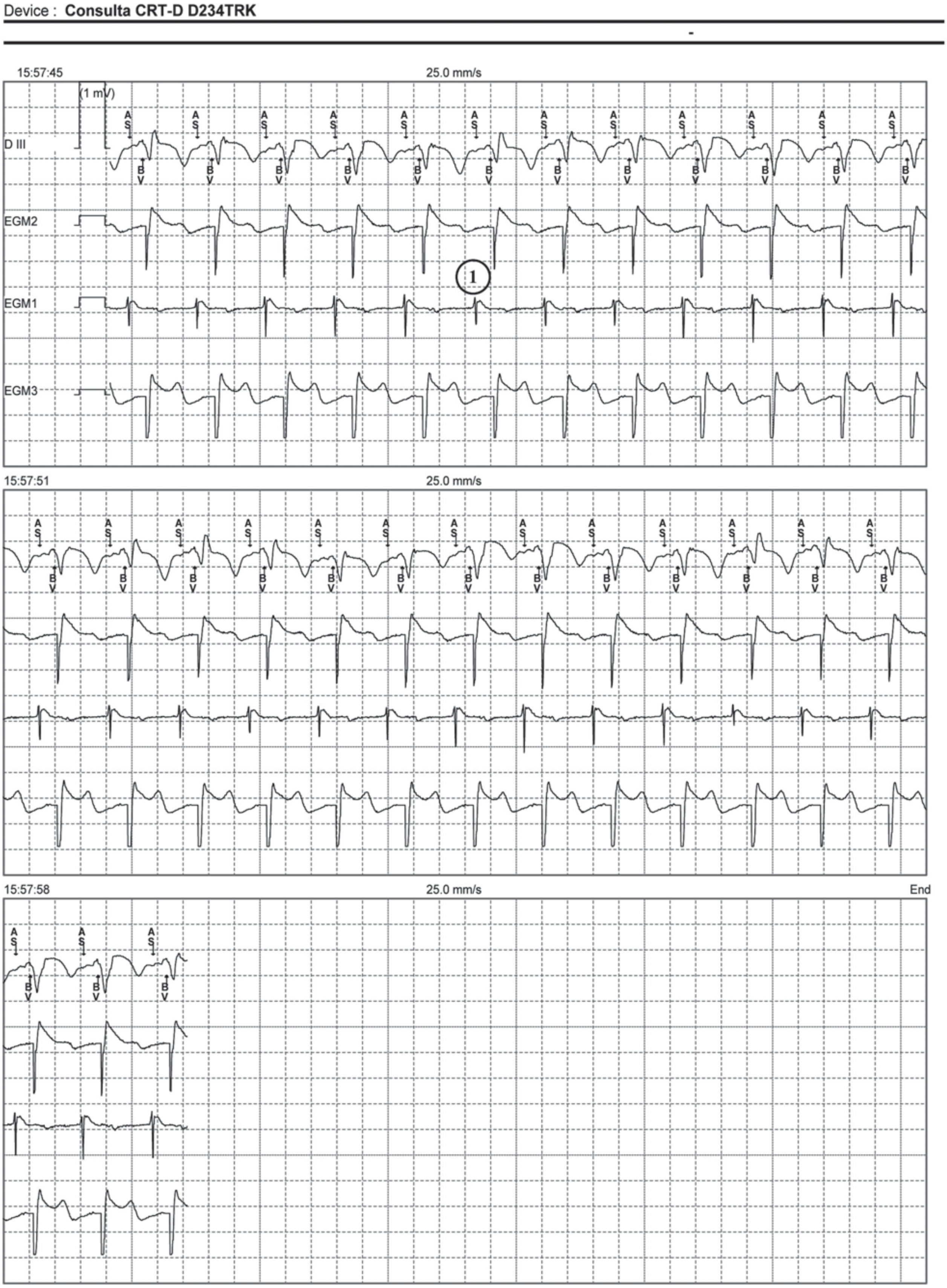
Tracing

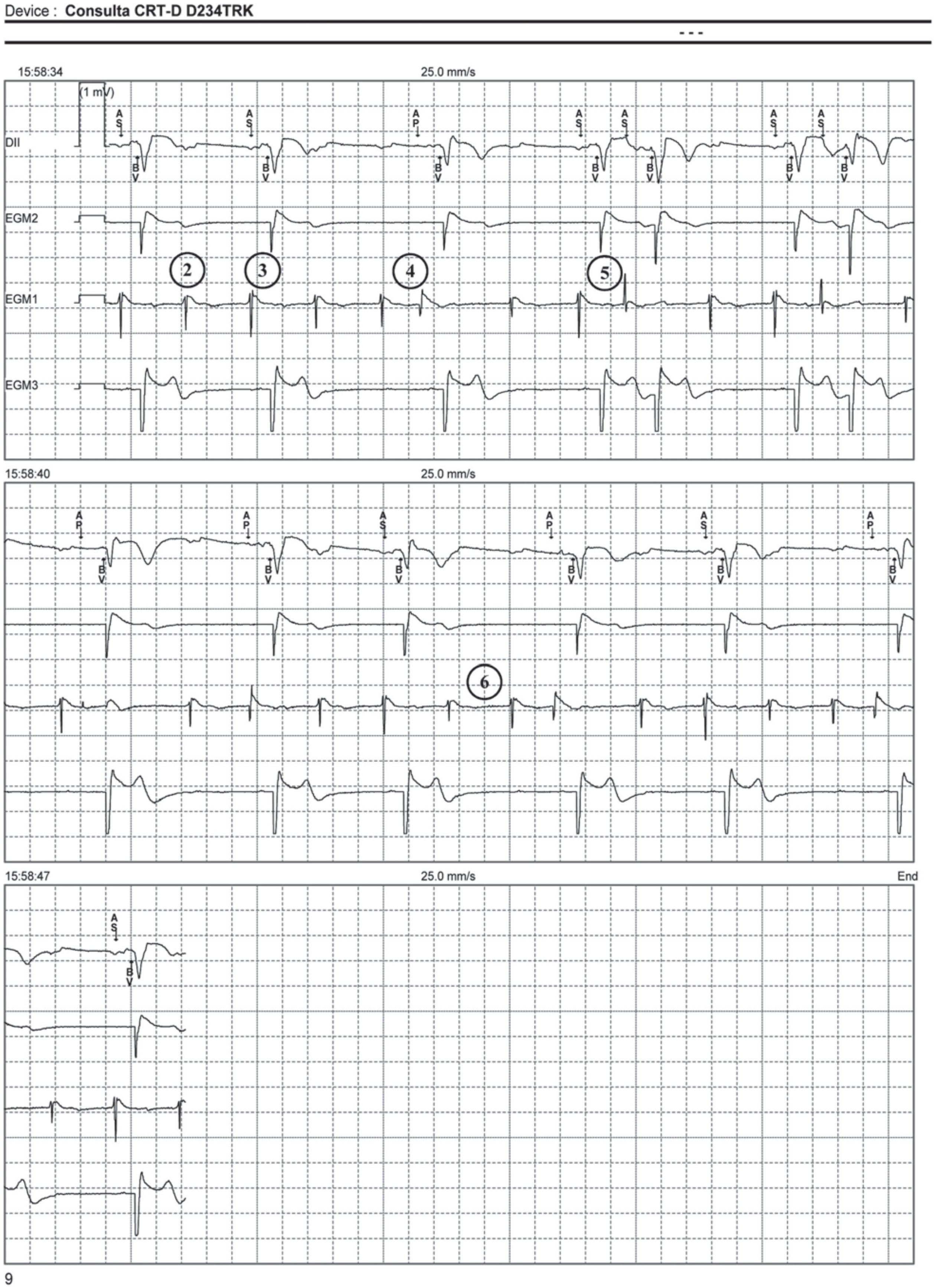
Stress test realized during the consultation (squats) with the telemetry wand placed over the device; atrial detection recently programmed at 0.8mV in the context of a ventriculo-atrial crosstalk; at rest, the atrial sensing is around 1.2mV; the first line corresponds to an ECG derivation with superimposed markers, the second line to the bipolar RV EGM, the third one to the bipolar atrial EGM and the fourth one to the far-field RV coil / LV tip EGM;

1: normal function AS-BV (shortening of the AV delay: rate adaptive AV delay); important variations of the atrial signal amplitude with the breathing;
2: at peak exercise (less than one minute after the previous tracing), persistent variation in the atrial signal amplitude; first undetected P-wave;
3: the next P-wave is detected (AS-BV cycle); pseudo-2:1 behavior aspect: one P-wave on 2 is undetected; sudden drop in the heart rate explaining the patients' symptoms;
4: prolonged episode of atrial undersensing with atrial stimulation at the minimal rate (rate responsive algorithm not activated, DDD mode);
5: transient recovery of the atrial detection (according to the breathing cycles);
6: alternation of detected and undetected P-waves with atrial stimulation;

Comments

This tracing illustrates the importance of a functional atrial lead for optimal resynchronization. This patient has intermittent episodes of atrial undersensing. The analysis of the atrial EGM demonstrates a large variability of the atrial signal amplitude with the breathing. In a patient with a preserved atrioventricular conduction, atrial undersensing is associated with the reappearing of spontaneous ventricles but no sudden drop of the heart rate and thus without significant symptoms. In contrast, in patients with a complete atrioventricular block (as in this case), the atrial undersensing causes a sudden drop in the heart rate and is often poorly tolerated. Atrial undersensing during exercise is the first cause of sudden rate drop during exercise, and is much more common than the 2:1 behavior, the ventricular oversensing or the loss of capture by the two ventricular leads (which are the other causes of sudden drop rate during exercise). In addition, the lack of adequate monitoring of the P-waves during exercise may also have a pro-arrhythmogenic effect if an atrial pacing is given during the vulnerable atrial period.


Device : Consulta CRT-D D234TRK
15:57:45
25.0 mm/s
(1 mV)
D III
EGM2
EGM1
EGM3
1
15:57:51
25.0 mm/s
15:57:58
25.0 mm/s
End



Device : Consulta CRT-D D234TRK
15:58:34
25.0 mm/s
(1 mV)
DII
EGM2
EGM1
EGM3
AS
AP
BV
2
3
4
5
15:58:40
25.0 mm/s
6
15:58:47
25.0 mm/s
End
9

Chapitre 6

Management of Arrhythmias and Leads Dysfunction

Management of arrhythmias and leads dysfunction

Resynchronization and atrial fibrillation

There is a vicious circle between heart failure and atrial fibrillation, one favoring the other and vice versa. The prevalence of atrial fibrillation in CRT candidates is high and increases with the functional class: approximately, 5% for patients in NYHA class I, 10 to 25% for patients in class II and III, 50% for patients in NYHA class IV. The presence atrial fibrillation reduces the probability of positive response after resynchronization, the complete and permanent biventricular capture (an essential prerequisite), being impaired in some patients with atrial fibrillation. A certain number of patients with atrial fibrillation present a rapid and irregular ventricular rhythm incompatible with a permanent LV capture. In addition, patients with atrial fibrillation are not resynchronized at the atrioventricular level that also contribute to the lower prevalence of positive results after resynchronization when compared to patients in sinus rhythm.

In a resynchronized patient, it is necessary to be relatively aggressive in the therapeutic approach to maintain the sinus rhythm as long as possible or to control the ventricular response.
The different therapeutic options include

1) the introduction of a loading dose of amiodarone and/or the electrical cardioversion of the patient; 2) treatment with amiodarone or ablation of the pulmonary veins and the left atrial substrate to maintain the sinus rhythm
3) introduction of rate control agents to maintain the heart rate as low as possible and promote biventricular pacing
4) programming specific algorithms forcing the stimulation on a detected ventricular activity and
5) ablation of the His bundle to suppress any competition between spontaneous rhythm and paced rhythm. The radiofrequency ablation of the atrioventricular junction is a well-validated treatment for restoring an adapted heart rate and a permanent biventricular pacing at rest as during exercise (with the programming of a rate responsive function).

The programming of algorithms forcing the ventricular stimulation on a detected ventricular event (pseudo-VVT mode) in a patient with AF seems poorly efficient because the heart rate remains high and progressive fusion with the spontaneous ventricular activity remains incomplete or absent (pseudo-fusion).
The ablation of the pulmonary veins and the left atrial substrate has been proposed even though the results in patients with heart failure and enlarged left atrium are sometimes imperfect.
Therefore, it seems logical to try first to restore and maintain the sinus rhythm to preserve atrial contribution to the LV filling and maintain a physiological rate at rest and during exercise. If this strategy fails, we prefer to control the ventricular response with a beta-blocker. In case of unsatisfactory results, we do not hesitate to propose the ablation of the His bundle since patients with a preserved AV conduction and low percentage of stimulation do not benefit from the resynchronization therapy.
It is also possible to program a number of algorithms that aim to prevent the occurrence of atrial fibrillation by using different mechanisms: increasing the percentage of atrial pacing, reducing the post-PVC pauses, non-competitive atrial pacing. There is yet no evidence of the effectiveness of these types of algorithms in CRT patients.

Resynchronization and defibrillation function

Discrimination of the arrhythmias with Medtronic CRT devices is based on the analysis of the PR Logic as described in the book on the defibrillators.
The new triple chamber defibrillator platform from Medtronic is equipped with new algorithms to optimize the discrimination and reduce the occurrence of inappropriate therapies in case of lead dysfunction or T-wave oversensing:
- the T-Wave Discrimination algorithm
- the Lead Integrity Alert (LIA)
- the lead noise discrimination

Tracing 1: decrease of the percentage of biventricular pacing due to frequent ventricular extrasystoles

Patient

68 years old man implanted with a triple chamber defibrillator Viva XT CRT-D for ischemic cardiomyopathy with left bundle branch block; non-responder to cardiac resynchronization; percentage of biventricular pacing of 78%;

Tracing

The first line corresponds to an electrocardiographic derivation with superimposed markers; the second line corresponds to the right ventricular EGM, and the third line to the right atrial EGM;

1: sinus rhythm and biventricular pacing (AS-BV);

2: ventricular extrasystole with atrial detection included in the post ventricular atrial blanking;

3: alternation of a biventricular stimulation and a PVC: ventricular bigeminism susceptible to explain the decrease in the percentage of biventricular stimulation;

4: persistent ventricular bigeminism;

Modification of the programming (increase of the minimal heart rate form 55 to 70bpm);

5: disappearing of the PVC and percentage of ventricular pacing at 100% during the rest of the consultation;

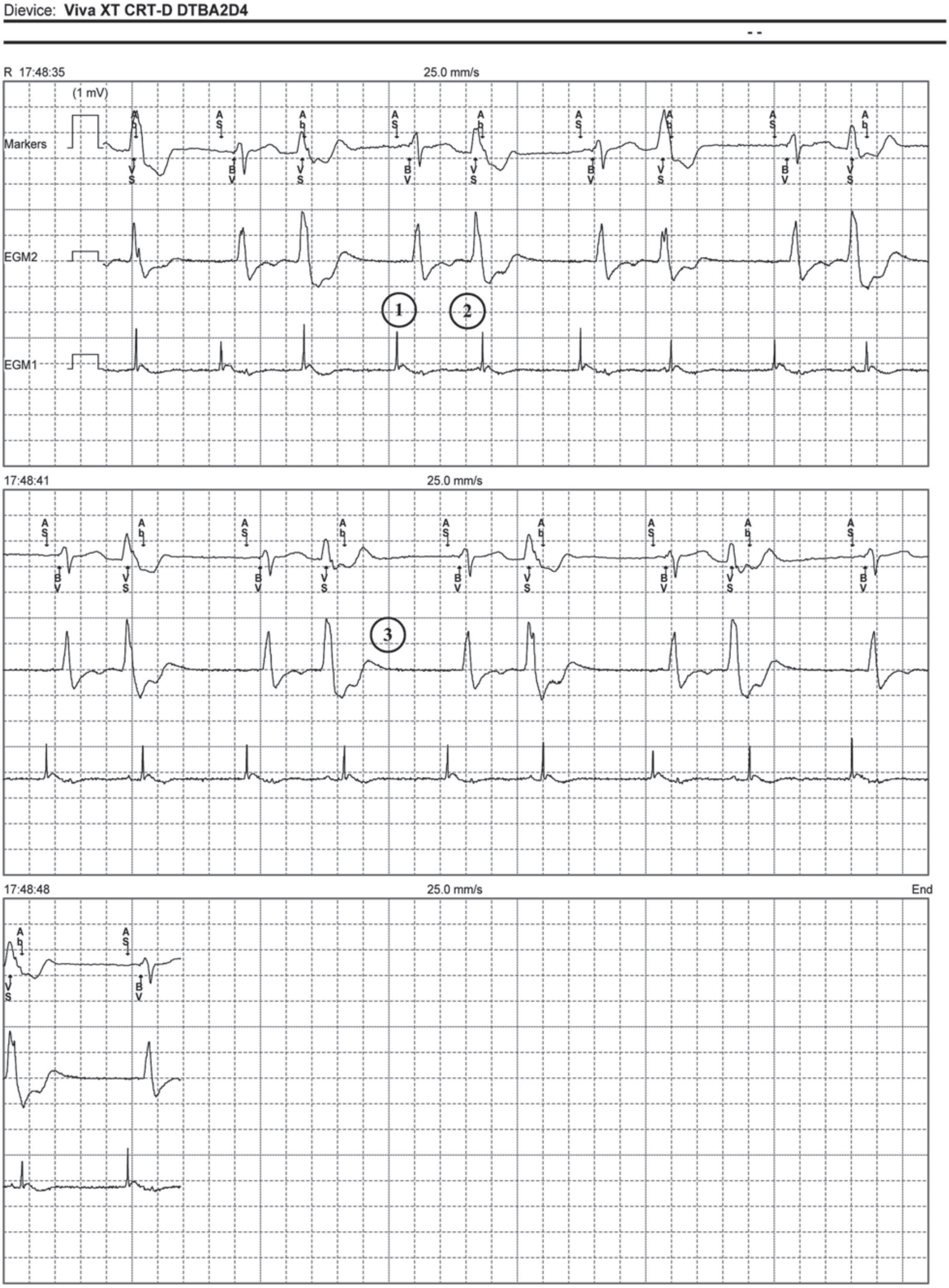
Comments

Frequent ventricular extrasystoles, isolated or paired, bigeminism or trigeminism, at rest or during exercise, is a common cause of decrease in the percentage of biventricular pacing. It also causes a relative bradycardia as the PVCs are relatively ineffective from an hemodynamical point of view. In a resynchronized patient, the evolution of the frequency of PVCs should be continuously monitored because they can be promoted by metabolic disorders and induced by drugs, or express the worsening underlying heart disease, or even being at the origin of clinical decompensation. In non-responder patients, suppressing the PVCs is a priority to allow an increase in the percentage of biventricular pacing and thus expect a positive response to the resynchronization therapy. Different options are possible:

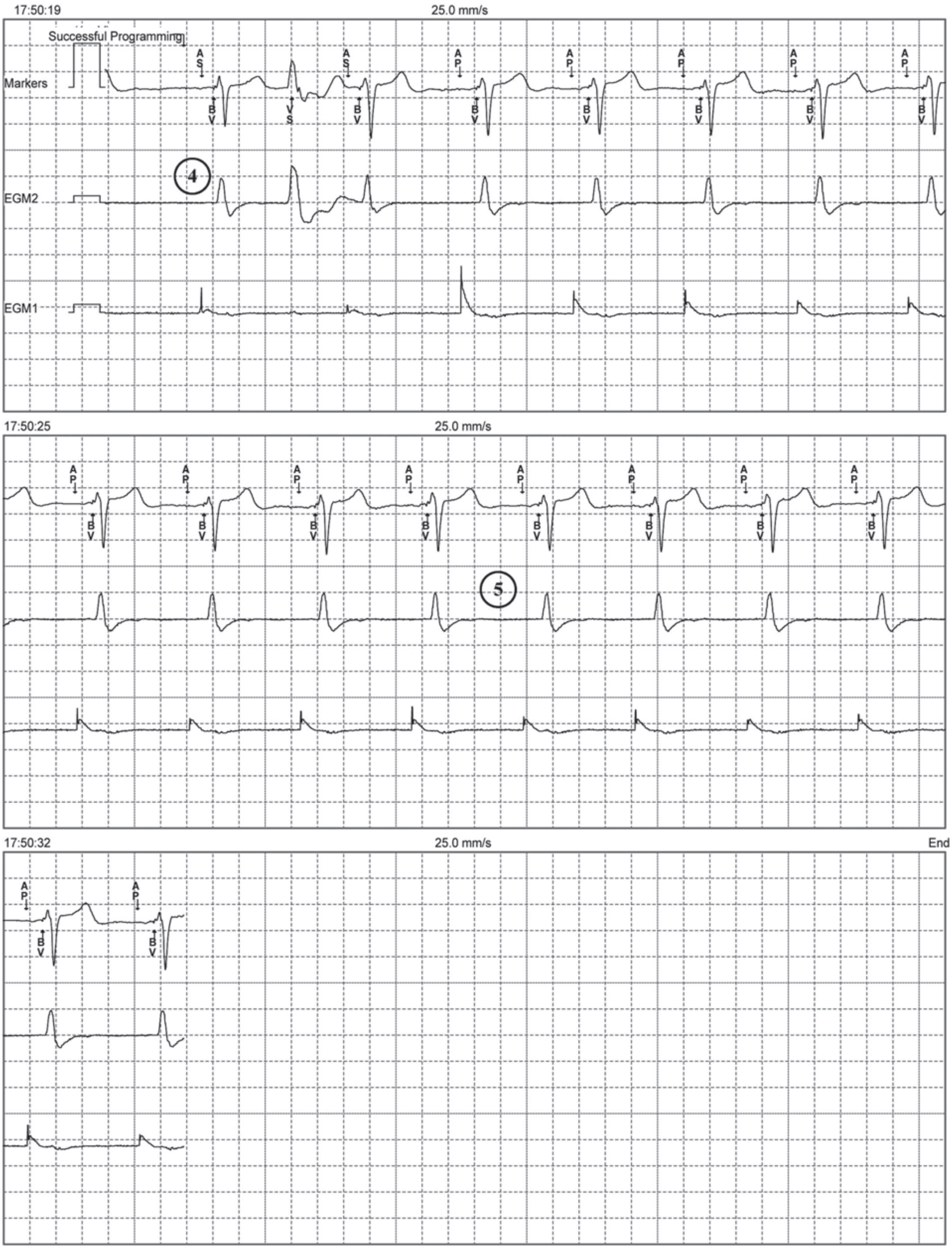
1) in this patient, an increase in the minimum rate at 70 bpm has eliminated the PVCs. A rate responsive function has also been programmed to force the atrial pacing during exercise. The effect of this type of programming on the PVC is however often incomplete or only temporarily effective. Moreover, it is occasionally necessary to program a relatively high heart rate at rest (> 80 bpm), which is difficult to accept on the long term in those patients with a severe heart failure;

2) the anti-arrhythmic drug therapy (beta-blockers, amiodarone) are rarely effective in this context;

3) In the presence of monomorphic extrasystole, a radiofrequency ablation procedure can be proposed. This last option is indicated in cases of impaired hemodynamic status. The evaluation of the correlation between the functional and the clinical abnormalities is essential for the decision making process.


Dievice: Viva XT CRT-D DTBA2D4
R 17:48:35
25.0 mm/s
(1 mV)
Markers
EGM2
EGM1
1
2
17:48:41
25.0 mm/s
3
17:48:48
25.0 mm/s
End

Device: **Viva XT CRT-D DTBA2D4**



Tracing 2: decrease in the percentage of biventricular pacing due to non sustained atrial and ventricular arrhythmias

Patient

47 years old man implanted with a triple chamber defibrillator Viva XT for dilated cardiomyopathy with left bundle branch block; routine follow-up; several episodes of non-sustained VT recorded by the device;

Plot

1: atrio-ventricular rhythm 1/1;
2: simultaneous acceleration of the atrial and the ventricular rhythm;
3: end of the episode;

Tracing

4: atrial detection and biventricular pacing (AS-BV);
5: the episode starts with a premature atrial contraction (suggesting an atrial tachycardia); the first atrial cycle is labeled AR because it falls in the PVARP of the previous AS-BV cycle, and does not trigger a new AV delay; spontaneous AV conduction with a long PR interval, the QRS is sensed and labeled VS; at the second cycle of the tachycardia, the PR interval prolongs again and the third cycle of the tachycardia falls in the post-ventricular atrial blanking (labeled Ab); in the next cycles, the PR interval shortens because the atrial rate slows-down, and the atrial cycles are labeled AR;
6: tachycardia at 170bpm with spontaneous ventricular rhythm;
7: the episode ends with no atrial event (in favor of atrial tachycardia);
8: end of the episode;

Text

9: episode wrongly classified as non-sustained VT;

Plot

10: atrio-ventricular rhythm;
11: acceleration of the ventricular rhythm without any modification of the atrial rhythm, suggesting a non-sustained ventricular arrhythmia;
12: end of the episode;

Tracing

13: atrial detection and biventricular pacing (AS-BV);
14: non-sustained VT: onset with a premature ventricular beat; detection of a fast ventricular rhythm at 190 bpm (TS); atrio-ventricular dissociation with more V than A;
15: spontaneous termination of the arrhythmia and end of the episode;

Text

16: episode diagnosed as « non-sustained VT »;

Comments

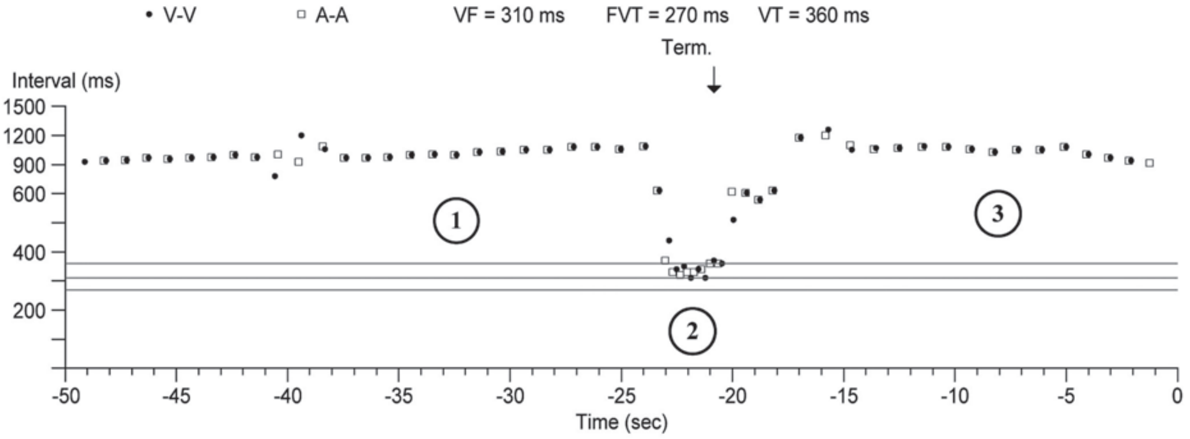
This patient presented with many episodes of non-sustained VT correctly diagnosed by the device but also many episodes of misdiagnosed atrial tachycardia (false diagnosis of non-sustained VT). This example illustrates the need to review all the episodes and control the diagnosis made by the device. Non-sustained VT and atrial tachycardia are common causes of temporary interruption of biventricular pacing. In this case, a treatment with amiodarone was introduced but did not strongly influence the occurrence of the different types of arrhythmias.

Non-sustained VT Episode #12

Device: **Viva XT CRT-D DTBA2D4** Serial Number: Date of Visit: **16-Apr-2013 09:05:23**

Patient: ID: Physician:

Type	ATP Seq	Shocks	Success	ID#	Date	Time hh:mm	Duration hh:mm:ss	Avg bpm A/V	Max bpm A/V	Activity at Onset
VT-NS				12	31-Mar-2013	05:45	:01	167/194		Rest



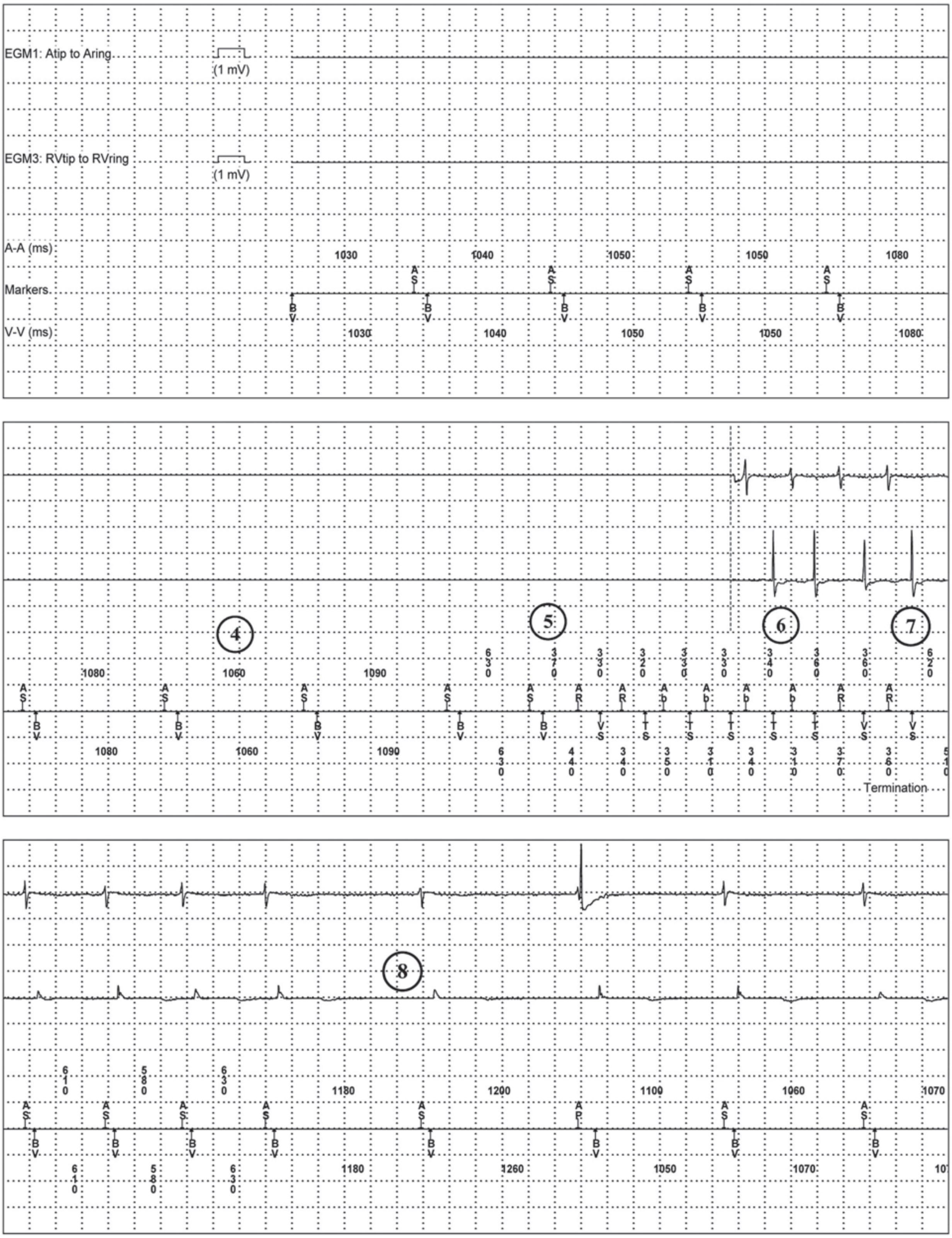
Page 1

Non-sustained VT Episode #12
Printed: **12-Feb-2014 12:29:23**

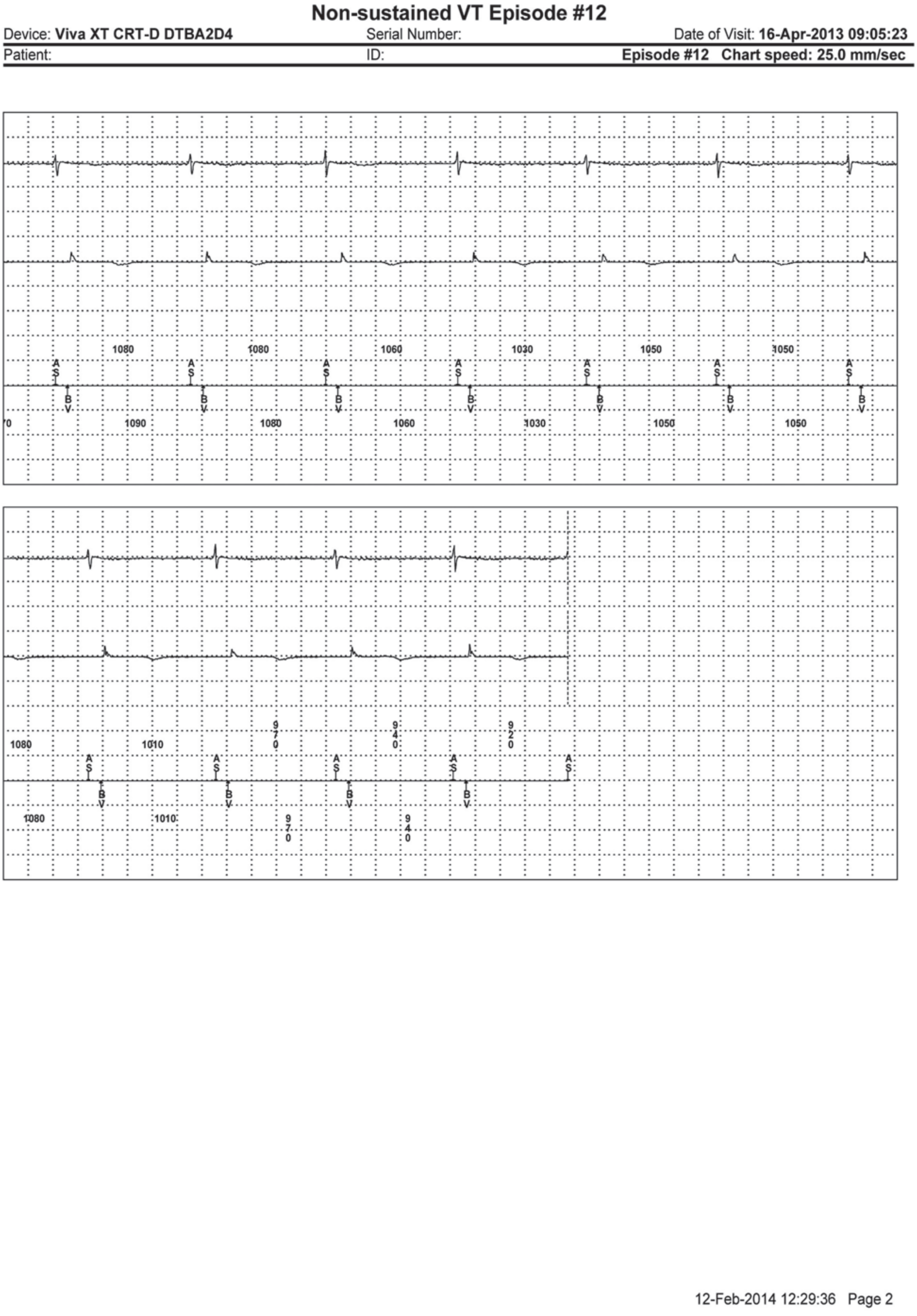
Non-sustained VT Episode #12

Device: **Viva XT CRT-D DTBA2D4** Serial Number: Date of Visit: **16-Apr-2013 09:05:23**

Patient ID: **Episode #12 Chart speed: 25.0 mm/sec**



12-Feb-2014 12:29:36 Page 1


Non-sustained VT Episode #12
Device: Viva XT CRT-D DTBA2D4
Serial Number:
Date of Visit: 16-Apr-2013 09:05:23
Patient:
ID:
Episode #12 Chart speed: 25.0 mm/sec
12-Feb-2014 12:29:36 Page 2

Non-sustained VT Episode #12

Device: **Viva XT CRT-D DTBA2D4** Serial Number: Date of Visit: **16-Apr-2013 09:05:23**

Patient: ID: Physician: - - -

Episode #12: 31-Mar-2013 05:45:40

Episode Summary	
Initial Type	VT Non-sustained (spontaneous)
Duration	1 sec (5 beats)
V. Median	136 bpm (440 ms)
Activity at onset	Rest, Sensor = 53 bpm

Parameter Settings		**Initial**	**Redetect**	**V. Interval (Rate)**
VF	On	24/32	12/16	310 ms (194 bpm)
FVT	via VF			270 ms (222 bpm)
VT	On	16	12	360 ms (167 bpm)
Monitor	Off	28		

9

Polarity	**RV**
Pace Polarity	Bipolar
Sense Polarity	Bipolar

EGM	**Source**	**Range**	**Sensitivity**	
EGM1	Atip to Aring	+/- 8 mV	Atrial	0.3 mV
EGM3	RVtip to RVring	+/- 8 mV	RV	0.3 mV

Page 1

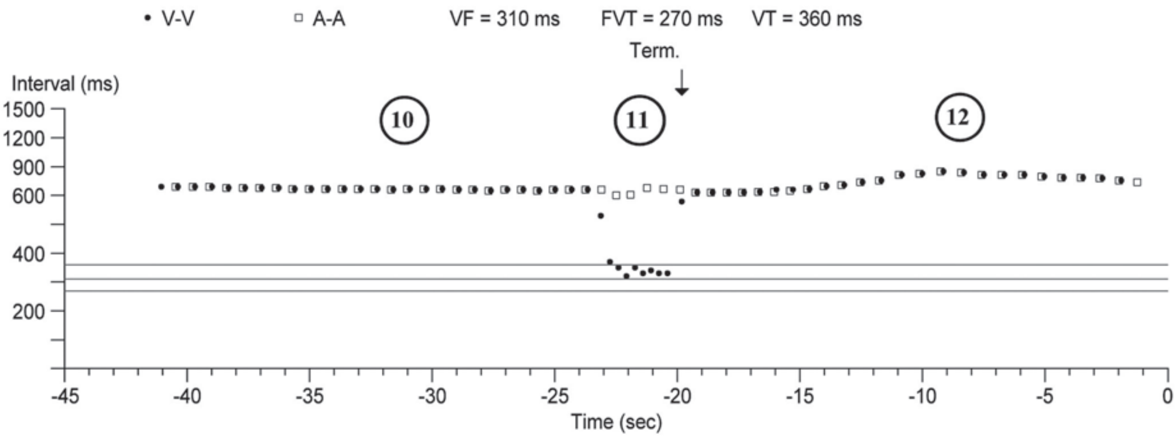
Non-sustained VT Episode #12
Printed: **12-Feb-2014 12:30:05**

Non-sustained VT Episode #8

Device: **Viva XT CRT-D DTBA2D4** Serial Number: Date of Visit: **16-Apr-2013 09:05:23**

Patient: ID: Physician: - -

Type	ATP Seq	Shocks	Success	ID#	Date	Time hh:mm	Duration hh:mm:ss	Avg bpm A/V	Max bpm A/V	Activity at Onset
VT-NS				8	17-Mar-2013	20:14	:01	90/180		Active



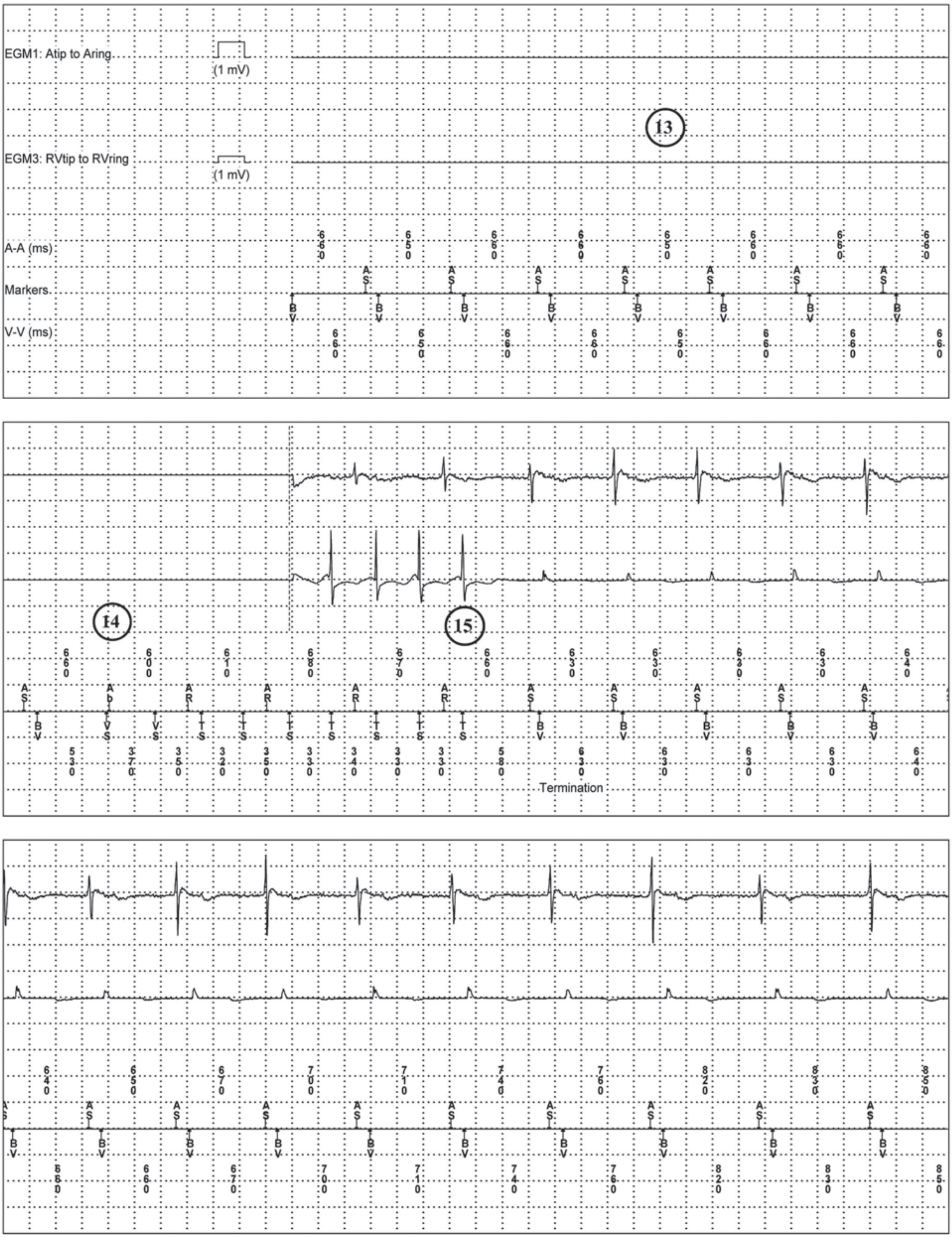
Page 1

Non-sustained VT Episode #8
Printed: **12-Feb-2014 12:30:20**

Non-sustained VT Episode #8

Device: **Viva XT CRT-D DTBA2D4** Serial Number: Date of Visit: **16-Apr-2013 09:05:23**

Patient: ID: **Episode #8 Chart speed: 25.0 mm/sec**

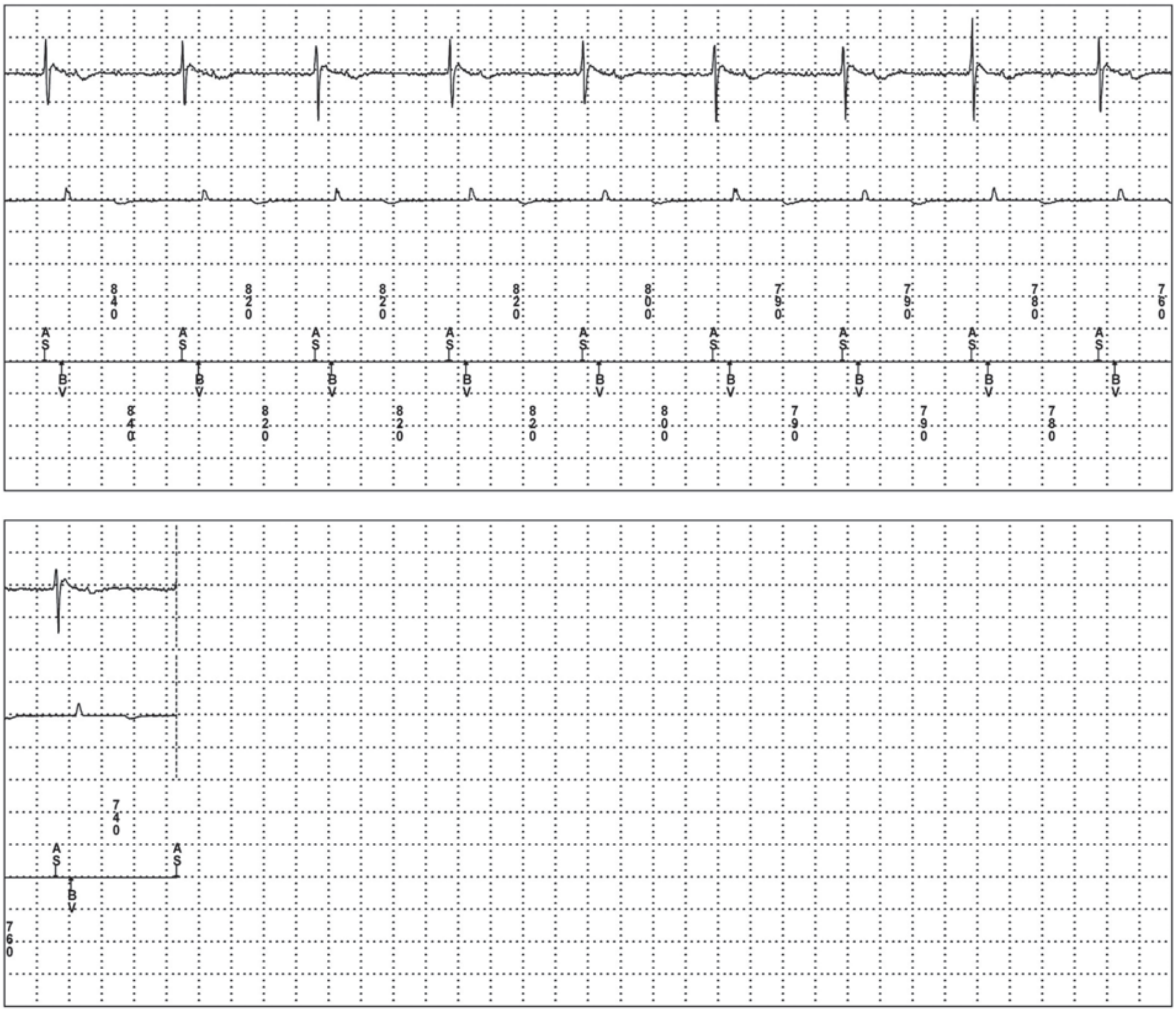


12-Feb-2014 12:30:36 Page 1

Non-sustained VT Episode #8

Device: **Viva XT CRT-D DTBA2D4** Serial Number: Date of Visit: **16-Apr-2013 09:05:23**

Patient: ID: **Episode #8 Chart speed: 25.0 mm/sec**



12-Feb-2014 12:30:36 Page 2

Non-sustained VT Episode #8

Device: **Viva XT CRT-D DTBA2D4**	Serial Number:	Date of Visit: **16-Apr-2013 09:05:23**
	ID:	Physician: - - -

Episode #8: 17-Mar-2013 20:14:03

Episode Summary	
Initial Type	VT Non-sustained (spontaneous)
Duration	1 sec (7 beats)
V. Median	171 bpm (350 ms)
Activity at onset	Active, Sensor = 90 bpm

Parameter Settings		**Initial**	**Redetect**	**V. Interval (Rate)**
VF	On	24/32	12/16	310 ms (194 bpm)
FVT	via VF			270 ms (222 bpm)
VT	On	16	12	360 ms (167 bpm)
Monitor	Off	28		

Polarity	**RV**
Pace Polarity	Bipolar
Sense Polarity	Bipolar

EGM	**Source**	**Range**	**Sensitivity**	
EGM1	Atip to Aring	+/- 8 mV	Atrial	0.3 mV
EGM3	RVtip to RVring	+/- 8 mV	RV	0.3 mV

Page 1

Non-sustained VT Episode #8
Printed: **12-Feb-2014 12:31:05**

Tracing 3: decrease in the percentage of biventricular pacing due to ventricular tachycardia

Patient

66 years old man implanted with a triple chamber defibrillator Protecta XT for very severe ischemic cardiomyopathy with left bundle branch block; episode of cardiac decompensation and palpitations;

Plots

1: atrio-ventricular rhythm 1/1;
2: acceleration of the ventricular rhythm (in the VT zone) with no modification of the atrial rhythm;
3: the ventricular rhythm remains faster than the atrial rhythm but stays under the VT zone;

Tracing

4: atrial rhythm and biventricular pacing (AS-BV);
5: onset of the episode triggered by a ventricular extrasystole; VT with AV dissociation in the VT zone and labeled (TS);
6: slowing of the tachycardia rate below the VT zone; false diagnosis of tachycardia termination;
7: slowing of the VT rate around 150 bpm;

Comments

This tracing demonstrates the difficulty of managing relatively slow VTs. In this patient, the tachycardia rate was too low to be treated and the VT lasted for several hours. Finally, it was responsible for an episode of cardiac decompensation, related to different mechanisms: loss of biventricular pacing, tachycardia, atrioventricular dissociation... Lowering the lower limit of the VT zone allowed for the treatment of this arrhythmia by anti-tachycardia pacing and prevented the occurrence of a new episode of cardiac decompensation.

Non-sustained VT Episode #53 Serial Number:

Device : **Protecta XT CRT-D D354TRG**

Date of visit : **11-Jun-2013 10:34:22**

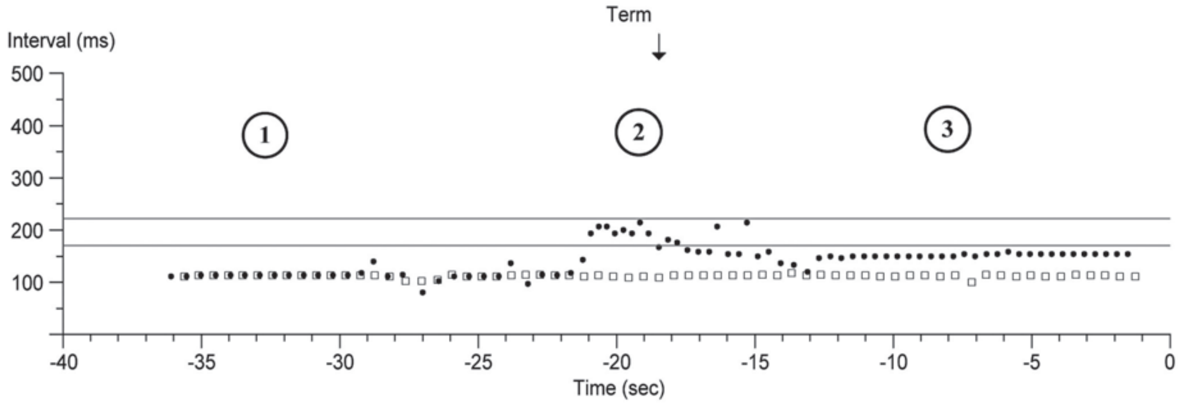
Patient :

ID :

Physician :

Type	ATP Seq	Shocks	Success	ID#	Date	Time hh:mm	Duration hh:mm:ss	Avg bpm A/V	Max bpm A/V	Activity at Onset
VT-NS				53	28-Apr-2013	09:12	:01	110/200		Rest

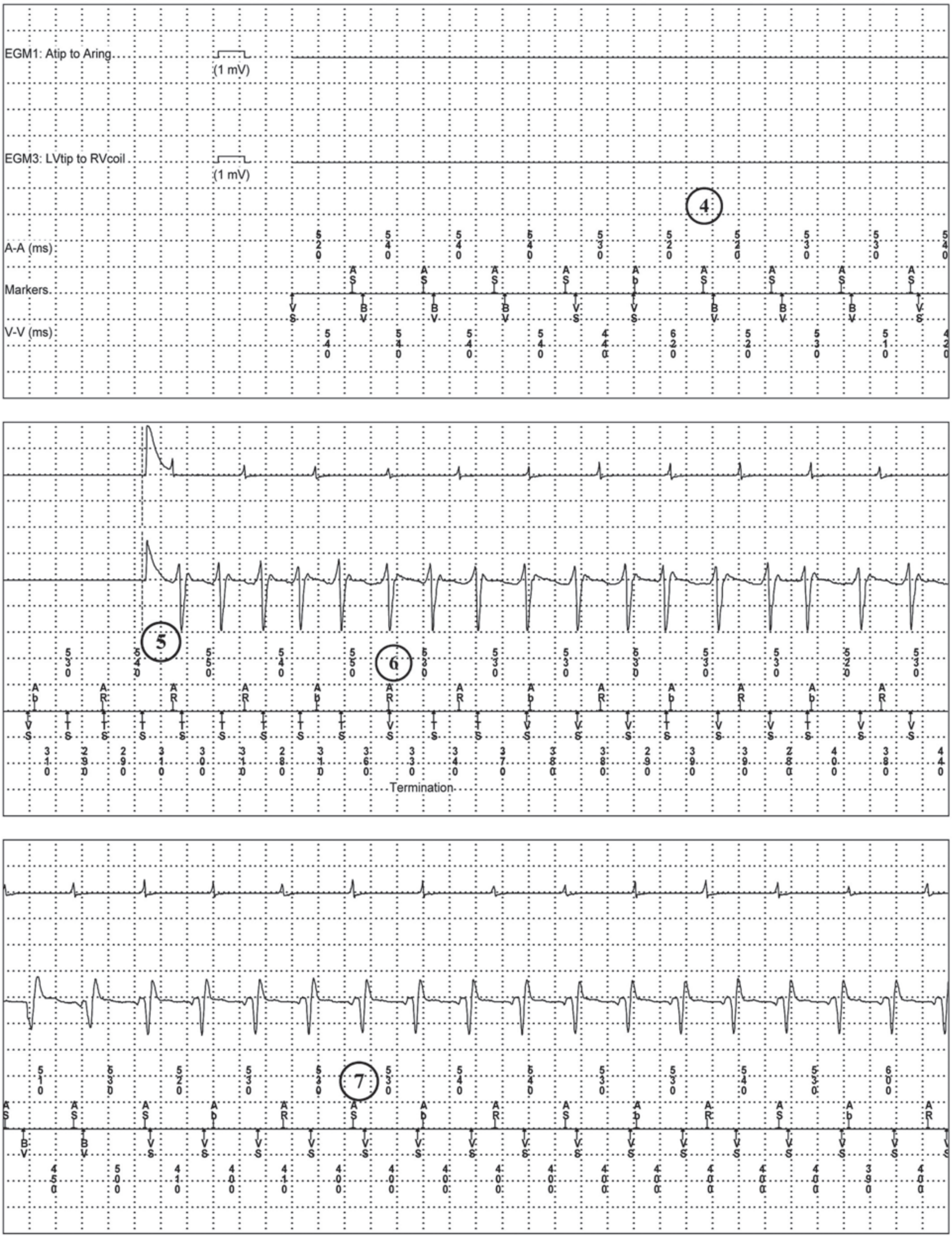
• V-V ▫ A-A VF = 222 ms VT = 171 min-¹



Non-sustained VT Episode #53

Device: **Protecta XT CRT-D D354TRG** Serial Number: Date of Visit: **12-Jun-2013 13:35:04**

Patient: **-** ID: **Episode #53 Chart speed: 25.0 mm/sec**



12-Feb-2014 12:39:06 Page 1

Non-sustained VT Episode #53

Device: **Protecta XT CRT-D D354TRG** Serial Number: Date of Visit: **12-Jun-2013 13:35:04**

Patient: ID: **Episode #53 Chart speed: 25.0 mm/sec**

12-Feb-2014 12:39:06 Page 2

Tracing 4: loss of biventricular pacing due to a prolonged episode of atrial arrhythmias

Patient

72 years old man implanted with a triple chamber defibrillator Viva XT CRT-D for ischemic cardiomyopathy with atypical bundle branch block and episodes of atrial fibrillation; device interrogation performed a few days after implant;

Tracing

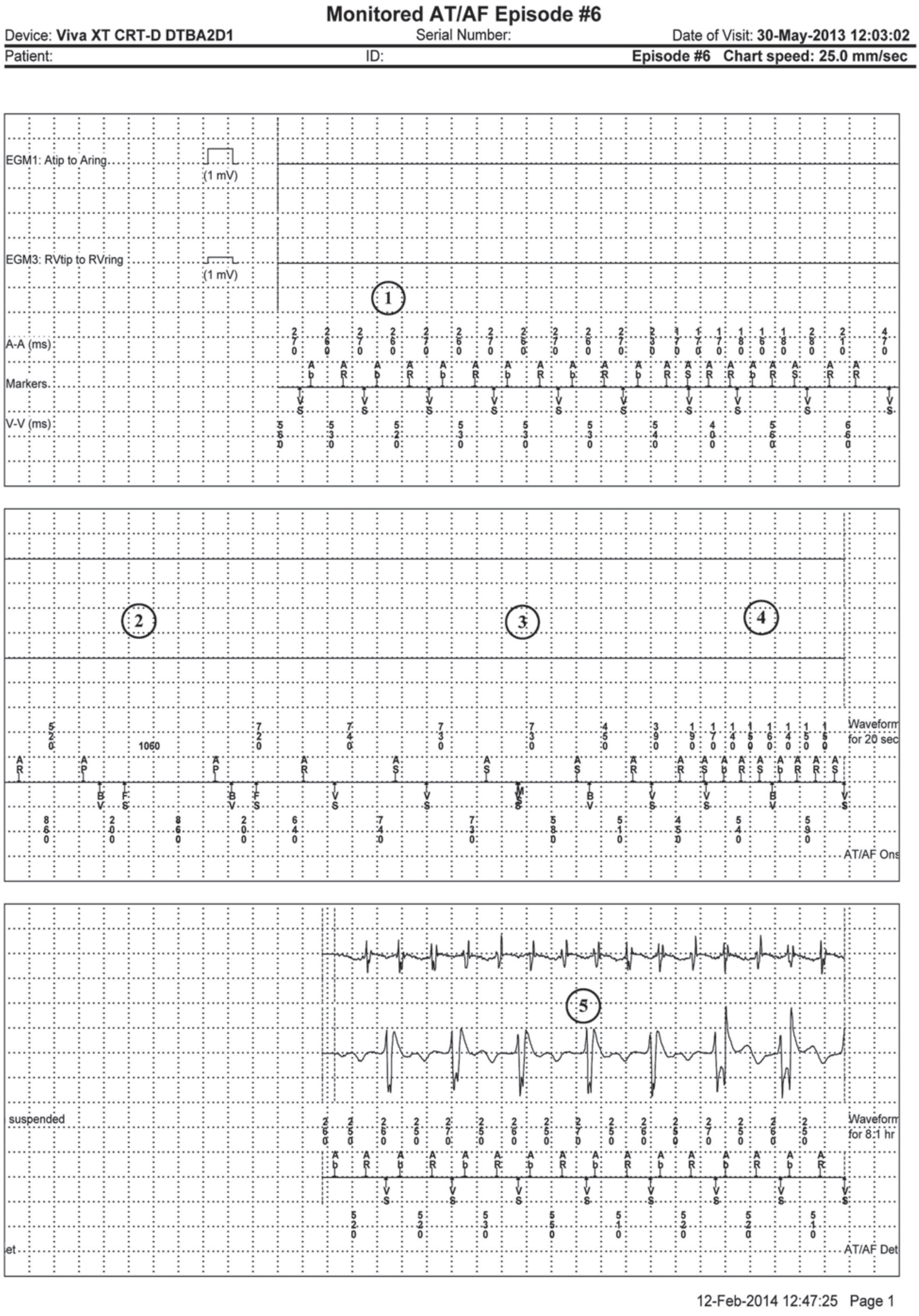
1: probable atrial arrhythmia with a 2/1 atrioventricular conduction and conducted ventricular activities, acceleration of the atrial arrhythmia followed by…
2: the termination of the atrial arrhythmia;
3: commutation (MS) to DDD mode with recovery of the atrioventricular synchronization;
4: recurrence of the arrhythmia rapidly conducted first then …
5: atrial tachycardia followed by a 2/1 atrio-ventricular response;

Interruption of the recording

6: degradation of the atrial arrhythmia in atrial fibrillation with the persistence of an irregular spontaneous ventricular response;
7: spontaneous termination of the atrial arrhythmia;
8: commutation (MS) to DDD mode;
9: recovery of a biventricular pacing;
10: the episode summary indicates that the episode lasted 8 hours (plot in the range > 220/min);
11: plot of atrial rate indicating episodes of atrial fibrillation rapidly conducted to the ventricles;
12: except for the episodes of atrial arrhythmia, the biventricular pacing is nearly permanent;
13: these plots also show that during the episodes of atrial arrhythmia, fast spontaneous ventricular rhythms are detected from 80 to 140 bpm;

Comments

Atrial fibrillation is probably the most common cause of prolonged loss of biventricular pacing in resynchronized patients with a preserved atrioventricular conduction. These episodes are regularly associated with a rapid deterioration of the hemodynamics by several combined mechanisms: increased heart rate, irregular ventricular rhythm with short diastole and LV filling disorder, loss of atrial systole and loss of biventricular resynchronization… This patient had multiple episodes of paroxysmal atrial arrhythmias that were not effectively controlled by the antiarrhythmic treatment. He was successfully treated by a pulmonary vein isolation procedure. The combined effect of ablation and resynchronization resulted in a significant improvement of the patient's symptomatology and in a reduction of the ventricular volumes.

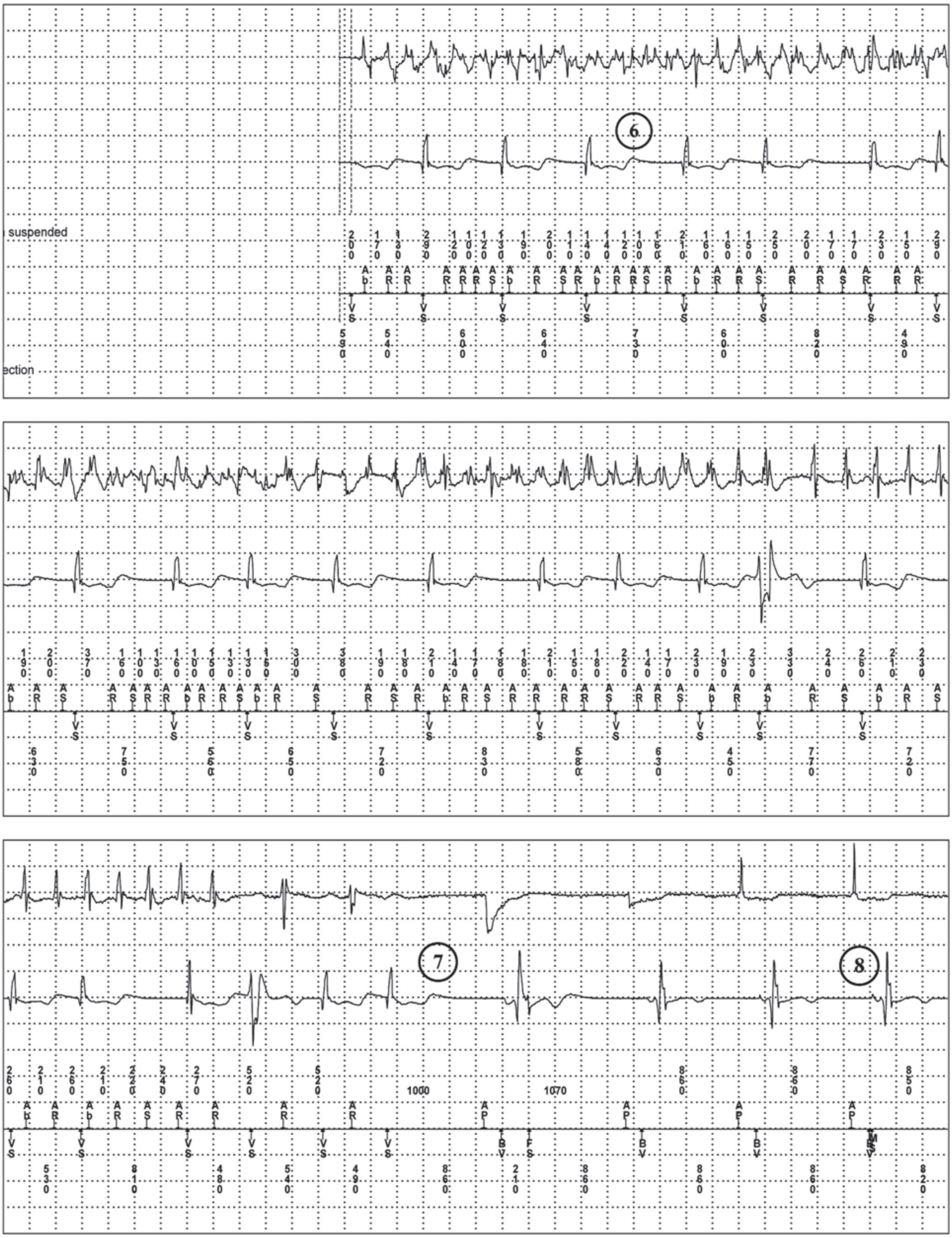


Monitored AT/AF Episode #6
Device: Viva XT CRT-D DTBA2D1
Serial Number:
Date of Visit: 30-May-2013 12:03:02
Patient:
ID:
Episode #6 Chart speed: 25.0 mm/sec
EGM1: Atip to Aring
(1 mV)
EGM3: RVtip to RVring
(1 mV)
A-A (ms):
Markers
V-V (ms):
1
2
3
4
5
1060
Waveform for 20 sec
AT/AF Ons
suspended
Waveform for 8.1 hr
AT/AF Det
12-Feb-2014 12:47:25 Page 1

Monitored AT/AF Episode #6

Device: **Viva XT CRT-D DTBA2D1** Serial Number: Date of Visit: **30-May-2013 12:03:02**

Patient: ID: **Episode #6 Chart speed: 25.0 mm/sec**

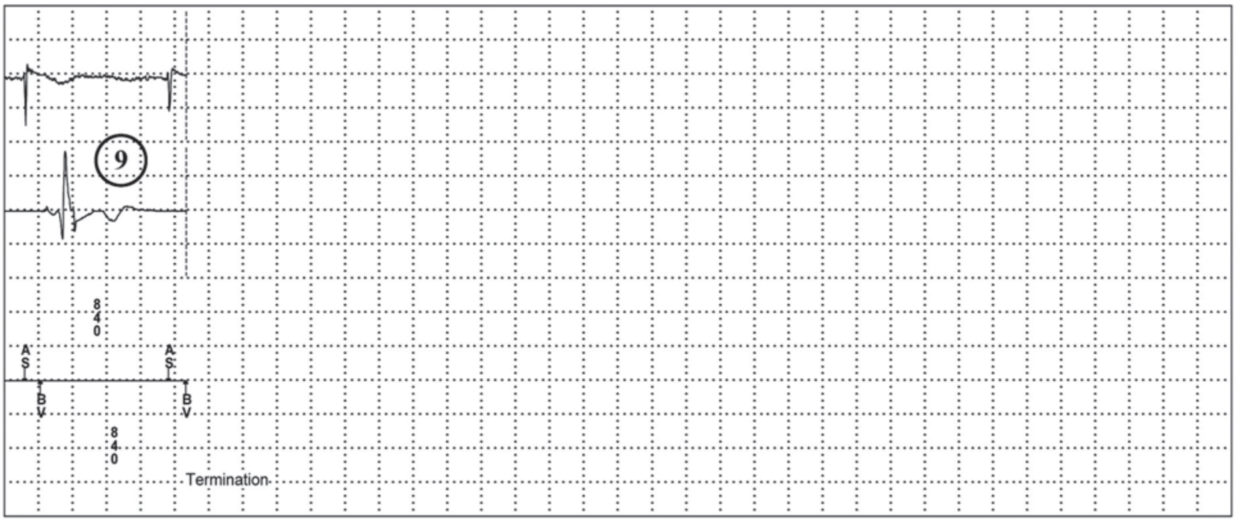


12-Feb-2014 12:47:25 Page 2

Monitored AT/AF Episode #6

Device: **Viva XT CRT-D DTBA2D1** Serial Number: Date of Visit: **30-May-2013 12:03:02**

Patient: ID: **Episode #6 Chart speed: 25.0 mm/sec**



12-Feb-2014 12:47:25 Page 3

Monitored AT/AF Episode #6

Device: **Viva XT CRT-D DTBA2D1** Serial Number: Date of Visit: **30-May-2013 12:03:02**

Patient: ID: Physician: - - -

Episode #6: 27-May-2013 12:18:23

Episode Summary	
Initial Type	AT/AF Monitor (spontaneous)
Duration	8.1 hr
A/V Max Rate	545 bpm/140 bpm
A. Median	231 bpm (260 ms)
Activity at onset	Rest, Sensor = 70 bpm

(10)

Parameter Settings		Zones		A. Interval (Rate)
AT/AF	Monitor	1	AT/AF	350 ms (171 bpm)

Polarity	RV
Pace Polarity	Bipolar
Sense Polarity	Bipolar

EGM	Source	Range	Sensitivity	
EGM1	Atip to Aring	+/- 8 mV	Atrial	0.3 mV
EGM3	RVtip to RVring	+/- 8 mV	RV	0.3 mV

Page 1

Monitored AT/AF Episode #6
Printed: **12-Feb-2014 12:47:52**

Rate Histograms

Device: **Viva XT CRT-D DTBA2D1** | Serial Number: | Date of Visit: **30-May-2013 12:03:02**

Patient: | ID: | Physician: - - -

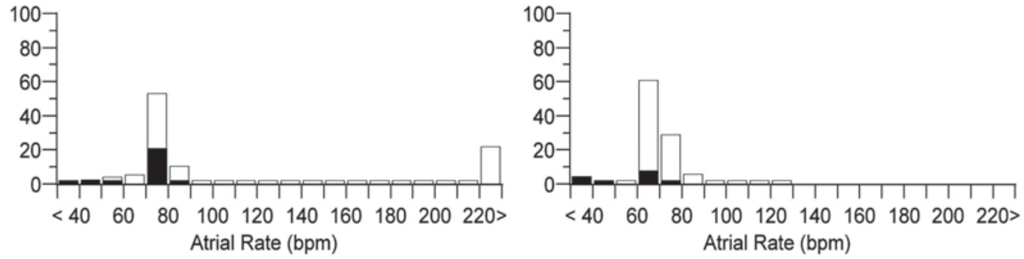
		Prior to Last Session 27-May-2013 to 29-May-2013 2 days	Since Last Session 29-May-2013 to 30-May-2013 22 hours
% of Time	**AS-VS**	19.3 %	1.8 %
	AS-VP	51.6 %	85.3 %
	AP-VS	< 0.1%	< 0.1%
	AP-VP	29.1 %	12.9 %
	Total VP	72.0 %	96.1 %
	VSR Pace	0.0 %	0.0 %
	VS	28.0 %	3.9 %
	CRT Pacing		
	Bi-V	99.9 %	100.0 %
	LV	(11) 0.0 %	0.0 %

Atrial

% of Time

□ AS

■ AP

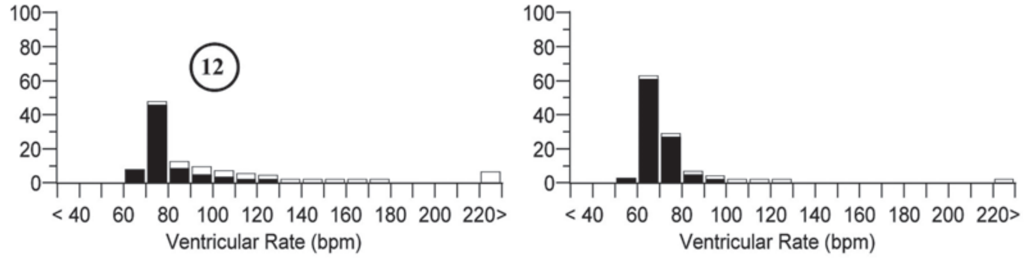


Ventricular

% of Time

□ VS

■ VP



Page 1

Rate Histograms

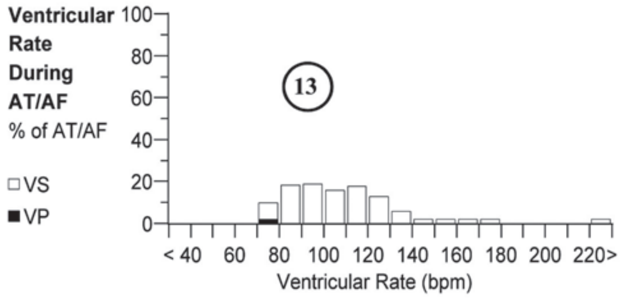
Printed: **12-Feb-2014 12:50:24**

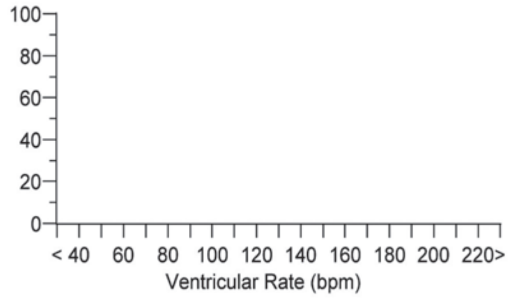
Rate Histograms

Device: **Viva XT CRT-D DTBA2D1** Serial Number: Date of Visit: **30-May-2013 12:03:02**

Patient: ID: Physician: - - -

	Prior to Last Session		Since Last Session
	27-May-2013 to 29-May-2013		29-May-2013 to 30-May-2013
	2 days		22 hours
	Time in AT/AF = 9 hours		**Time in AT/AF = 0 seconds**
% of AT/AF	**VP**	1.6 %	
	VSR Pace	0.0 %	
	VS	98.4 %	





Page 2

Rate Histograms
Printed: **12-Feb-2014 12:50:24**

Tracing 5: AF and His bundle ablation

Patient

69 years old man implanted with a triple chamber defibrillator Viva XT CRT-D for valvular cardiomyopathy with permanent AF (no atrial lead implanted) and a narrow QRS; device interrogation performed a few hours after the implant;

Tracing

1: after the implant, rapidly conducted AF, percentage of biventricular pacing at 0% and fast ventricular response (peak HR around 150, 160 bpm);

The patient underwent a His bundle ablation; device interrogation the day after the ablation procedure

2: permanent biventricular pacing (rate responsive function ON); the patient was still lying down in his bed, which explain the absence of heart rate acceleration;

Comments

Two different types of AF patients benefit form a resynchronization therapy: 1) patients with slow AF and a bundle branch block 2) AF patients with a rapid ventricular response and a narrow or wide QRS. In the latter type of patients, the rate control is essential once the patient resynchronized. This rate control can be achieved by using rate control medications. However the results is often imperfect. The ablation of the His bundle is often necessary to enable the high percentages of biventricular stimulation essential to the success of this therapy. His ablation is now part of the recommendations of the international guidelines for the treatment of patients with chronic AF and poorly controlled heart rate. After the ablation of the His bundle, a rate responsive function must be programmed.

Rate Histograms

Device: **Viva XT CRT-D DTBA2D4** Serial Number: Date of Visit: **10-Apr-2013 08:31:32**

Patient: ID: Physician: - - -

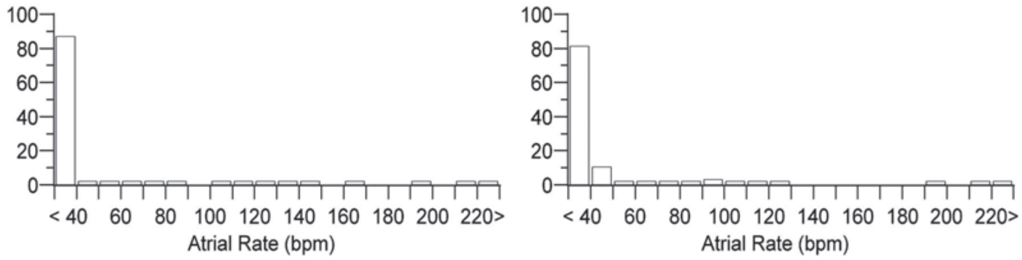
		Prior to Last Session 08-Apr-2013 to 09-Apr-2013 21 hours	Since Last Session 09-Apr-2013 to 10-Apr-2013 24 hours
% of Time	**AS-VS**	100.0 %	33.8 %
	AS-VP	0.0 %	66.2 %
	AP-VS	0.0 %	0.0 %
	AP-VP	0.0 %	0.0 %
	Total VP	0.0 %	97.6 %
	VSR Pace	0.0 %	0.0 %
	VS	100.0 %	2.4 %
	CRT Pacing		
	Bi-V	0.0 %	99.9 %
	LV	0.0 %	0.0 %

Atrial

% of Time

□ AS

■ AP

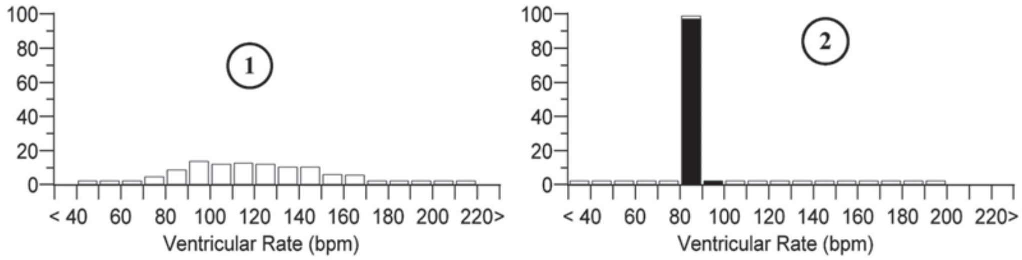


Ventricular

% of Time

□ VS

■ VP



Page 1

Rate Histograms
Printed: **12-Feb-2014 12:58:49**

Tracing 6: AF and remote monitoring

Patient

53 years old man implanted with a triple chamber defibrillator Consulta CRT-D for idiopathic cardiomyopathy with left bundle branch block; remote monitoring follow-up;

Tracing

1: remote transmission of an episode of AF with alternating paced and spontaneous QRS;
the Cardiac Compass report received identifies:
2: a long standing episode of AF, lasting several days, one episode of arrhythmia lasting the all day;
3: an increase in the ventricular heart rate;
4: a significant drop in the percentage of biventricular pacing with a clear cut-off at the onset of the AF episode;
5: a relatively high ventricular rate, particularly during the day;
6: a decrease in the patient activity.

Comments

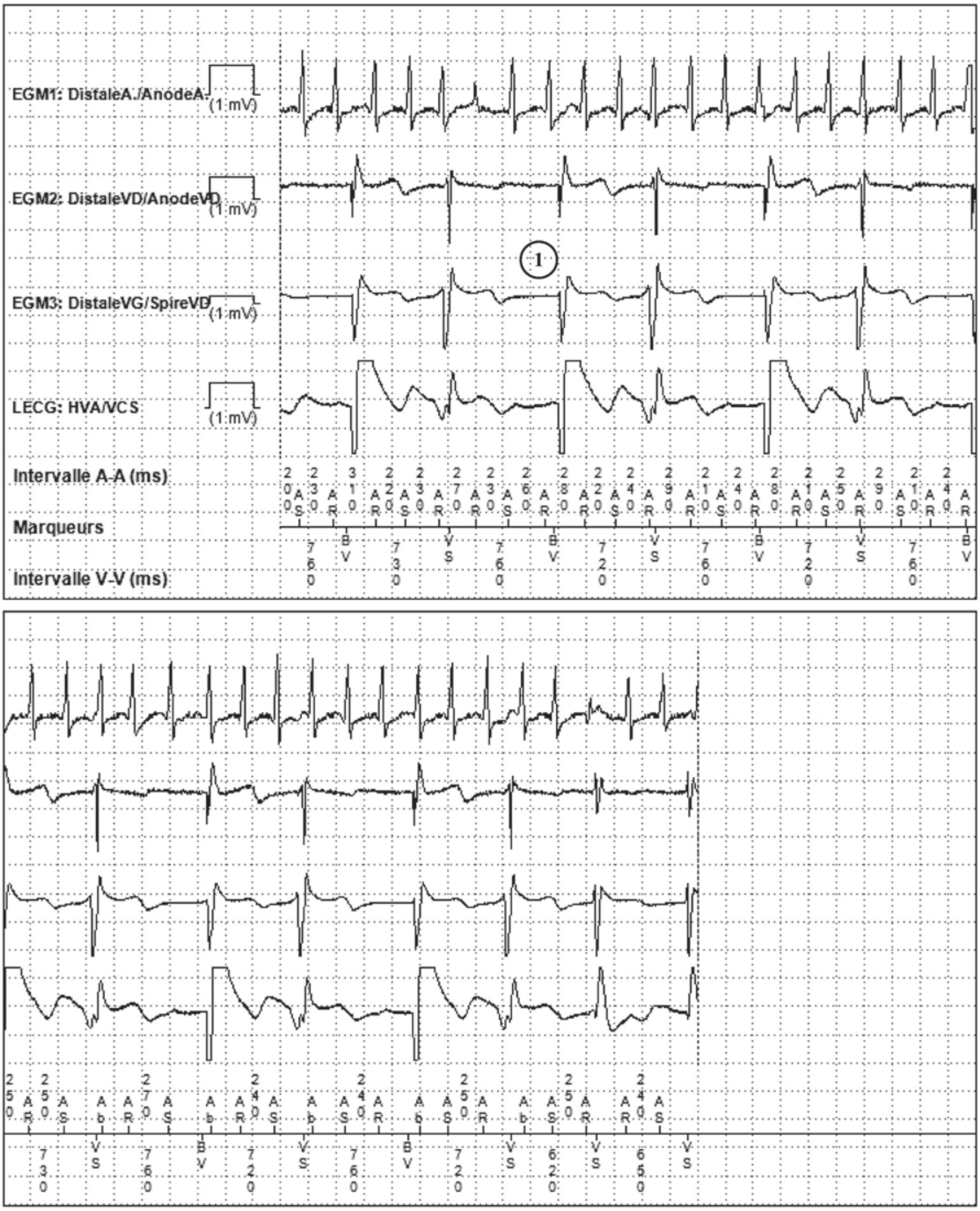
This tracing highlights the various advantages of a remote monitoring in a resynchronized patient with episodes of atrial arrhythmia:

1) the diagnosis is confirmed by the analysis of the transmitted EGM; this allows to eliminate false diagnoses arrhythmia atrial (crosstalk, noise...)
2) the diagnosis is quickly performed even if the patient is asymptomatic
3) anticoagulant therapy could be introduced early to reduce the risk of stroke
4) the treatment with an anti-arrhythmic was also introduced; the effectiveness of this treatment can be remotely assessed on a daily basis through the remote monitoring follow-up.

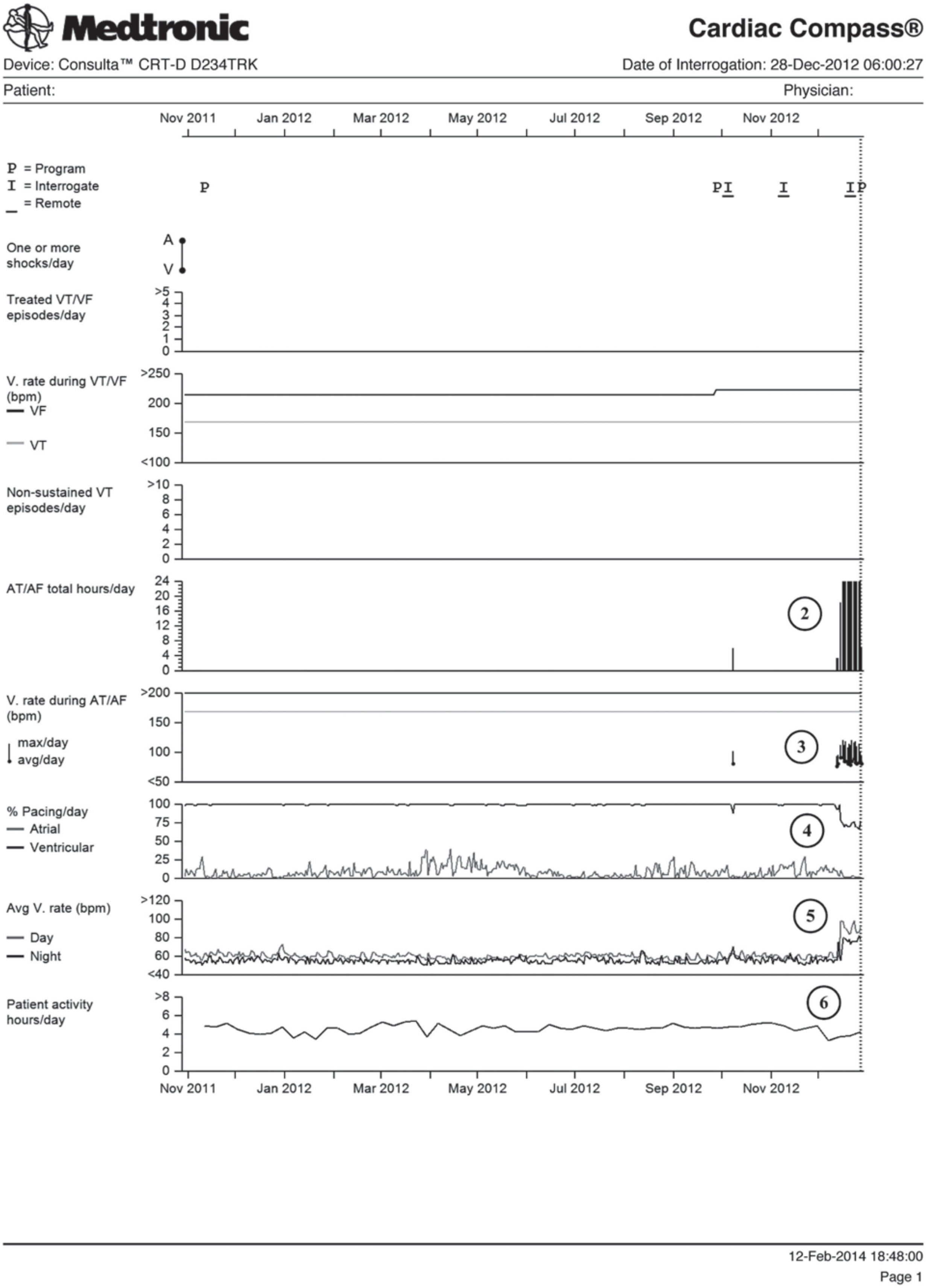
EGM

Device: Consulta™ CRT-D D234TRK

Date of interrogation : 28-Dec-20 06:00:27



16-Apr-2013 17:14:56
Page 1


Medtronic
Cardiac Compass®
Device: Consulta™ CRT-D D234TRK
Date of Interrogation: 28-Dec-2012 06:00:27
Patient:
Physician:
Nov 2011 Jan 2012 Mar 2012 May 2012 Jul 2012 Sep 2012 Nov 2012
P = Program
I = Interrogate
_ = Remote
One or more shocks/day
Treated VT/VF episodes/day
V. rate during VT/VF (bpm)
VF
VT
Non-sustained VT episodes/day
AT/AF total hours/day
V. rate during AT/AF (bpm)
max/day
avg/day
% Pacing/day
Atrial
Ventricular
Avg V. rate (bpm)
Day
Night
Patient activity hours/day
2
3
4
5
6
12-Feb-2014 18:48:00
Page 1

Tracing 7: loss of biventricular capture following an episode of noise on the atrial lead

Patient

59 years old woman implanted with a defibrillator Concerto II CRT-D in the context of a dilated cardiomyopathy with a left bundle branch block; good responder to resynchronization; device interrogation identifying several episodes of atrial arrhythmias;

Plots

1: fast and irregular atrial rhythm;
2: organization of the atrial rhythm;

Tracing

3: presence of a very fast atrial signal compatible with a 50 Hz signal ; interruption of the biventricular pacing;
4: episode of AF made by the device;
5: spontaneous atrial activities are not followed by a biventricular stimulation (Switch mode - DDIR);

Text

6: this episode is wrongly classified as an episode of AF by the device;

Comments

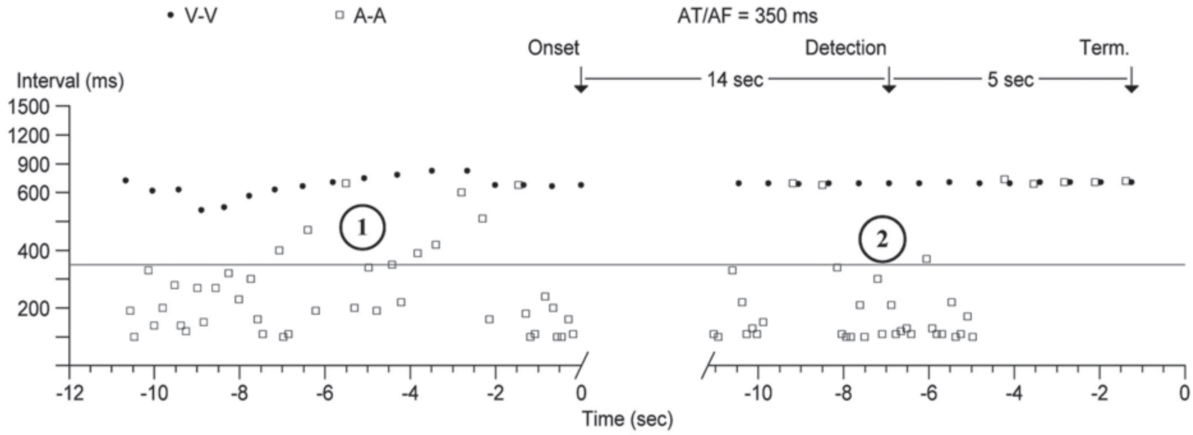
This tracing reflects once again the need to systematically check the defibrillator memories in order to avoid misdiagnosis of atrial arrhythmia. The detection of spontaneous ventricles and the temporarily inhibition of the biventricular stimulation was secondary to the detection of an external noise on the atrial lead. At the time of the detection of this episode, the patient was using a poorly insulated appliance. The treatment in this context consists in the identification of the emitting source to prevent further recurrences.

Monitored AT/AF Episode #11

Device: **Concerto II CRT-D D294TRK** Serial Number: Date of Visit: **18-Mar-2013 11:17:40**

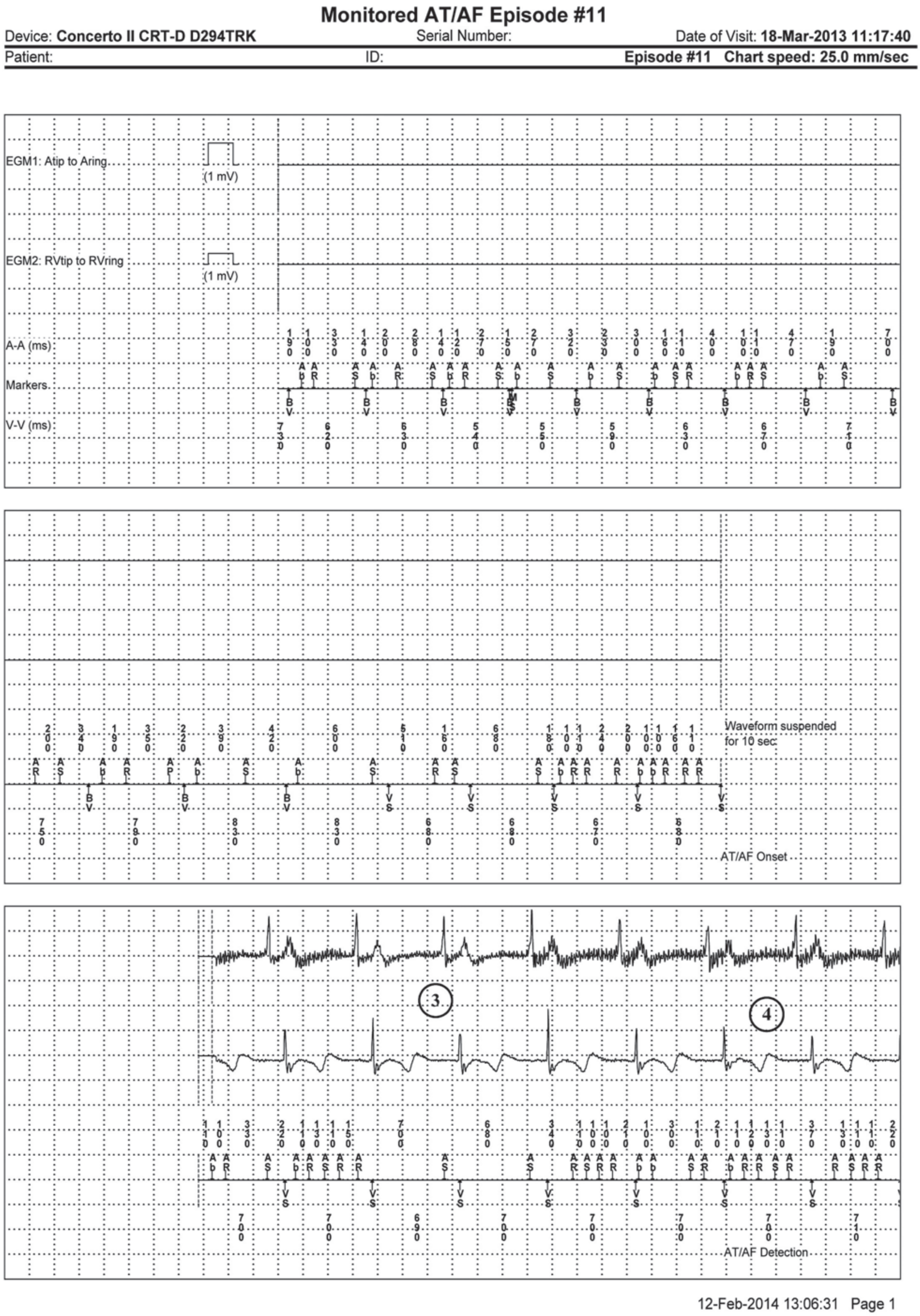
Patient: ID: Physician: - -

Type	ATP Seq	Shocks	Success	ID#	Date	Time hh:mm	Duration hh:mm:ss	Avg bpm A/V	Max bpm A/V	Activity at Onset
AT/AF				11	22-Mar-2012	19:15	:19	201/85	545/86	Rest



Page 1

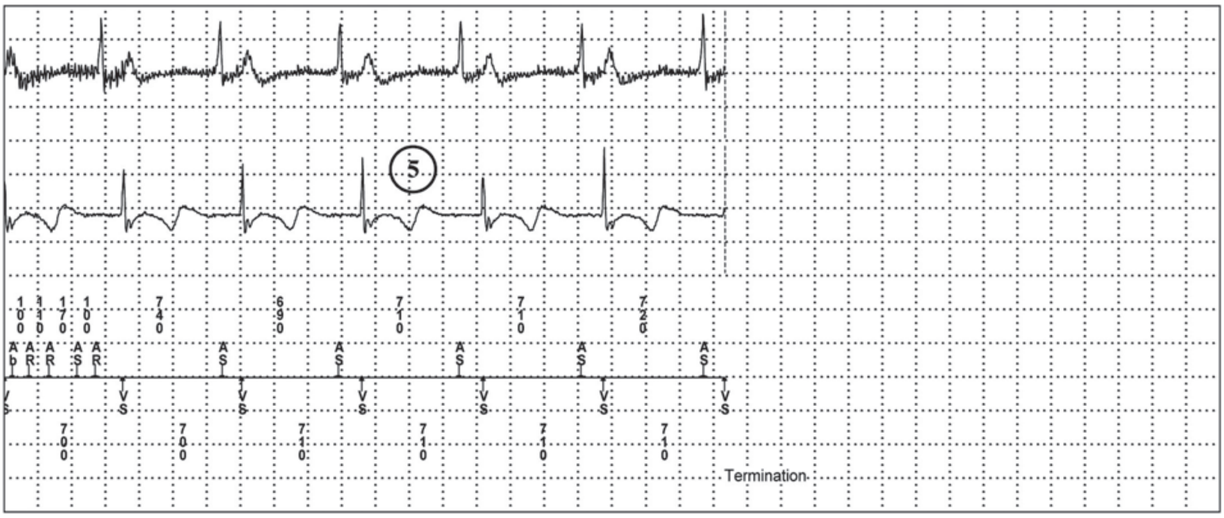
Monitored AT/AF Episode #11
Printed: **12-Feb-2014 13:06:22**


Monitored AT/AF Episode #11
Device: Concerto II CRT-D D294TRK
Serial Number:
Date of Visit: 18-Mar-2013 11:17:40
Patient:
ID:
Episode #11 Chart speed: 25.0 mm/sec
EGM1: Atip to Aring
(1 mV)
EGM2: RVtip to RVring
(1 mV)
A-A (ms)
Markers
V-V (ms)
Waveform suspended
for 10 sec
AT/AF Onset
3
4
AT/AF Detection
12-Feb-2014 13:06:31 Page 1

Monitored AT/AF Episode #11

Device: **Concerto II CRT-D D294TRK** Serial Number: Date of Visit: **18-Mar-2013 11:17:40**

Patient: ID: **Episode #11 Chart speed: 25.0 mm/sec**



12-Feb-2014 13:06:31 Page 2

Monitored AT/AF Episode #11

Device: **Concerto II CRT-D D294TRK** Serial Number: Date of Visit: **18-Mar-2013 11:17:40**

Patient: ID: Physician: - - -

Episode #11: 22-Mar-2012 19:15:23

Episode Summary	
Initial Type	AT/AF Monitor (spontaneous)
Duration	19 sec
A/V Max Rate	545 bpm/86 bpm
A. Median	400 bpm (150 ms)
Activity at onset	Rest, Sensor = 59 bpm

(6)

Parameter Settings		Zones		A. Interval (Rate)
AT/AF	Monitor	1	AT/AF	350 ms (171 bpm)

EGM	Source	Range	Sensitivity	
EGM1	Atip to Aring	+/- 8 mV	Atrial	0.45 mV
EGM2	RVtip to RVring	+/- 8 mV	RV	0.3 mV

Page 1

Monitored AT/AF Episode #11
Printed: **12-Feb-2014 13:06:52**

Tracing 8: loss of biventricular capture secondary to an episode of noise on the right ventricular lead

Patient

61 years old man implanted with a triple chamber defibrillator Viva XT CRT-D for ischemic cardiomyopathy with a wide QRS; interrogation of the device with the recording of several episodes of non-sustained VT;

Plots

1: atrio-ventricular rhythm;
2: acceleration of the ventricular rhythm with very short cycles close to the ventricular blanking limit and extremely short cycles of a few dozen of ms;
3: regularization of the ventricular rhythm;
4: novel episode of acceleration of the ventricular rate;

Tracing

5: atrial stimulation and biventricular pacing (AP-BV);
6: very fast ventricular signal detected at the limit of the ventricular blanking (120 ms) within the FV zone (FS), inhibiting the biventricular stimulation;
7: detection of a signal in the safety window, triggering a ventricular safety pacing at the end of the safety window (110 ms), with very short VS-VP cycles corresponding to the shortest cycle represented on the plot;
8: interruption of the oversensing and recovery of a biventricular stimulation;
9: oversensing restarts;

Comments

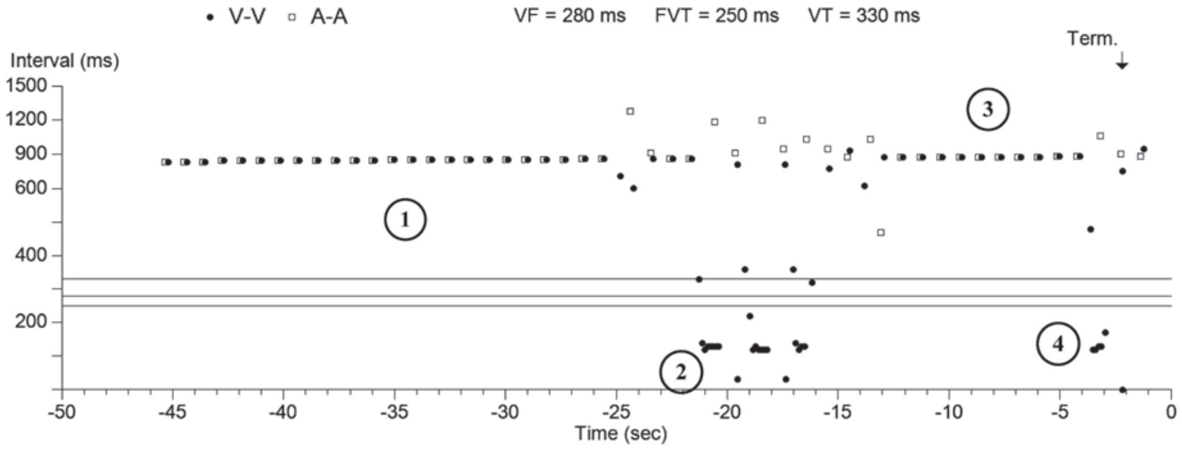
This tracing corresponds to the oversensing by the right ventricular lead of a 50 Hz signal emitted by a poorly insulated electric saw. This noise temporarily inhibits the biventricular stimulation. This type of episode may be symptomatic in a pacemaker dependent patient (which is not the case of this patient) by inducing a more or less prolonged ventricular pause. As for the previous tracing, treatment consists in recognizing the emitting source to prevent recurrences.

Medtronic **Non-sustained VT Episode #8**

Device: Viva™ XT CRT-D Serial Number: Date of Interrogation: 22-May-2013 23:37:55

Patient: Physician: - - -

Type	ATP Seq	Shocks	Success	ID#	Date	Time hh:mm	Duration hh:mm:ss	Avg bpm A/V	Max bpm A/V	Activity at Onset
VT-NS				8	22-May-2013	14:42	<:01	66/353		Rest



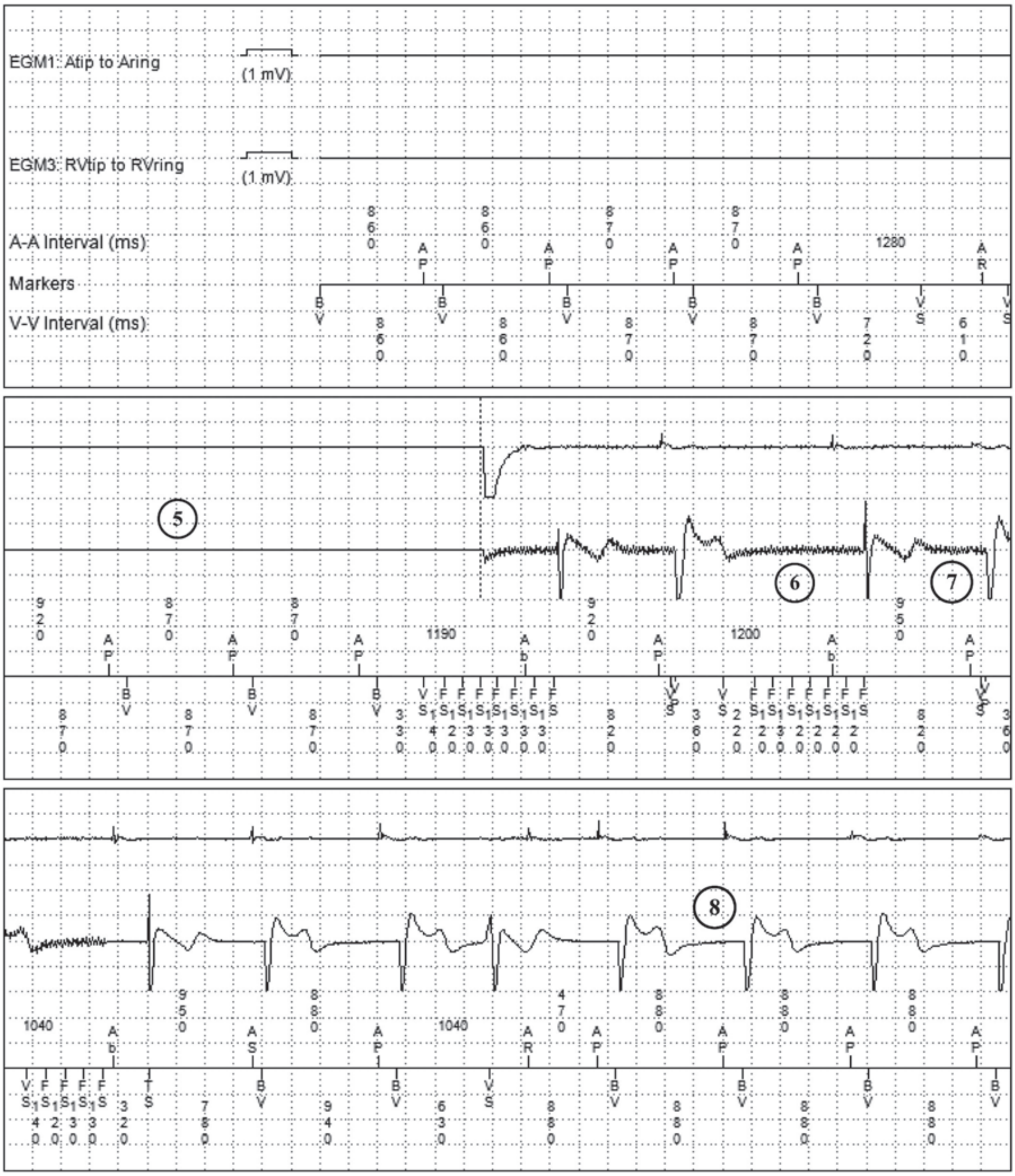
12-Feb-2014 18:59:33
Page 1

Medtronic

Non-sustained VT Episode #8

Device: Viva™ XT CRT-D DTBA2D1 Serial Number: Date of Interrogation: 22-May-2013 23:37:55

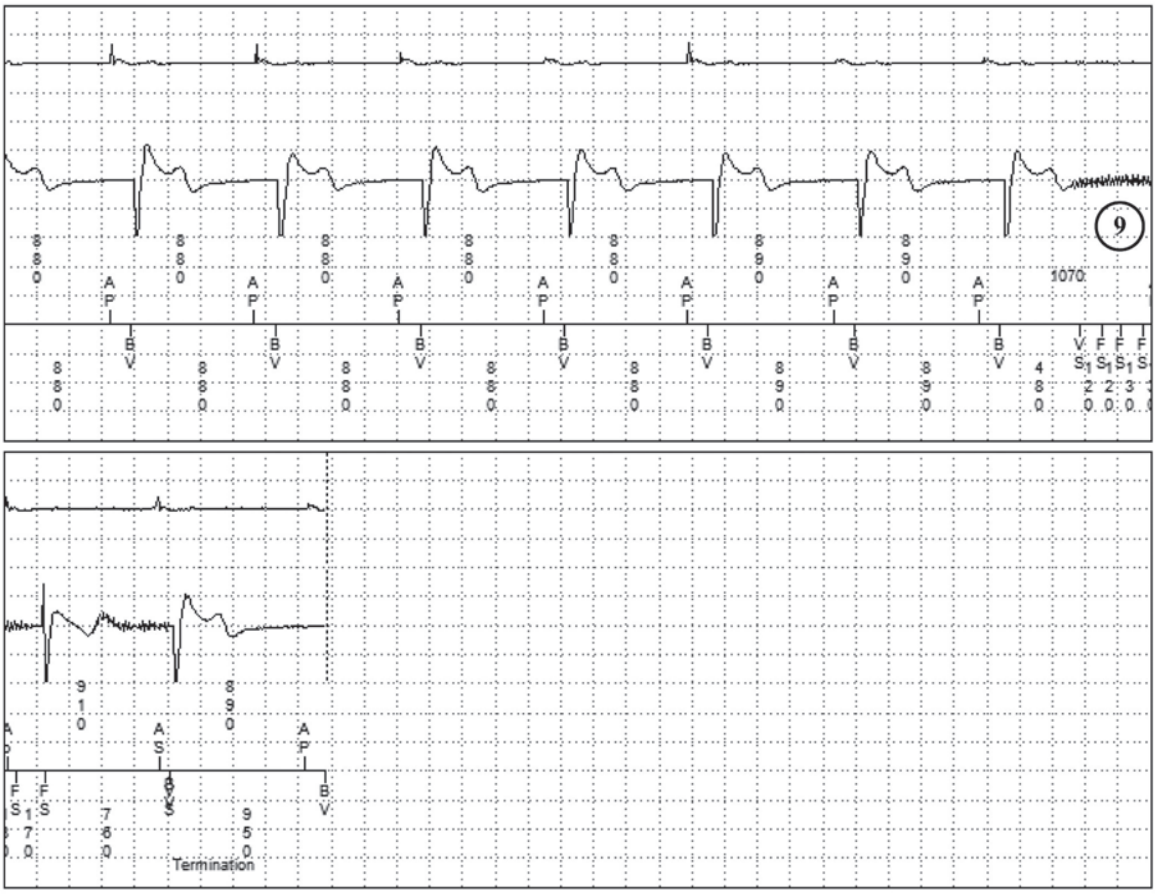
Patient: Episode #8 Chart speed: 25.0 mm/sec



Non-sustained VT Episode #8

Device: Viva™ XT CRT-D DTBA2D1 Serial Number: Date of Interrogation: 22-May-2013 23:37:55

Patient: , Episode #8 Chart speed: 25.0 mm/sec



12-Feb-2014 18:59:34
Page 2

Medtronic

Non-sustained VT Episode #8

Device: Viva™ XT CRT-D DTBA2D1 Serial Number: Date of Interrogation: 22-May-2013 23:37:55

Patient: , Physician: - - -

Episode #8: 22-May-2013 14:42:09

Episode Summary	
Initial Type	VT Non-sustained (spontaneous)
Duration	<1 sec (5 beats)
V. Median	79 bpm (760 ms)
Activity at onset	Rest, Sensor = 76 bpm

Parameter Settings		**Initial**	**Redetect**	**V. Interval (Rate)**
VF	On	30/40	12/16	280 ms (214 bpm)
FVT	via VF			250 ms (240 bpm)
VT	On	16	12	330 ms (182 bpm)
Monitor	Off	32		

Polarity	**RV**
Pace Polarity	Bipolar
Sense Polarity	Bipolar

EGM	**Source**	**Range**	**Sensitivity**	
EGM1	Atip to Aring	+/- 8 mV	Atrial	0.3 mV
EGM3	RVtip to RVring	+/- 8 mV	RV	0.3 mV

12-Feb-2014 18:59:34

Page 1

Tracing 9: loss of biventricular capture related a dysfunction of the right ventricular lead.

Patient

79 years old man implanted with a triple chamber defibrillator Consulta XT CRT-D for ischemic cardiomyopathy with a wide QRS (the device was implanted 8 years ago and already replaced once); the consultation is motivated by several electrical shocks received while he was working in his garden;

Plots

1: scattered repartition at the ventricular level (great variability of the cycles length with very short intervals);
2: electrical cardioversion;
3: short ventricular cycles;
4: end of the oversensing;

Tracing

5: ventricular oversensing of anarchical signals in the VT and VF zones;
6: intermittent biventricular stimulation;
7: spontaneous ventricular activities;
8: NID in the VF zone is reached; detection of an episode of VF and charge of the capacitors;
9: end of charge (CE);
10: confirmation: 4 consecutive VS, the therapy is abandoned;
11: new detection of a FV and new charge of the capacitors;
12: end of charge (very short, the capacitors had no time to discharge);
13: no confirmation for this redetected episode; immediate delivery of an electrical shock (34.3 Joules);
14: temporary interruption of the oversensing and biventricular stimulation;
15: new episode of oversensing;
16: end of the episode;

Comments

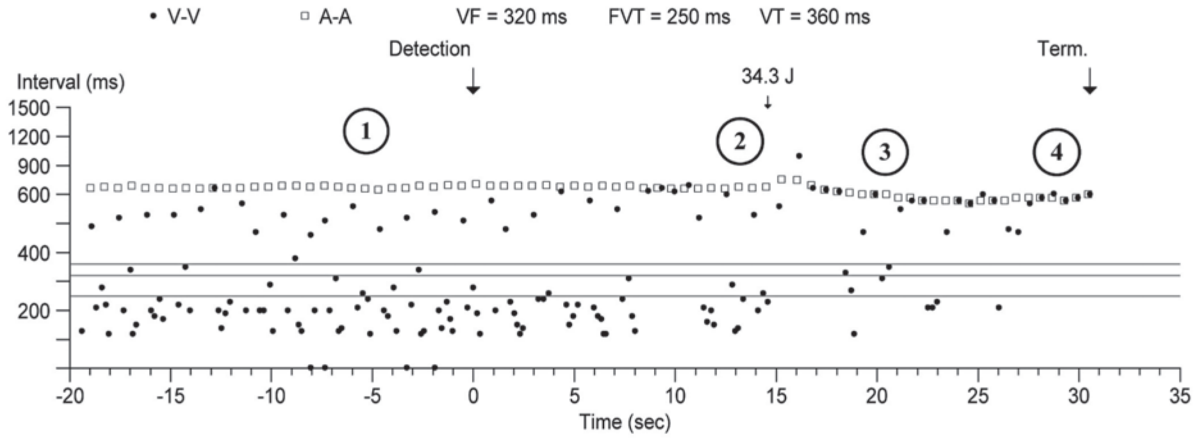
This patient presented with a fracture of the right ventricular lead. This patient was initially implanted for primary prevention in the context of a severe heart failure. He had never presented any episodes of arrhythmia during the entire follow-up. However, he presented with a very significant clinical and echocardiographic improvement form the resynchronization therapy. Regarding the diagnosis of lead fracture, different options are possible. The easiest would be probably to disable the defibrillation function of the device to prevent any recurrence of inappropriate therapies while maintaining a biventricular pacing. However, this tracing shows the limits of this strategy since the oversensing also inhibits the biventricular pacing. It is likely that with the progression of the lead problem, the oversensing will increase and result in a significant drop in the percentage of biventricular pacing. A second option is to add a new defibrillation lead (this option was chosen in this patient) or a right ventricular pacing lead. The management of the former broken lead was difficult. It was left in place in the patient. Indeed, its extraction was probably not justified in a patient of this age, especially if we consider the associated risk of damaging the left ventricular functional lead.

Treated VT/VF Episode #1651

Device: **Consulta CRT-D D234TRK** Serial Number: Date of Visit: **12-Mar-2013 18:24:51**

Patient: ID: Physician: - - -

Type	ATP Seq	Shocks	Success	ID#	Date	Time hh:mm	Duration hh:mm:ss	Avg bpm A/V	Max bpm A/V	Activity at Onset
VF	0	35J	Yes	1651	12-Mar-2013	11:23	:18:26	87/214	103/286	Rest



Page 1

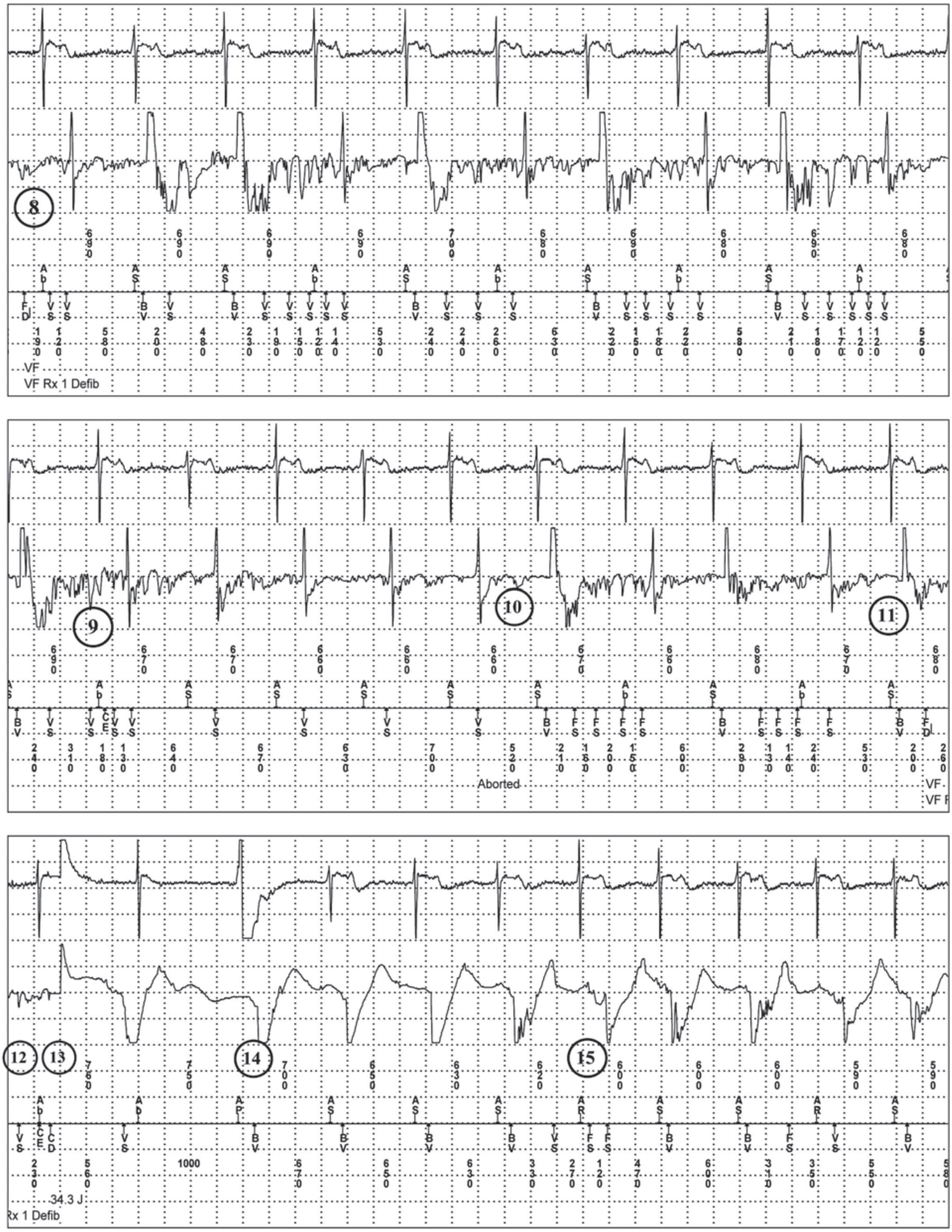
Treated VT/VF Episode #1651
Printed: **12-Feb-2014 13:18:49**


Treated VT/VF Episode #1651
Device: Consulta CRT-D D234TRK
Serial Number:
Date of Visit: 12-Mar-2013 18:24:51
Patient:
ID:
Episode #1651 - VF Chart speed: 25.0 mm/sec
EGM1: Atip to Aring
(1 mV)
EGM2: RVtip to RVring
(1 mV)
A-A (ms)
Markers
V-V (ms)
5
6
7
12-Feb-2014 13:18:59 Page 1

Treated VT/VF Episode #1651

Device: **Consulta CRT-D D234TRK** Serial Number: Date of Visit: **12-Mar-2013 18:24:51**

Patient: ID: **Episode #1651 - VF Chart speed: 25.0 mm/sec**

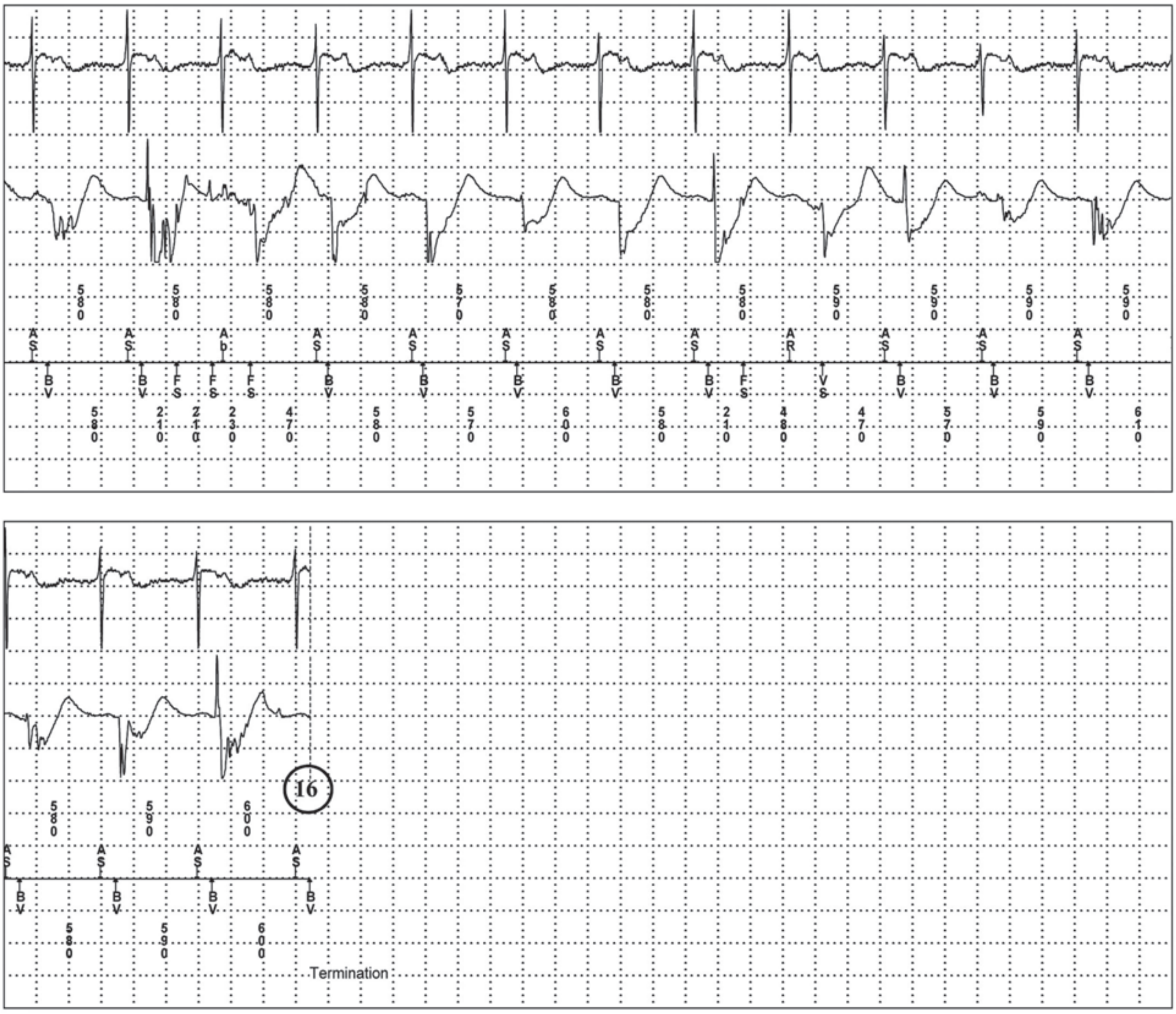


12-Feb-2014 13:18:59 Page 2

Treated VT/VF Episode #1651

Device: **Consulta CRT-D D234TRK** Serial Number: Date of Visit: **12-Mar-2013 18:24:51**

Patient: ID: **Episode #1651 - VF Chart speed: 25.0 mm/sec**



12-Feb-2014 13:18:59 Page 3

Tracing 10: loss of biventricular pacing following noise detection on the right ventricular lead

Patient

54 years old man implanted with a triple chamber defibrillator Protecta XT CRT-D for ischemic cardiomyopathy with a wide QRS; device interrogation demonstrating an episode of noise appropriately diagnosed by the device;

Plots

1: variable ventricular rhythm;
2: very short cycles close to the post-ventricular ventricular blanking limit;
3: detection of VT/VF suspended;
4: end of the episode;

Tracing

5: very high amplitude signals saturating the amplifiers and detected in the VF zone; interruption of the biventricular pacing;
6: interruption of the detection, the device has made the diagnosis of noise oversensing (N: noise);

Text

7: episode classified as noise by the device;

Comments

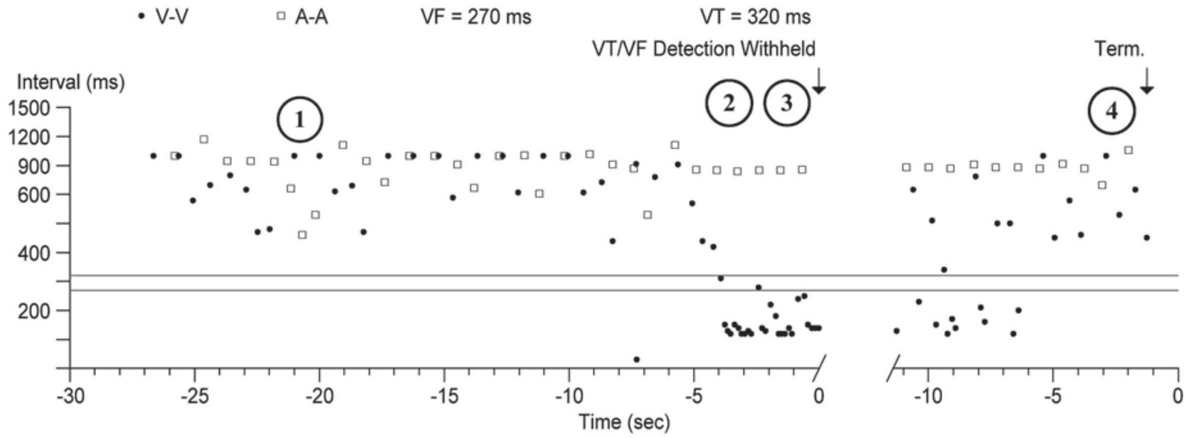
The most recent triple chamber defibrillators from Medtronic benefit of the new discrimination platform including the RV lead noise discrimination algorithm, the RV lead integrity alert, the T-Wave discrimination algorithm, and the wavelet added to the PR Logic. This tracing illustrates the interest of the RV lead noise discrimination algorithm that avoids in this patient several inappropriate shocks. The RV lead noise discrimination algorithm differentiates RV lead noise from VT/VF by comparing a far field EGM signal to near field sensing. If lead noise is identified (tachycardia detected on the bipolar EGM but not on the far field EGM), VT/VF detection is withheld, and an RV Lead Noise alert is triggered.

V. Oversensing Episode #3

Device: **Protecta XT CRT-D D354TRG** Serial Number: Date of Visit: **23-Feb-2011 08:36:06**

Patient: **???** ID: **???** Physician: **??? ???**

Type	ATP Seq	Shocks	Success	ID#	Date	Time hh:mm	Duration hh:mm:ss	Avg bpm A/V	Max bpm A/V	Activity at Onset
V. Oversensing-Noise				3	14-Feb-2011	16:32	:35	71/429	72/462	Rest

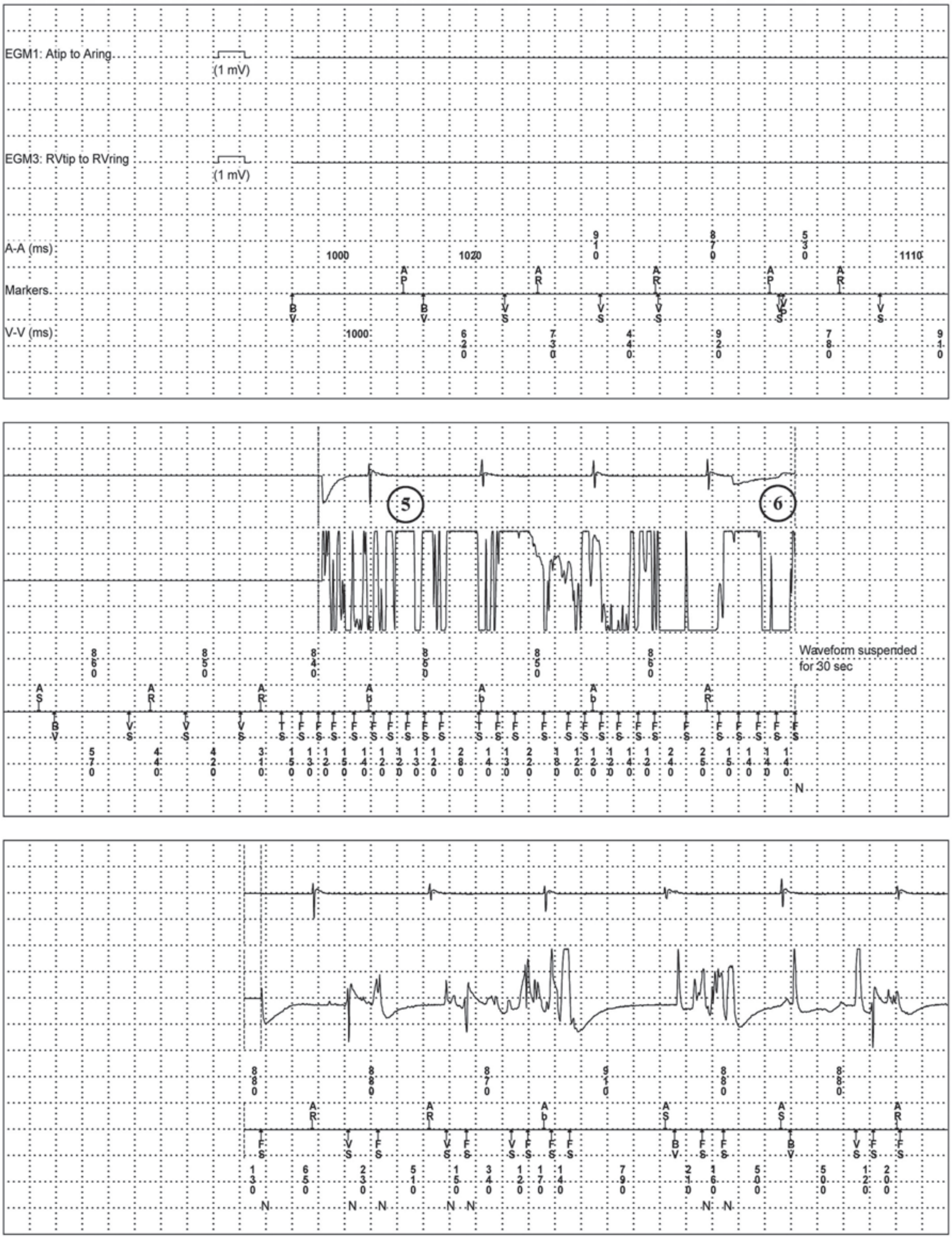


V. Oversensing Episode #3
Page 1 Printed: **12-Feb-2014 13:25:04**

V. Oversensing Episode #3

Device: **Protecta XT CRT-D D354TRG** | Serial Number: | Date of Visit: **23-Feb-2011 08:36:06**

Patient: **???** | ID: **???** | **Episode #3 Chart speed: 25.0 mm/sec**

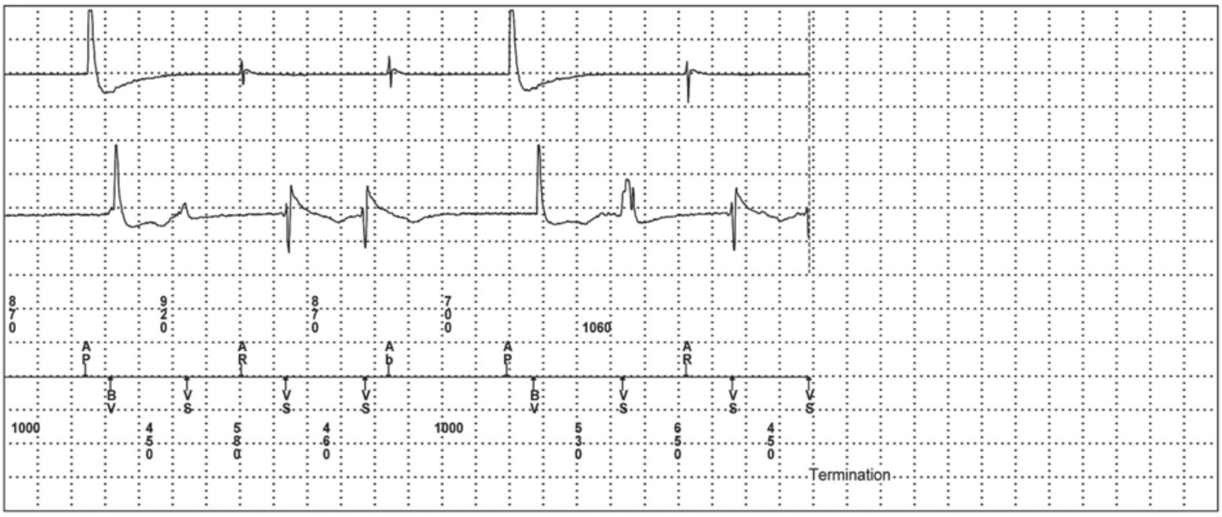


12-Feb-2014 13:25:12 Page 1

V. Oversensing Episode #3

Device: **Protecta XT CRT-D D354TRG** Serial Number: Date of Visit: **23-Feb-2011 08:36:06**

Patient: **???** ID: **???** **Episode #3 Chart speed: 25.0 mm/sec**



12-Feb-2014 13:25:13 Page 2