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Biotronik Encyclopedia

From basics to essentials

Biomonitor
Implantable Cardiac Pacemaker
Implantable Cardioverter Defibrillator

STIMUPRAT Editions

www.cardiocases.com
www.epcases.com
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www.rhythmopedia.com
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The authors of the Stimuprat team are pleased to present this encyclopedia dedicated to the specificities of the interrogation and programming of the various devices marketed by BiotronikTM.

Telemedicine represents a technological revolution with the potential to meet some of the current challenges faced by our various health systems such as the aging of the population, the increase in chronic diseases, the unequal regional distribution of health professionals and budgetary constraints. The remote monitoring of implantable prostheses has rapidly evolved over the last decade from an experimental technology to a mature, large-scale follow-up strategy used in day-to-day clinical practice as a result of publications demonstrating its feasibility, safety and a certain number of potential clinical benefits. The BiotronikTM remote monitoring system has been a forerunner in the field, and still remains today the benchmark for the entire device industry.

Modern implantable devices, whether implantable loop recorders, cardiac pacemakers or implantable cardioverter defibrillators, store an increasing amount of diagnostic information relative to the operational functioning of the device and, importantly, to the occurrence of ventricular or supraventricular rhythm disorders. The frequent or even continuous monitoring of the device memory enables early detection of the dysfunctions, although necessitates a comprehensive understanding of electrocardiographic tracings which are difficult to interpret if the physician or medical assistant under the responsibility of the physician does not have a perfect knowledge of the operation and specificities of each implanted prosthesis.

This publication revisits the various phases of the interrogation and programming of the BiotronikTM devices through an atlas of telemedicine tracings or derived from the programmer depicting the different clinical situations encountered during the follow-up of an implanted patient. The reading of each tracing is didactically detailed, followed by a practical commentary proposing a solution to the illustrated problem with a reminder of good practices. It appeared appropriate to group together in this work tracings from the same manufacturer in order to detail the generic functions of the different devices, while concurrently attempting to gain a better grasp of the "philosophy" that led to the development of the different algorithms proposed by this company.

Portions of the contents of this book are available in French and English on the "Pacingdefibrillation.com" website. This site, freely accessible, reviews the state of the art in the field along with details of the specific features of the various devices for pacing, defibrillation and resynchronization. It can also foster the exchange of ideas through a discussion forum with the possibility of submitting tracings and subsequently discussing the diagnoses as well as the most suitable treatment options.

Pleasant reading !!!

Acknowledgements

The various authors of the Stimuprat team particularly wish to thank David Bossi and Sylvain Dubor for the help given to the collection of these tracings.

Biomonitor

Case studies based
on **Biotronik™** tracings

Tracing 1 ↘ Patient-triggered recording

Patient

78-year-old man participating in the LBBB-TAVI study.

Tracing

Patient-triggered tracing;

① no change in heart rate throughout the tracing; pattern consistent with a stable sinus rhythm and a heart rate slightly under 90 beats/minute; on the tracing, QRS complexes and T waves are easily identifiable, P waves are of lower amplitude but remain nonetheless visible;

② recording triggered by the patient (50 seconds of tracing prior to activation and 10 seconds thereafter).

Comments

All Biomonitor tracings analyzed in this chapter stem from implanted patients in the setting of the LBBB-TAVI study. Indications for implantation of a TAVI have increased exponentially in recent years. The occurrence of a left bundle branch block furthermore complicates this type of procedure in 5 to 40% of patients and is associated with impaired prognosis in conjunction with an increased risk of atrioventricular block, heart failure, ventricular rhythm disorders and sudden death. Management of these patients varies depending to the centers with more or less aggressive strategies. The main objective of the LBBB-TAVI study was to validate a decision algorithm in patients implanted with a TAVI and presenting a left bundle branch block during follow-up. An electrophysiological study was systematically performed. If the HV interval was prolonged (> 70 ms), a dual-chamber pacemaker was implanted. Otherwise, a BioMonitor implantable loop recorder was positioned and monitored remotely by telemedicine. This explains why in almost all of the tracings presented, the patients present a widened QRS, with the presence of a left bundle branch block being an inclusion criterion. The results of this study are still pending.

The traditional indication of this type of device nonetheless remains the work-up of unexplained syncopes. Indeed, since its introduction some twenty years ago, the implantable loop recorder has positioned itself as a diagnostic tool of reference in this setting. Syncope is a major public health concern, with between 40% and 50% of the general population experiencing an episode of syncope in their lifetime and syncopes accounting for 1-6% of hospital admissions. While the anamnesis, interrogation and clinical examination allow a diagnosis of certainty in a majority of patients with reflex syncopes, the yield of conventional investigations is much less in the setting of cardiac syncopes. The implantable loop recorder is a subcutaneous device positioned in the left subclavian region and allows the loop recording of a bipolar electrocardiographic tracing over a prolonged ambulatory period of time. The device has a rolling memory which records and stores the electrocardiogram after activation by the patient or a witness during the course of a symptomatic episode but can also automatically record electrocardiograms according to pre-programmed sensing criteria. Technological developments, as part of the development of nanotechnologies and telecommunications, has enabled the miniaturization of the monitor and the possibility of remote interrogation.

While the correlation between symptoms experienced by the patient and the electrocardiographic recording represents the gold standard in syncope work-up, it nonetheless remains difficult to obtain with the traditional methods of electrocardiogram monitoring given the sporadic nature of the symptoms. The main objective of the implantable loop recorder is therefore to allow the recording of an electrocardiogram in a contemporaneous manner upon the occurrence of symptoms. The patient assistant, which is a portable battery-powered telemetry device, allows the patient to memorize the traces corresponding to a symptomatic episode. To trigger the recording, the patient must apply the assistant on the skin facing the Biomonitor and then press the button for 3 seconds; the device emits an audible signal and a continuous yellow light appears on the assistant for 3 seconds. If the device has in fact recorded a tracing, a continuous green light emitted for a maximum of 30 seconds indicates proper operation; otherwise, a flashing yellow light indicates the

absence of recording. When the patient activates the recording, the device freezes 50 seconds of tracing prior to activation and 10 seconds thereafter.

The diagnosis is made in 3 settings: 1) highlighting of significant bradycardia, 2) highlighting of tachycardia, 3) persistence of a normal electrocardiographic pattern enabling to eliminate a bradyarrhythmic cause of the syncope. This patient had presented syncope in the setting of abdominal pain. The tracing allowed to formally eliminate the diagnosis of conduction disturbance or rhythm disorder to explain the loss of consciousness.

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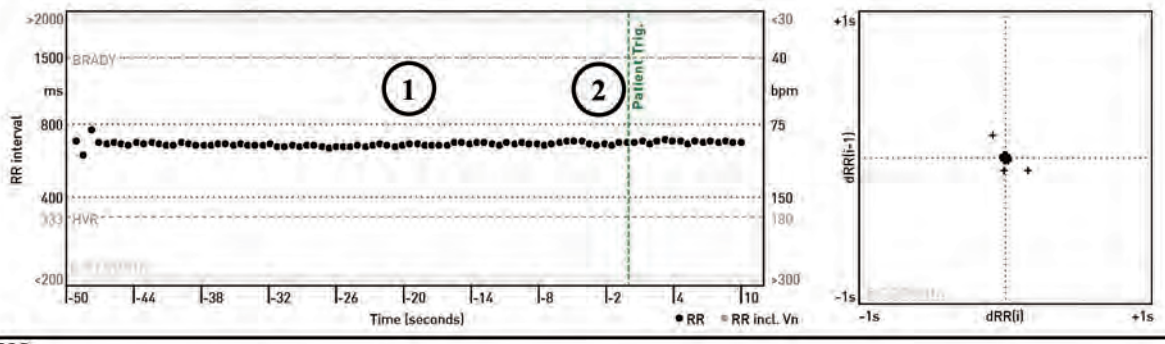
Recordings

Recordings - Episode 294:

General	
Episode number	294
Episode type	Patient triggered
Detection	Oct 7, 2016 5:58:30 PM
Termination	---
Duration	---
Device settings no.	3
Mean ven. rate / RR interval [ms]	663

Tachogram and Lorenz plot



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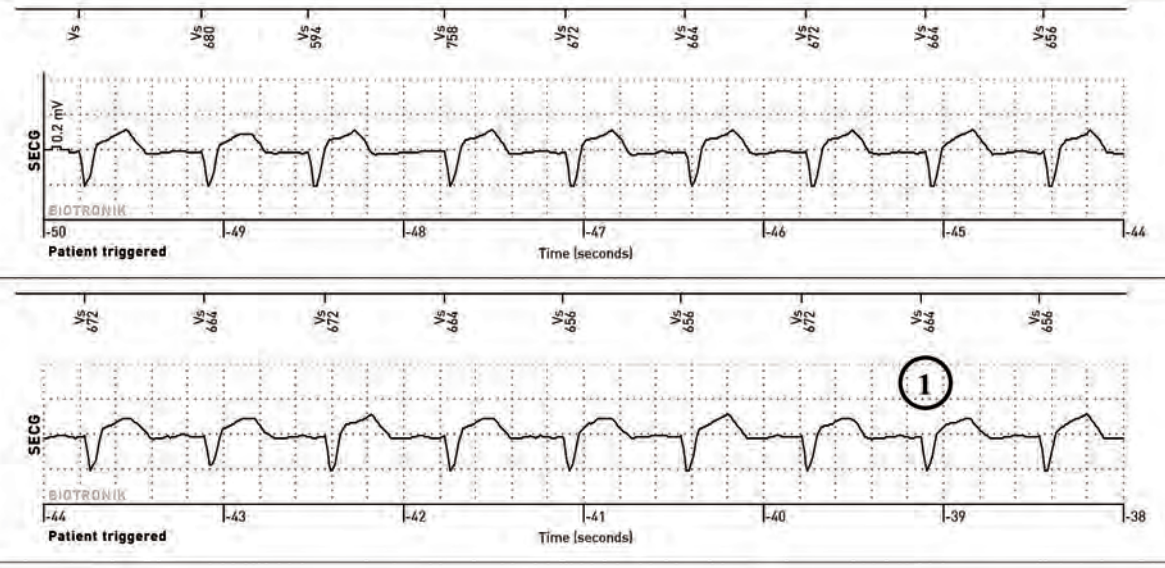

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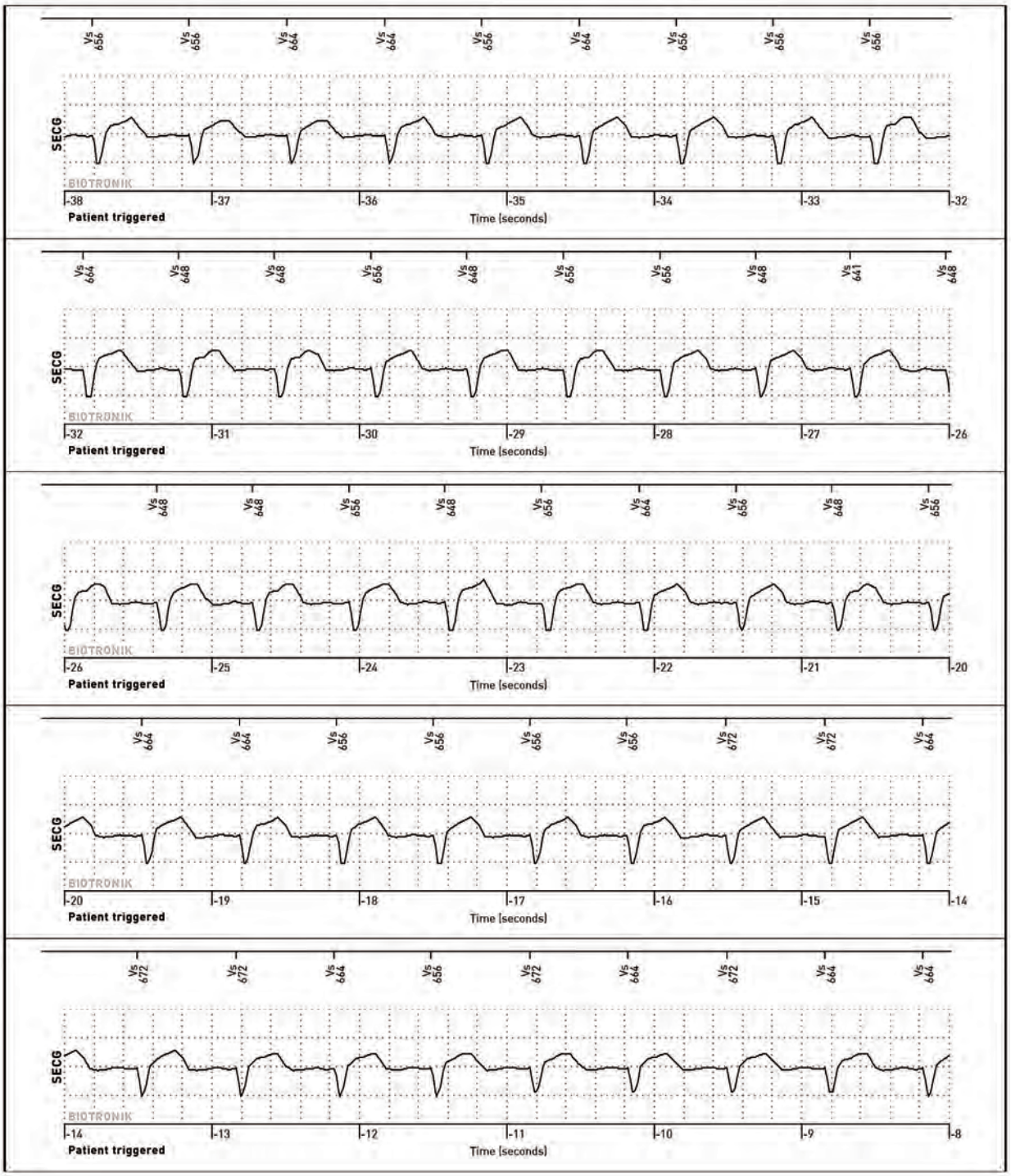

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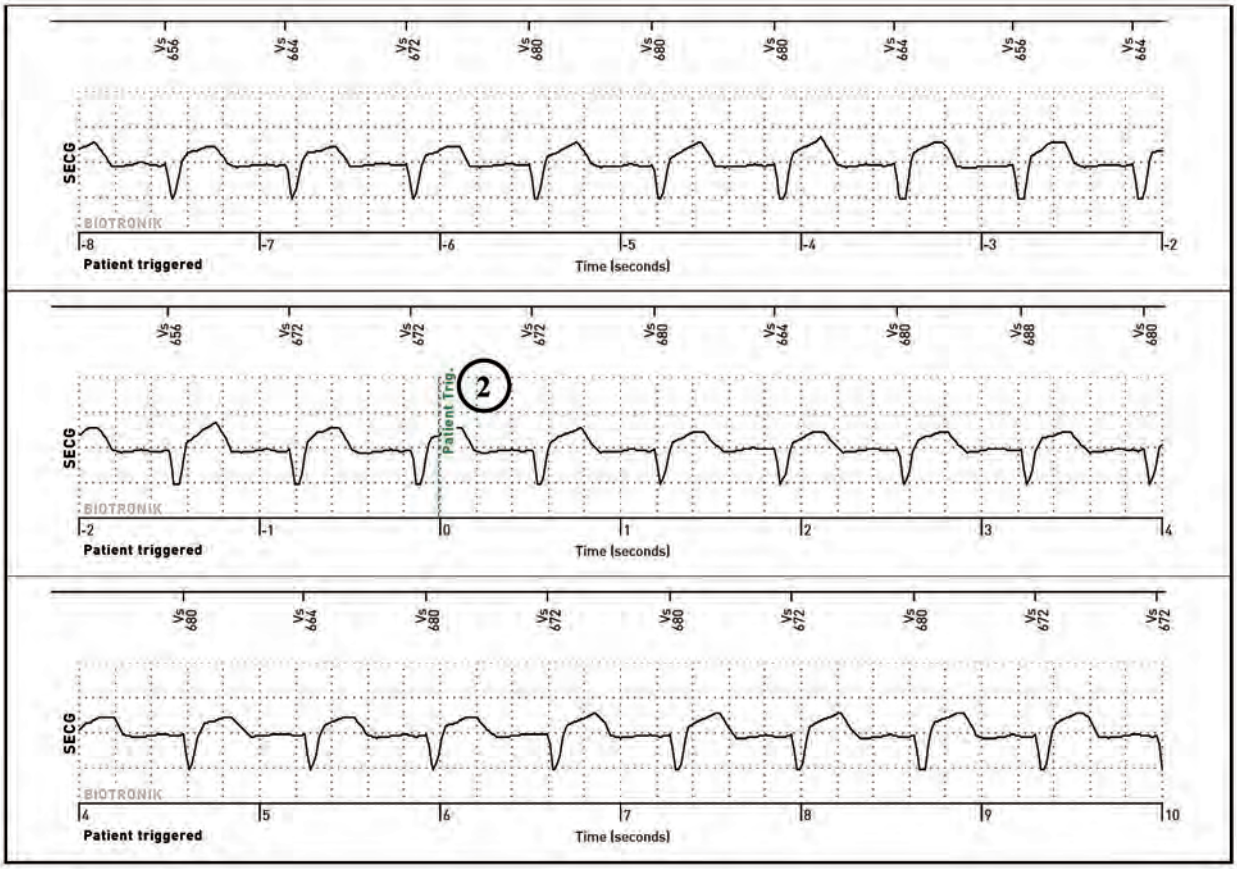

Tracing 2 ↘ Periodic tracing

Patient

83-year-old woman participating in the LBBB-TAVI study.

Tracing 2a

Periodic tracing in the setting of remote monitoring;

① the tachogram shows a stable heart rate slightly above 60 beats/minute (mean RR intervals of 943 ms);

② the Lorenz plot depicts the variation in the duration of the RR interval of a cycle relative to the previous cycle; when the rhythm is perfectly stable, all points are grouped in the center of the diagram; the pattern in this patient is very evocative of a stable sinus rhythm with minimal variation in RR intervals; intervals classified as Vn (noise) appear on the graph in light grey;

③ stable sinus rhythm with good visualization of P waves, QRS complexes and T waves;

④ the total duration of the tracing is 1 minute.

Patient

85-year-old woman participating in the LBBB-TAVI study.

Tracing 2b

Periodic tracing in the setting of remote monitoring;

⑤ tachogram and Lorenz plot patterns compatible with a stable sinus rhythm;

⑥ stable sinus rhythm with intermittent visualization of the P wave (filtered on most complexes).

Comments

The BioMonitor was developed to allow an automatic recording of episodes diagnosed as atrial fibrillation, bradycardia, asystole, sudden drop in rate or high ventricular rate. As observed on the previous tracing, the recording may be triggered by the patient following a symptomatic episode. The device can also periodically transmit an electrocardiographic tracing, the frequency of which is programmable. By definition, these random periodic tracings are not intended to be of diagnostic value and their analysis is often overlooked. However, they allow verifying the quality of the tracings even in the absence of recorded episodes. The reliability and diagnostic capacity of the system is largely contingent on the quality of the tracings and the possibility of correctly identifying the various components of the electrocardiogram (P waves, QRS complexes, T waves) without interference from an external source (myopotentials, external noise, etc.). The implantation of an implantable loop recorder is usually performed under local anesthesia in the same operative theater as that used for pacemakers. After extensive disinfection of the left thoracic region, the device is positioned between the first intercostal space and fourth rib. The quality of future recorded tracings, the ability to avoid oversensing of artifacts saturating the memory and the ability to correctly discriminate between different types of arrhythmia directly depend on the optimization of the implantation procedure. Two elements require particular consideration:

1) the optimization of R wave collection; small variations in the orientation of the device may lead to significant variations in amplitude and morphology of the sensed signals. There are two possible types of recording: patient-triggered recordings following occurrence of symptoms and automatic recordings in conjunction with the detection of bradycardia or tachycardia. During a patient-triggered recording, proper visualization of P waves, R waves and T waves facilitates the differentiation between ventricular tachycardia and supraventricular tachycardia but also between sinus pause and atrioventricular block episode. In contrast, automatic recording is based solely on the analysis of ventricular rhythm analysis and on R wave

counting, the specificity of which can be altered by oversensing of P waves or T waves by the device. It is therefore essential to obtain a proper balance between sensing of all R waves without oversensing of P or T waves in order to avoid memory saturation (episodes diagnosed as bradycardia if undersensing, episodes diagnosed as tachycardia if oversensing) while effectively visualizing the P waves to allow differentiation between sinus dysfunction and atrioventricular block during an episode of bradycardia or asystole.

2) reducing the risk of myopotential oversensing; to ensure the reliability of the automatic detection of episodes, it is important to minimize device movement within the subcutaneous pocket. Accordingly, the pocket should not be too large to avoid movement or too small to avoid the externalization of the device.

It should be noted that there are 2 different filter levels. For the sensing of QRS complexes and classification of intervals, the frequency band used by the device is between 10 and 40 Hz to avoid oversensing of low-frequency (T waves, P waves) and high-frequency (myopotentials and electromagnetic interference) signals. To facilitate the interpretation of the tracings by the physician from the programmer, different filters are used (0.5 to 40 Hz) in order to allow the visualization of low frequency signals while excluding high frequency signals (artifacts, etc.).

As can be seen on the second tracing, the P waves can be visualized on only a few complexes while the majority are filtered. If a ventricular pause occurs, it will be difficult or even impossible to differentiate between sinus pause and atrioventricular block.

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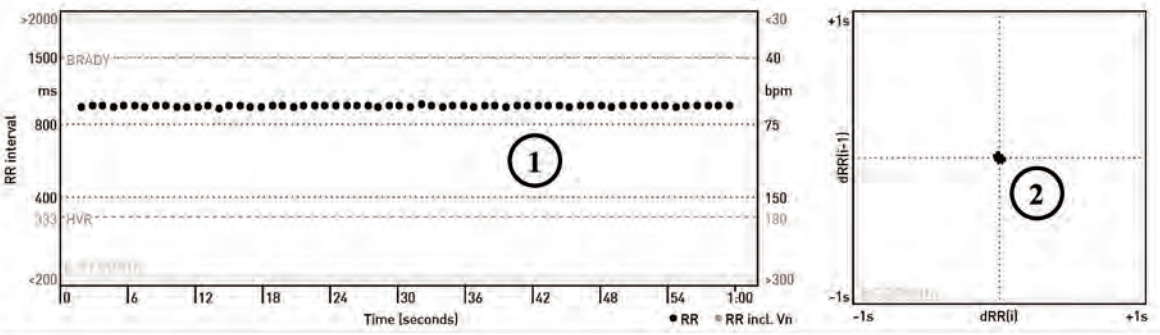
Recordings

Recordings - Episode 5:

General	
Episode number	5
Episode type	Periodic
Detection	Jun 15, 2017 1:22:00 AM
Termination	---
Duration	---
Device settings no.	3
Mean ven. rate / RR interval [ms]	943

Tachogram and Lorenz plot



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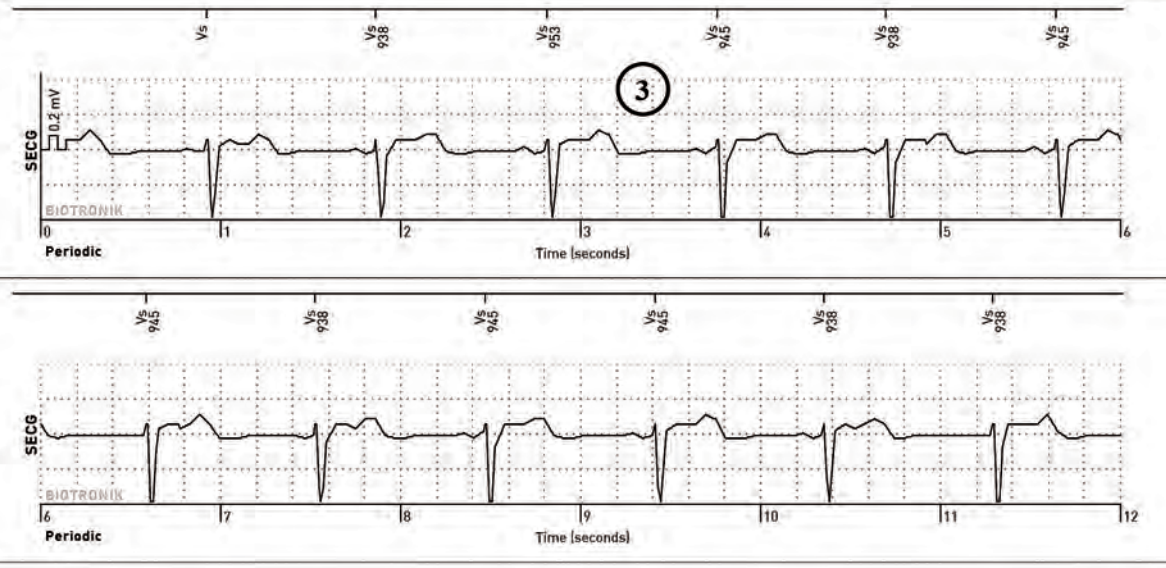

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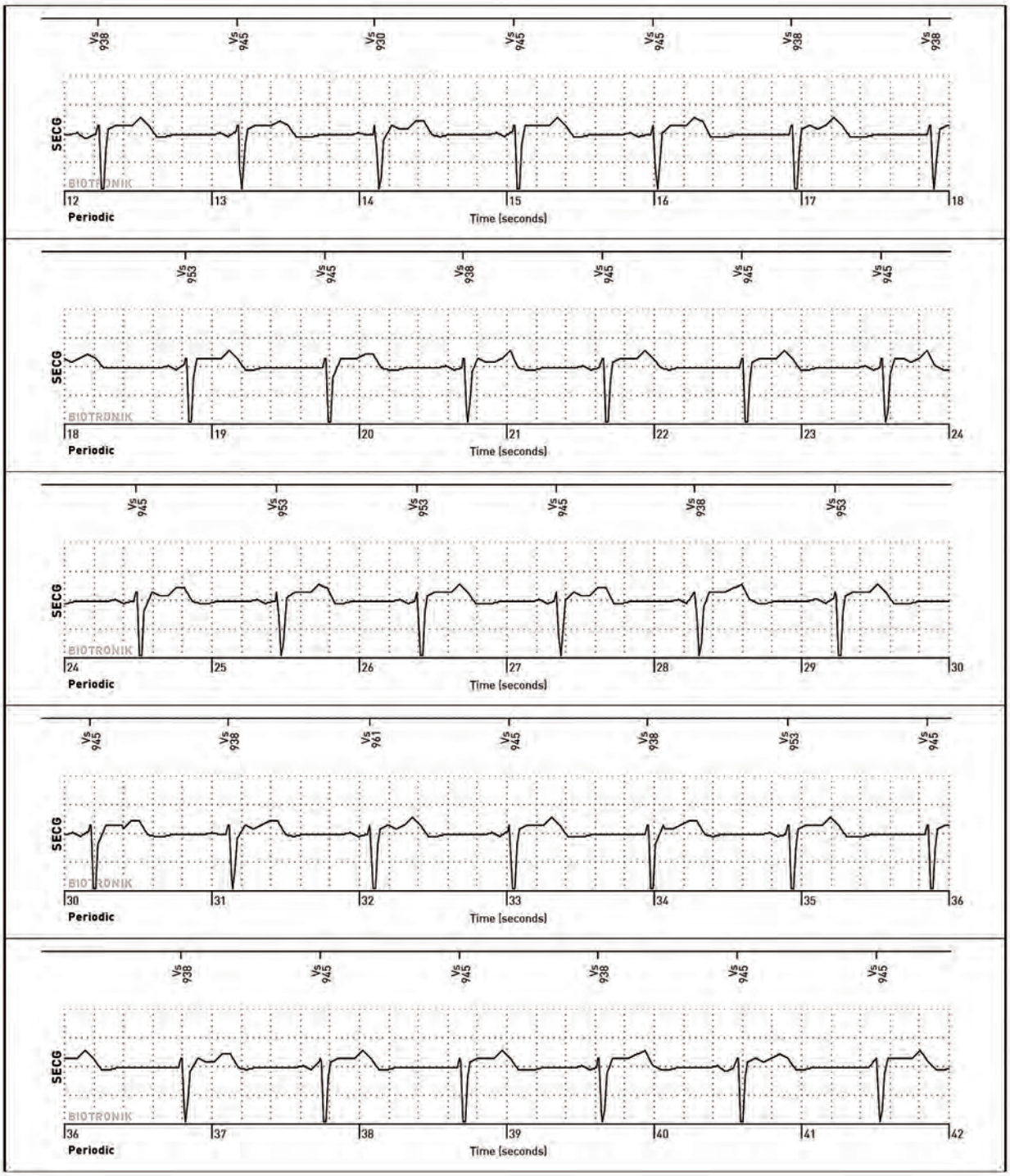

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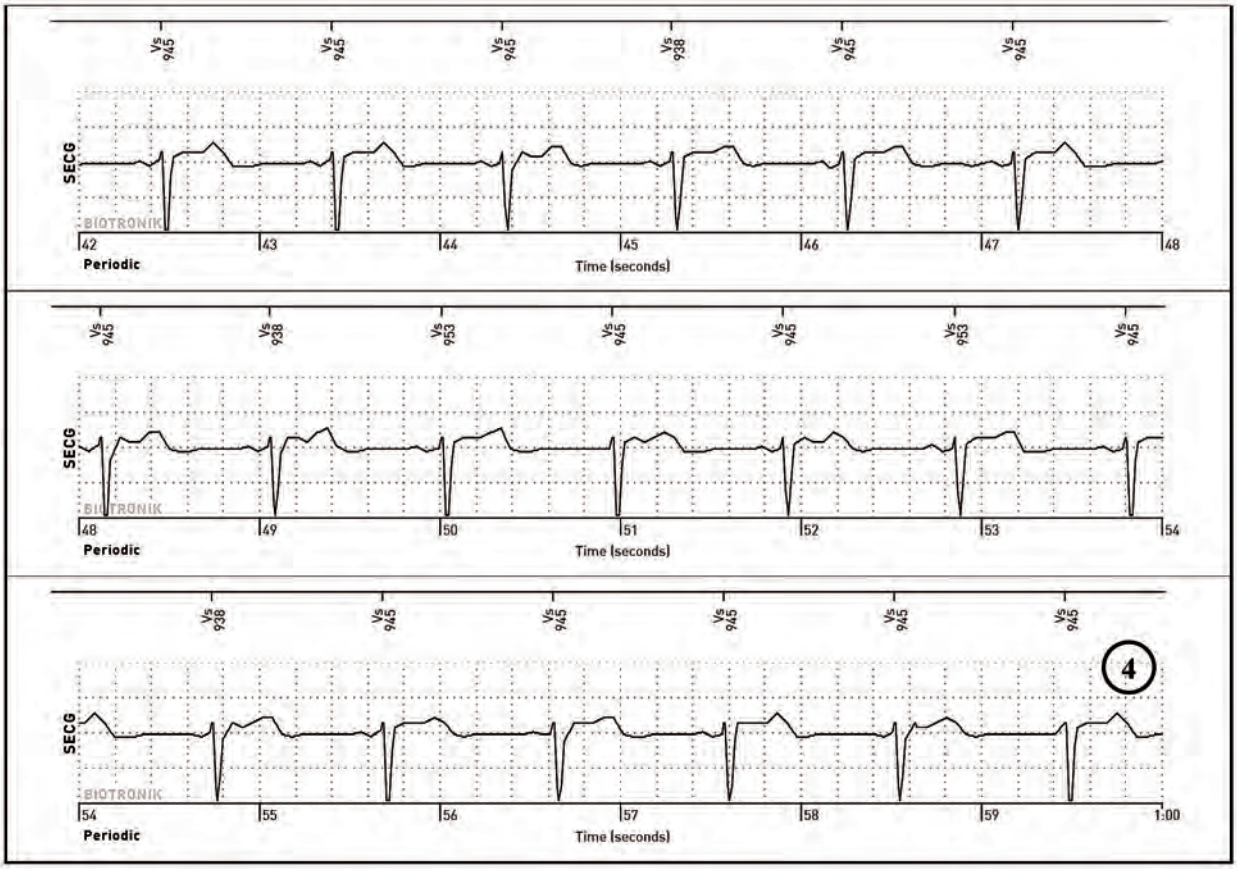

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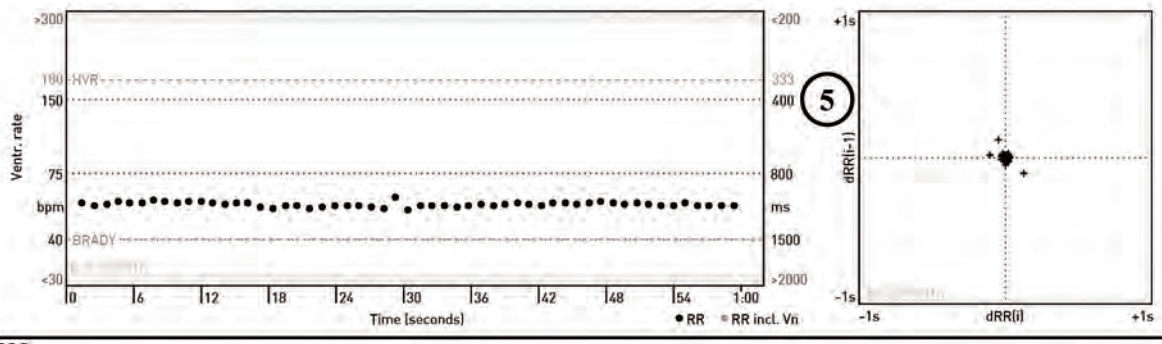
Recordings

Recordings - Episode 249:

General	
Episode number	249
Episode type	Periodic
Detection	Jan 28, 2017 1:27:00 AM
Termination	---
Duration	---
Device settings no.	3
Mean ven. rate / RR interval [bpm]	56

Tachogram and Lorenz plot



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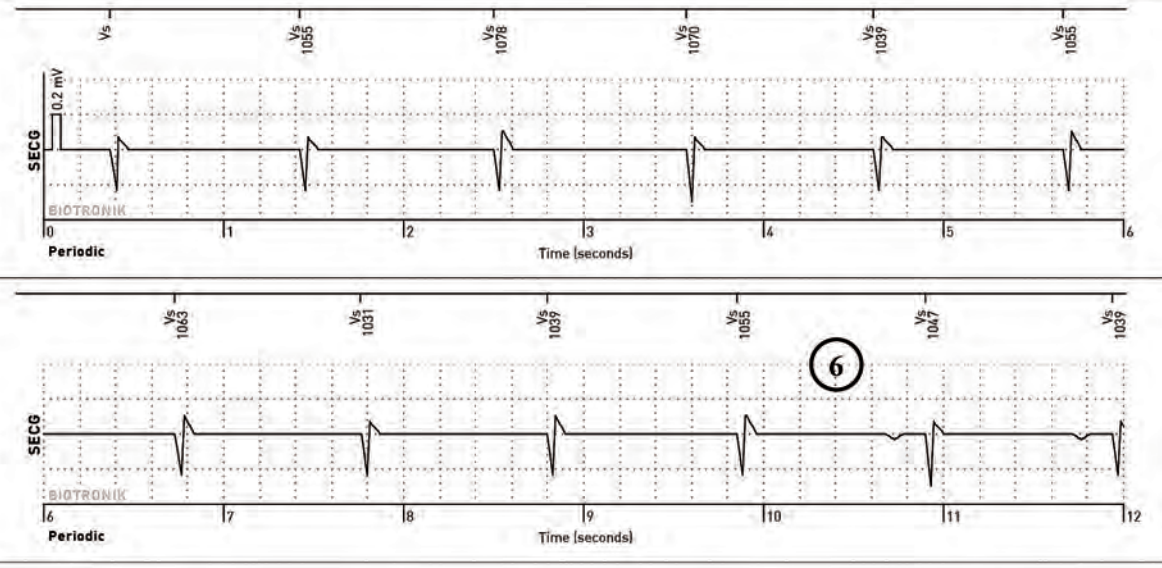

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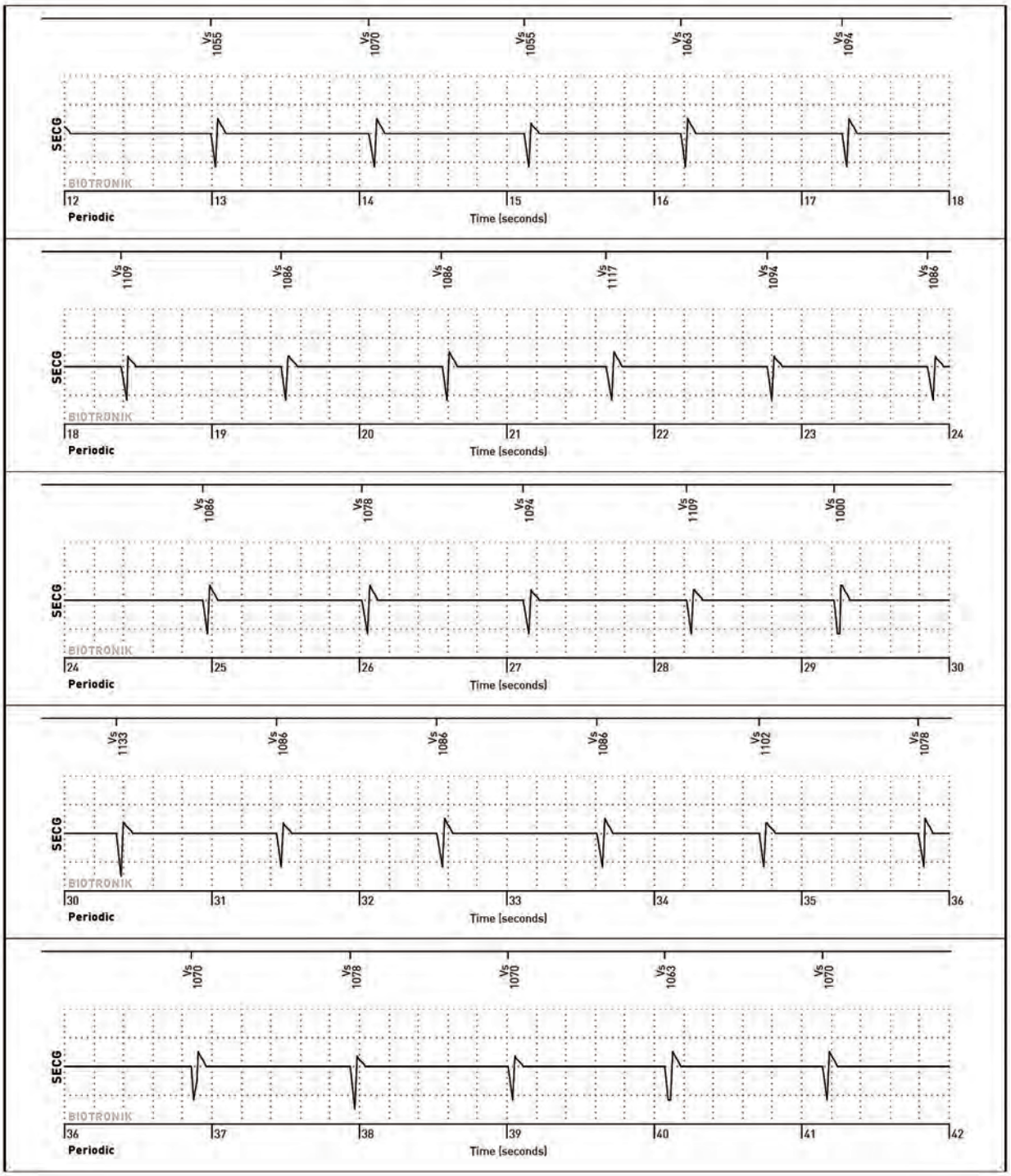

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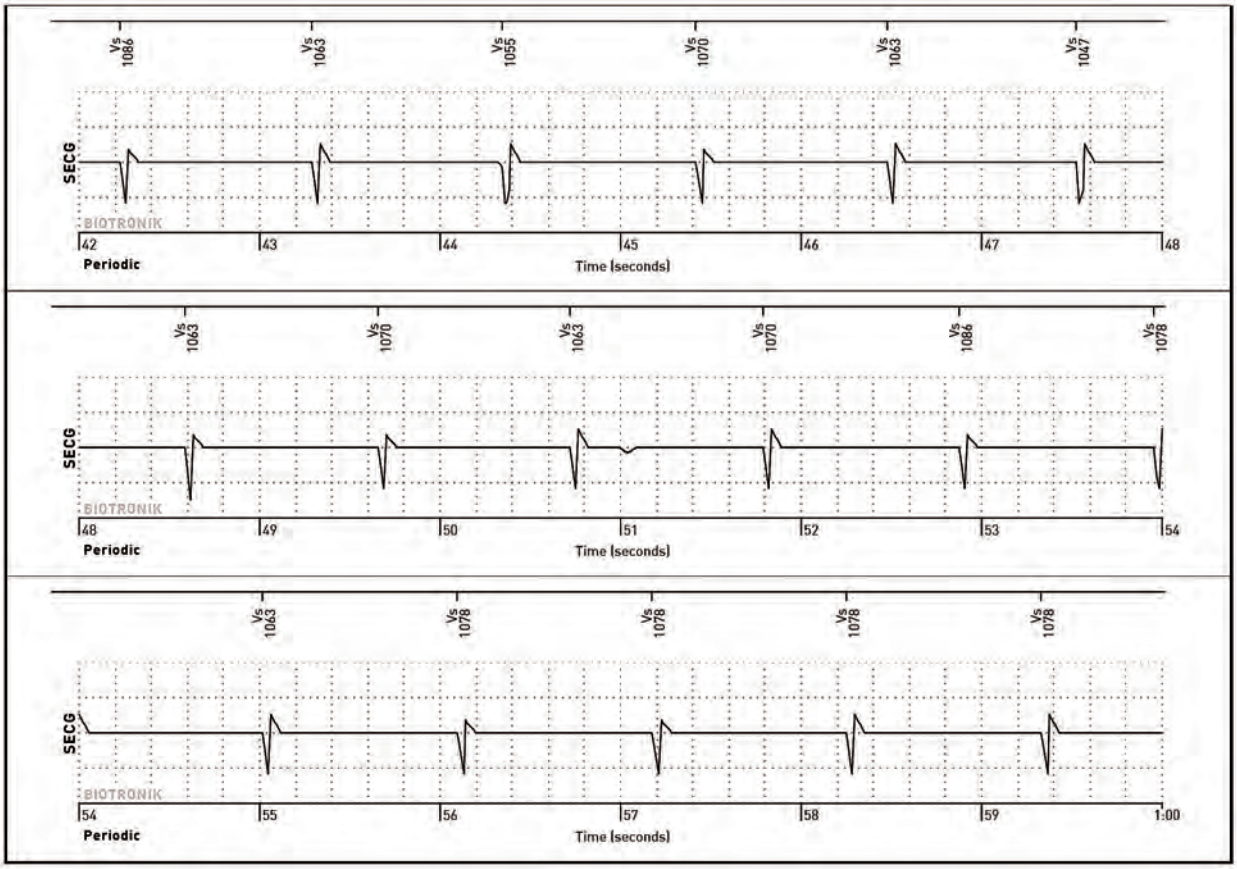

Tracing 3 ↘ Sinus bradycardia

Patient

84-year-old man participating in the LBBB-TAVI study.

Tracing 3a

Episode of nocturnal bradycardia automatically recorded by the device;

① sinus bradycardia with rate slightly above 40 beats/minute;

② slight decrease in heart rate (< 40 beats/minute);

③ diagnosis of an episode of bradycardia by the device; the average heart rate over the previous 10 seconds is below the programmed threshold of 40 beats/minute.

Patient

79-year-old man participating in the LBBB-TAVI study; lipothymia in the morning after breakfast; heat-type prodromes, vertigo followed by "malaise" without loss of consciousness; the patient did not use the assistant to trigger the recording.

Tracing 3b

Episode of bradycardia contemporaneous with symptoms automatically recorded by the device;

① on the tracing, stable rhythm initially at a rate close to 70 beats/minute;

② a relatively sudden drop in rate leading to the diagnosis of bradycardia;

③ normalization of the rate;

④ the tracing confirms the presence of an initially stable sinus rhythm (difficulty in properly visualizing the P waves);

⑤ significant slowing of the heart rate with sinus bradycardia;

⑥ diagnosis of an episode of bradycardia by the device; the mean heart rate over the previous 10 seconds is below the programmed threshold of 40 beats/minute.

Comments

The first patient presented episodes of nocturnal sinus bradycardia. A so-called normal sinus rate corresponds by definition to a resting rate of between 50-60 and 100 beats/minute. The difference between physiological and pathological bradycardia is sometimes difficult to determine. It is indeed frequent and without pathological nature to observe during the day or more often at night, a slowing of the heart rate with sinus activity sometimes falling under 40 beats/minute. A vagal hypertonia frequently observed in athletic patients may explain a physiological bradycardia without the need for special investigation or treatment. A drug etiology is also frequently observed (beta-blocker, digoxin, amiodarone, calcium channel blocker, etc). It is common to define a sinus bradycardia as pathological when it causes the onset of symptoms. It was decided not to implant this asymptomatic patient presenting a perfectly normal daytime heart rate and a preserved chronotropic competence (normal acceleration of the heart rate during exercise).

The second patient presented with a paroxysmal sinus dysfunction occurring in a manifest vagal setting. When in presence of a pause or paroxysmal sinus bradycardia, it is imperative to search for a triggering factor

(vagal context, violent pain, fear, stress, urination, etc) in order to differentiate patients presenting a true anatomic sinus (fibrosis, etc) or electrophysiological dysfunction (inability of sinus cells to spontaneously depolarize) and those patients with a reflex pause occurring in a vagal context (prolongation of the spontaneous depolarization slope of sinus cells or sinus activity conduction block in conjunction with a vagal brake), the therapeutic consequences of which differ completely. It was also decided not to implant this pauci-symptomatic patient in a vagal context in the absence of any significant pause.

The device automatically records an episode of bradycardia if the heart rate drops below a programmable value (between 30 and 80 beats/minute, nominal value 40 beats/minute) for a programmable duration (between 5 and 30 seconds, nominal value 10 seconds).

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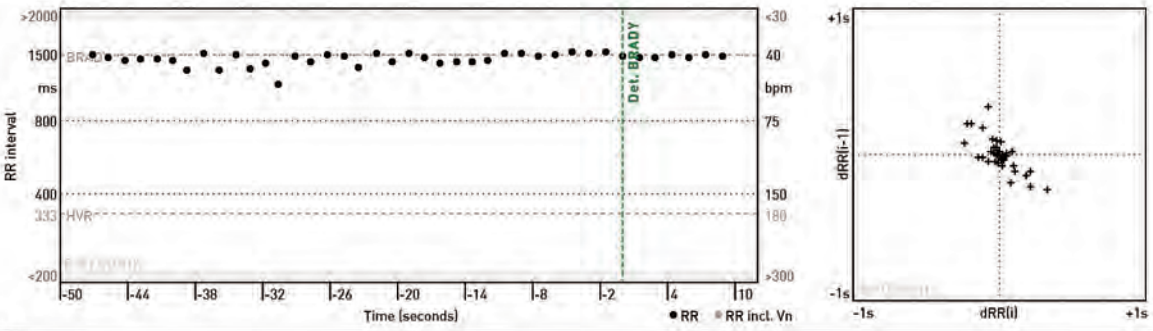
Recordings

Recordings - Episode 445:

General	
Episode number	445
Episode type	Bradycardia
Detection	Jun 1, 2017 12:54:36 AM
Termination	Jun 1, 2017 12:54:50 AM
Duration	14s
Device settings no.	2
Mean ven. rate / RR interval [ms]	1513

Tachogram and Lorenz plot



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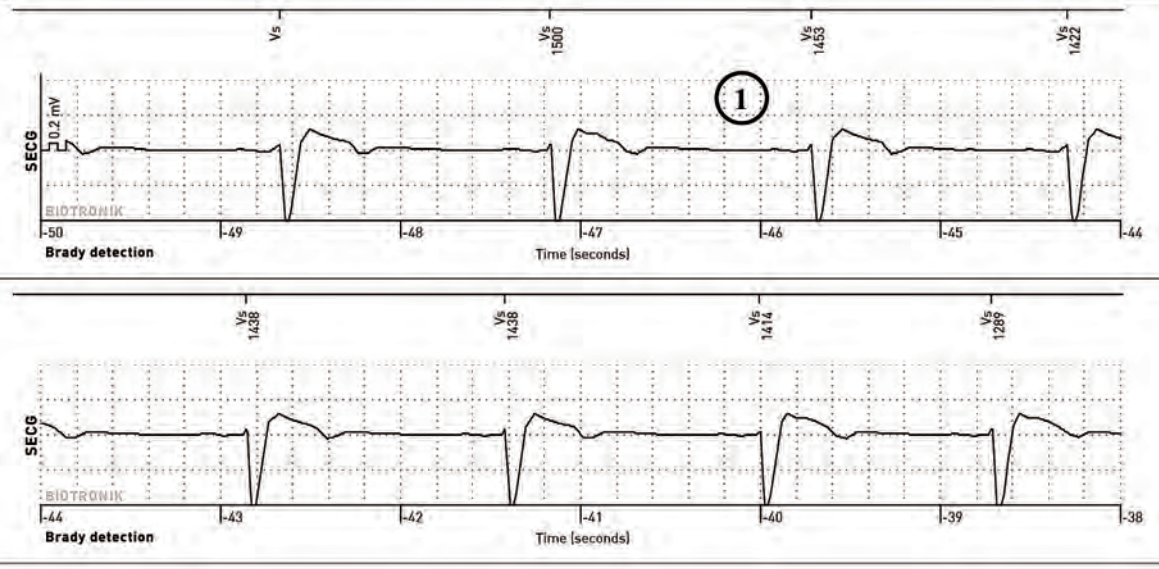

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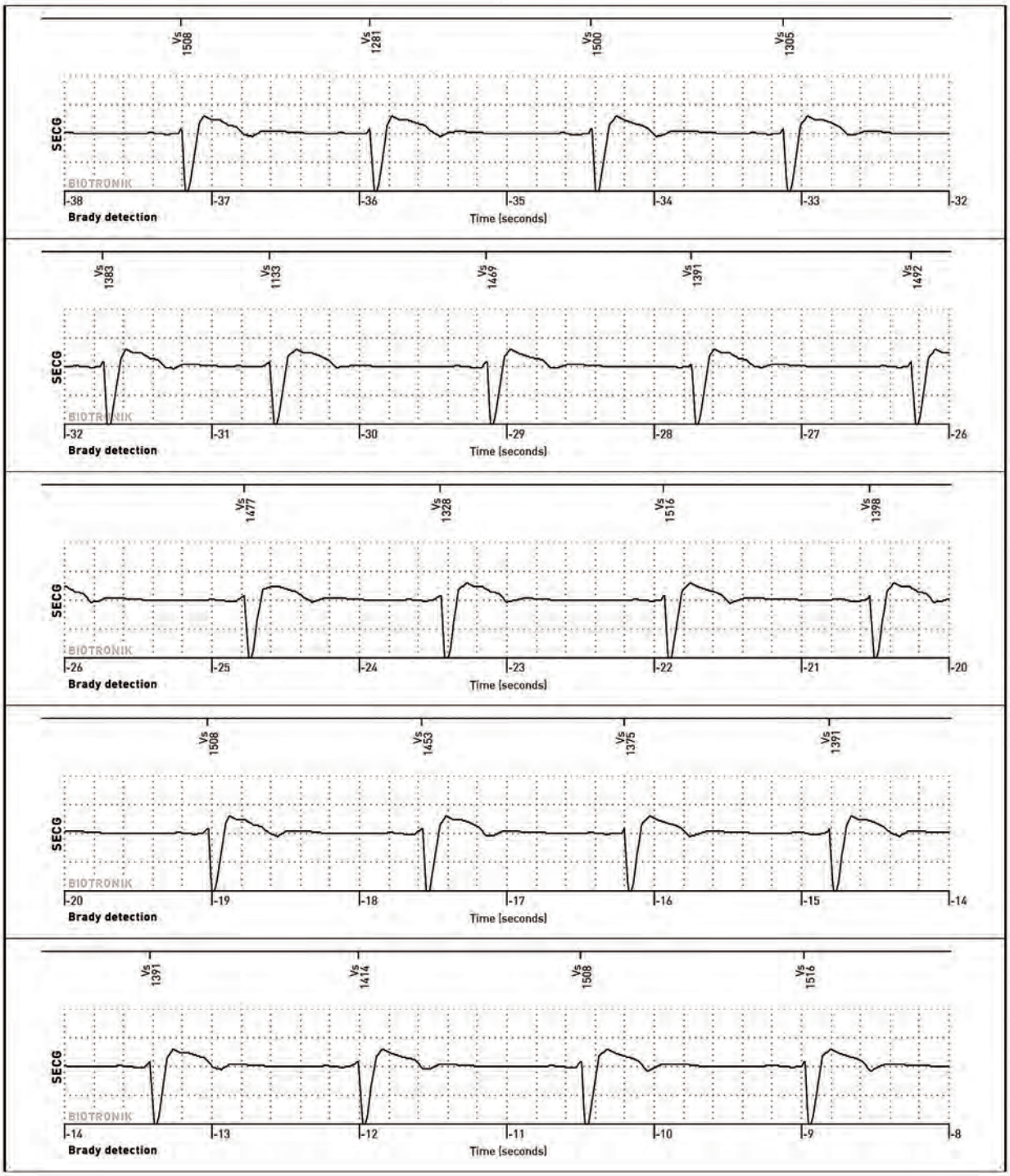

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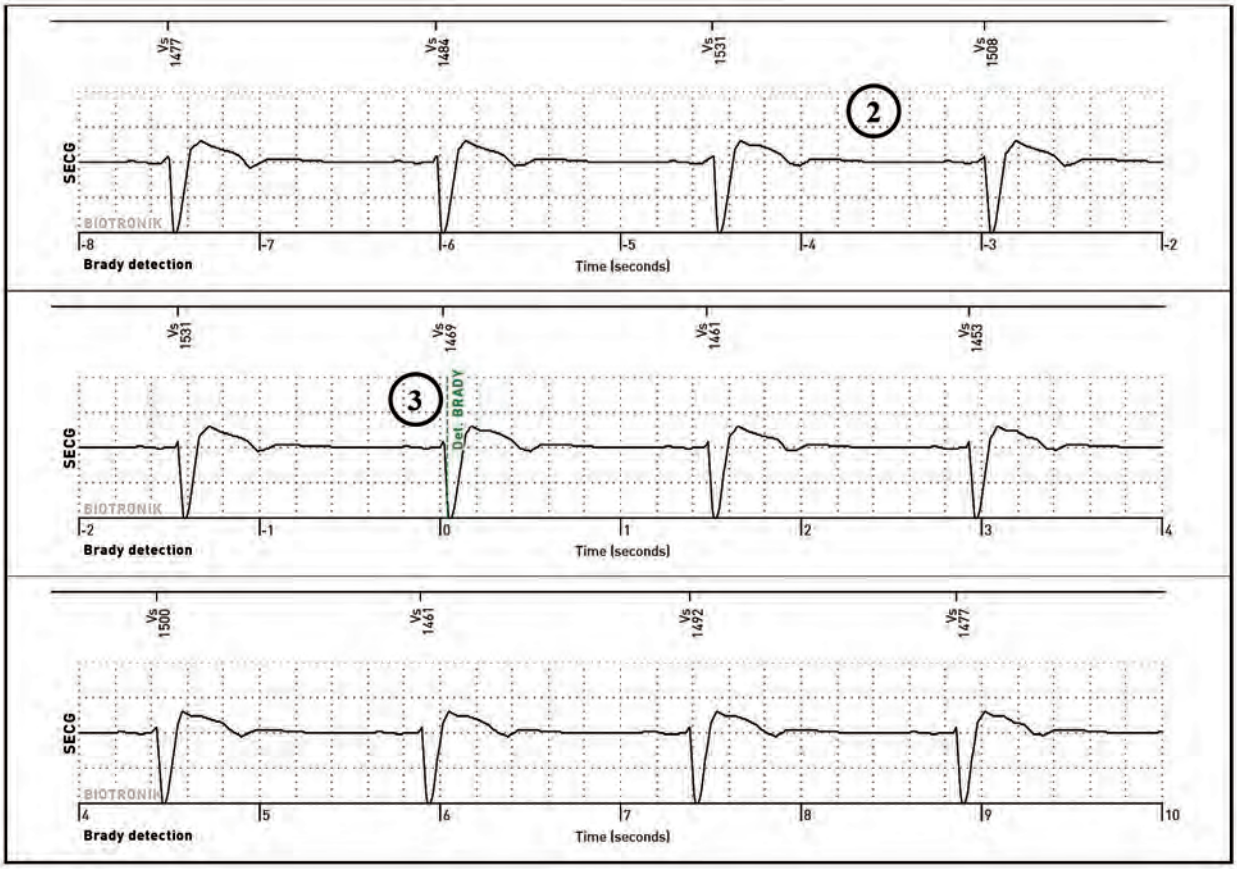

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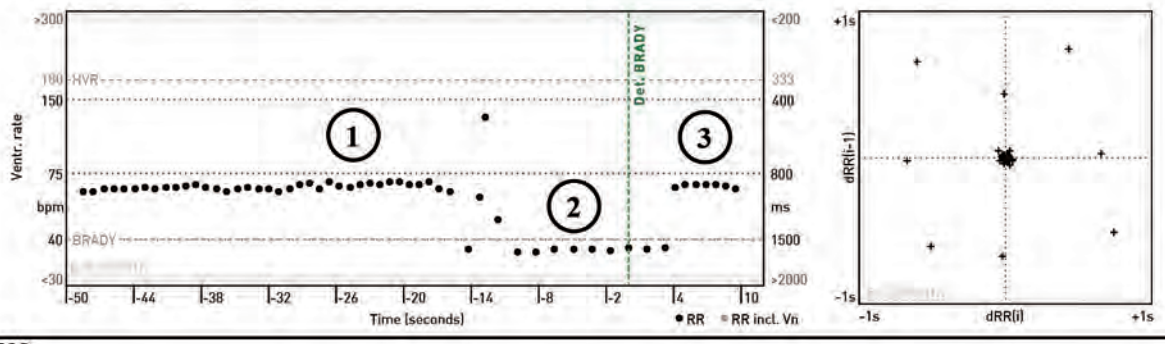
Recordings

Recordings - Episode 2:

General	
Episode number	2
Episode type	Bradycardia
Detection	May 22, 2016 7:14:28 AM
Termination	May 22, 2016 7:14:40 AM
Duration	12s
Device settings no.	2
Mean ven. rate / RR interval [bpm]	36

Tachogram and Lorenz plot



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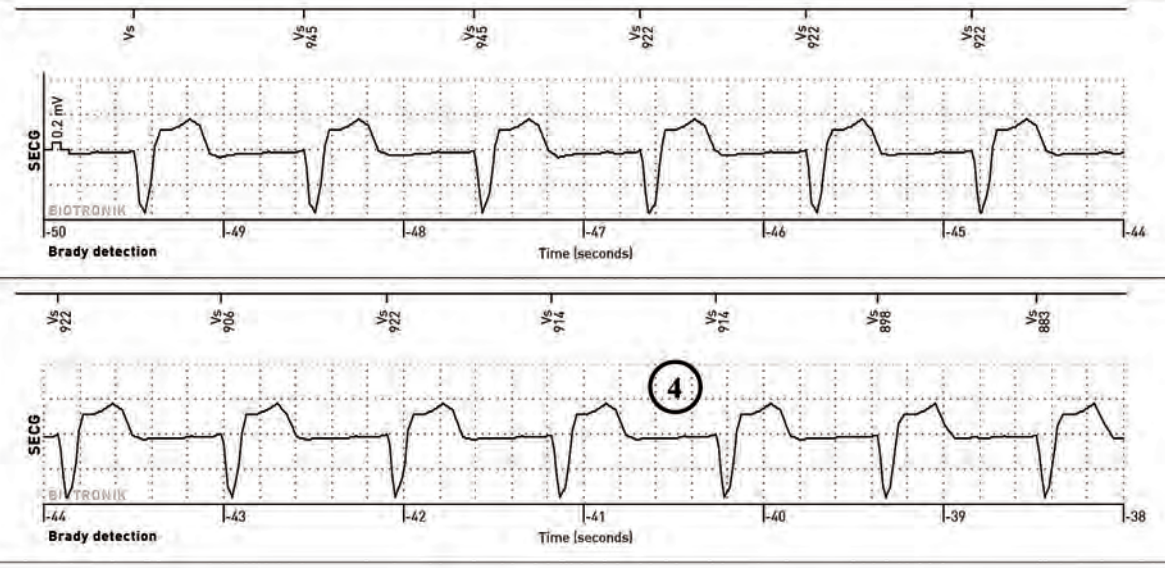

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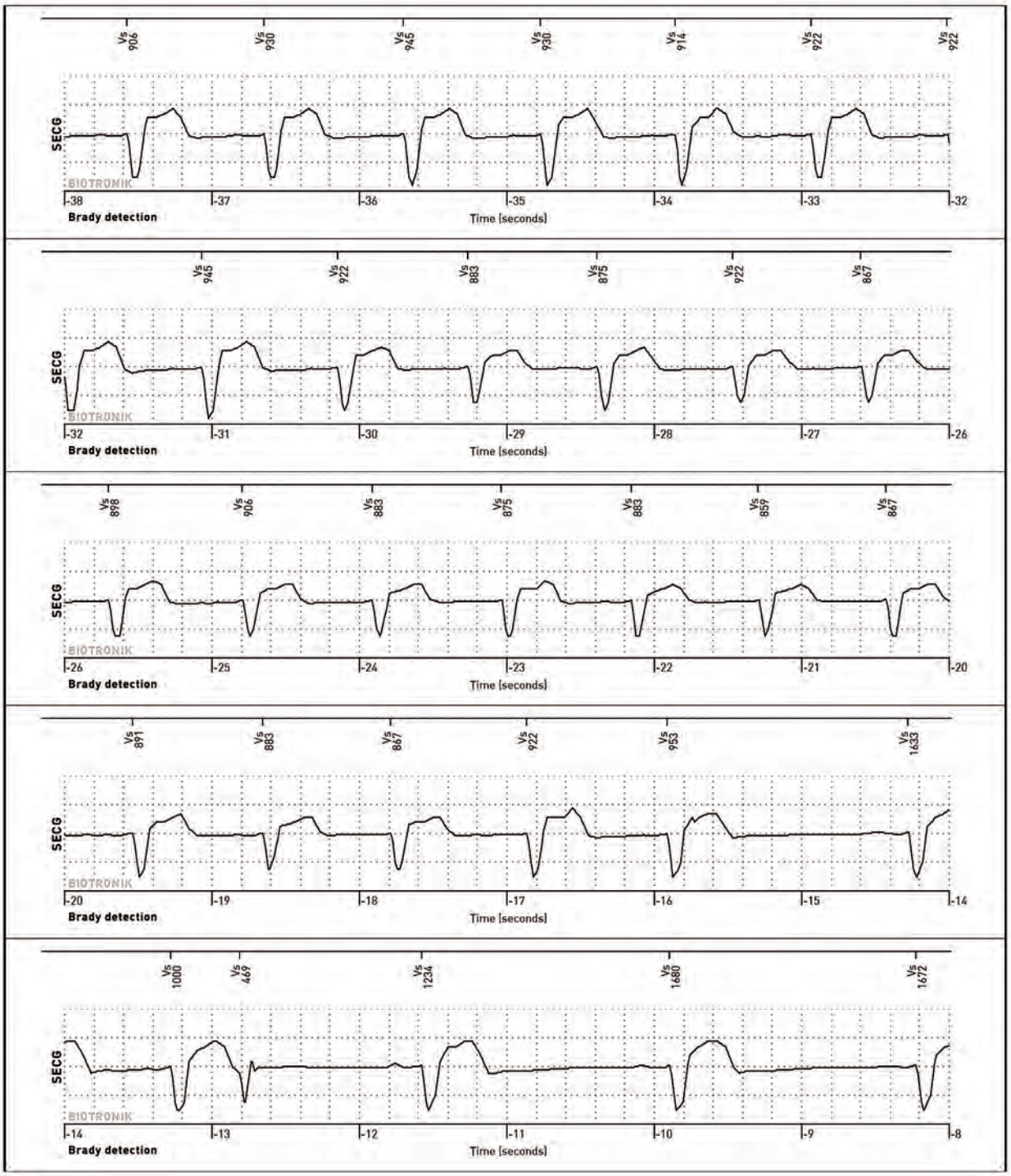

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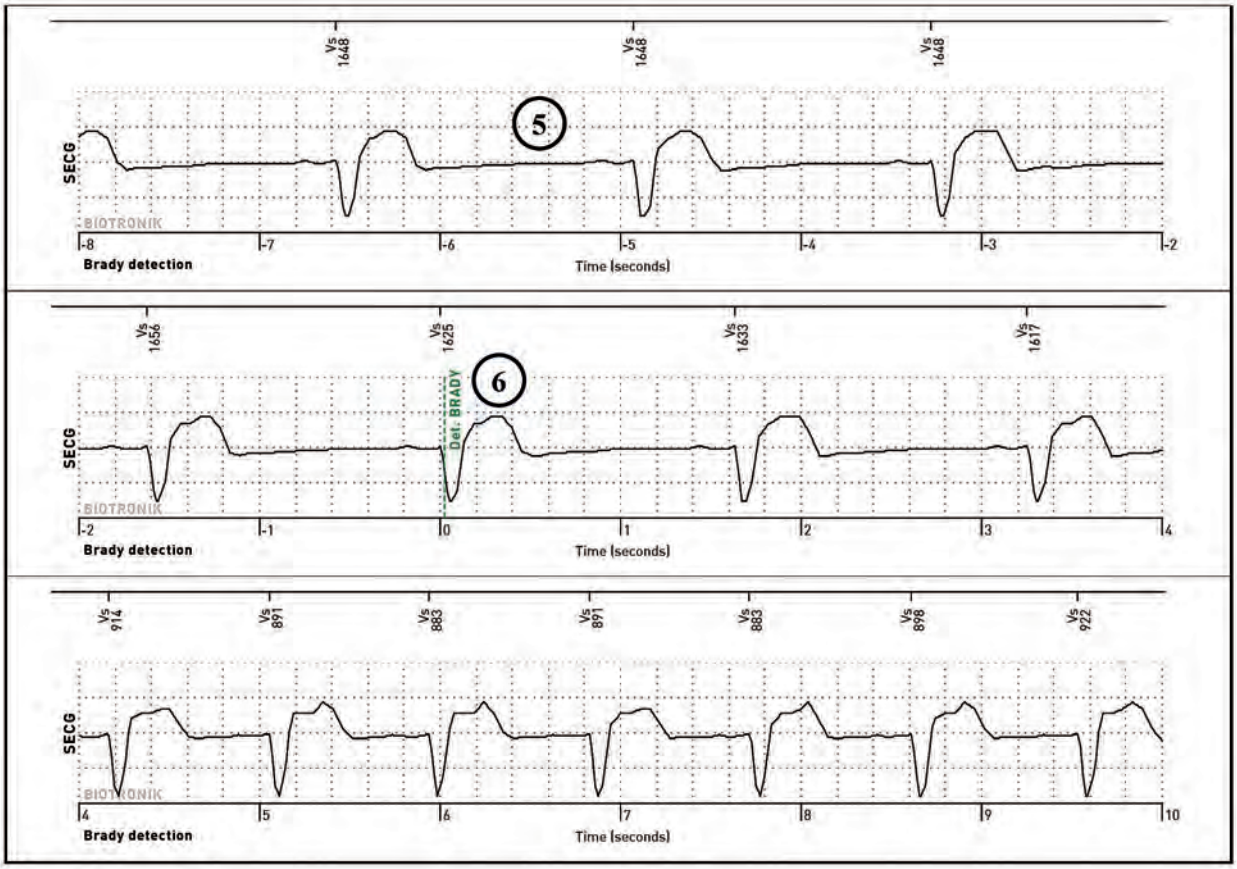

Tracing 4 ↘ Syncope and complete atrioventricular block

Patient

81-year-old man participating in the LBBB-TAVI study; sudden syncope with facial trauma; as a result of the fall, the patient was not able to use the assistant and trigger the recording.

Tracing

Asystole episode recorded automatically by the device;

① long PR with left bundle branch block pattern;

② prolonged pause with several consecutive blocked P waves; complete atrioventricular block;

③ escape with oversensing;

④ new ventricular pause with blocked P waves;

⑤ new pause and diagnosis of asystole.

Comments

In some patients, activation of the patient assistant after the occurrence of a symptom is impossible: patients with traumatic syncope and temporary inability to move or altered consciousness following the fall, patients with permanent cognitive disorders, patients with moderate mobility and impaired manual dexterity. The automatic recording sometimes allows diagnosis as in the present case. This patient had presented an episode of syncope in conjunction with a paroxysmal complete atrioventricular block and underwent the implantation of a pacemaker which enabled preventing recurrences.

The device automatically records an asystole episode when the delay between 2 sensed QRS complexes exceeds a programmable value (2 to 10 seconds, nominal value 3 seconds). An asystole can only be diagnosed from 2 VS intervals, the signals classified as noise (Vn) being excluded from the analysis.

Patients implanted with a Biomonitor can benefit from remote monitoring. The Biotronik telemonitoring system is oriented more towards remote monitoring than teleconsultation. The patient has no specific action to perform, the transmission between the implantable loop recorder and the transmitter (CardioMessenger) being automatic (the patient is passive). The Biomonitor automatically transmits the data as an encrypted SMS to the company's service center. The data are then decoded, analyzed and organized in the form of a report (Cardio Report) made available to the cardiologist on a secured website. The cardiologist also receives alert messages (by fax, SMS or email) in the case of a particular event of which he or she has previously set the nature. Telemedicine follow-up combines a calendar remote monitoring system that allows punctual verification of the functioning of the implanted device at the dates defined by the cardiologist and an event remote monitoring system that ensures automatic and continuous monitoring by sending a message to the cardiologist during the recording of an episode. Every night at a fixed time, the prosthesis transmits the contents of the memory bank and the technical parameters to a transmitter which relays the latter to the service center of the company by mobile phone networks. The objectives of telemedicine are, on the one hand, to improve the quality of life of the patients by limiting the inconveniences caused by the displacements and prolonged absences both from home and the workplace and, on the other, to optimize patient safety by reducing the intervention time when an episode of arrhythmia or bradycardia is detected. In patients implanted for a cryptogenic stroke, for example, remote monitoring significantly reduces the time needed for intervention and introduction of anticoagulant therapy when the device diagnoses an episode of asymptomatic AF.

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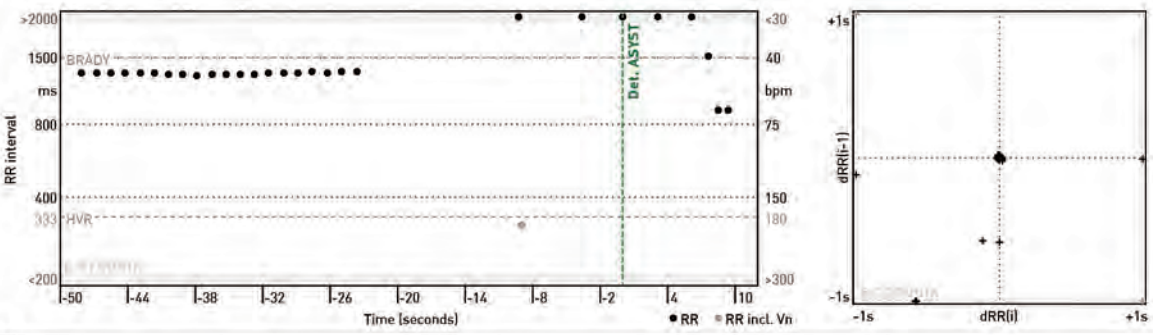
Recordings

Recordings - Episode 6:

General	
Episode number	6
Episode type	Asystole
Detection	Jan 25, 2017 12:39:26 AM
Termination	---
Duration	---
Device settings no.	3
Mean ven. rate / RR interval [ms]	---

Tachogram and Lorenz plot



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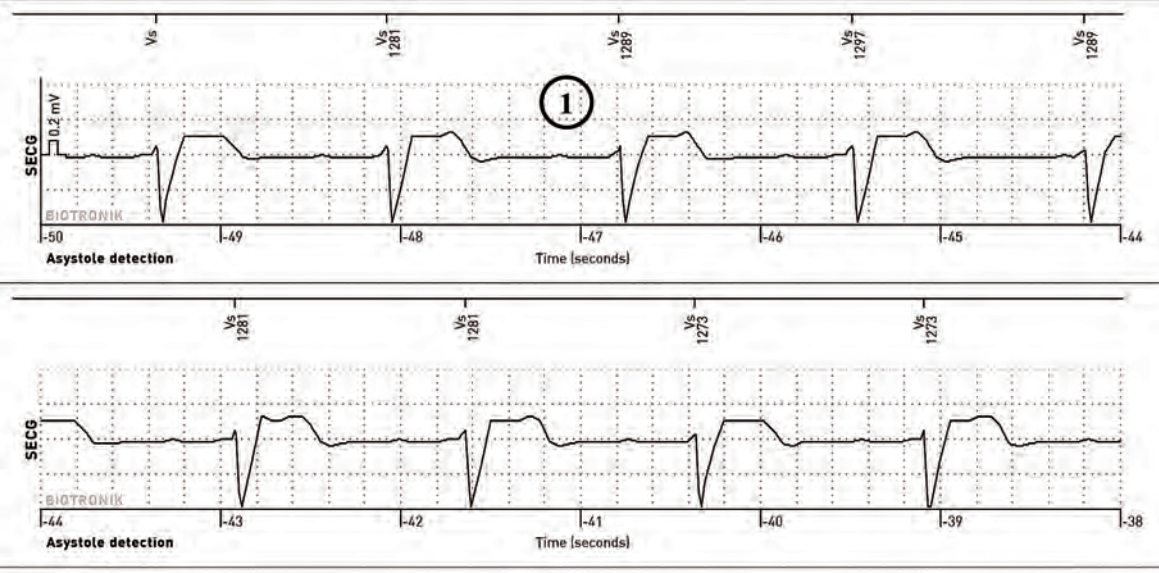

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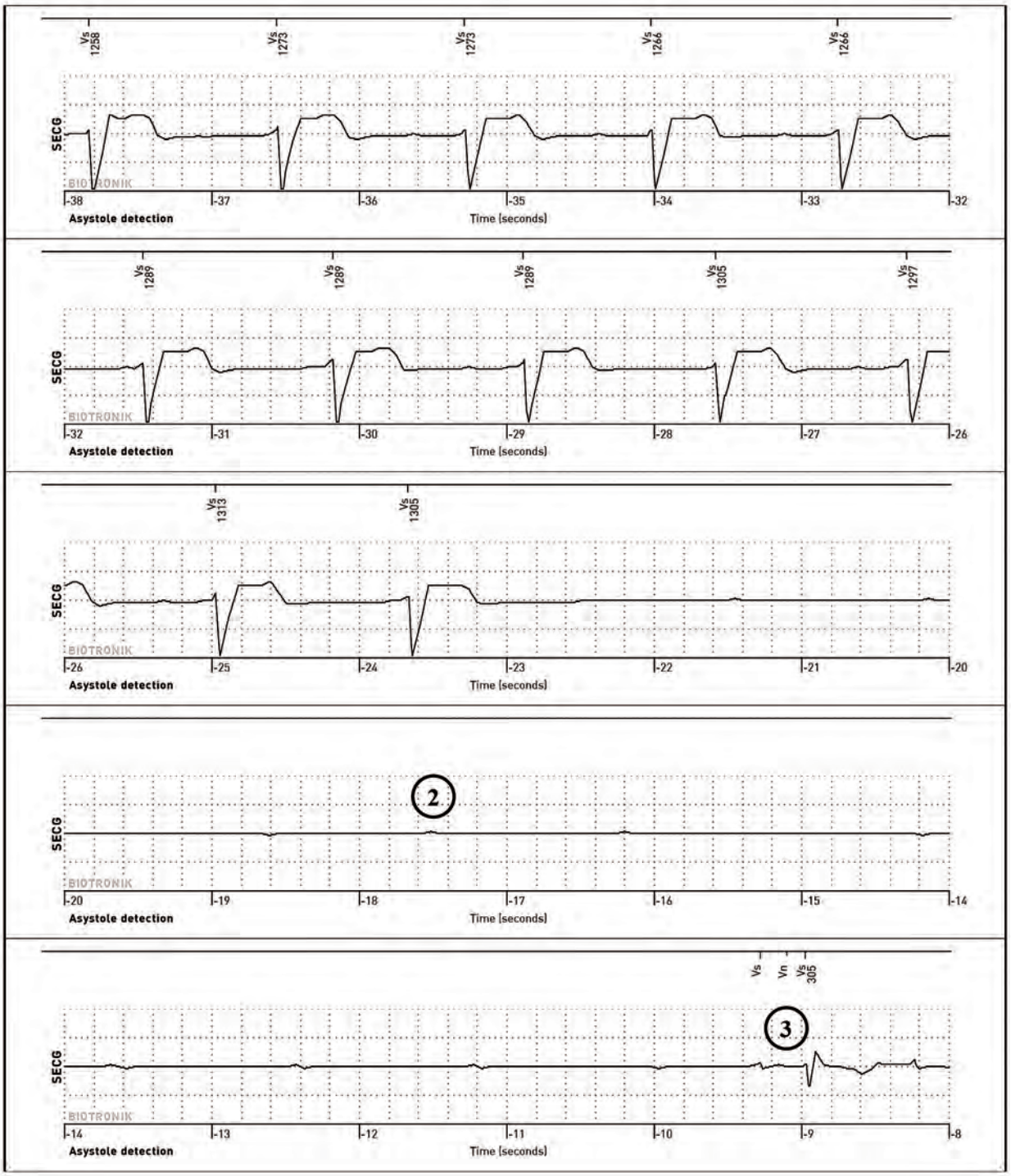

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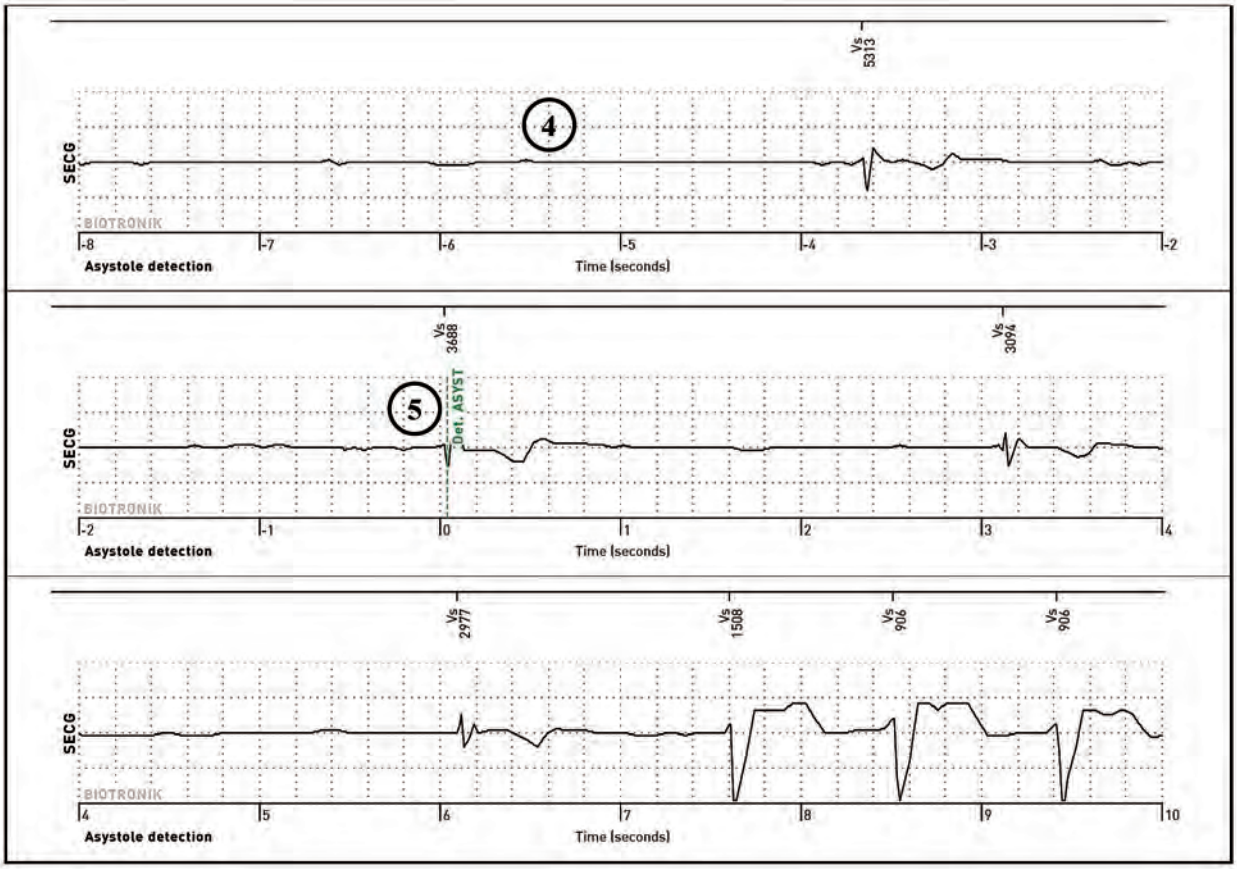

Tracing 5 ↘ Lipothymia and atrial disease

Patient

81-year-old woman participating in the LBBB-TAVI study; paroxysmal AF; in the aftermath of implantation, palpitations, episodes of lipothymia and a syncopal episode.

Tracing 5a

Diagnosed AF episode;

① the tachogram and Lorenz plot strongly suggest an AF episode with highly irregular and relatively rapid ventricular intervals;

② the pattern confirms the presence of conducted AF with a relatively rapid rate and irregular ventricular intervals;

③ diagnosis of AF by the device;

Tracing 5b

Episode diagnosed as asystole;

④ on the plot and on the tracing, the pattern is initially suggestive of a conducted AF;

⑤ ventricular pause of more than 3 seconds leading to the diagnosis of asystole by the device;

⑥ resumption of a stable sinus rhythm; it was therefore a post-conversion pause;

Tracing 5c

Episode diagnosed as bradycardia;

⑦ the tachogram, the Lorenz plot and the tracing are suggestive of a nocturnal sinus bradycardia; 10 seconds with a rate under 40 beats per minute leading to the diagnosis of bradycardia;

Tracing 5d

Episode diagnosed as asystole;

⑧ stable sinus rhythm;

⑨ sinus pause leading to the diagnosis of asystole;

⑩ return to a stable sinus rhythm.

Comments

Bradycardia-tachycardia syndrome is characterized by alternating episodes of supraventricular tachycardia (atrial tachycardia, AF, common flutter) and episodes of bradycardia in conjunction with a sinus dysfunction. Symptomatology combines secondary clinical signs with tachycardia (palpitations, heart failure) and bradycardia (fatigue, cognitive disorders, dyspnea, lipothymia, syncope). This association suggests the presence of diffuse atrial organic lesions with degenerative impairment of sinus node automatic cells but also fibrosis extending to the atrial myocardium and sometimes to the specific tissue of the atrioventricular junction explaining the possible concomitant observation of atrioventricular conduction disorders. It is common to differentiate bradycardia-tachycardia syndrome (absence of a chronological link between tachycardia and bradycardia episodes) and post-conversion pauses (sinus pauses observed exclusively during

the termination of atrial arrhythmias). This patient concurrently presented symptomatic post-conversion pauses, nocturnal sinus bradycardia and pauses occurring during baseline sinus rhythm. She underwent implantation of a pacemaker which allowed preventing syncopal recurrences. The introduction of beta blocker therapy also limited the increase in heart rate of conducted AF episodes.

Status report - Sep 20, 2016

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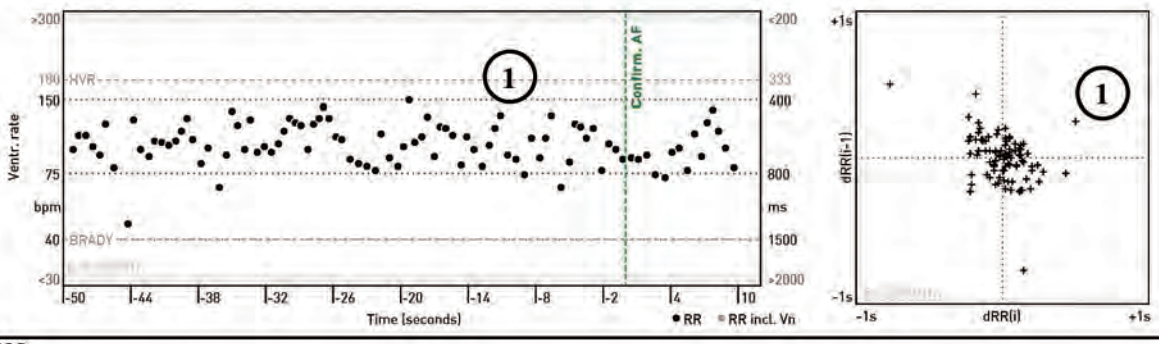
Recordings

Recordings - Episode 16:

General	
Episode number	16
Episode type	AF
Detection	Sep 19, 2016 8:24:30 PM
Termination	Sep 19, 2016 8:46:46 PM
Duration	22min 16s
Device settings no.	2
Mean ven. rate / RR interval [bpm]	95

Tachogram and Lorenz plot



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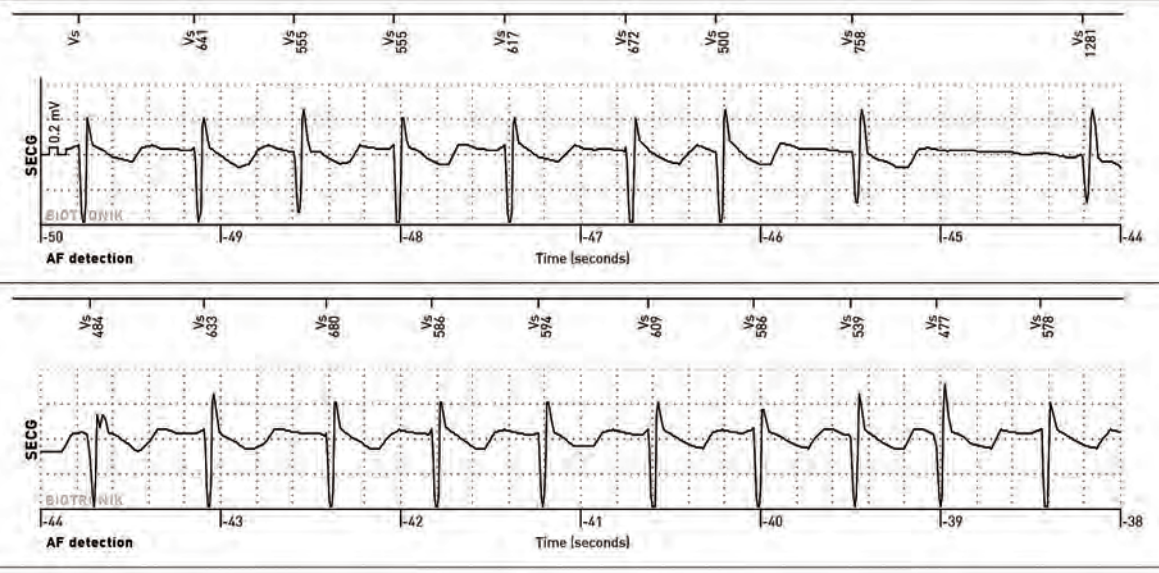

Status report - Sep 20, 2016

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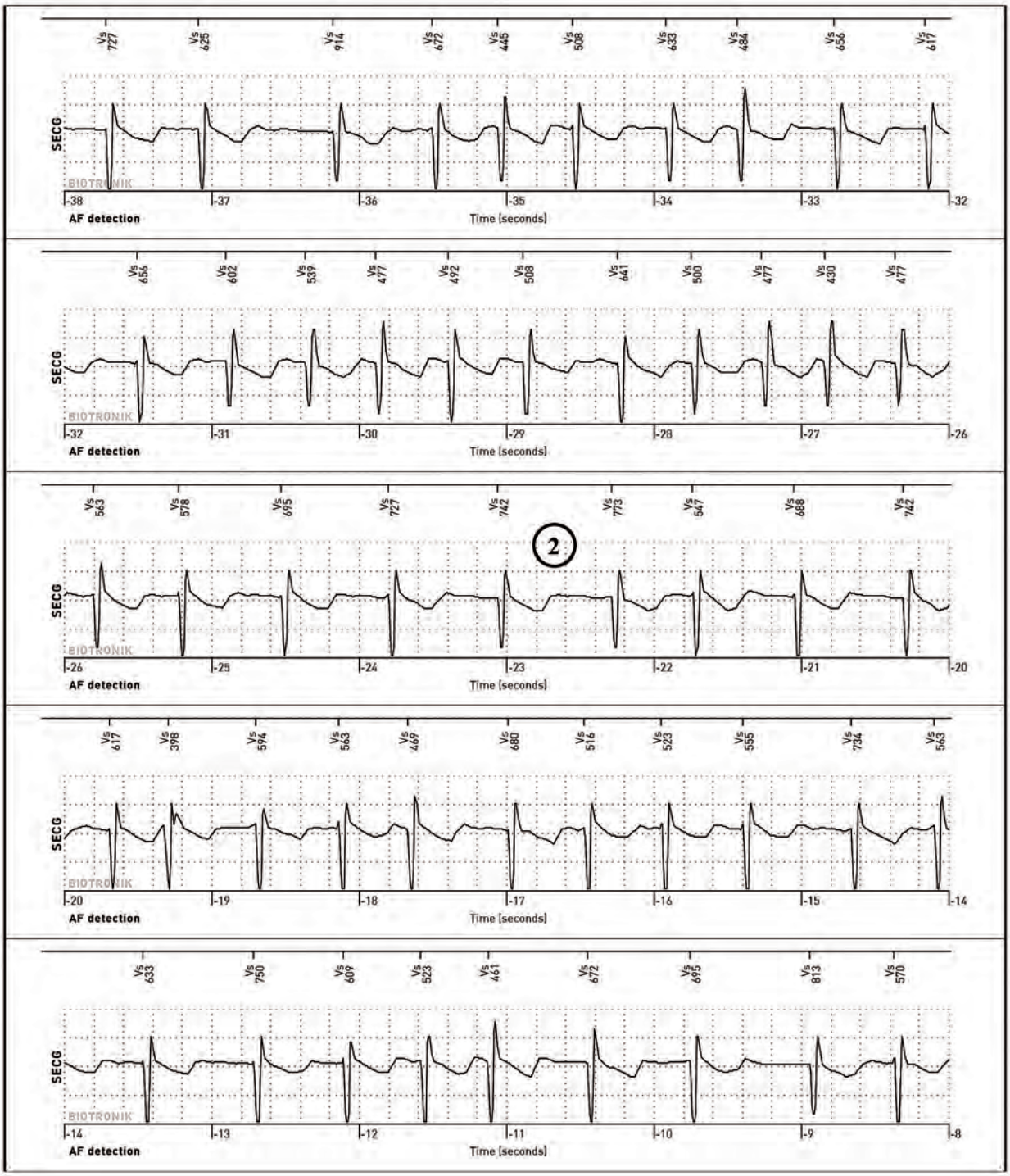

Status report - Sep 20, 2016

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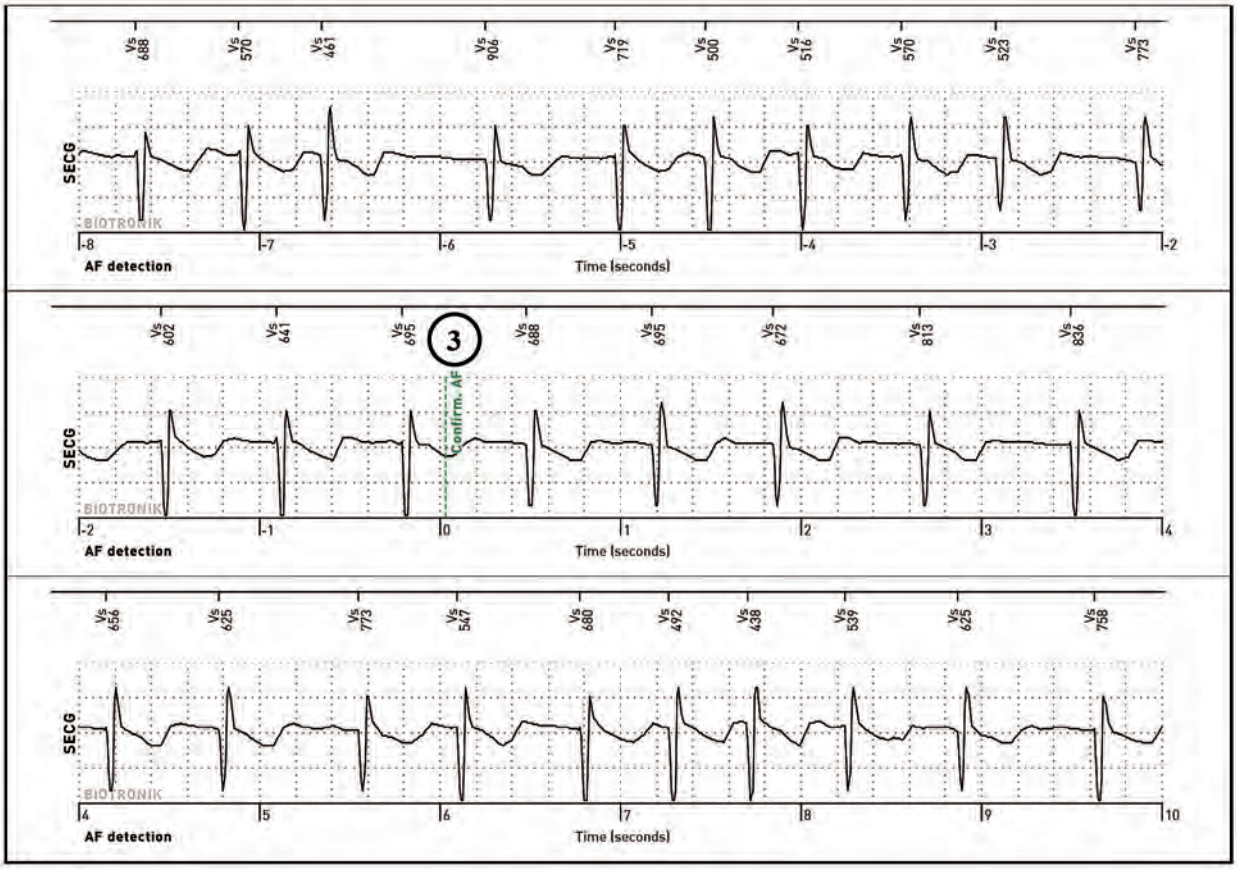

Status report - Jun 28, 2017

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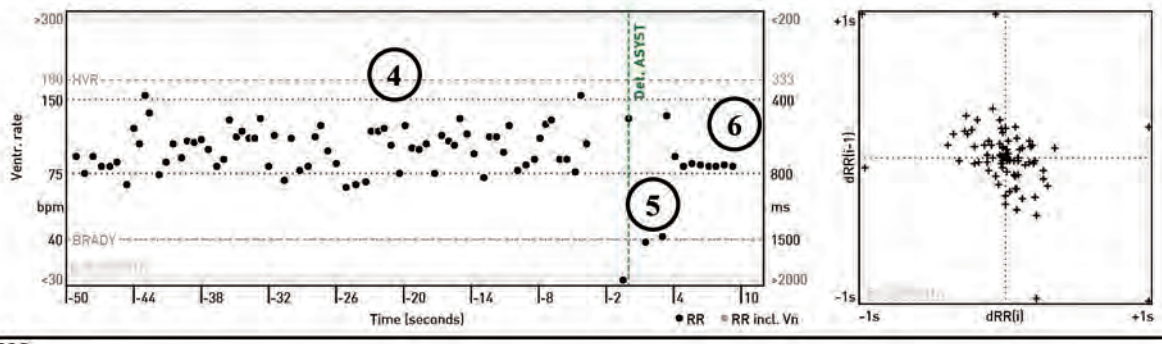
Recordings

Recordings - Episode 85:

General	
Episode number	85
Episode type	Asystole
Detection	Apr 16, 2017 7:39:46 PM
Termination	---
Duration	---
Device settings no.	2
Mean ven. rate / RR interval [bpm]	---

Tachogram and Lorenz plot



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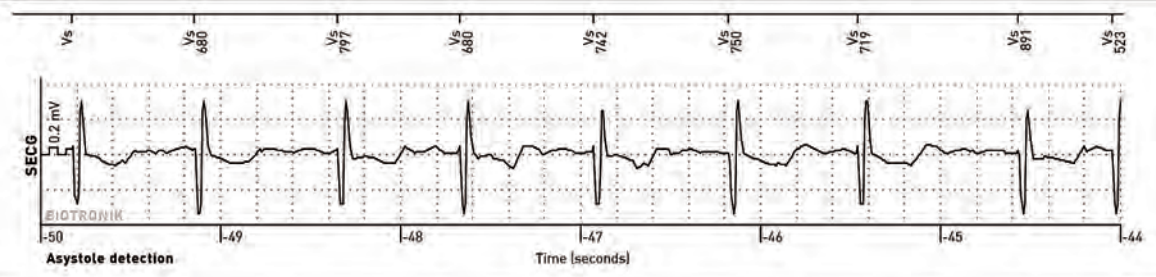

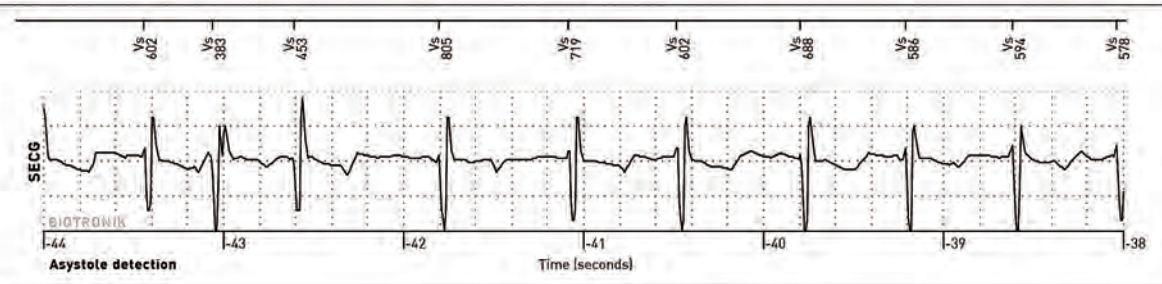

Status report - Jun 28, 2017

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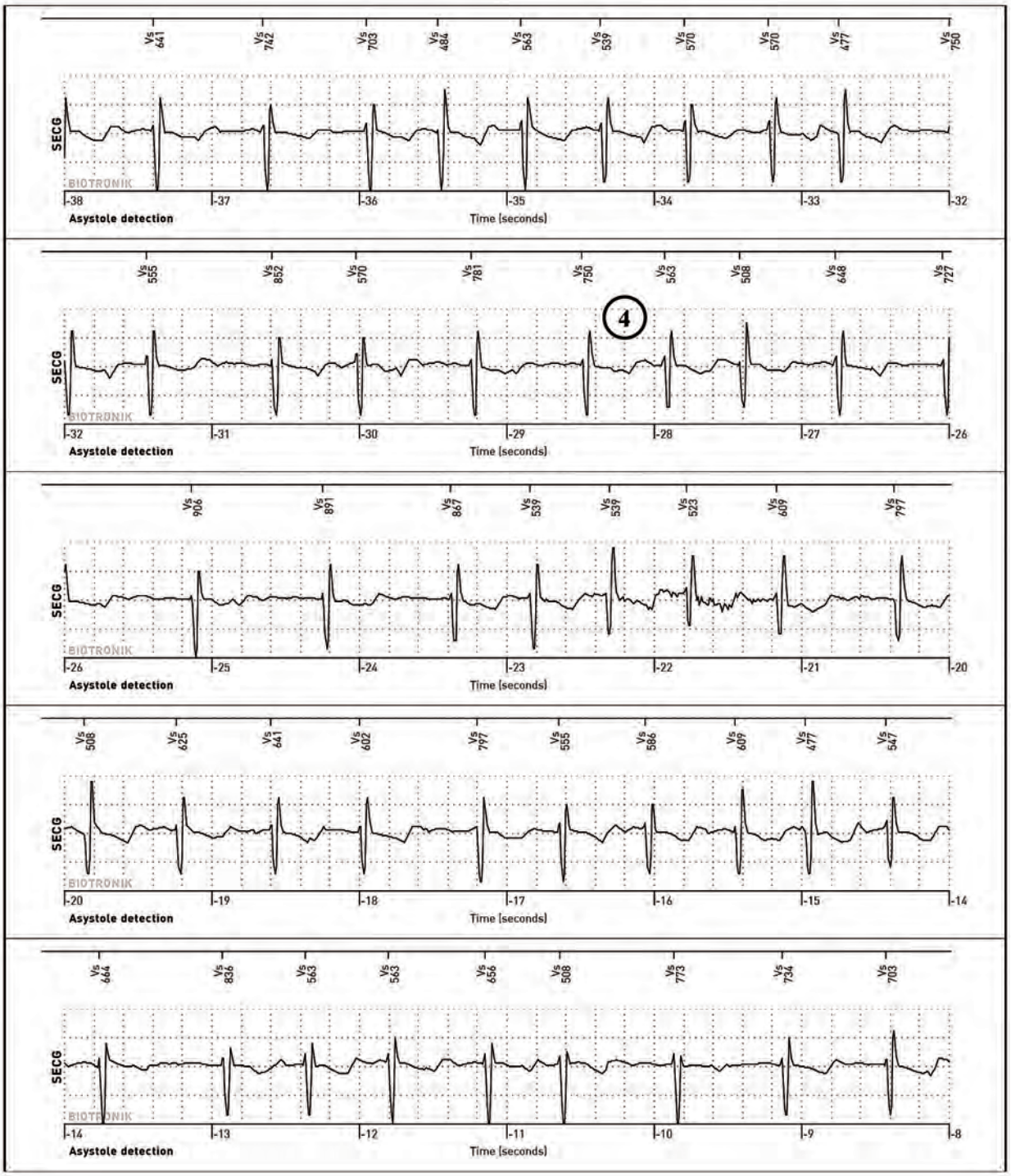

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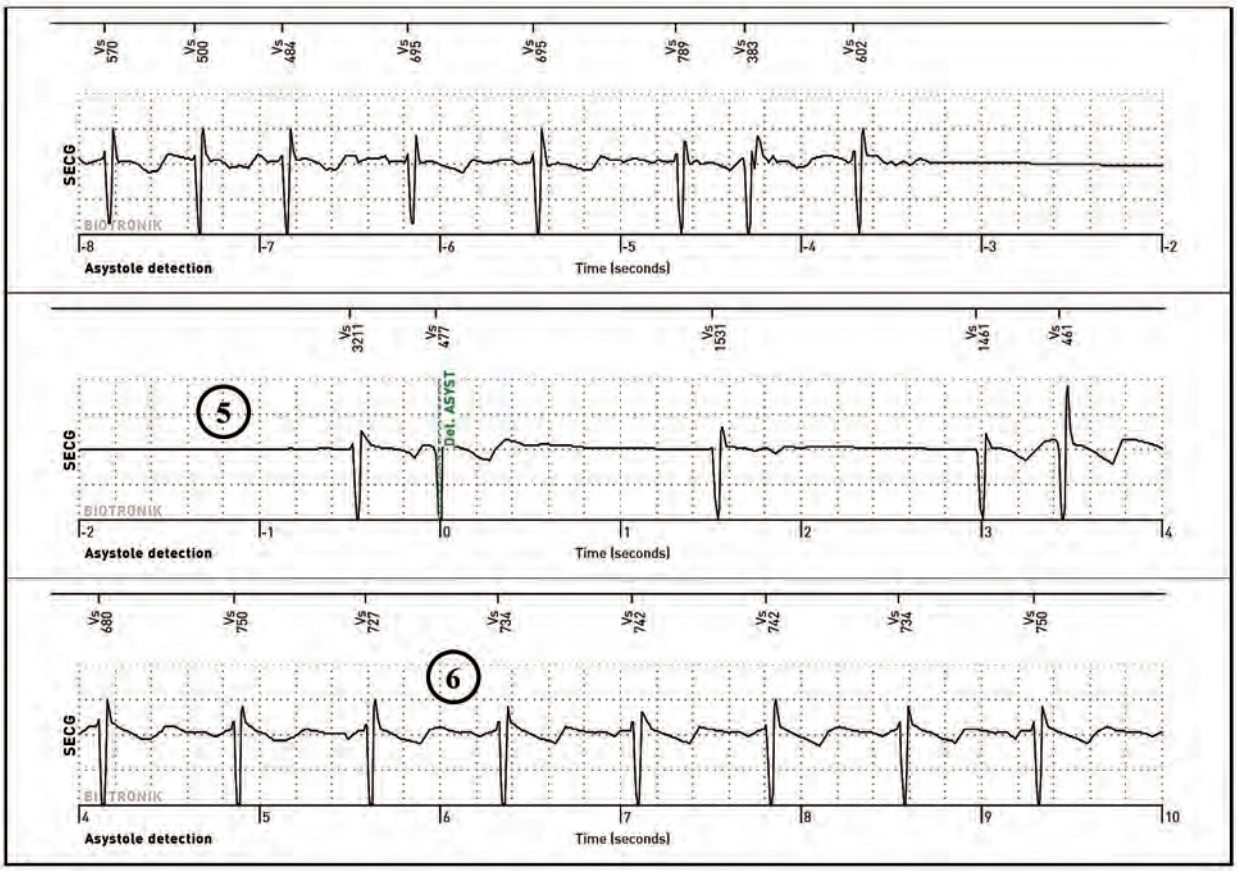

Status report - Jun 28, 2017

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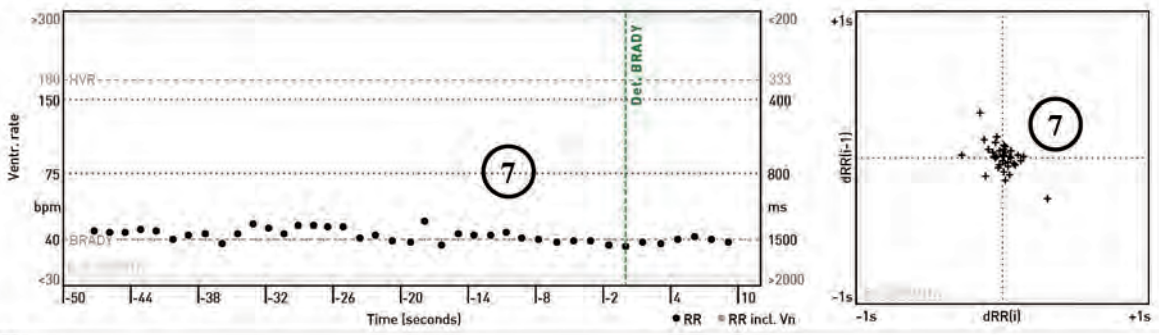
Recordings

Recordings - Episode 50:

General	
Episode number	50
Episode type	Bradycardia
Detection	Dec 15, 2016 5:27:24 AM
Termination	Dec 15, 2016 5:27:52 AM
Duration	28s
Device settings no.	2
Mean ven. rate / RR interval [bpm]	39

Tachogram and Lorenz plot



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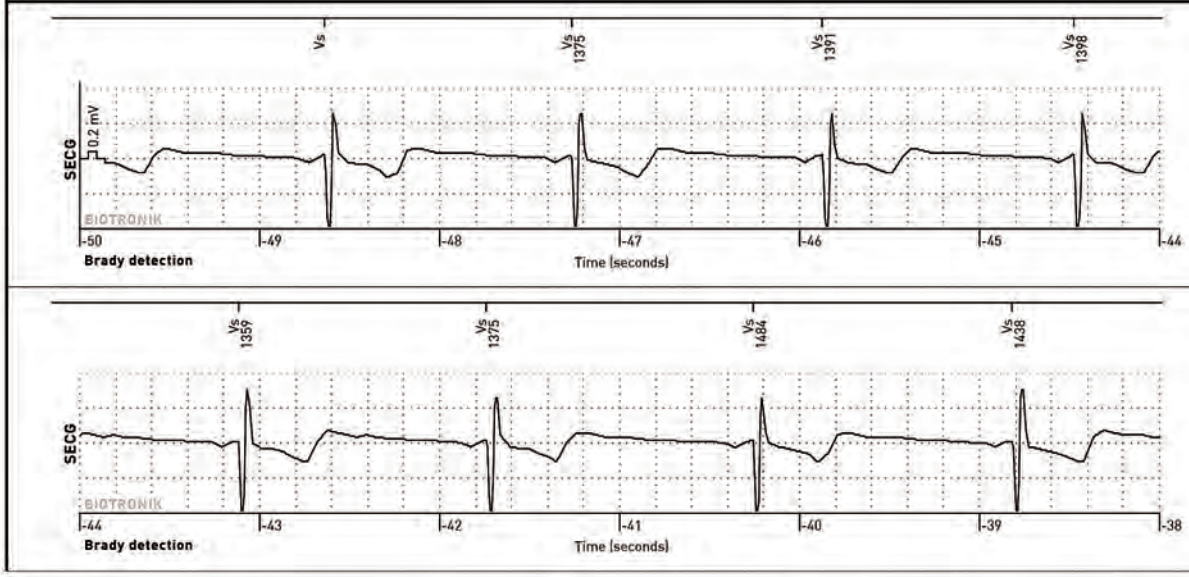

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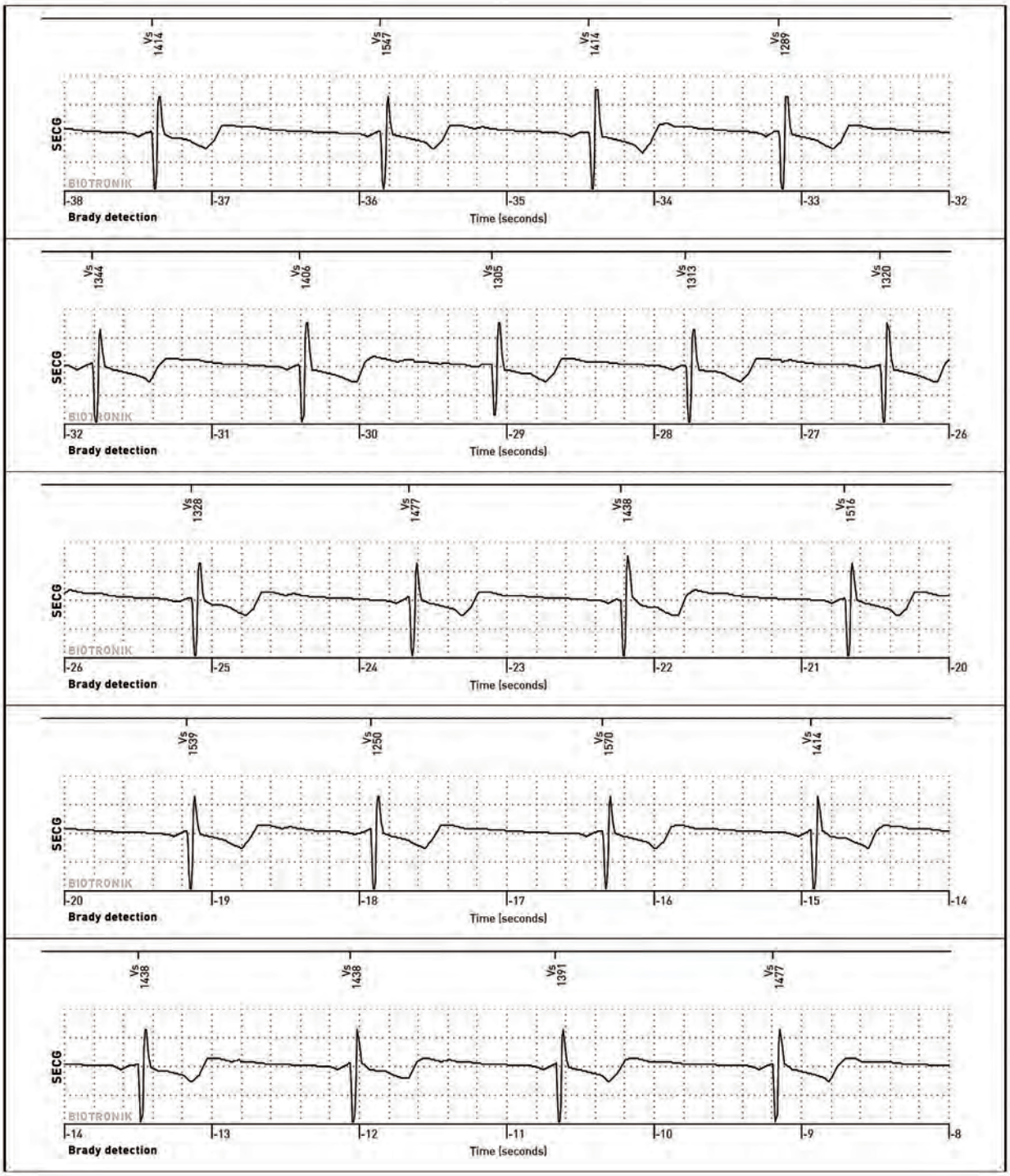

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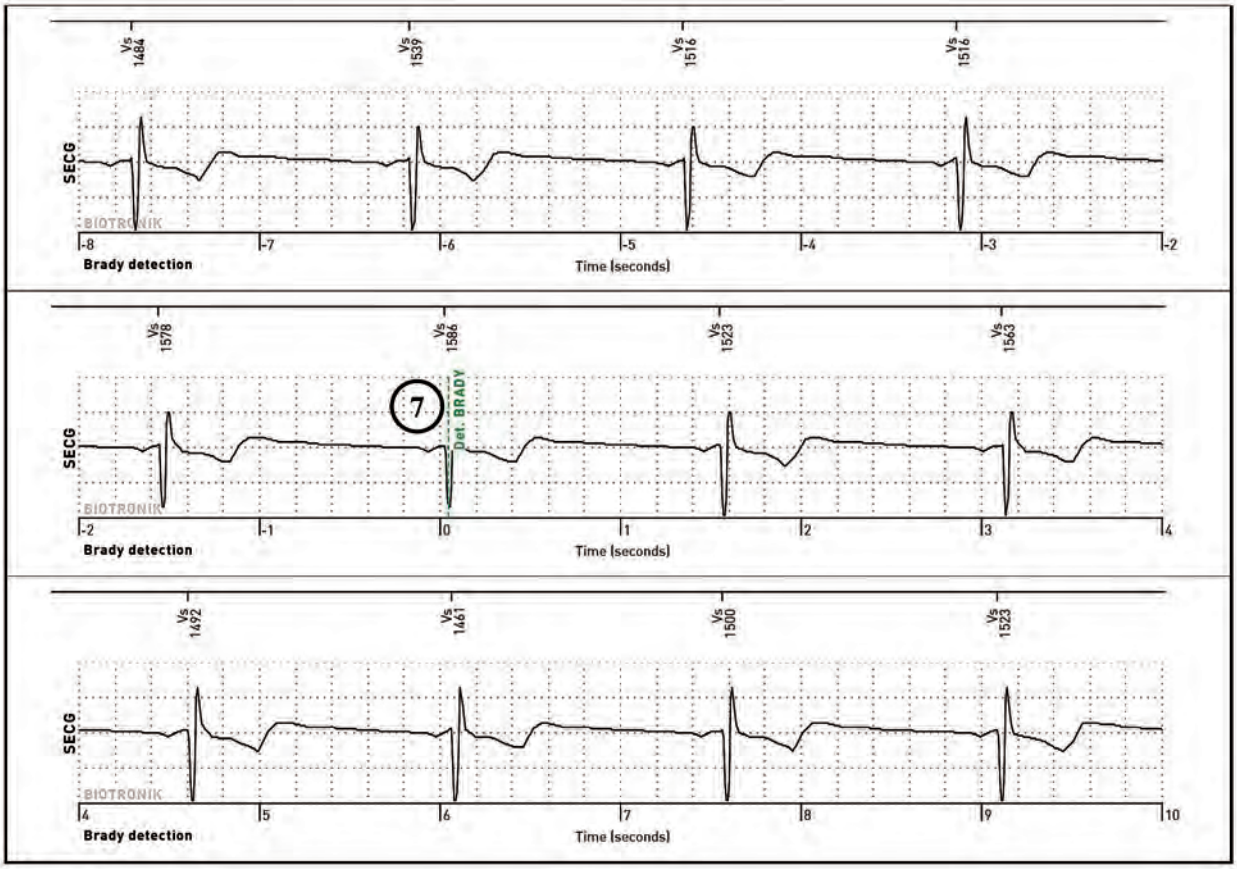

Status report - Jun 28, 2017

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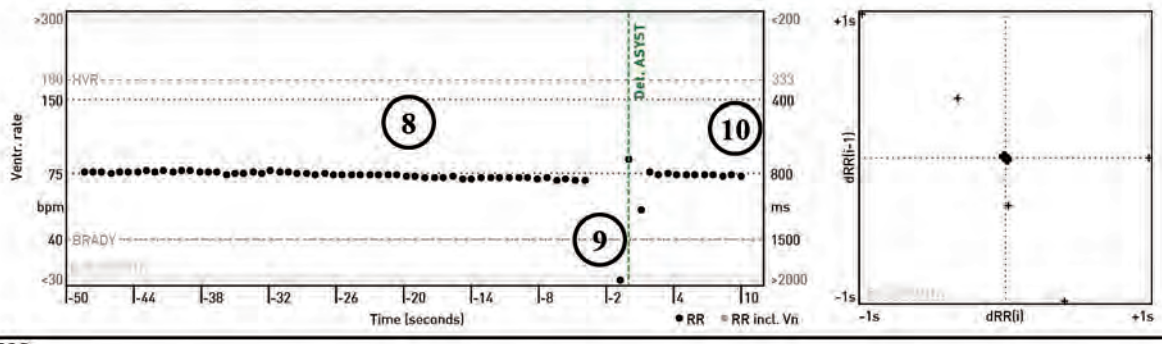
Recordings

Recordings - Episode 67:

General	
Episode number	67
Episode type	Asystole
Detection	Feb 9, 2017 9:35:14 AM
Termination	---
Duration	---
Device settings no.	2
Mean ven. rate / RR interval [bpm]	---

Tachogram and Lorenz plot



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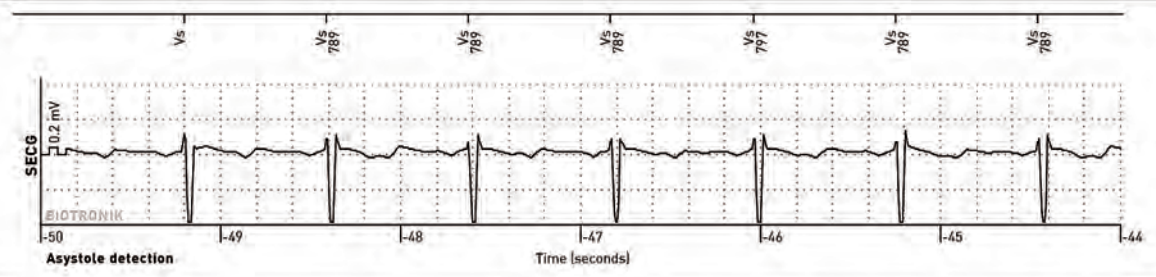

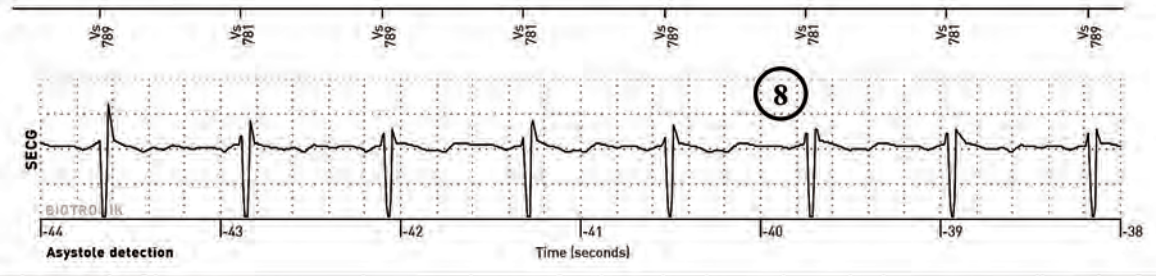

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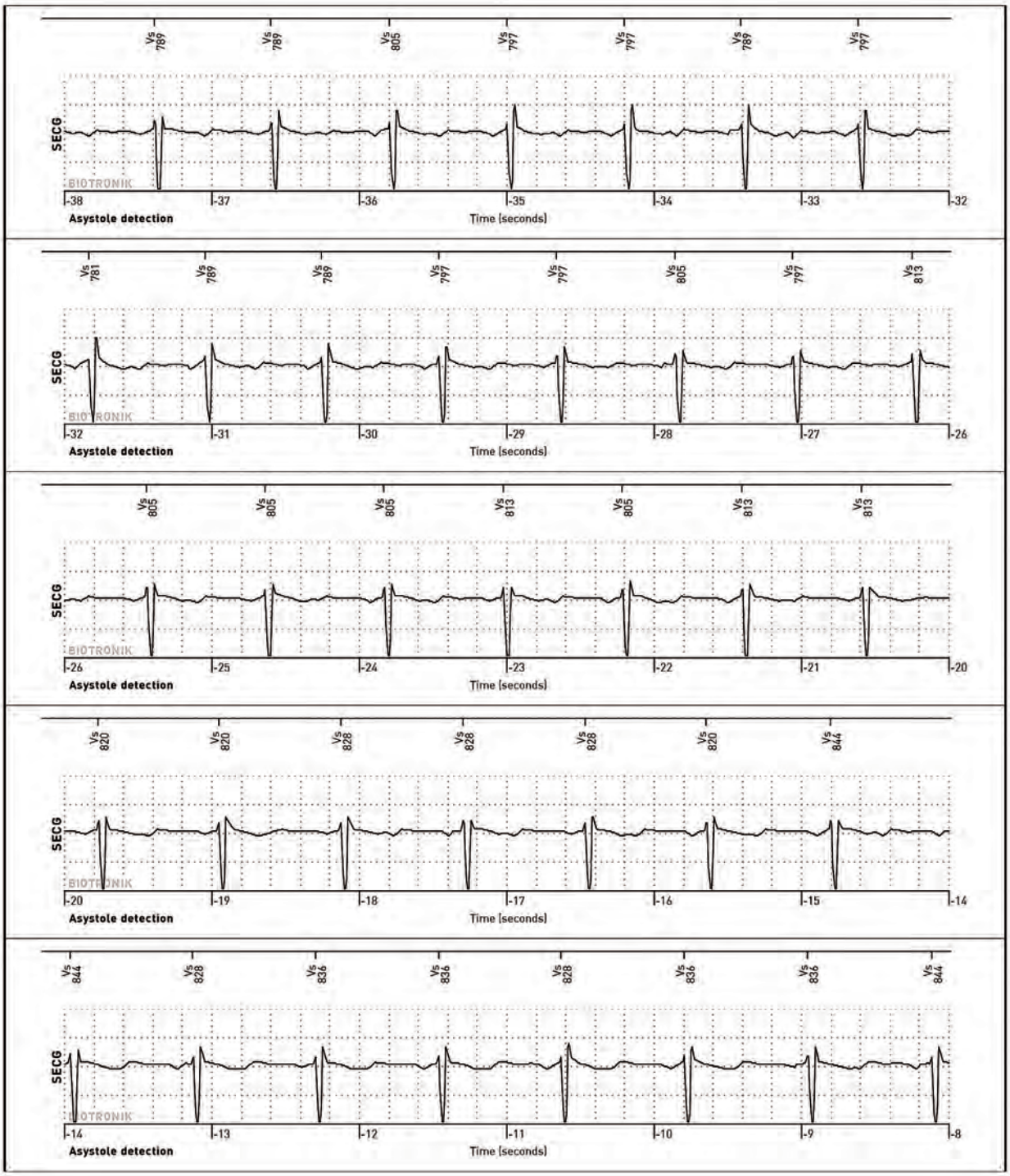

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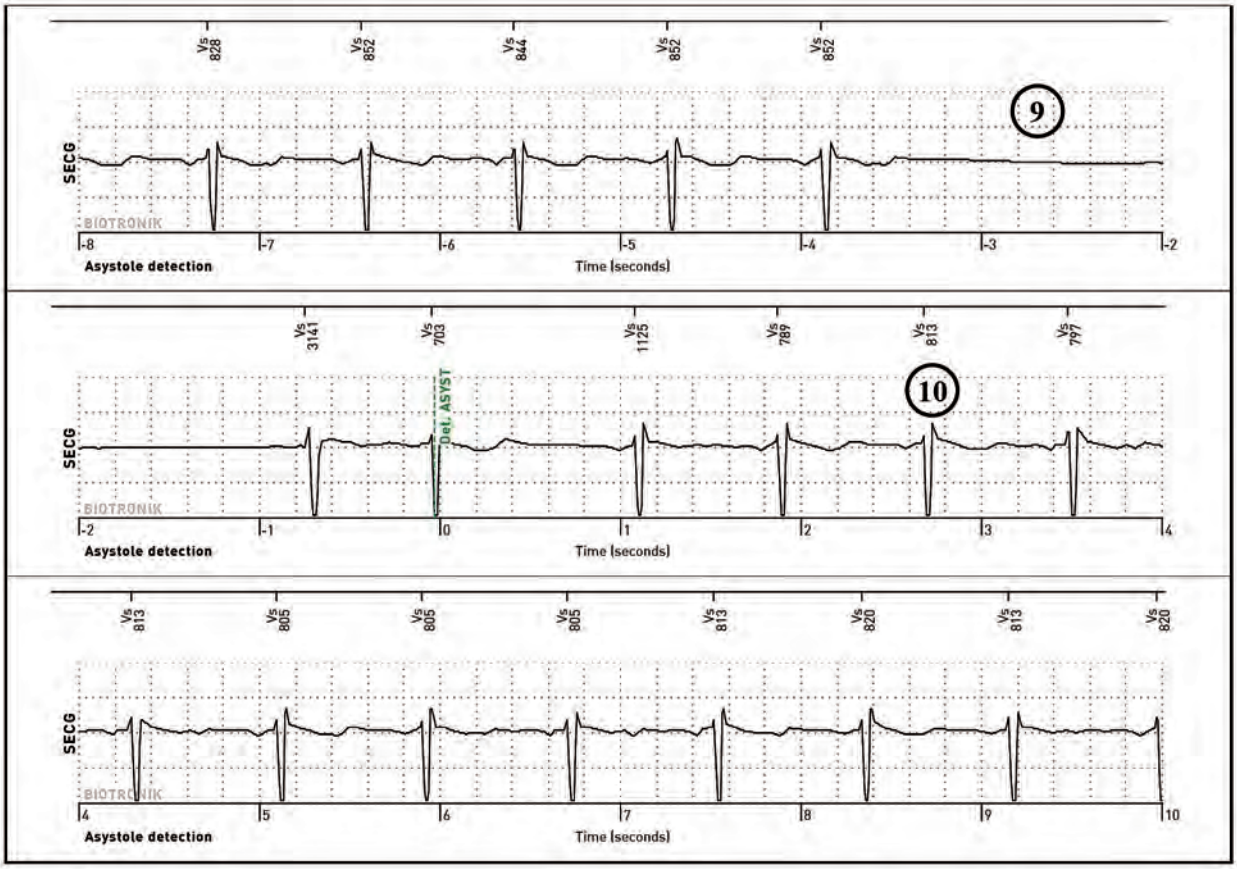

Tracing 6 ↘ Ventricular arrhythmia

Patient

82-year-old woman with ischemic cardiomyopathy participating in the LBBB-TAVI study; palpitations and lipothymia during moderate exertion.

Tracing 6a

Episode diagnosed as HVR classification;

① sinus tachycardia;

② PVC;

③ sudden acceleration of the ventricular rhythm with tachycardia at 190 beats/minute, stable with modification of the QRS complex pattern relative to the sinus rhythm; identical pattern to that of the PVC; HVR classification

Patient

85-year-old man participating in the LBBB-TAVI study.

Tracing 6b

Episode diagnosed as HVR classification;

④ probable sinus rhythm (difficulty in properly discerning the P waves);

⑤ sudden acceleration of the ventricular rhythm with stable tachycardia (190 beats/minute) with modification of the QRS pattern; HVR classification;

⑥ spontaneous termination.

Comments

These 2 tracings are evocative of a ventricular rhythm disorder, sustained in the first instance and non sustained in the second. One of the difficulties in interpreting implantable loop recorder tracings is that there is only one lead and that the differentiation between ventricular tachycardia and supraventricular tachycardia is sometimes hazardous in the sense that the analysis of per-tachycardia atrial activity is most often impossible. Similarly, variations in morphology of the QRS complexes may be limited in this single lead. The therapeutic consequences are obviously significant since the demonstration of a symptomatic and sustained rhythm disorder must evoke the prospect of ICD implantation. In the second patient (NSVT), a beta-blocker therapy was introduced. The first patient underwent coronary angiography, which did not reveal any lesions potentially generating ischemia leading to a ventricular arrhythmia. During hospitalization, this patient presented a sustained and syncopal episode of ventricular tachycardia suggesting that the implantable loop recorder recording most likely corresponded to a ventricular rhythm disorder. The patient underwent implantation of an ICD with an increase in beta-blocker treatment.

Two parameters must be programmed in order for the device to trigger a recording on a high ventricular rate (HVR): 1) rate limit: programmable between 110 and 200 beats per minute with a nominal value of 180; 2) fast interval counter: programmable between 8 and 64 with a nominal value of 16; the counter is incremented for each interval exceeding the programmed limit value (+1) and is decremented for each slower interval (-1); when the counter is filled, an HVR episode is diagnosed; when noise is sensed (interval classified as Vn), the counter is systematically reset to 0 to avoid memory saturation due to oversensing; the episode is considered as terminated by the device when 5 consecutive intervals are slower than the programmed rate (intervals classified as Vn have no effect on the end-of-episode counter).

Status report - Jun 28, 2017

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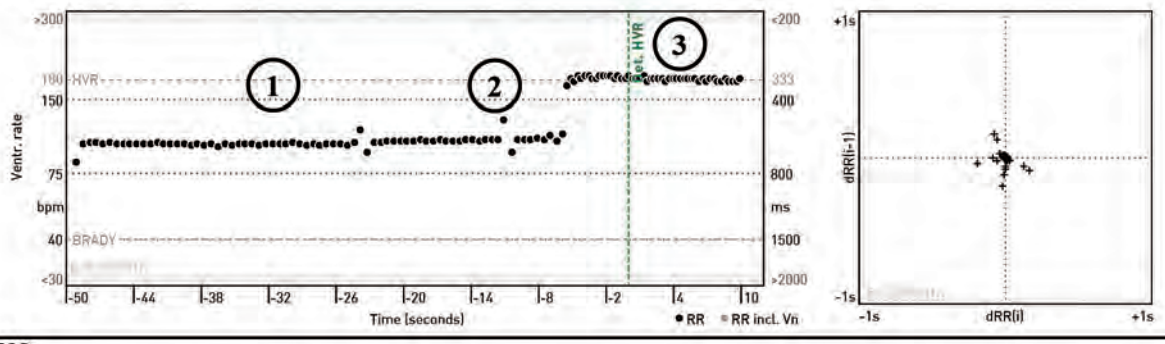
Recordings

Recordings - Episode 87:

General	
Episode number	87
Episode type	HVR
Detection	Apr 24, 2017 4:13:26 PM
Termination	Apr 24, 2017 4:13:50 PM
Duration	24s
Device settings no.	2
Mean ven. rate / RR interval [bpm]	185

Tachogram and Lorenz plot



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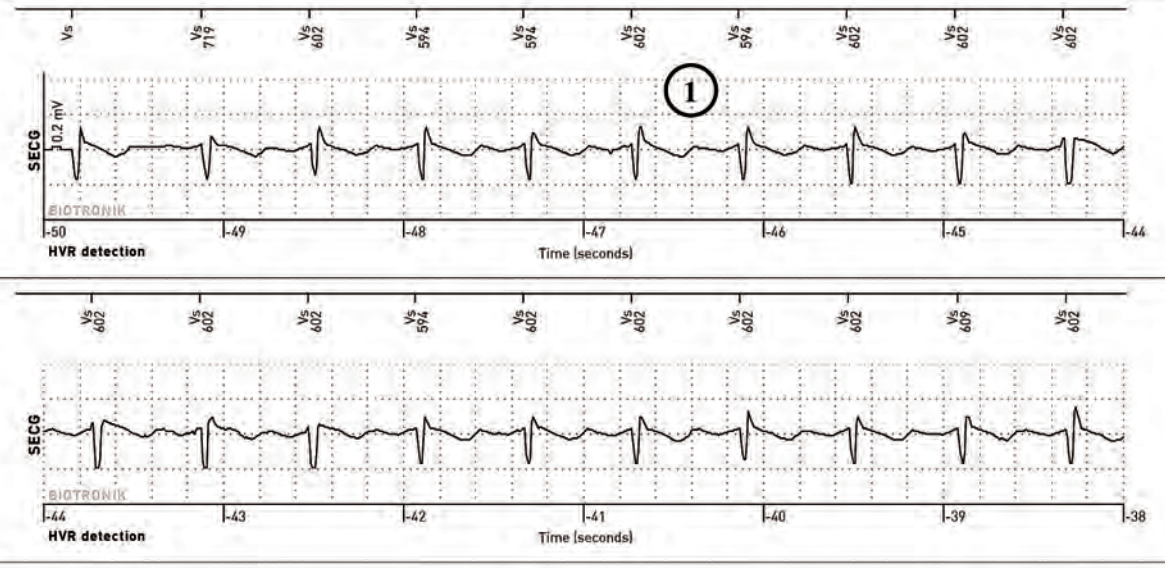

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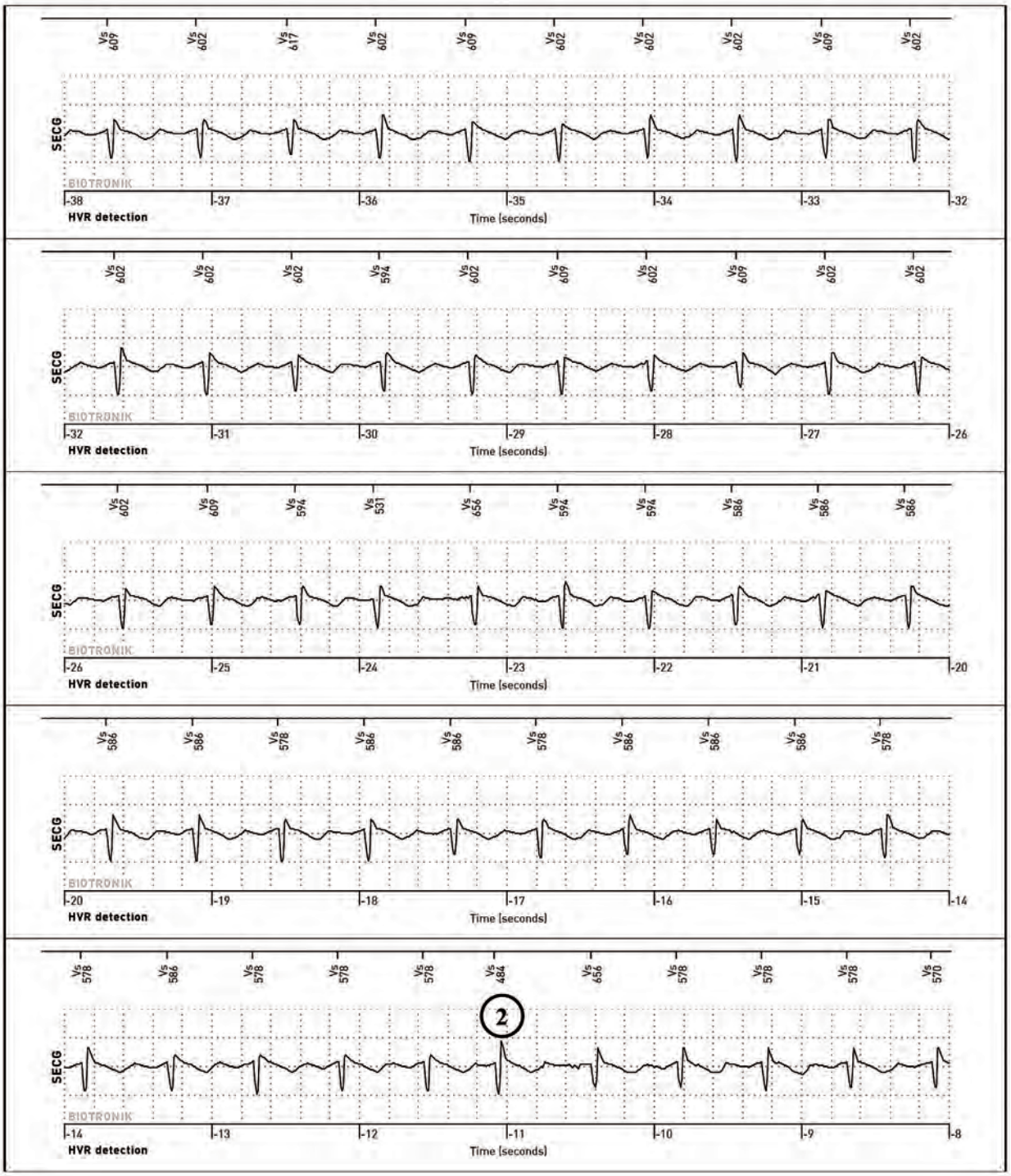

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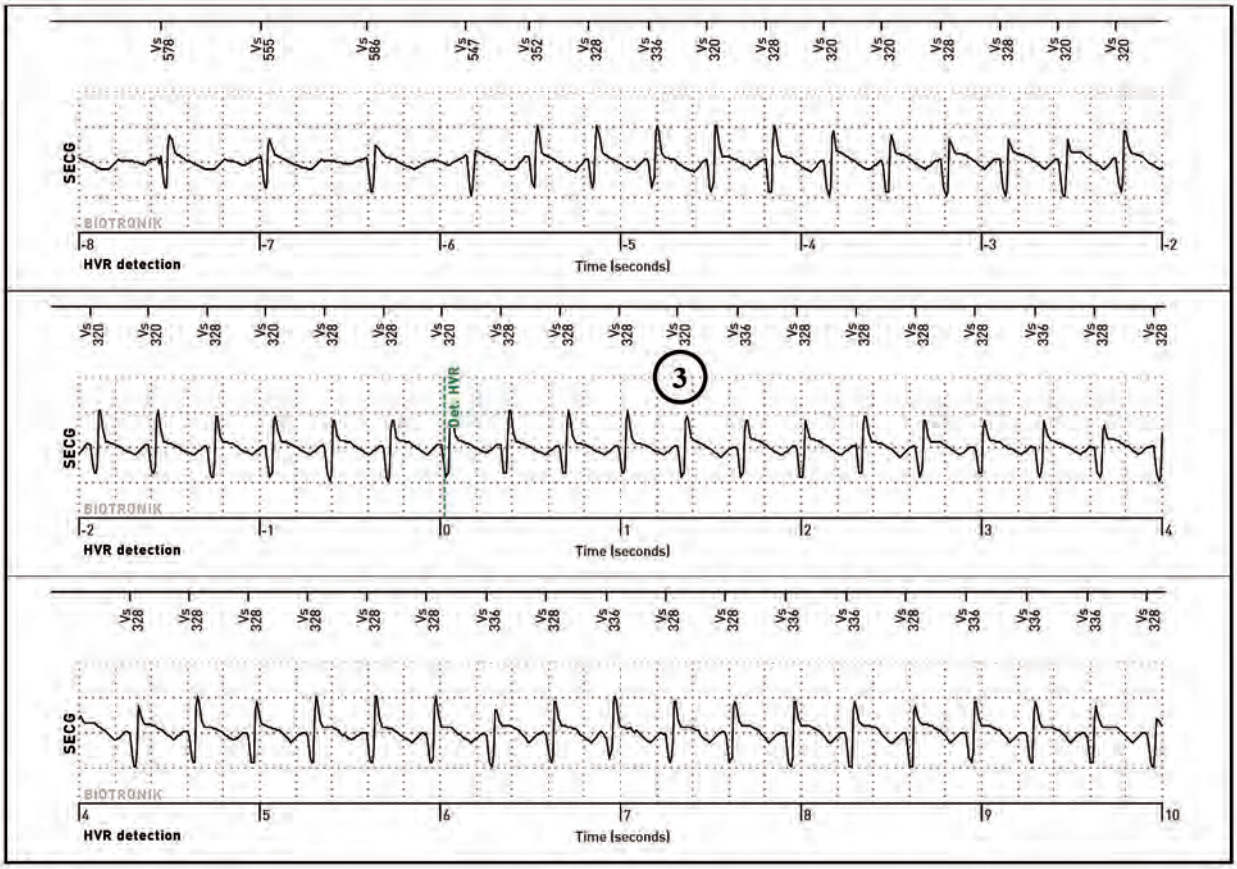

Status report - Jun 28, 2017

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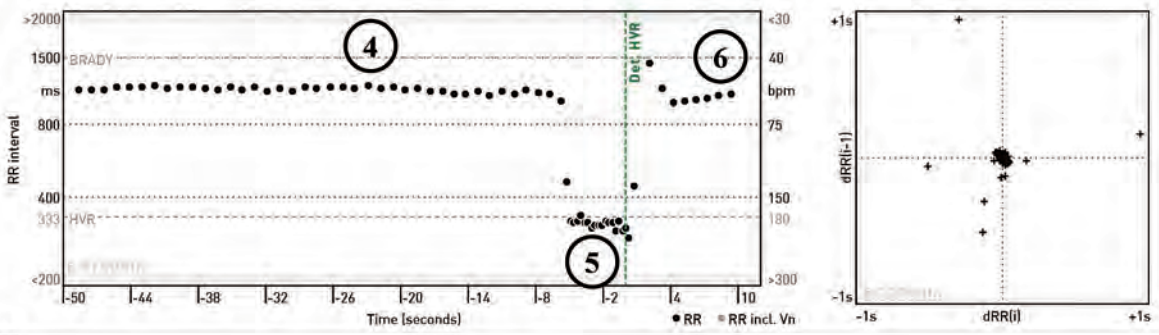
Recordings

Recordings - Episode 10:

General	
Episode number	10
Episode type	HVR
Detection	Oct 29, 2016 8:43:42 PM
Termination	Oct 29, 2016 8:43:48 PM
Duration	6s
Device settings no.	2
Mean ven. rate / RR interval [ms]	303

Tachogram and Lorenz plot



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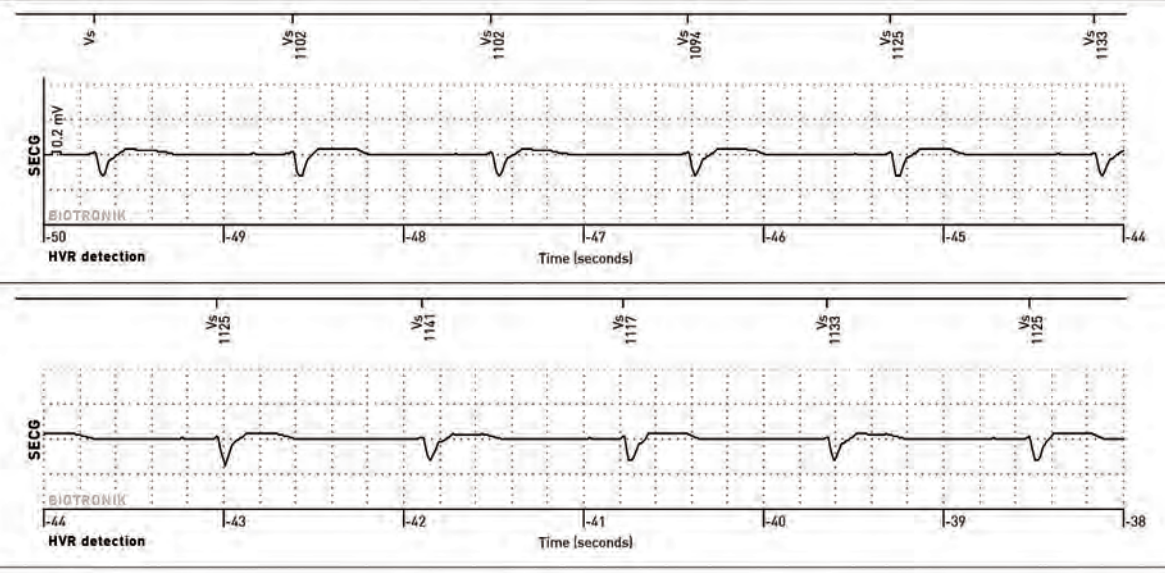

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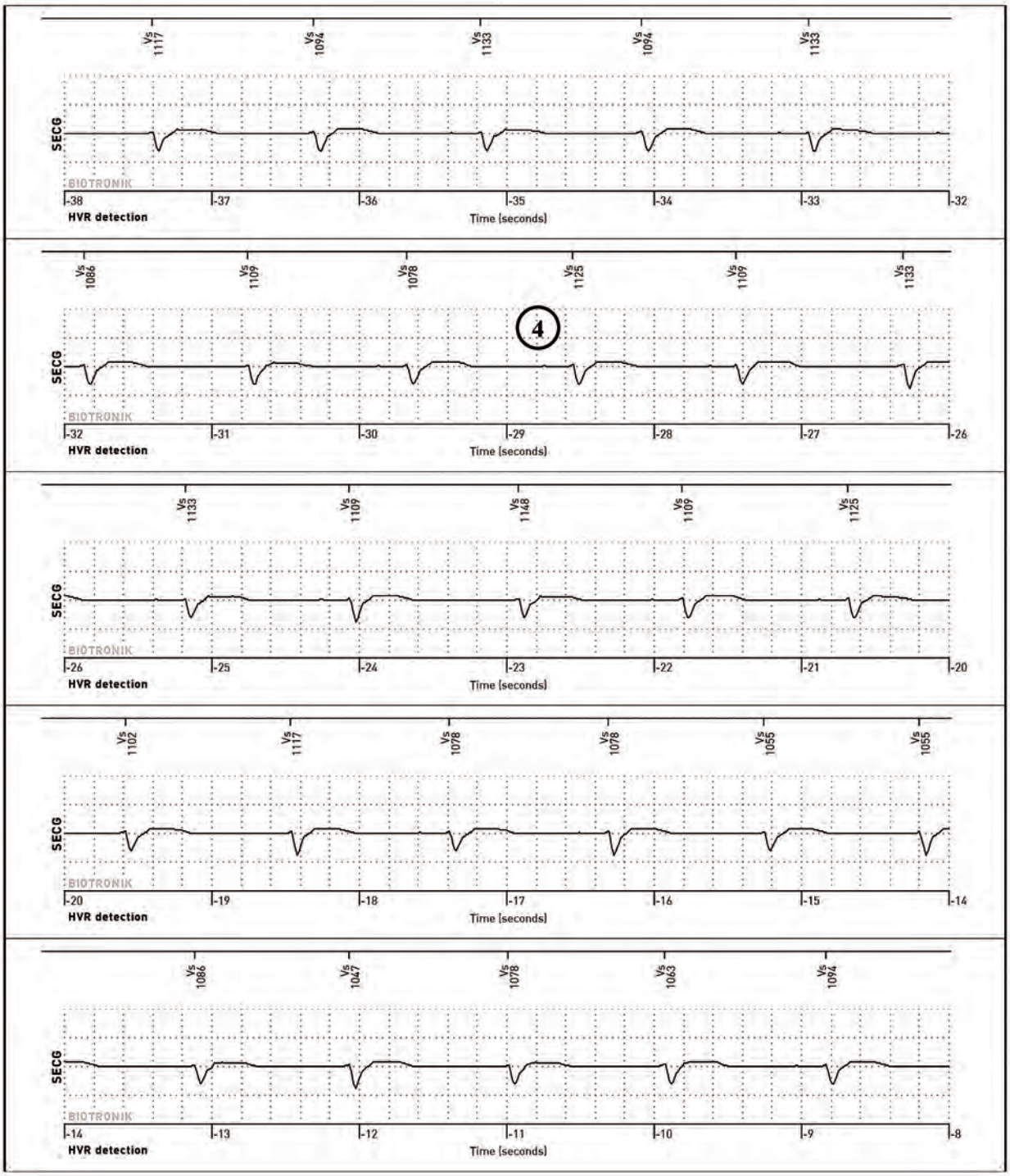

Status report - Jun 28, 2017

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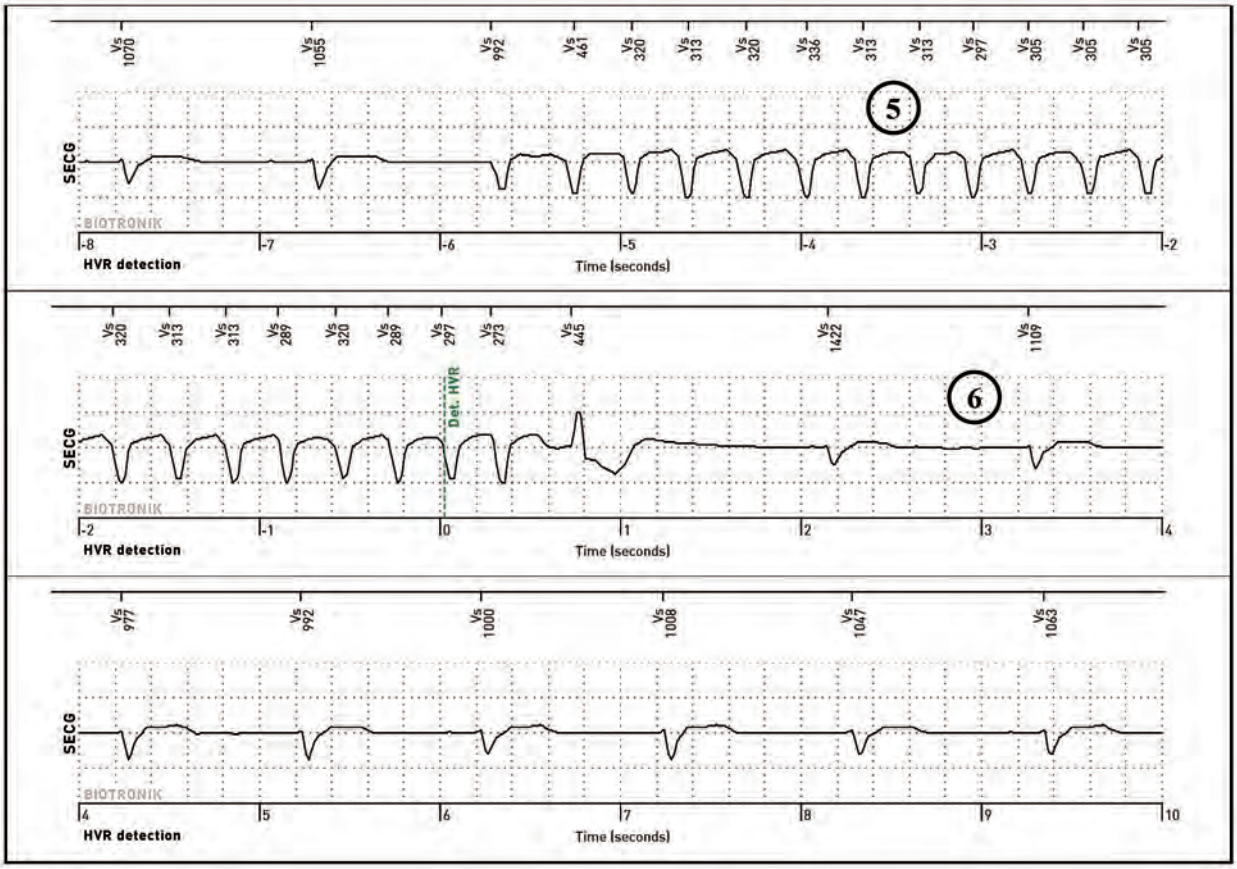

Tracing 7 ↘ Diagnosis of atrial fibrillation

Patient

81-year-old man participating in the LBBB-TAVI study.

Tracing

Episode diagnosed as AF;

① the tachogram and Lorenz plot are highly suggestive of rapidly conducted AF with significant cycle-to-cycle variability in sensed ventricular intervals;

② the tracing confirms the diagnosis of AF;

③ diagnosis of AF by the device.

Comments

Long-term electrocardiogram monitoring in order to diagnose asymptomatic atrial fibrillation in patients with stroke constitutes a new preferential indication for the implantation of an implantable loop recorder. Indeed, approximately 25% of ischemic strokes remain unexplained after performing a complete work-up, including telemetric monitoring and 24- to 48-hour loop recording, and are thus labeled cryptogenic. The probability of recording an episode of atrial arrhythmia increases with the prolonging of the electrocardiogram monitoring time. Integrating an automatic AF detection algorithm by the device in order to allow diagnosis even when episodes are asymptomatic is a necessary prerequisite for the implantable loop recorder to be positioned in the decision tree of cryptogenic stroke. Evidence of AF cannot be based on a direct analysis of atrial activity (rapid and uncontrolled), the atrial signals not being sufficiently voluminous and the various settings rather favoring the sensing of QRS complexes. For the Biomonitor, the diagnosis of AF is based on the analysis of the stability of QRS complexes, the difficulty being to differentiate AF from other conditions associated with an irregular rhythm (atrial extrasystoles, ventricular extrasystoles, etc.).

The RR intervals are continuously analyzed and intervals classified as noise (Vn) are excluded from the analysis. Various parameters are programmable:

1) RR interval variability: this parameter corresponds to the maximum value in terms of interval-to-interval variation between 2 Vs-Vs intervals for the rhythm to be considered as stable by the device; the lower the programmed value, the higher the sensitivity of the AF diagnosis; all intervals with greater variability than the programmed value are considered AF intervals and thus increment the episode onset counter.

2) the episode onset window and the number of intervals required at the onset of an episode: it is possible to determine the number of consecutive intervals on which rhythm stability is studied (onset window) as well as the minimum number of unstable intervals required in this window for the rhythm to be considered unstable; programming at 8 and 5 implies that the device continuously analyzes the stability over 8 consecutive intervals and that the rhythm is deemed to be unstable in this window if at least 5 intervals are considered unstable; when two consecutive windows are considered unstable, the device suspects an AF episode.

3) an AF episode is diagnosed and recorded, when instability persists for a programmable period of time; the nominal confirmation time is relatively long (6 minutes) although the latter can be changed (between 1 and 30 minutes); an episode is only recorded when this confirmation criterion is completed.

4) the end-of-episode window and the number of intervals necessary to determine the end of an episode: it is possible to determine the number of consecutive intervals on which the study of stability is performed for establishing the end of the episode (termination window) as well as the minimum number of unstable intervals required in this window for the rhythm to be considered as systematically unstable; a programming of 16 and 1 implies that the device continuously analyzes the stability over 16 consecutive intervals and

that the rhythm is considered to be systematically unstable in this window if at least 1 interval is considered unstable (all intervals must be stable for the episode to be considered terminated); 2 consecutive windows with rhythm deemed stable are necessary for the end-of-episode diagnosis.

It is possible to program 3 sensitivity levels for the diagnosis of AF (low, intermediate and high) with predetermined values for the various parameters of the algorithm. It is also possible to program these different parameters independently. Low is the least sensitive level; therefore, more variability between RR intervals is required over a longer period of time to arrive at a diagnosis of AF. Conversely, less variability over fewer intervals is required when a high level is programmed.

Status report - Jun 28, 2017

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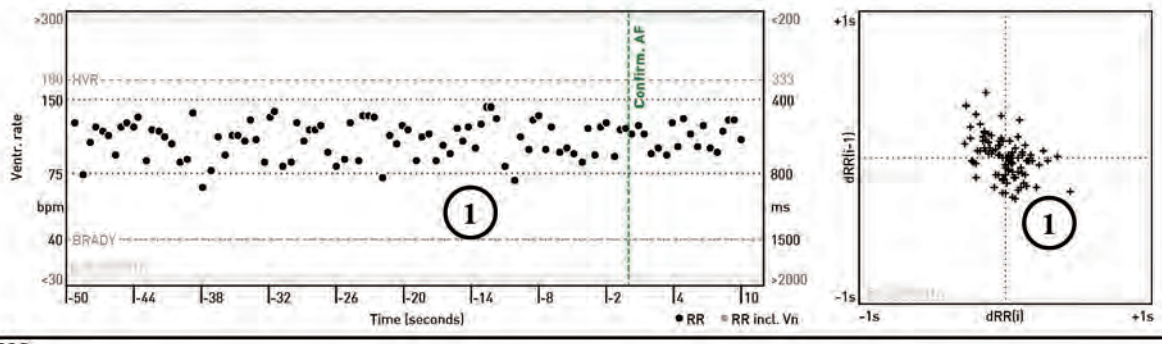
Recordings

Recordings - Episode 1:

General	
Episode number	1
Episode type	AF
Detection	Jun 22, 2016 9:56:00 PM
Termination	---
Duration	---
Device settings no.	2
Mean ven. rate / RR interval [bpm]	108

Tachogram and Lorenz plot



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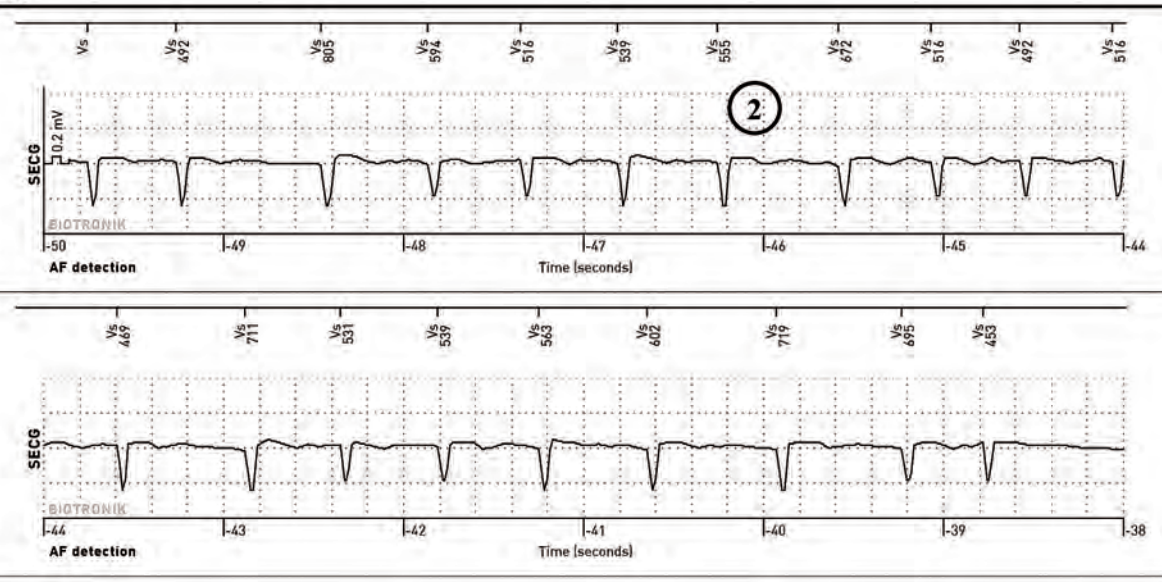

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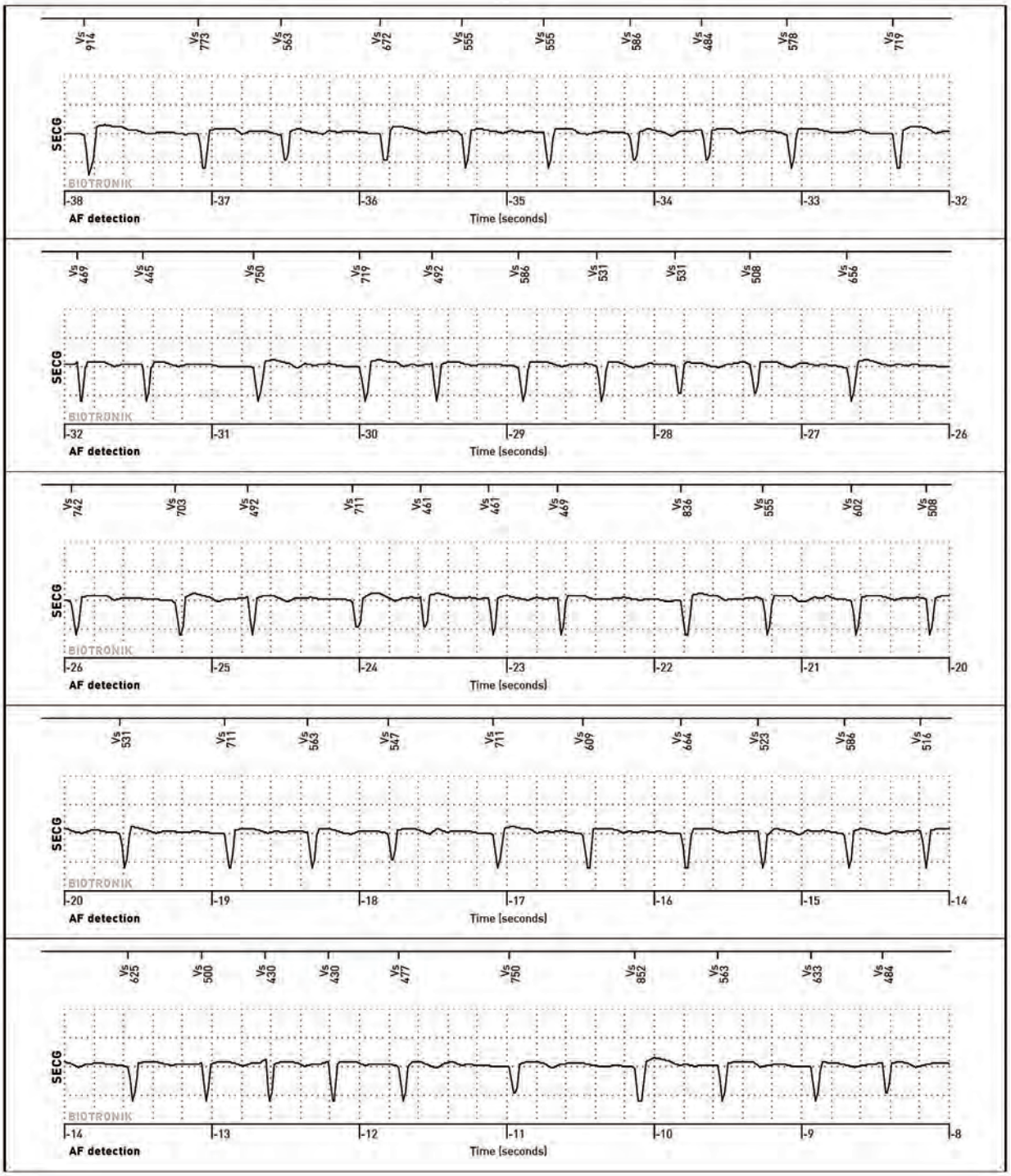

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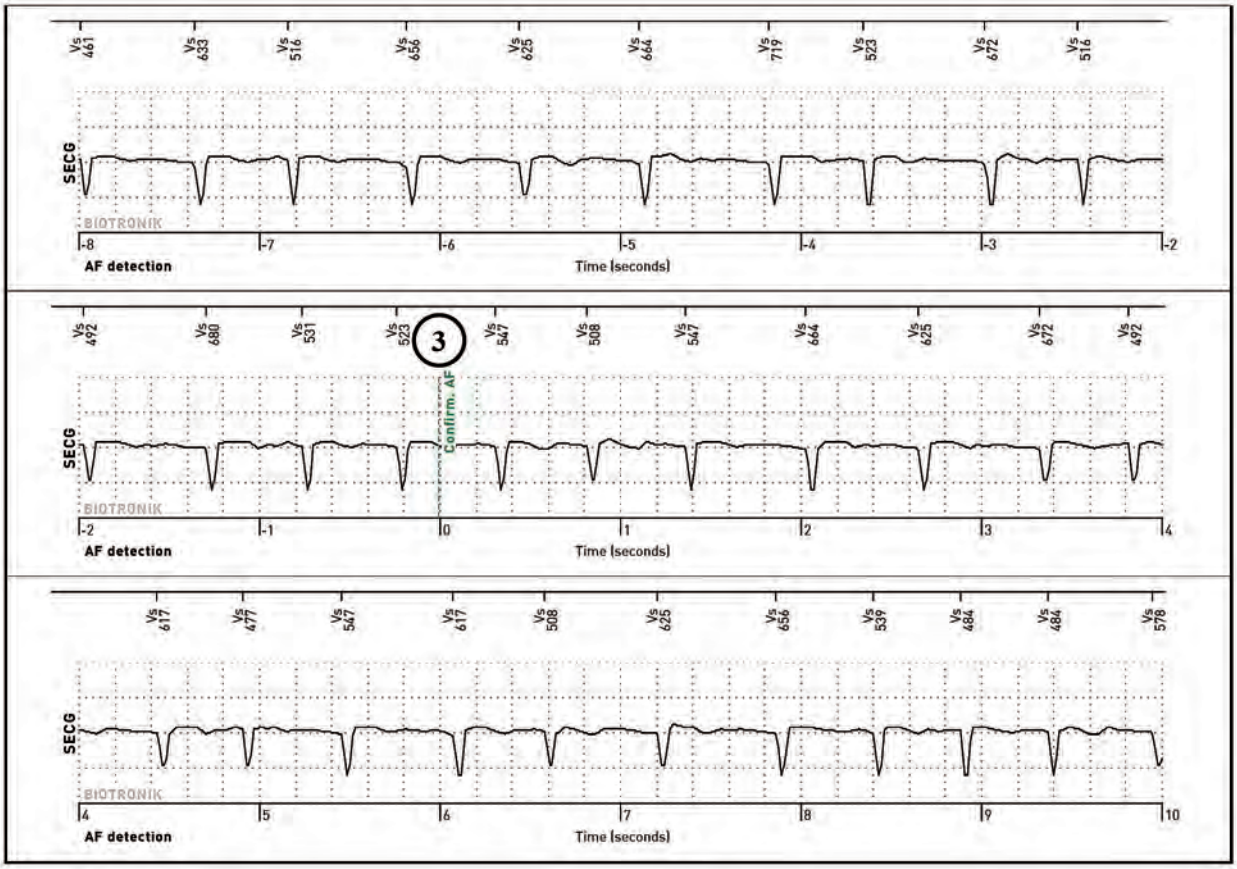

Tracing 8 ↘ False diagnosis of bradycardia or asystole due to sensing failure

Patient

70-year-old woman participating in the LBBB-TAVI study; asymptomatic.

Tracing 8a

Episode diagnosed as asystole;

① stable ventricular rhythm; atrial activity difficult to discern;

② marked undersensing of the QRS complexes in conjunction with a progressive decrease in signal amplitude;

③ diagnosis of asystole by the device in conjunction with this undersensing.

Patient

82-year-old man participating in the LBBB-TAVI study.

Tracing 8b

Episode diagnosed as bradycardia;

④ characteristic pattern (tachogram, Lorenz plot, ECG tracing) of PVC with premature complex followed by compensatory pause;

⑤ undersensing of sinus complexes following the PVC;

⑥ bradycardia diagnosis by the device in conjunction with this undersensing.

Patient

82-year-old man participating in the LBBB-TAVI study.

Tracing 8c

Diagnosed episode as bradycardia;

⑦ sinus rhythm correctly sensed;

⑧ likely PVC not sensed by the device;

⑨ diagnosis of bradycardia by the device in conjunction with this undersensing together with the compensatory pause following the PVC.

Comments

The automatic recording of episodes of bradycardia or tachycardia allows increasing the diagnostic yield of the implantable loop recorder. The asymptomatic and symptomatic episodes in patients occurring in patients without the ability to actively trigger the recording are thus memorized. However, an important limitation of this function is the frequent spurious recording of false arrhythmias such as bradycardia due to undersensing of ventricular signals or tachycardia due to sensing of noise or other intra-cardiac signals

such as P waves or T waves or double counting of the R wave. This implies that all the episodes stored in the memory need to be verified. The recording of spurious arrhythmia episodes is frequent since found in over half of the implanted patients.

It is possible to modify the programming in order to avoid the iterative recording of false bradycardia episodes. Four programming options are available with different filter and target threshold values (standard, variable amplitude, T wave suppression, premature ventricular contraction detection): 1) the high-pass filter: the higher the value, the more the signal corresponding to the baseline but also to the T wave is filtered (this value is programmed at 18 Hz for the T wave suppression option and 10 for the 3 others); 2) the initial threshold: when a signal is sensed, the sensitivity level adapts to the amplitude of this signal and increases progressively during the interval; depending on the choice between the 4 configurations, the initial threshold varies between 100% (T wave suppression, the device is poorly sensitive at the beginning of the interval in order to avoid sensing of the T wave) and 62.5% (sensing of extrasystoles, device highly sensitive at the beginning of the interval to allow the sensing of a premature interval of moderate amplitude); 3) the target sensing threshold: the objective is to modify the level of sensitivity at the moment when the next signal occurs (if ventricular rhythm is stable); depending on the 4 options, this value varies between 25 (sensing of extrasystoles) and 50% (standard programming); the lower the value, the greater the probability of sensing even when the amplitude of the intervals is highly variable (as in the last two patients with premature ventricular contractions).

Sensing Consult	Initial Threshold	Target sensing threshold [%]	Threshold Decay Step	Target Threshold
Standard	75	50	12.50%	25%
T-wave suppression	100	40	25%	25%
Variable amplitude	87.5	35	25%	25%
PVC detection	62.5	25	25%	25%

Status report - May 25, 2016

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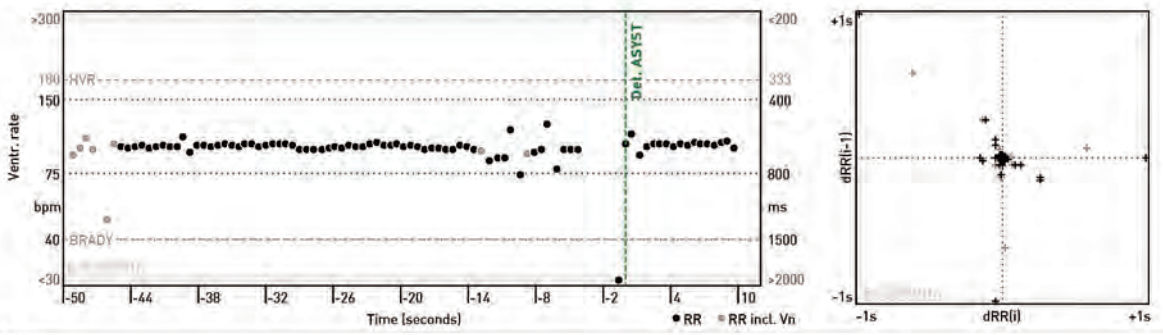
Recordings

Recordings - Episode 1:

General	
Episode number	1
Episode type	Asystole
Detection	Apr 22, 2016 7:42:14 AM
Termination	---
Duration	---
Device settings no.	2
Mean ven. rate / RR interval [bpm]	---

Tachogram and Lorenz plot



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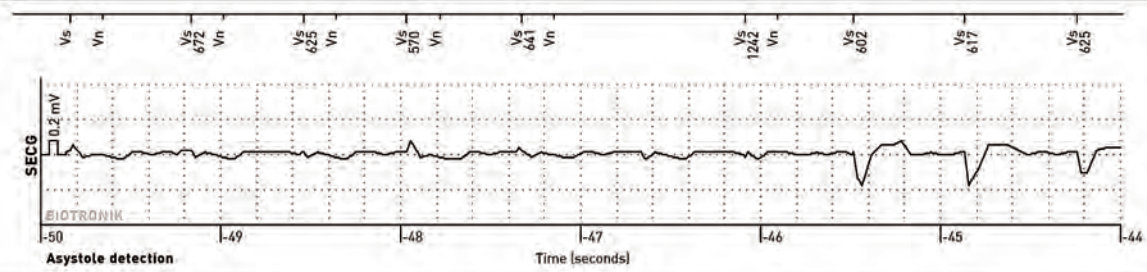

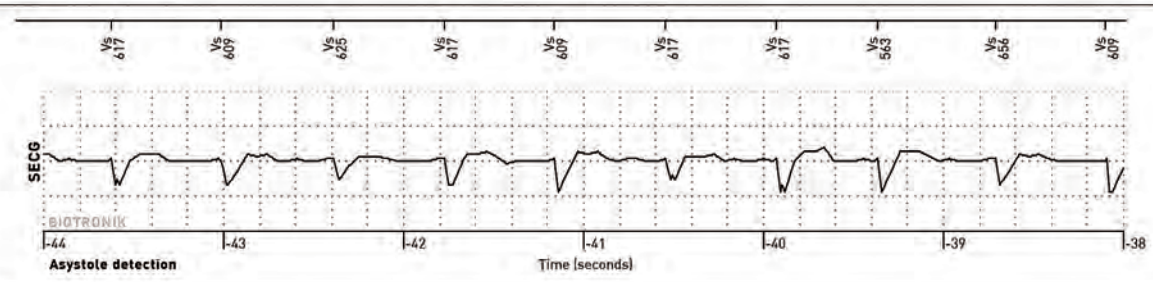

Status report - May 25, 2016

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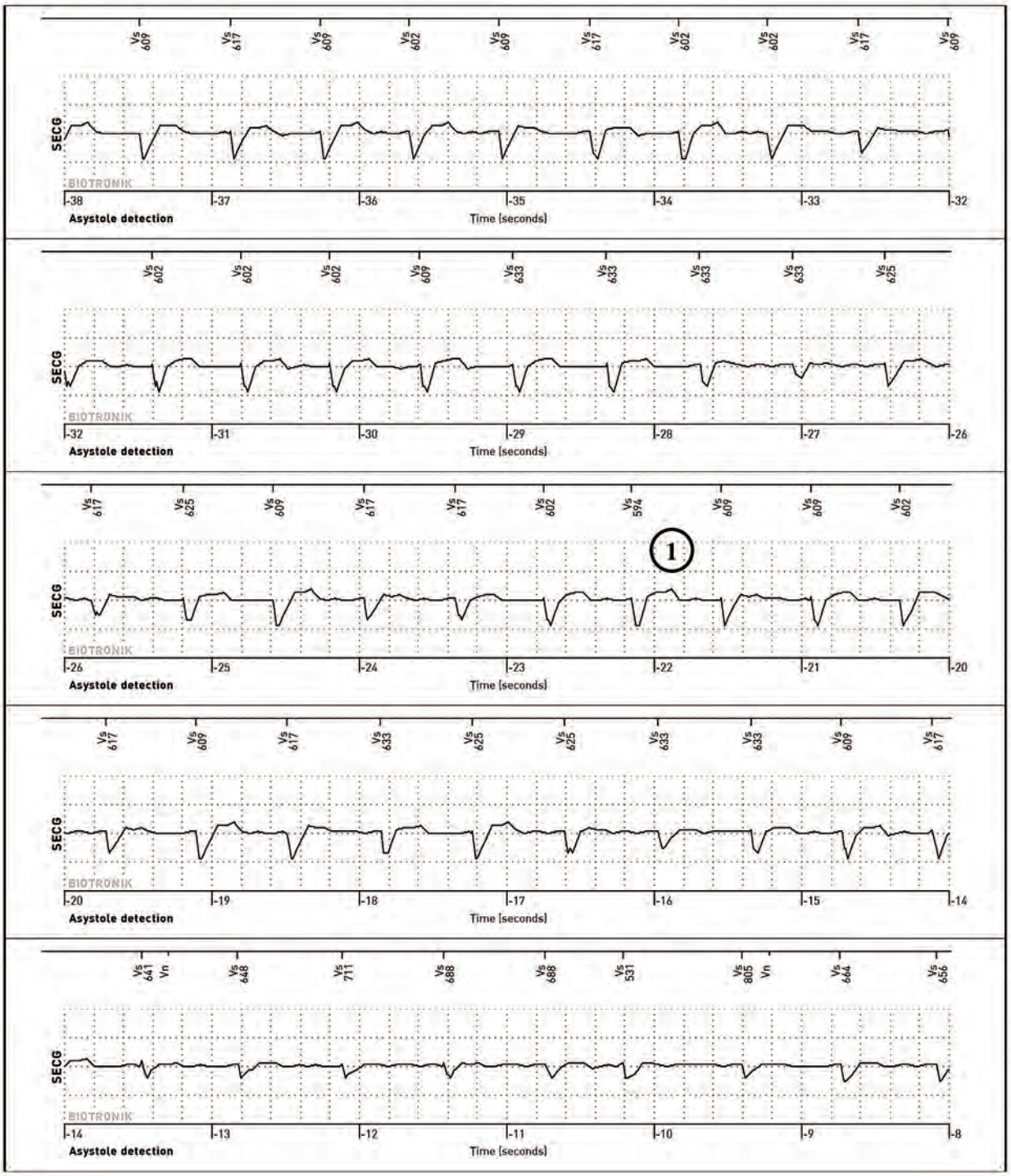

Status report - May 25, 2016

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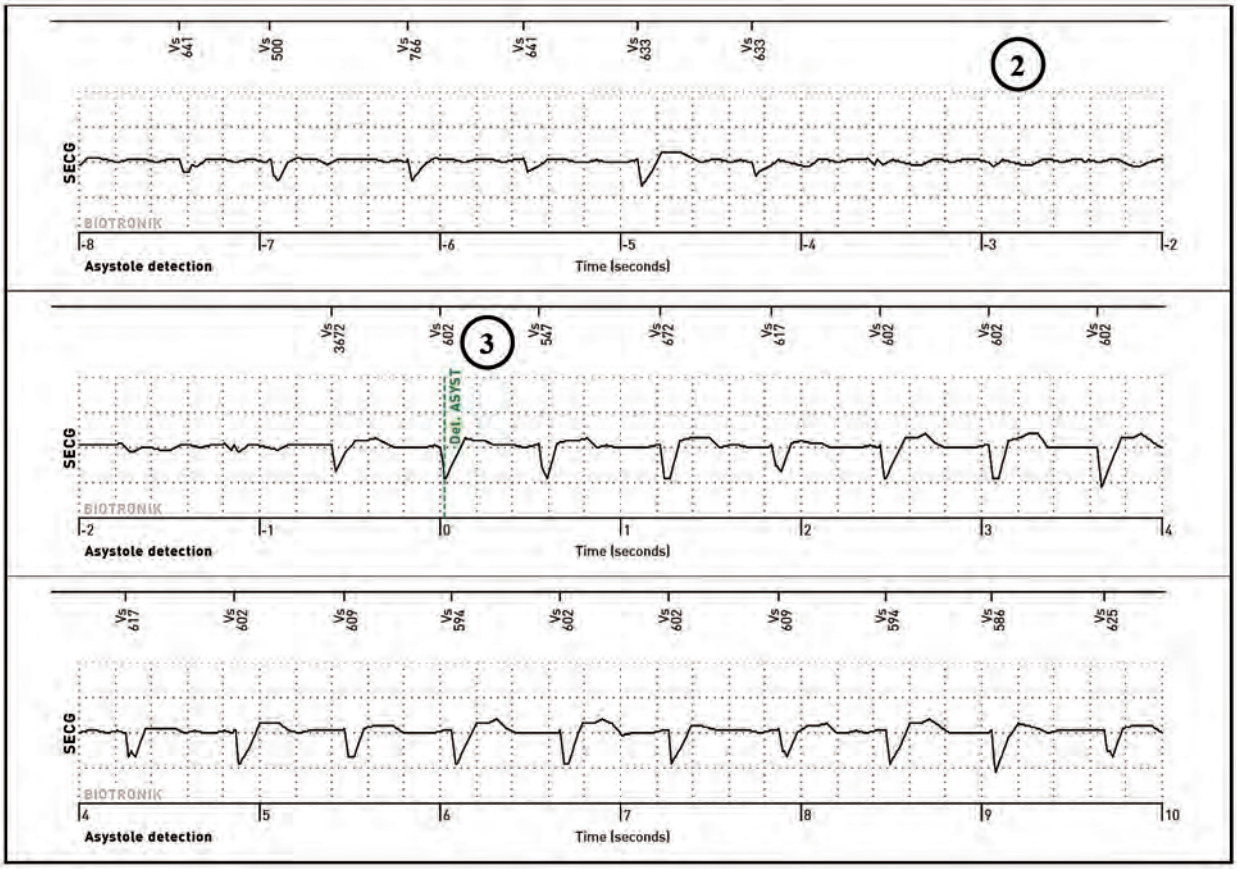

Status report - Jun 28, 2017

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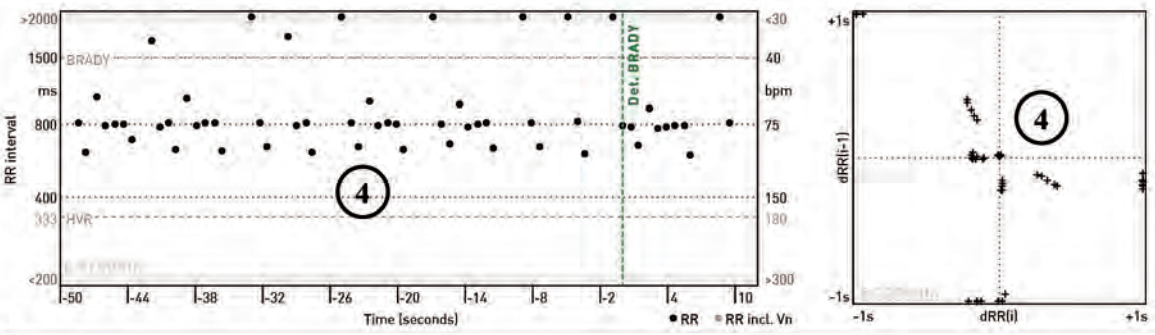
Recordings

Recordings - Episode 23:

General	
Episode number	23
Episode type	Bradycardia
Detection	Jan 9, 2017 4:24:50 AM
Termination	Jan 9, 2017 4:25:16 AM
Duration	26s
Device settings no.	3
Mean ven. rate / RR interval [ms]	1652

Tachogram and Lorenz plot



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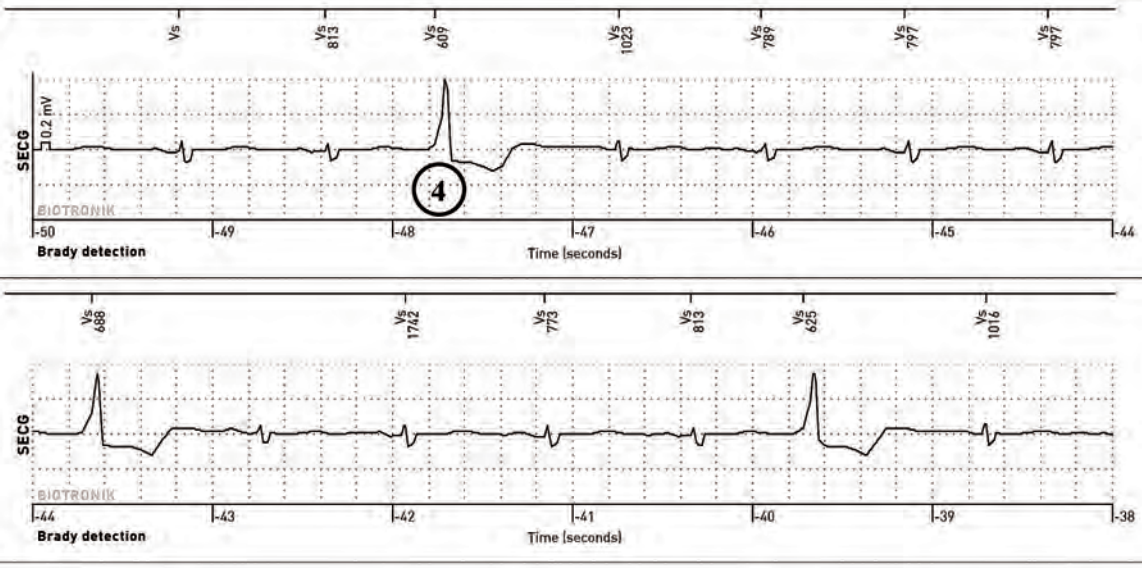

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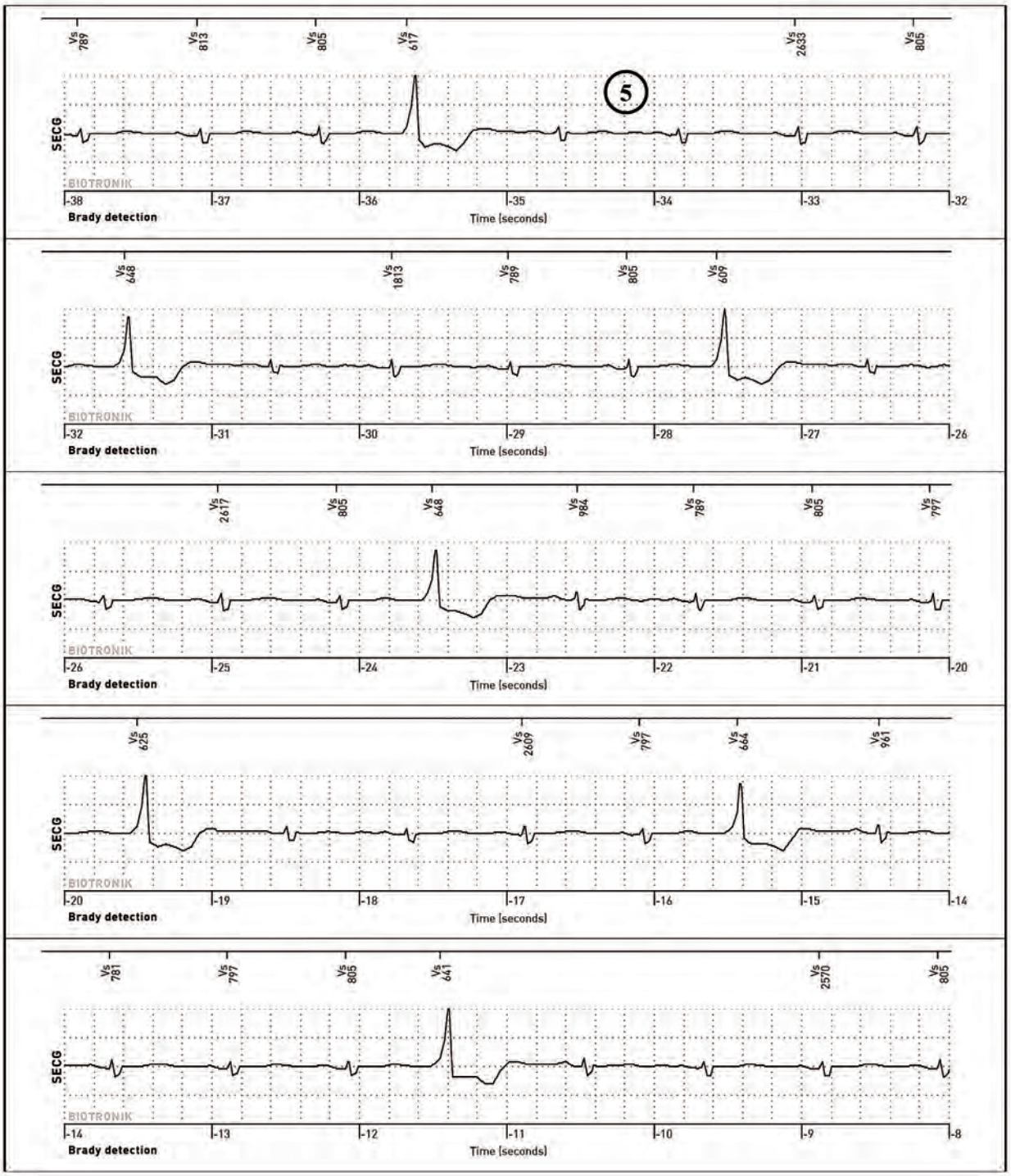

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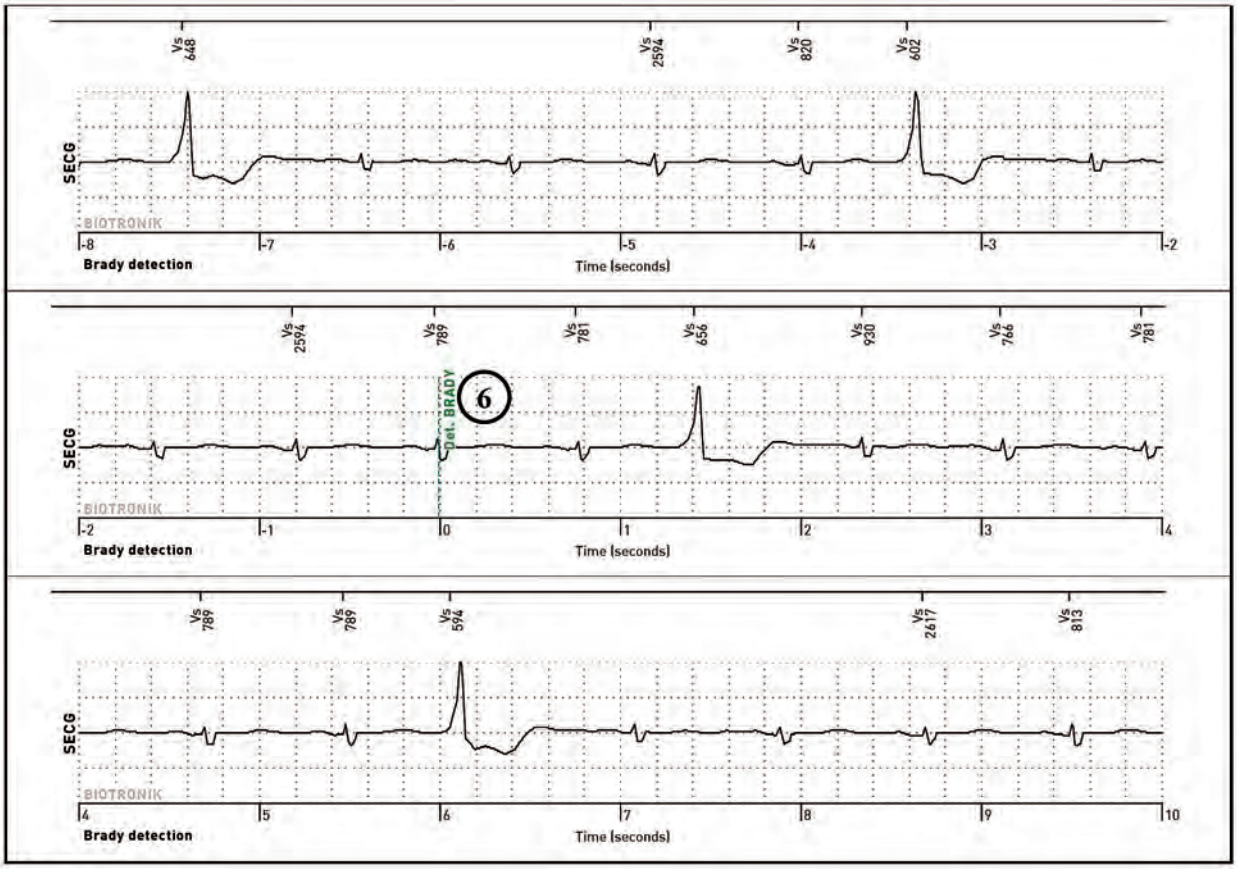

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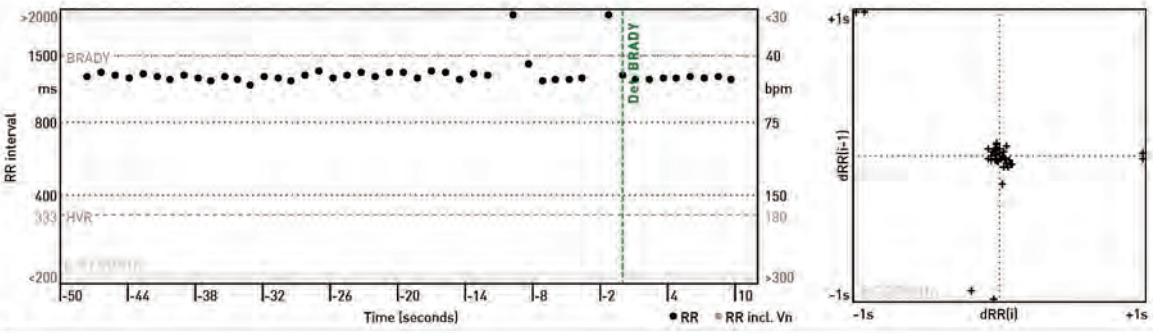
Recordings

Recordings - Episode 39:

General	
Episode number	39
Episode type	Bradycardia
Detection	May 28, 2016 2:07:32 AM
Termination	May 28, 2016 2:07:44 AM
Duration	12s
Device settings no.	2
Mean ven. rate / RR interval [ms]	1481

Tachogram and Lorenz plot



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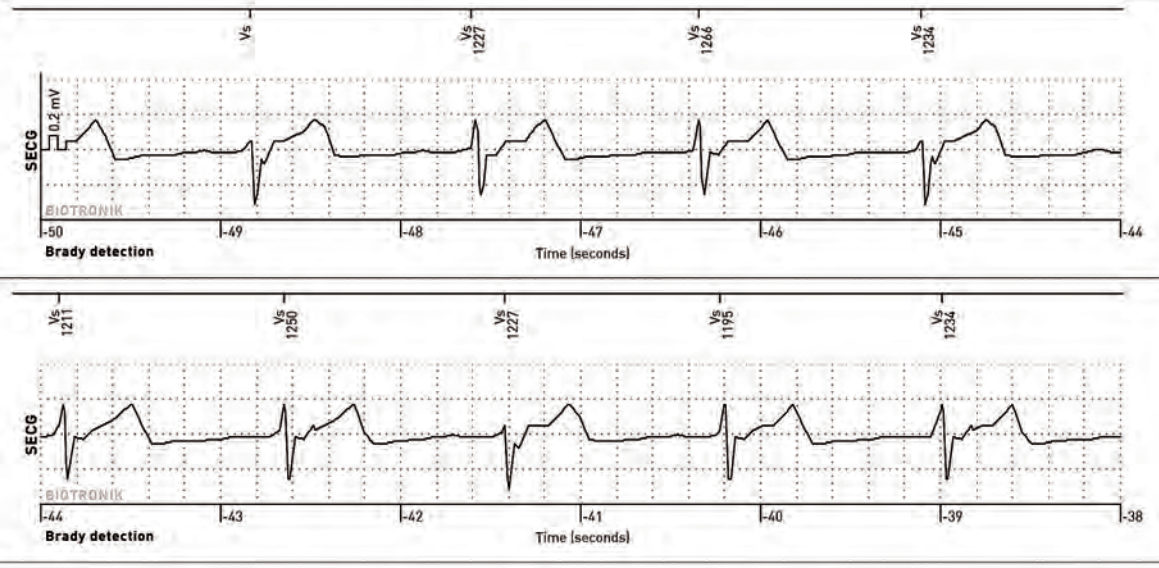

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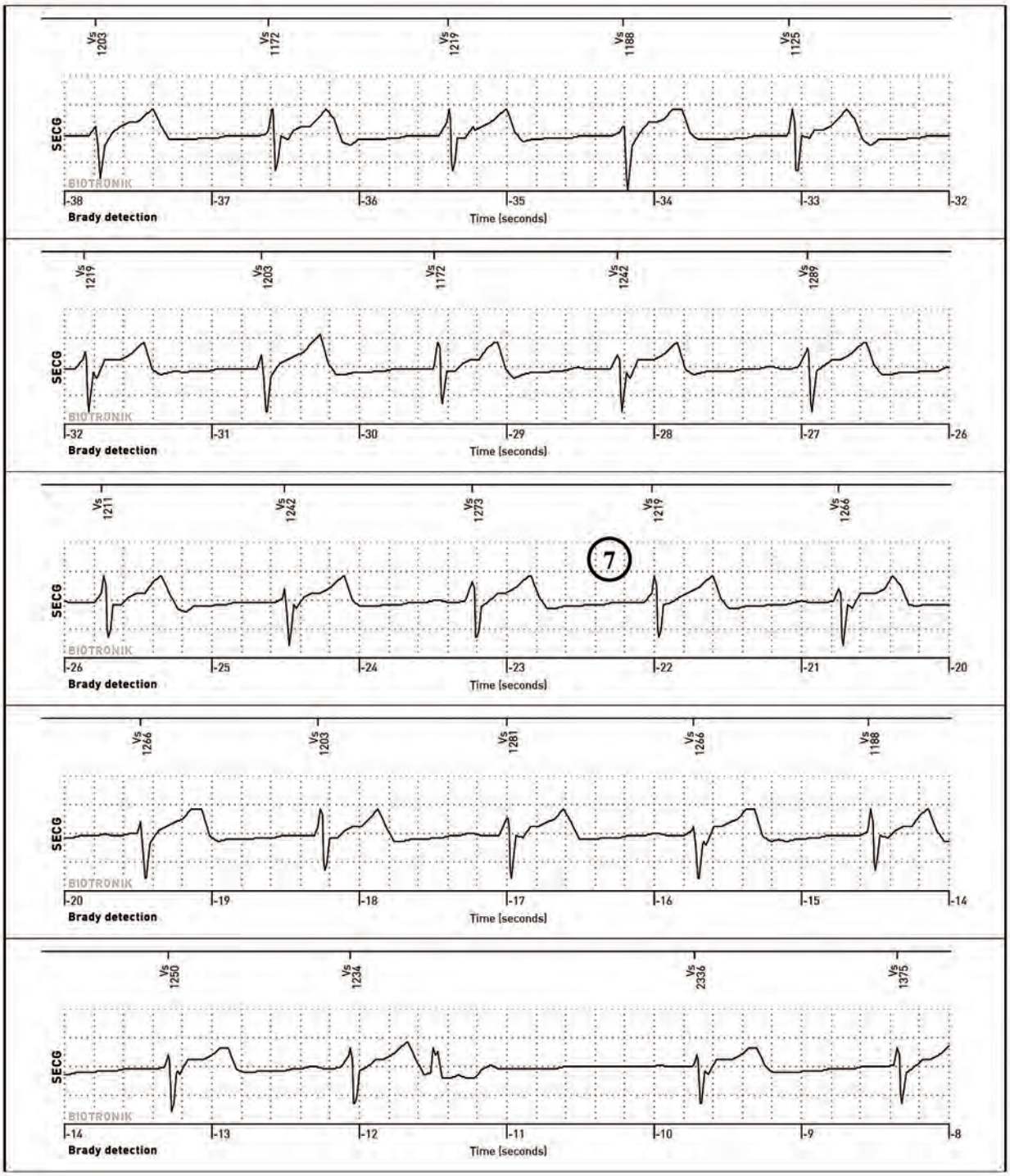

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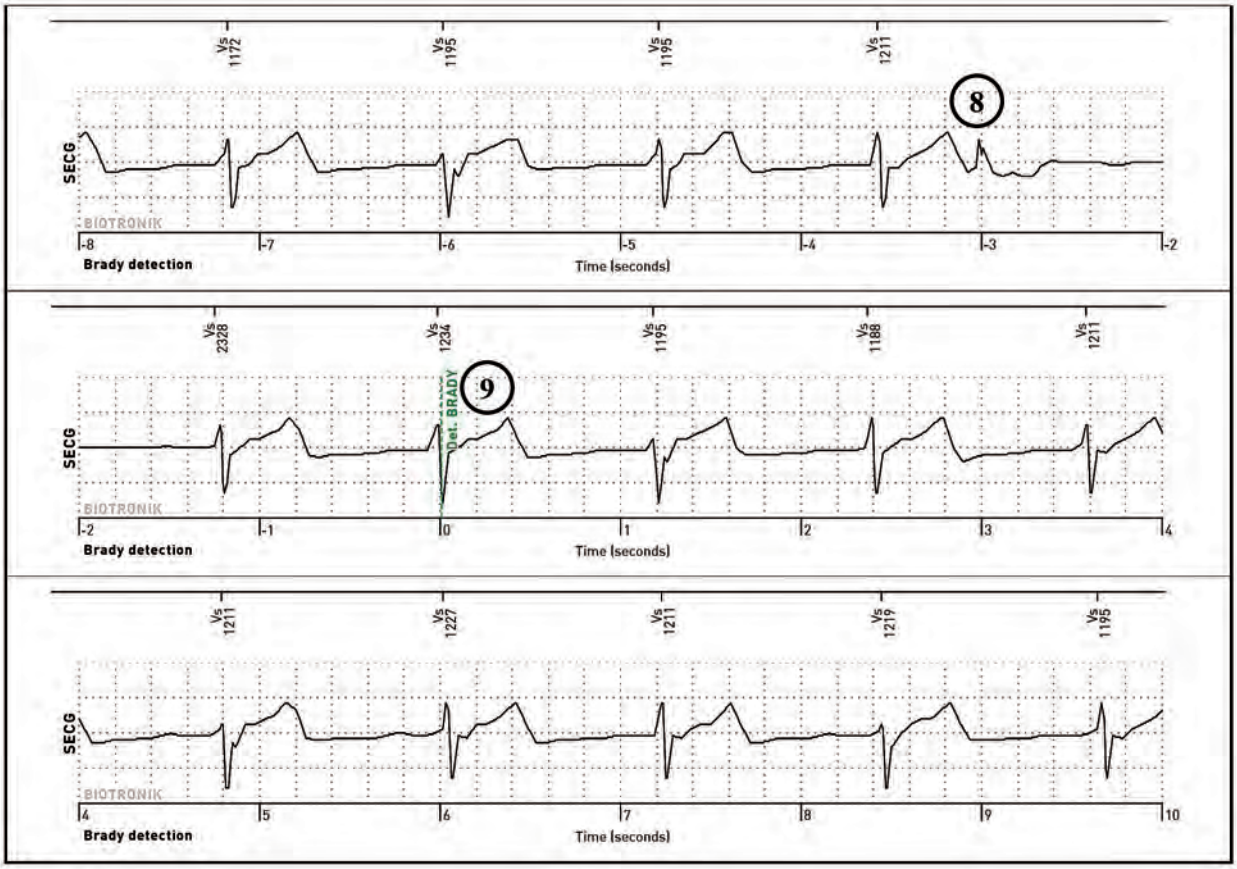

Tracing 9 ↘ False diagnosis of tachycardia due to an oversensing issue

Patient

90-year-old woman participating in the LBBB-TAVI study.

Tracing 9a

Episode diagnosed as HVR;

① well sensed QRS complex;
② T wave oversensing;
③ diagnosis of HVR by the device in conjunction with this systematic T wave oversensing.

Patient

85-year-old woman participating in the LBBB-TAVI study.

Tracing 9b

Episode diagnosed as HVR;

④ railroad track pattern of the tachogram evoked by the oversensing of a physiological signal (P wave, T wave, double counting of the R wave);
⑤ well sensed QRS complex;
⑥ P wave oversensing;
⑦ diagnosis of HRV by the device in conjunction with this systematic P wave oversensing.

Patient

92-year-old woman participating in the LBBB-TAVI study.

Tracing 9c

Episode diagnosed as HVR;

⑧ noise interference of the baseline with intervals classified as Vn;
⑨ tracing slightly less artifactual with intervals classified as Vs which leads to the diagnosis of HVR.

Comments

To avoid the recording of multiple episodes of false tachycardias saturating the memory bank, two options are preferred: 1) at the time of implantation, it is important to optimize the positioning of the device in order to obtain ventriculograms of sufficient amplitude without significant variation between intervals. Likewise, it is important to adjust the size of the subcutaneous pocket in order to reduce movement of the device and to avoid the oversensing of noise artifacts; 2) optimization of the programming can reduce the risk of oversensing of the P wave, the T wave and the double counting of the R wave.

The first patient presented T wave oversensing and multiple false diagnoses of HVR recorded in memory. T wave oversensing is favored by a decrease in R wave amplitude. Indeed, the sensing threshold is adjusted as a function of the amplitude of the previous R wave. For a T wave of similar size, the oversensing is thus all the more likely if the previous R wave is of small amplitude. In this example, the amplitude of the R wave is appropriate; on the other hand, the T wave is of high amplitude leading to oversensing. To correct the problem, it is possible to program the T wave suppression option with modification of the filters (elimination of low frequency signals) as well as the initial threshold (100% in order to reduce sensitivity at the beginning of the cycle) and the threshold target.

The second patient presented P wave oversensing, with a characteristic railroad track pattern on the tachogram (alternation between 2 intervals) observed during the sensing of an additional cardiac signal (double counting of the R wave; P wave or T wave oversensing).

For the last patient, the diagnosis of noise is obvious and initially correctly diagnosed by the device. The device classifies a sensed interval as noise under 2 conditions: 1) when the signal is of too weak amplitude (small signals); signals < 44µV are never sensed (maximum sensing capacity of the device); signals with an amplitude between 44 and 88µV are considered as low amplitude and are classified as Vn in order to avoid oversensing and improve specificity; 2) when the signal is of too high frequency (very rapid signals); following the sensing of a signal, there is a noise window to prevent oversensing of non-physiological signals; when a signal is sensed in the noise window, it is classified as Vn; when the noise is continuous, a Vn marker appears on the marker chain every 200 ms; it is possible to prolong this window with a risk of undersensing of a fast ventricular rhythm.

The sensing of intervals classified as Vn interferes with the various counters. Vs/Vn intervals are never integrated in the arrhythmia count. The HVR and the drop in rate counters are systematically reset to 0 after each interval classified as Vn. If the noise counter exceeds 25% (at least 1 interval out of 4 classified as Vn) on 2 consecutive windows, the sensing and confirmation of the AF are canceled.

Status report - Jun 28, 2017

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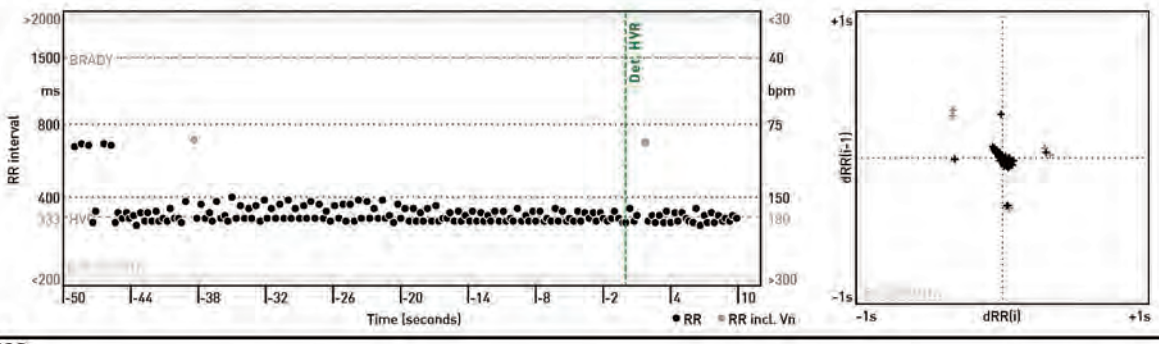
Recordings

Recordings - Episode 25:

General	
Episode number	25
Episode type	HVR
Detection	May 8, 2016 4:24:02 PM
Termination	May 8, 2016 4:27:24 PM
Duration	3min 22s
Device settings no.	2
Mean ven. rate / RR interval [ms]	330

Tachogram and Lorenz plot



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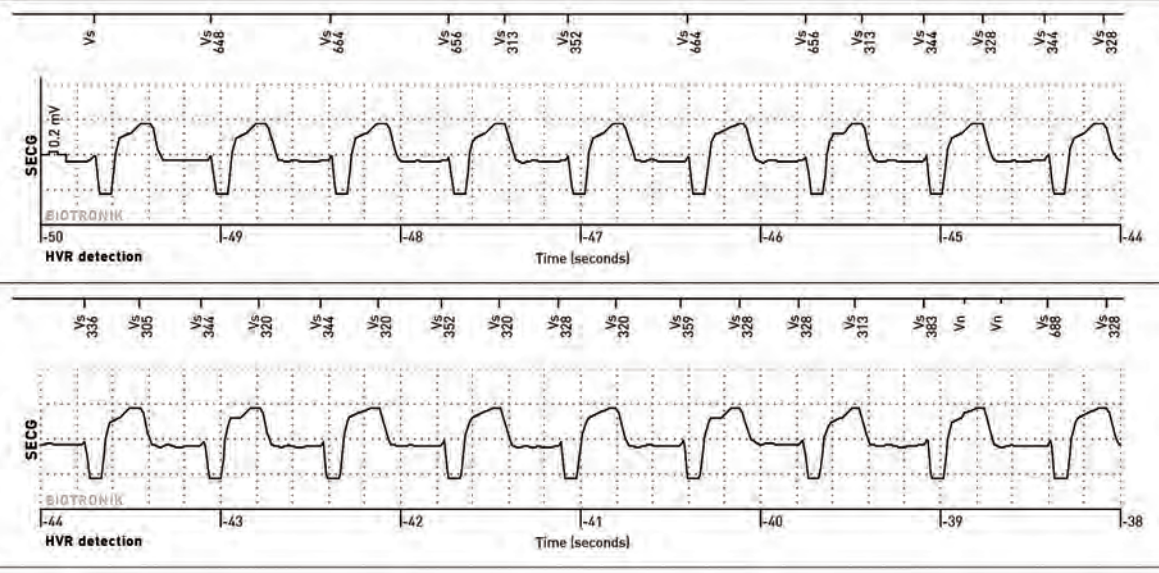

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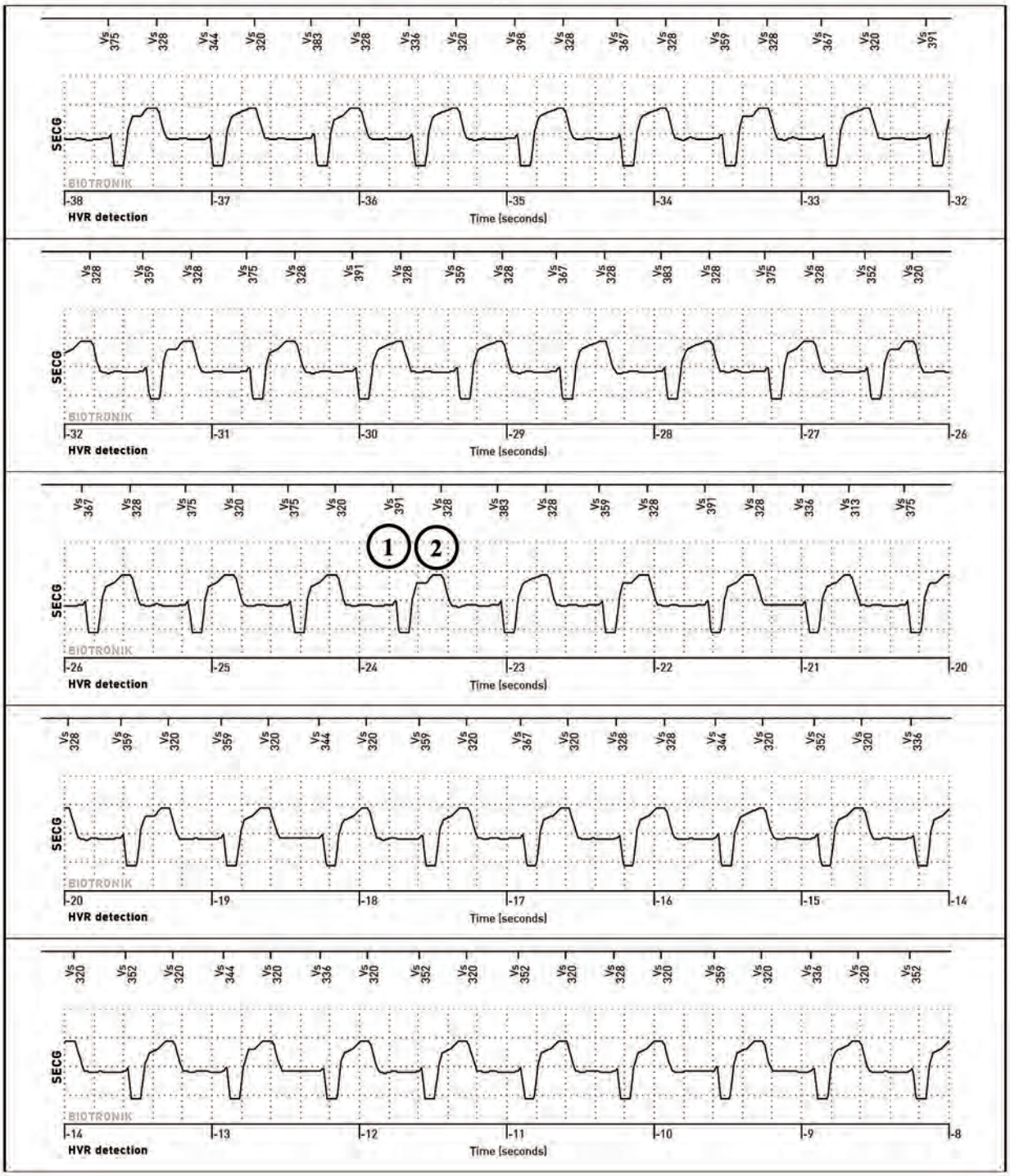

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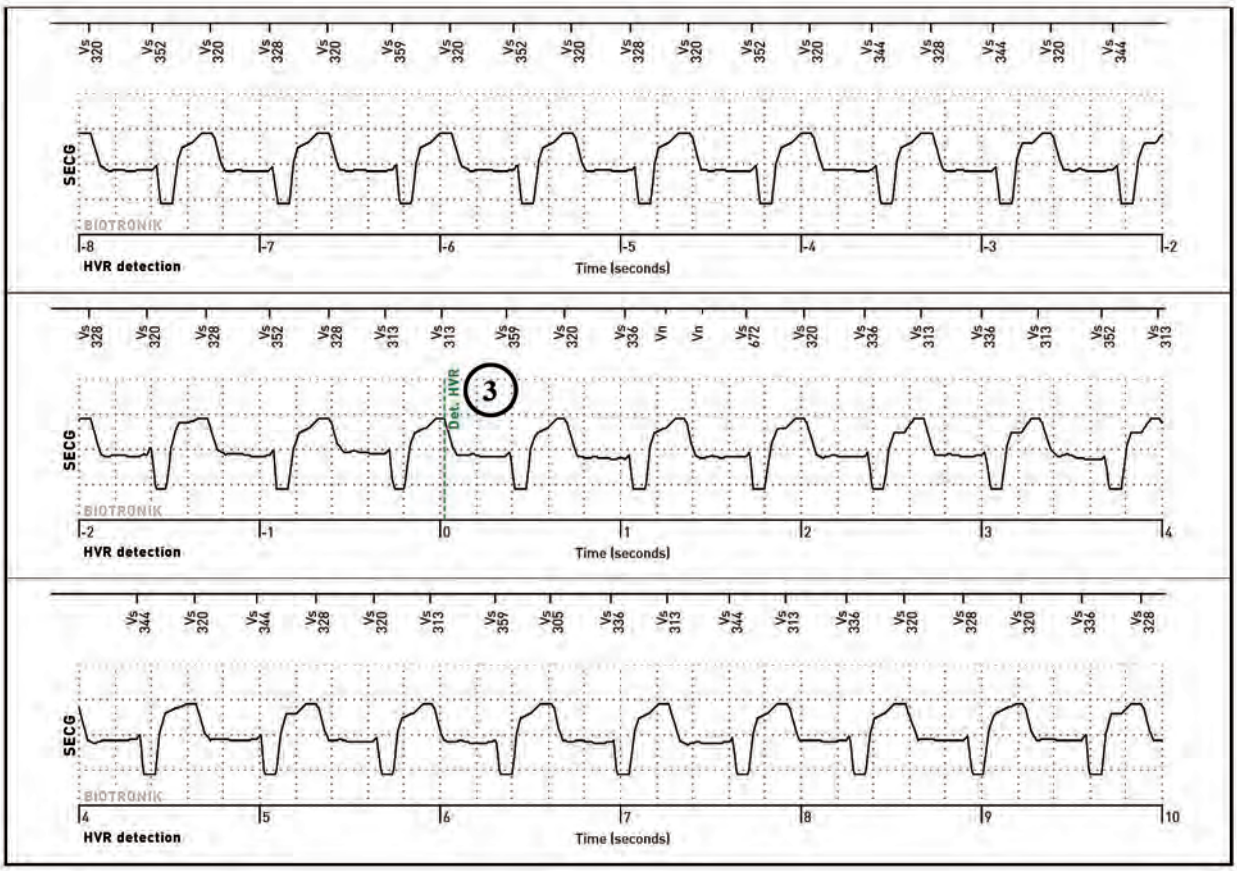

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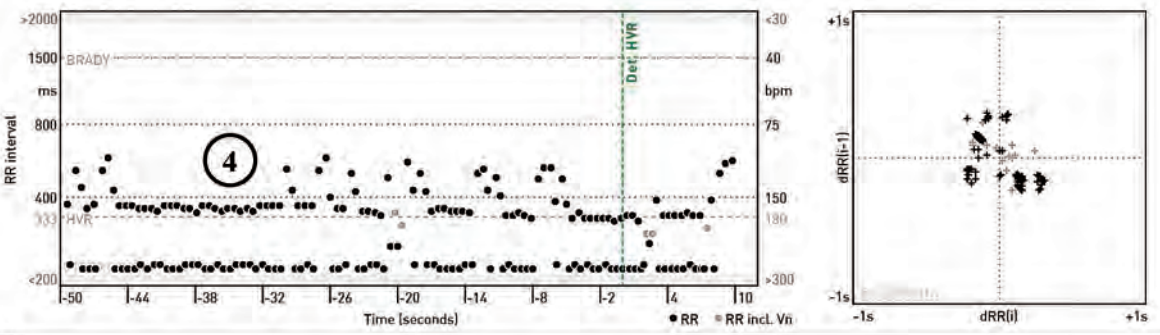
Recordings

Recordings - Episode 24:

General	
Episode number	24
Episode type	HVR
Detection	Sep 4, 2016 7:04:50 PM
Termination	Sep 4, 2016 7:05:00 PM
Duration	10s
Device settings no.	3
Mean ven. rate / RR interval [ms]	264

Tachogram and Lorenz plot



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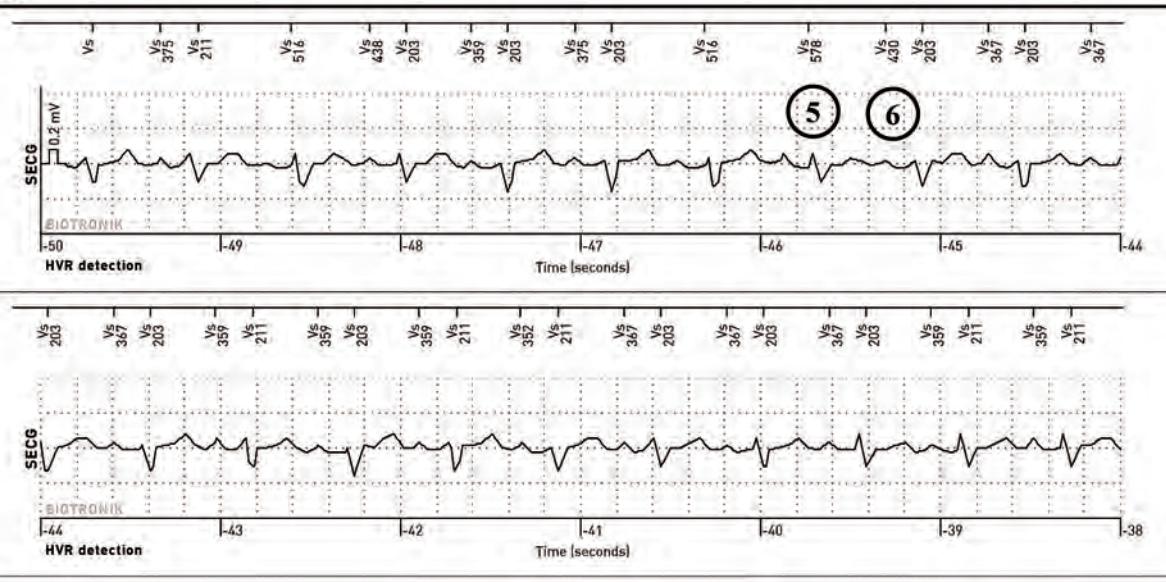

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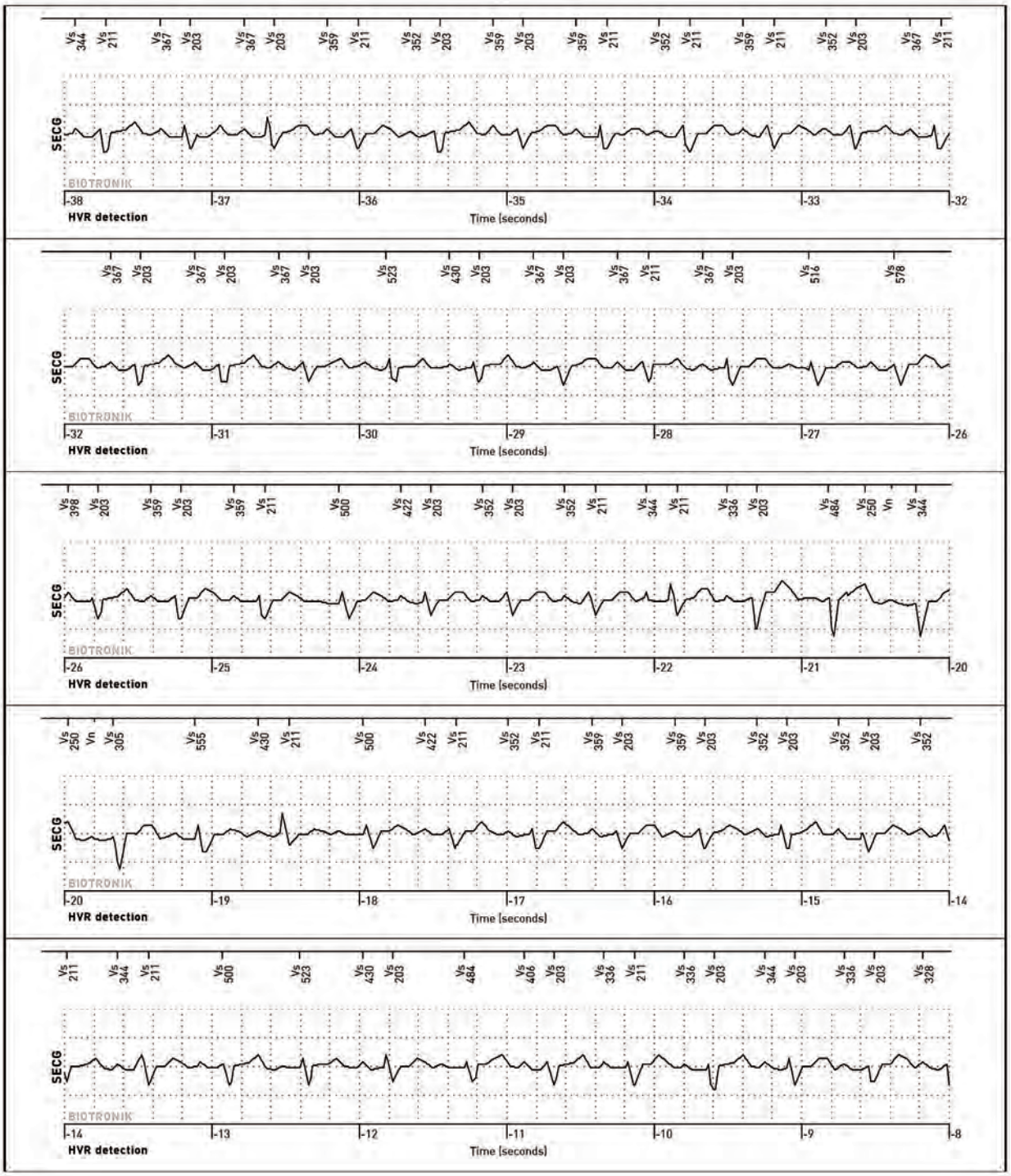

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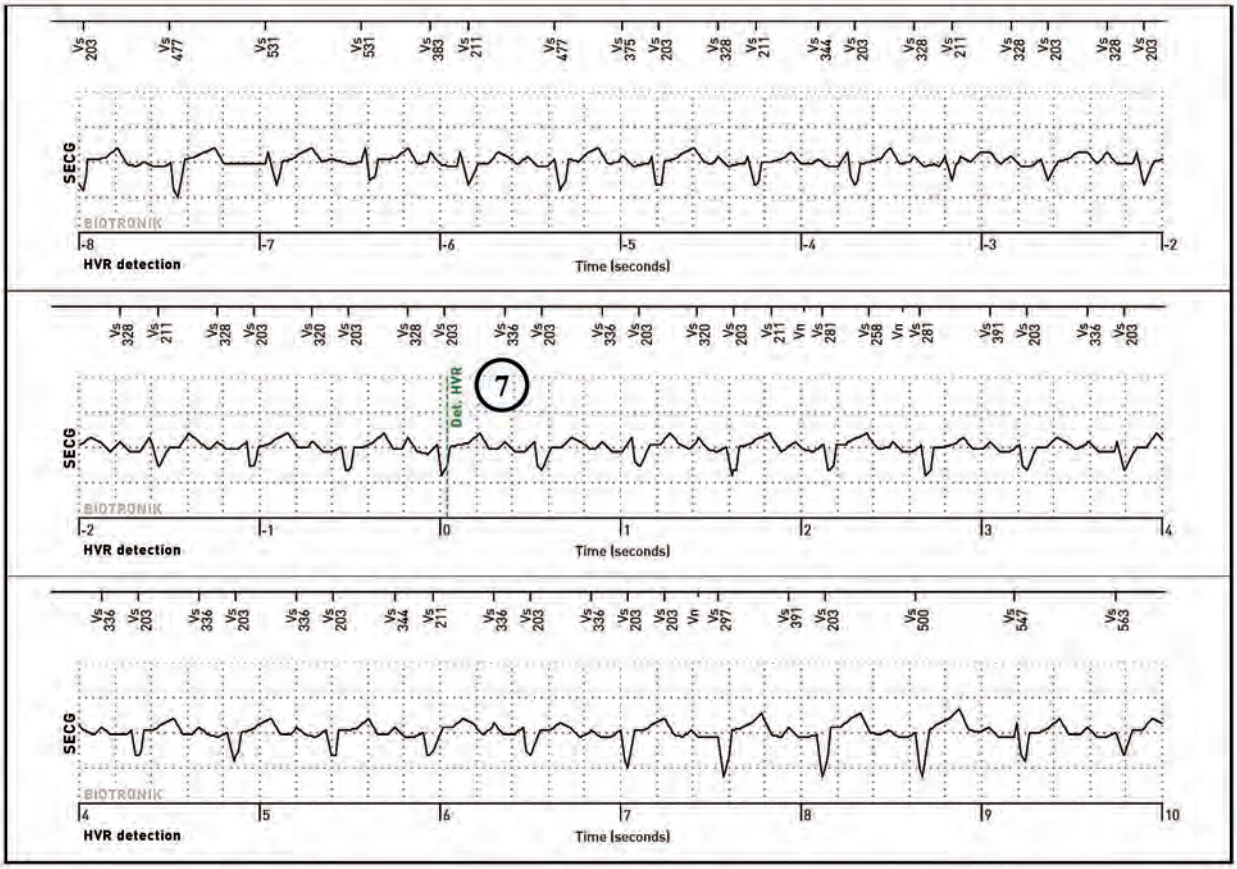

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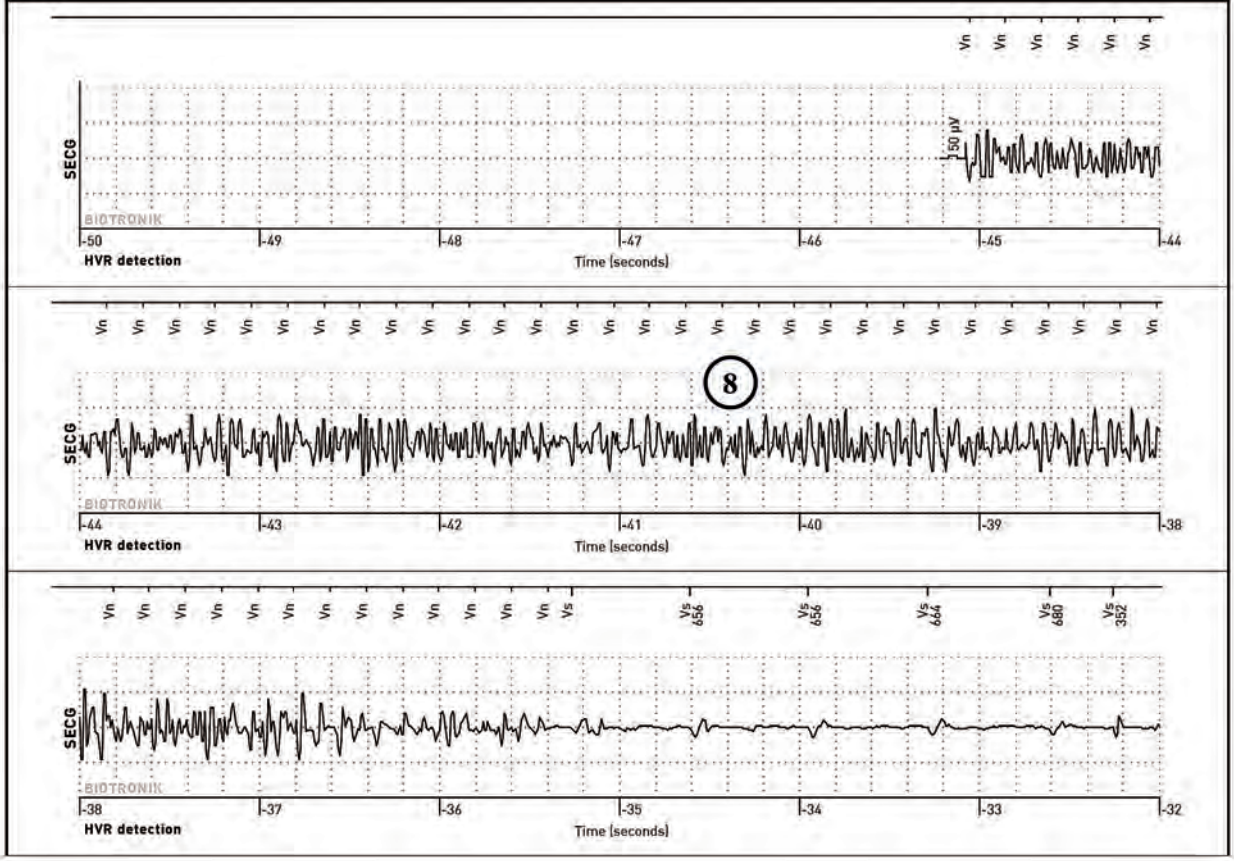
Recordings

Recordings - Episode 146:

General	
Episode number	146
Episode type	HVR
Detection	Dec 24, 2015 12:45:08 PM
Termination	Dec 24, 2015 12:45:22 PM
Duration	14s
Device settings no.	4
Mean RR at initial detection [ms]	312

SECG



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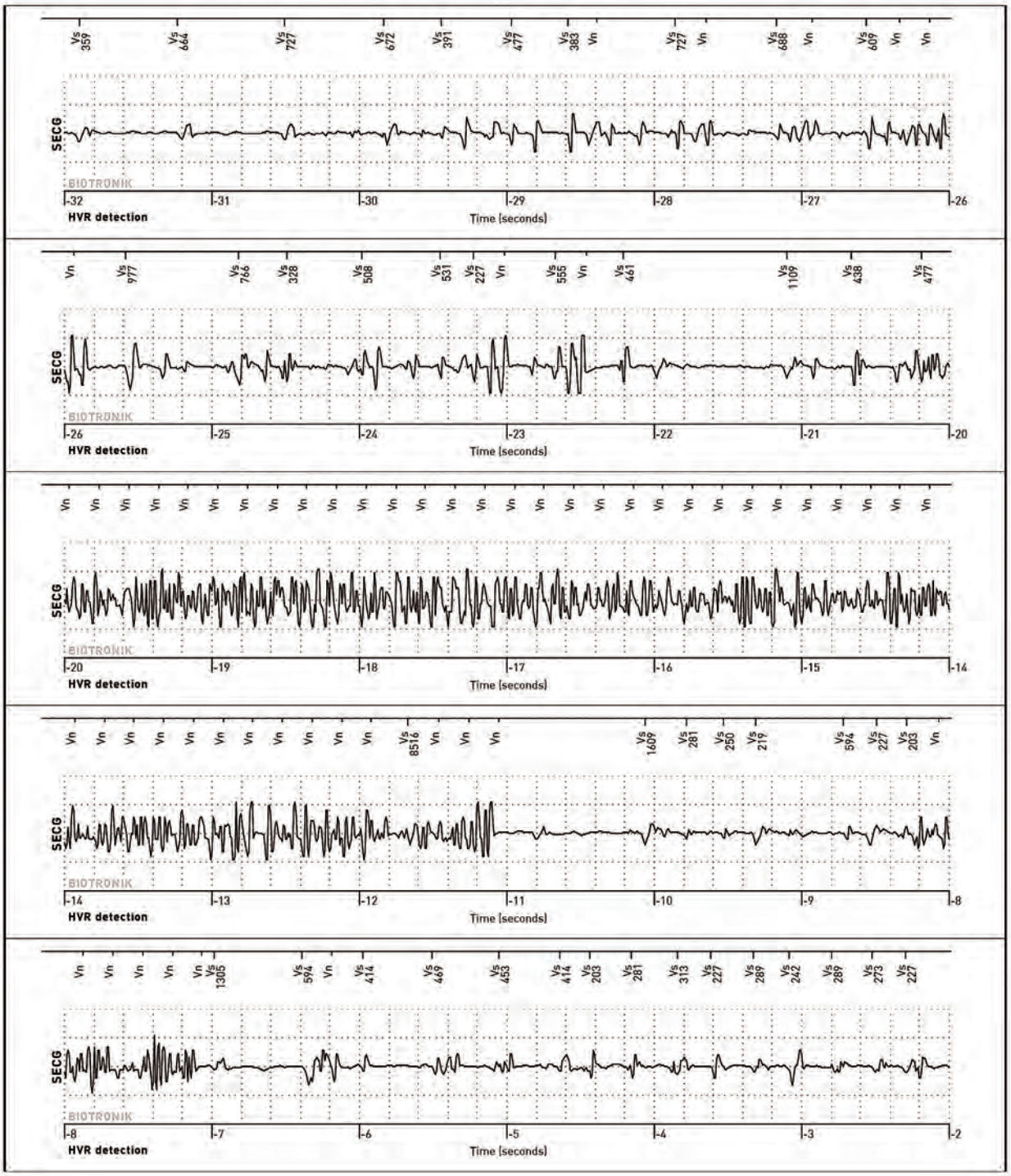

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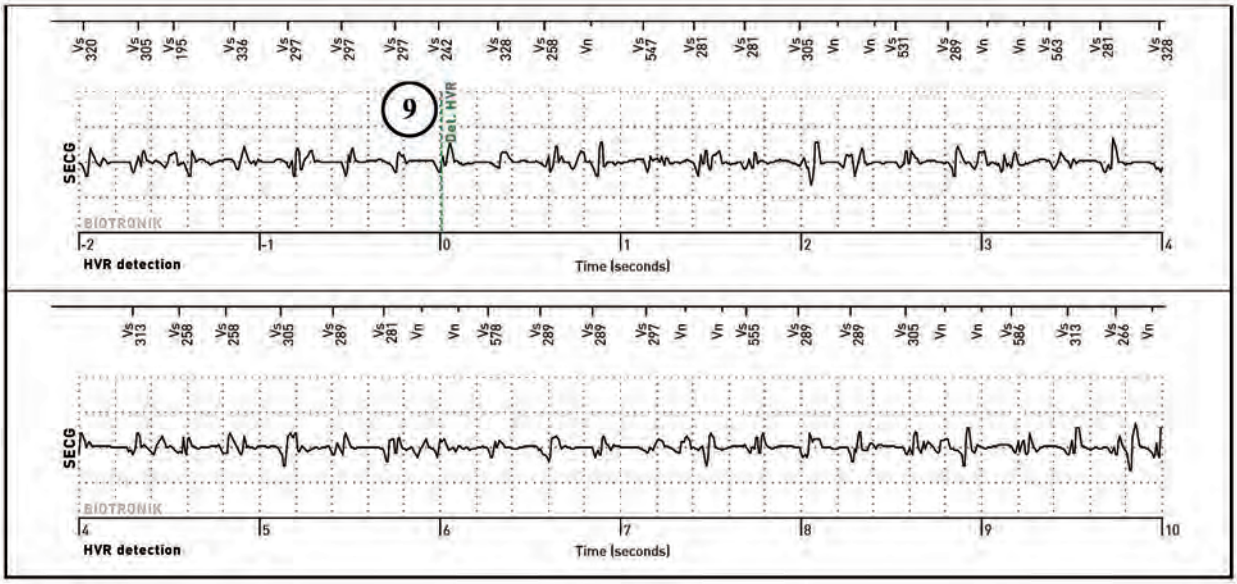

Tracing 10 ↘ False diagnosis of AF due to premature ventricular contractions

Patient

75-year-old man participating in the LBBB-TAVI study.

Tracing

Episode diagnosed as AF;

① characteristic pattern of the tachogram suggestive of an extrasystole (premature beat followed by compensatory rest);

② characteristic pattern of the Lorenz plot suggestive of an extrasystole (5 different groups of points);

③ the tracing confirms the presence of premature ventricular contractions (premature beat followed by compensatory rest) on a background of sinus rhythm; throughout the tracing, there is no fixed periodicity (bigeminism, trigeminism, quadrigeminism, etc.);

④ diagnosis of AF with the persistence of extrasystoles.

Comments

This patient presented numerous premature ventricular contractions on a background of stable sinus rhythm triggering the automatic recording of tracings erroneously classified as atrial fibrillation. The pattern of the tachogram is characteristic with a stable baseline rhythm and presence of short intervals followed by a longer interval (compensatory rest). The pattern of Lorenz plot is also very evocative of an extrasystole with the highlighting of clearly distinct groups of points (one in the center and 4 in periphery). The variability of the ventricular intervals leads to a false diagnosis of AF which is based on the analysis of the difference between the duration of 2 consecutive sensed ventricular intervals (n, n+1). The characteristic sequence of a premature ventricular contraction (premature beat followed by a compensatory pause and then return of the baseline rhythm) if repeated over two consecutive windows leads the device to suspect the diagnosis of AF and the recording of false positives. While the interval-to-interval analysis reveals an instability in the event of an extrasystole, an analysis over several intervals conversely reveals a periodicity if the occurrence of extrasystoles is regular with bigeminism (second-order periodicity, short interval-long interval), trigeminism (third-order periodicity, normal-interval-short interval-long interval), quadrigeminism (fourth-order periodicity, normal interval-normal interval-short interval-long interval), etc.

The algorithm for the rejection of extrasystoles, in addition to interval-to-interval variability, assesses the variations in intervals on pairs of intervals in the search of a characteristic periodicity. The diagnosis of AF is only made if the device does not find a pattern compatible with a bigeminism, trigeminism or quadrigeminism. This algorithm significantly reduces the AF "load" by decreasing the number of recorded false AF episodes. Its operation however requires the presence of a regular periodicity. In this example, this periodicity is imperfect (trigeminism alternating with a quadrigeminism followed by a few intervals without extrasystole) and the algorithm is duped.

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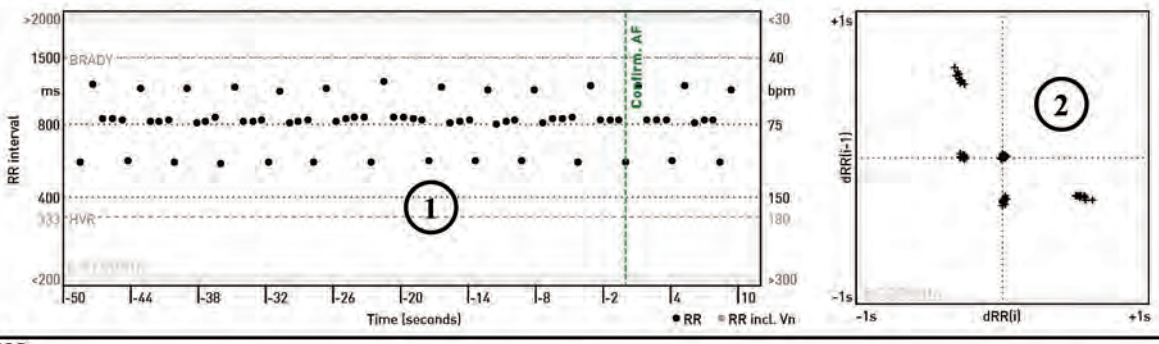
Recordings

Recordings - Episode 701:

General	
Episode number	701
Episode type	AF
Detection	Jun 7, 2017 9:48:58 PM
Termination	Jun 7, 2017 10:12:12 PM
Duration	23min 14s
Device settings no.	3
Mean ven. rate / RR interval [ms]	914

Tachogram and Lorenz plot



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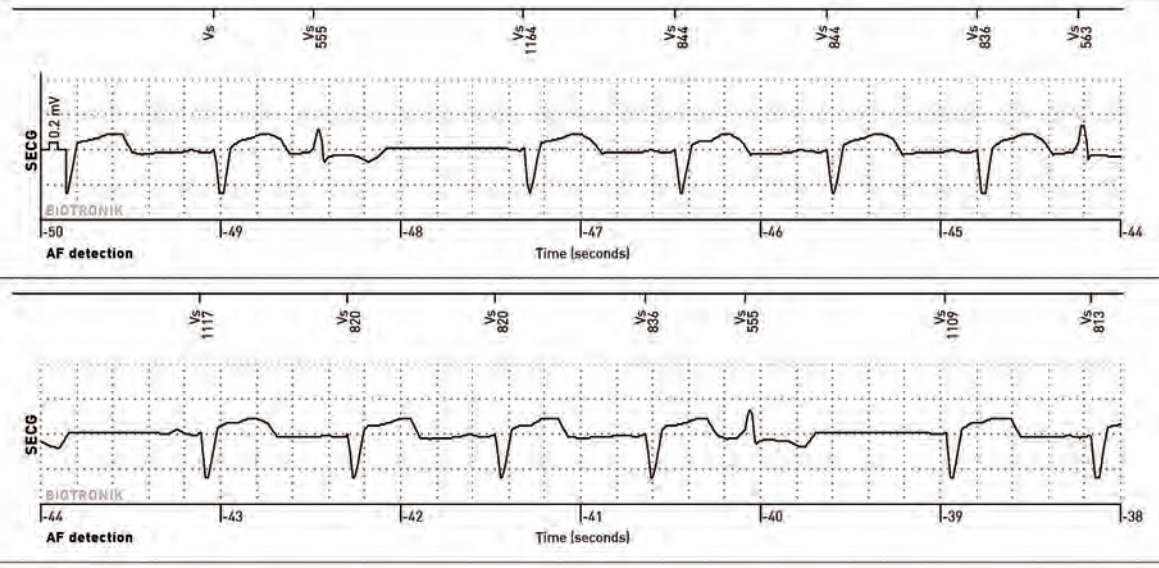

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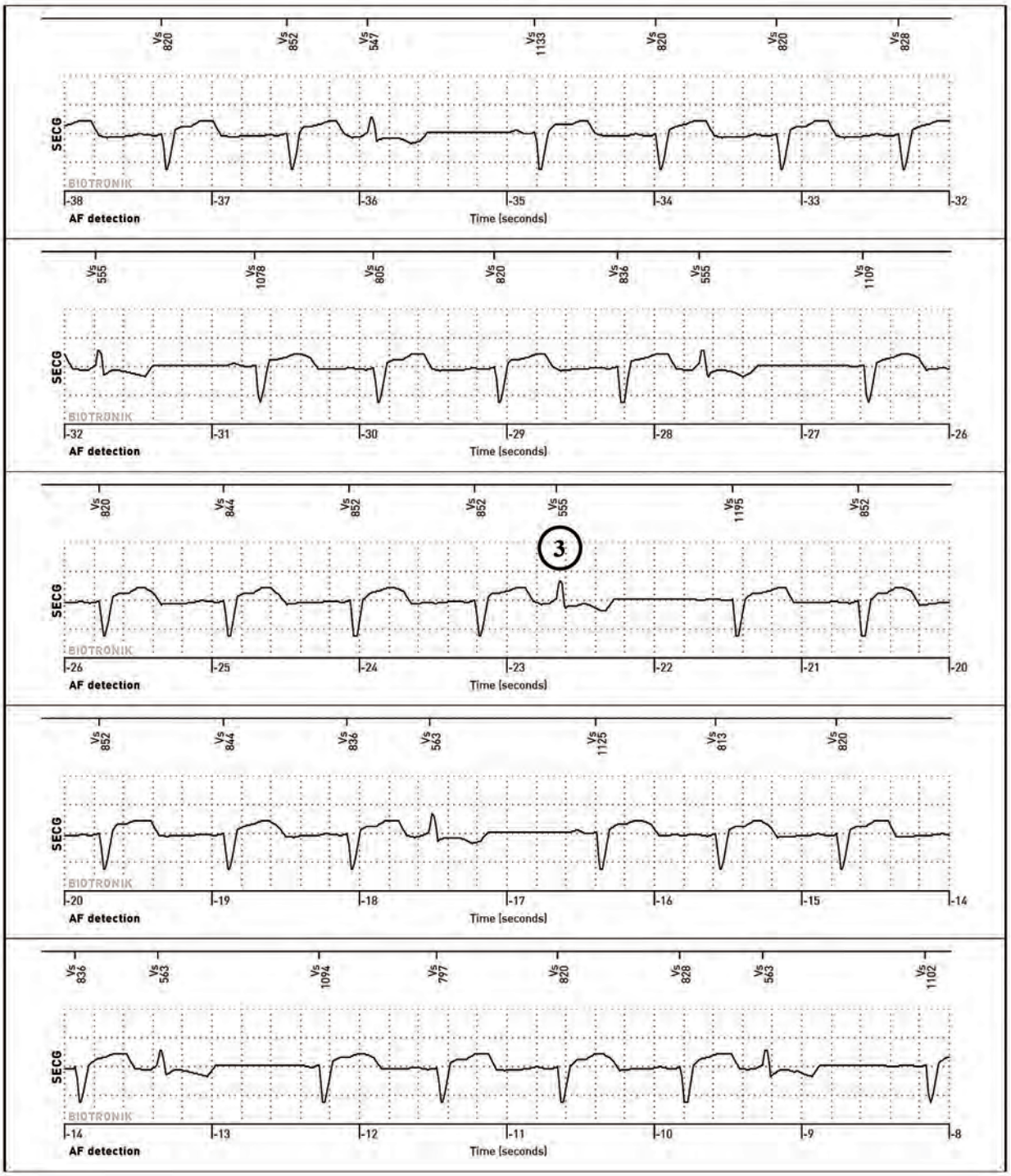

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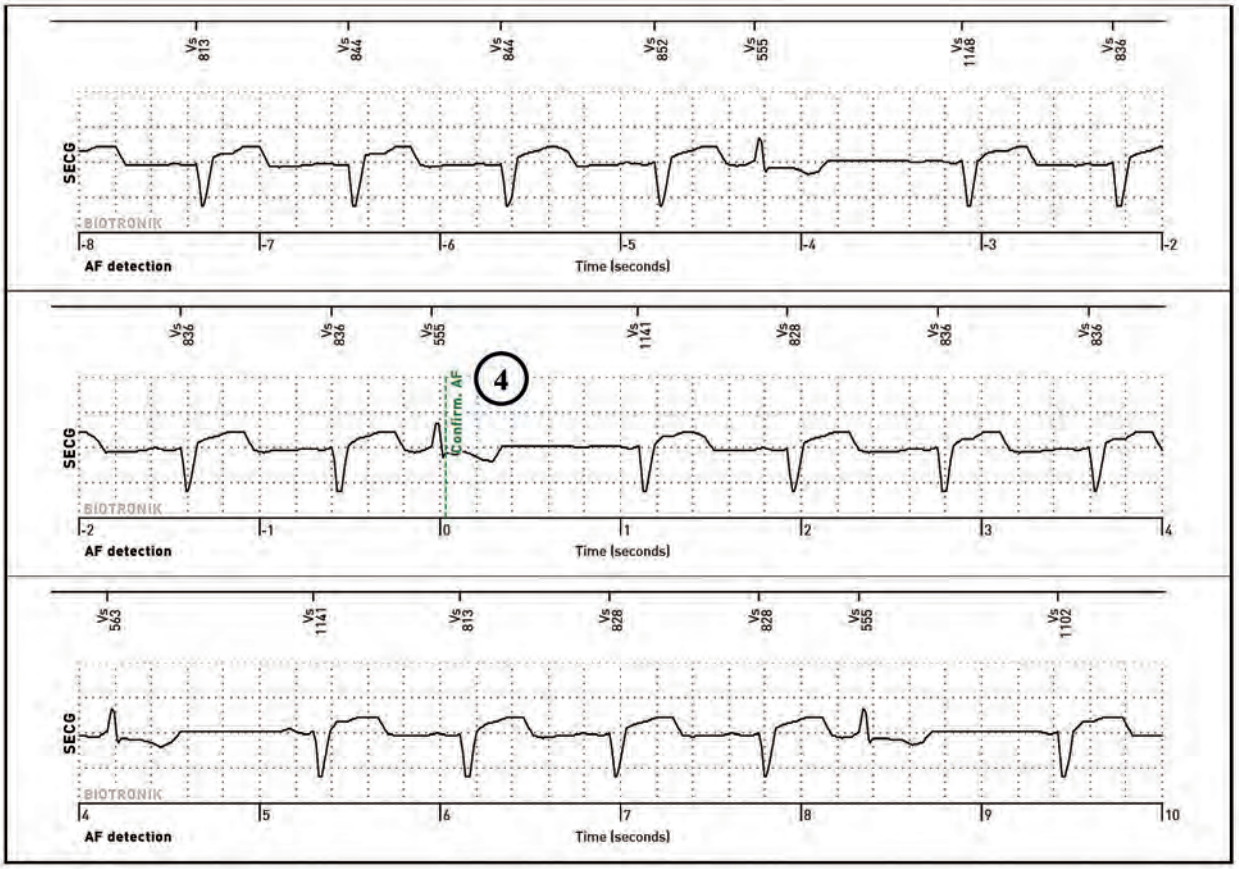


Implantable Cardiac Pacemaker

Case studies based
on **Biotronik™** tracings

Implantable Cardiac Pacemaker - chapter 1

Pacing Modes

Tracing 1 ↘ DDD mode

Patient

71-year-old man implanted with a dual-chamber Biotronik™ pacemaker for symptomatic sinus dysfunction with prolonged PR interval; programming in DDD mode at 60 bpm; 6 months after implantation, ventricular pacing at 100% and atrial pacing at 85%; during the device follow-up control, programming of various pacing modes and recording of the tracings; this first tracing corresponds to the programmed mode (DDD 60 bpm).

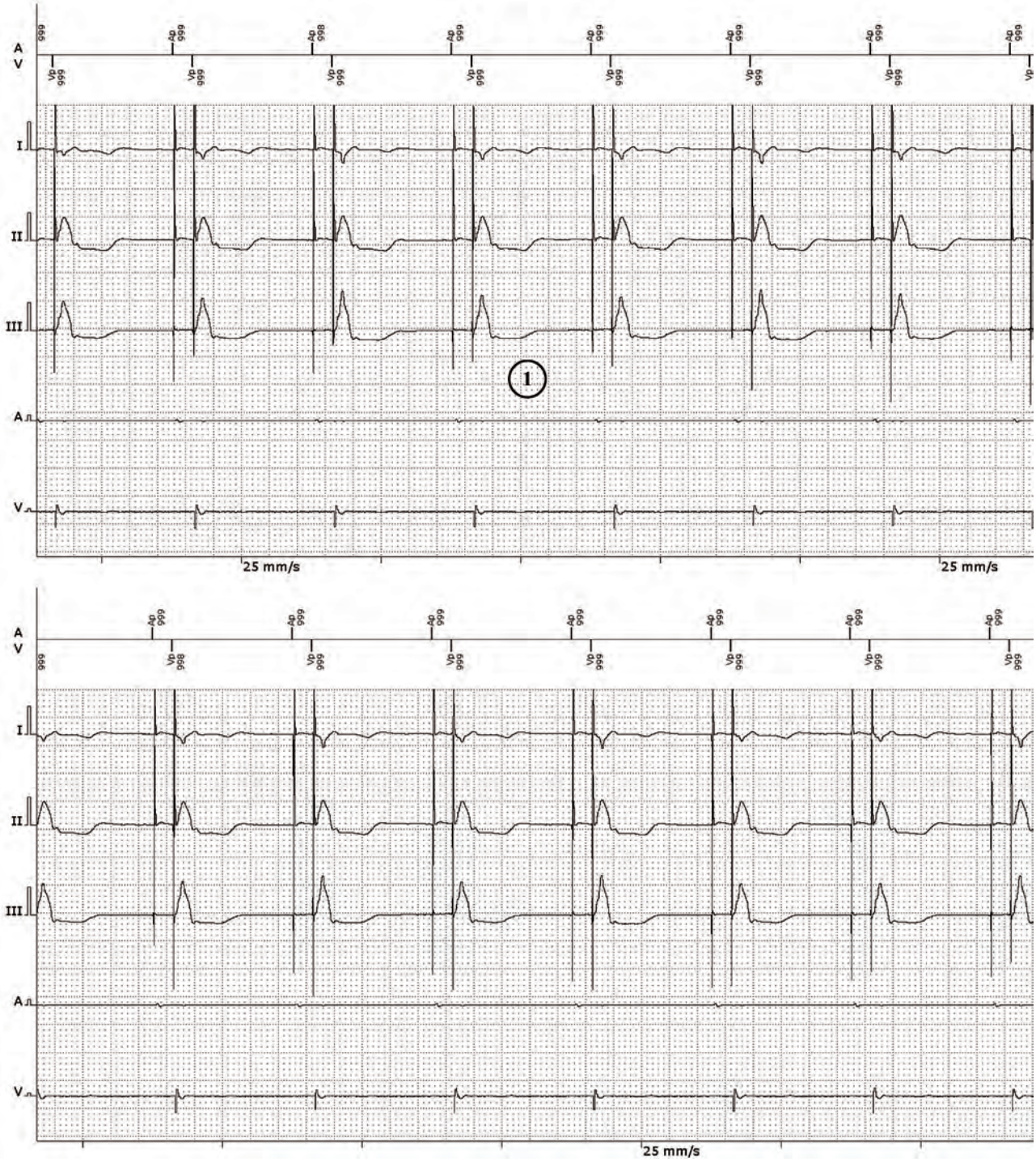
Tracing

In this and the following tracings, the first 3 lines correspond to ECG lead I, lead II and lead III, the fourth and fifth lines to the atrial EGM and ventricular EGM, respectively;

① atrial pacing and ventricular pacing.

Comments

The basic principle of the DDD mode is to synchronize ventricular pacing with atrial sensing (triggered function) or atrial pacing. A spontaneous atrial or ventricular activity sensed outside the refractory period respectively inhibits atrial or ventricular pacing (inhibited function). This mode thus allows atrioventricular (AV) synchrony to be preserved for low sinus rates up to high rates (maximum tracking rate limit). The programming of the DDD mode hence appears satisfactory in this patient. However, follow-up highlighted a permanent ventricular pacing, which could correspond to a functioning deemed normal and appropriate. Nonetheless, this patient exhibits preserved AV conduction in spite of a prolonged PR interval. One of the priorities of the programming of a pacemaker is to avoid unnecessary right ventricular pacing. This prevents excessive battery drainage and prolongs the life of the device and, above all, avoids right ventricular pacing which is associated with short, medium and long term effects along with adverse effects on ventricular remodeling and on the occurrence of atrial arrhythmias. Indeed, right ventricular pacing induces an asynchronous interventricular and intraventricular activation and relaxation sequence. A high percentage of ventricular pacing in a patient with preserved AV conduction should alert the physician at the time of the interrogation and raise the possibility of using specific algorithms favoring spontaneous conduction.


A
V
I
II
III
A
V
1
25 mm/s
25 mm/s
A
V
I
II
III
A
V
25 mm/s

Tracing 2 ↘ Asynchronous modes

Patient

Same patient as in tracing 1.

Tracing 2a

Programming in DOO mode 50 beats/minute;

① atrioventricular pacing with effective and complete capture (AP-VP);

② absence of sensing of the atrium and ventricle with ineffective asynchronous atrioventricular pacing since occurring in the atrial and ventricular refractory periods;

③ new asynchronous atrioventricular pacing; the ventricular stimulus occurs at the peak of the T wave in a vulnerable ventricular period without capture;

Tracing 2b

Programming in VOO mode 50 beats/minute;

④ asynchronous ventricular pacing in the vulnerable period of the preceding unsensed spontaneous ventricular complex;

Tracing 2c

Programming in VOO mode 60 beats/minute;

⑤ ventricular capture at a rate slightly higher than the sinus rate;

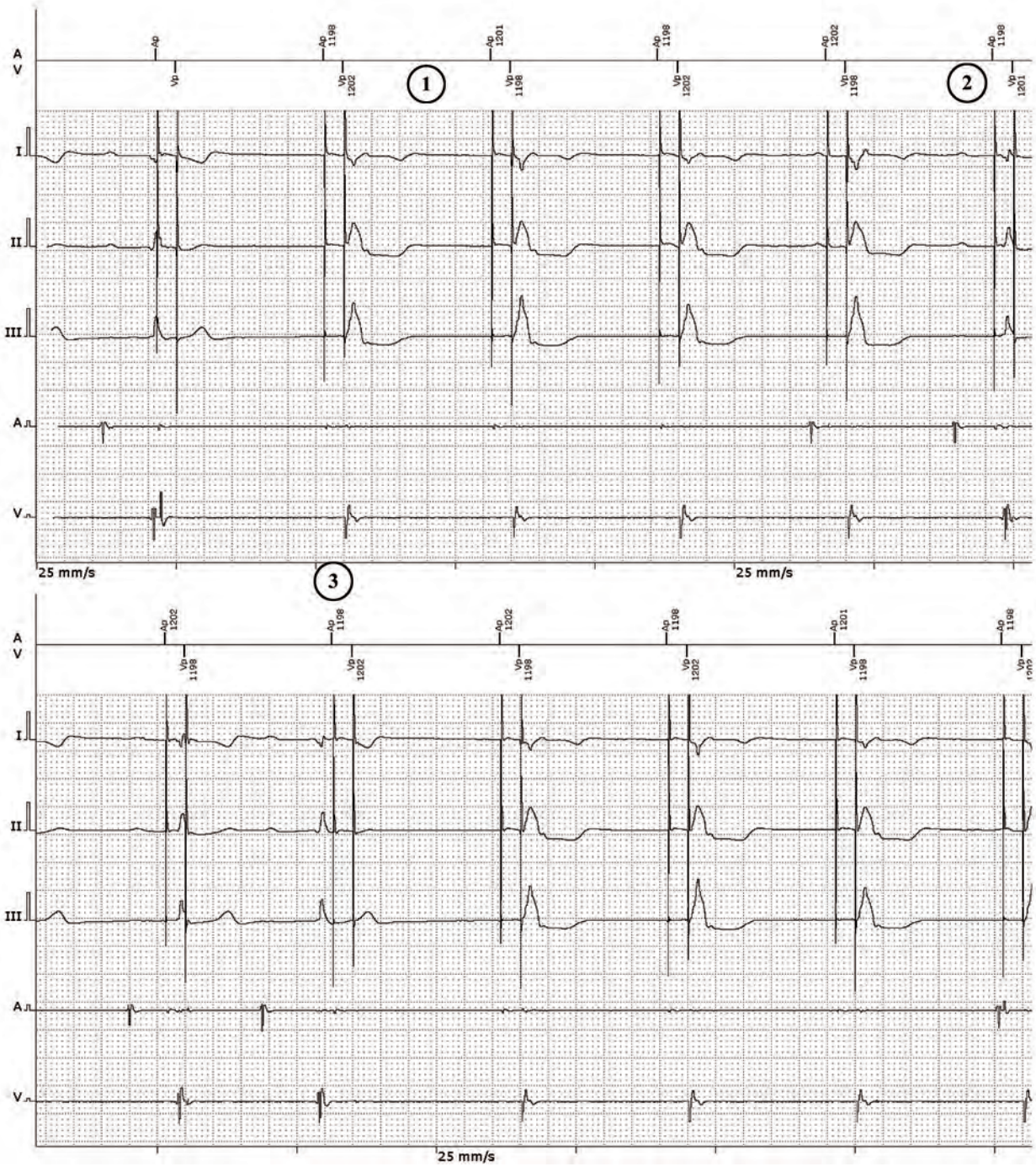
⑥ ventricular pacing in a vulnerable period of an unsensed premature ventricular contraction.

Comments

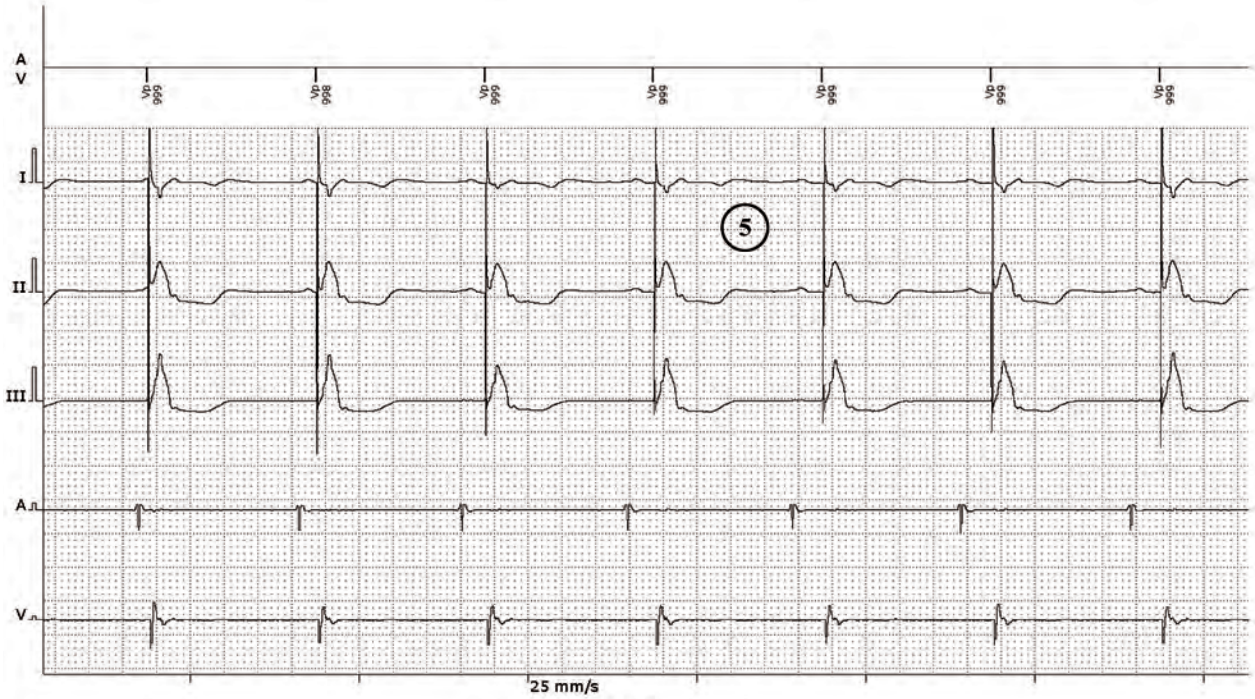
Asynchronous modes at fixed rates were the only available modes on the first-generation pacemaker models. The D00 mode induces asynchronous atrioventricular sequential pacing, without inhibition by intrinsic events. As seen on this tracing, when the patient is not pacemaker-dependent, a parasystole occurs with competition between spontaneous activities and paced activities. This mode allows verifying the effectiveness of the pacing and avoids inhibition in case of exposure to external interference (for example, an electric scalpel in a pacemaker-dependent patient). Pacing is effective and captures atrial or ventricular activity when it occurs outside the absolute physiological refractory period following a spontaneous atrial or ventricular event.

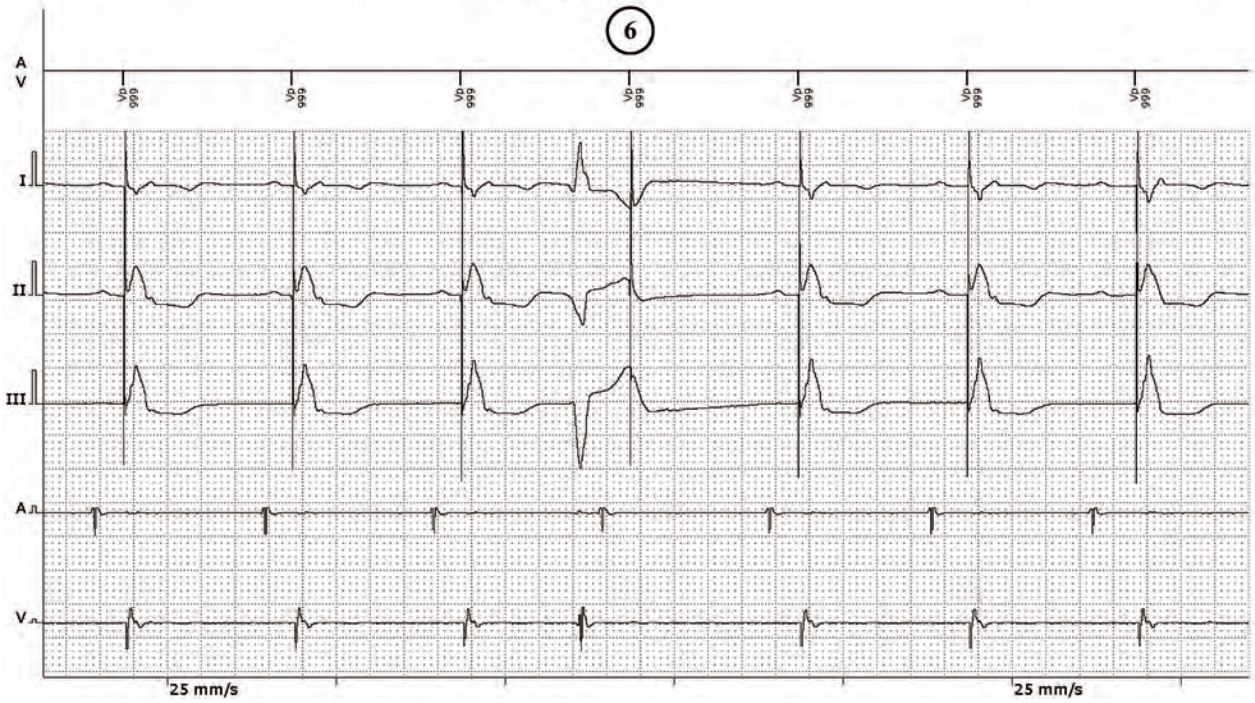
These tracings illustrate the risks associated with this type of mode. Several ventricular pacing pulses occur at the peak of the T wave of an unsensed spontaneous QRS. This is the vulnerable period with risk of induction of a ventricular rhythm disorder. While the risk of ventricular fibrillation is limited, it does increase considerably in the presence of myocardial ischemia or metabolic disorder (hypokalemia and long QT). Similarly, asynchronous atrial pacing in the atrial vulnerable period may induce atrial fibrillation. Increasing the minimal pacing rate promotes ventricular capture and reduces the risk of pacing during a vulnerable period. However, tracing 3 shows that the risk of pacing in a vulnerable phase of a premature ventricular contraction nonetheless persists.

Asynchronous modes are now obsolete and are only used in 2 specific circumstances: 1) in magnetic or magnet mode, in which the application of a magnet leads to a A00, V00 or D00 pacing according to the programmed mode; 2) the D00 mode can be programmed temporarily in pacemaker-dependent patients with an MRI-compatible device who are scheduled to undergo an MRI.


A
V
Ap
Vp
1
2
3
I
II
III
A
V
25 mm/s
25 mm/s
25 mm/s

Pacing Modes


A
V
I
II
III
A
V
5
25 mm/s


6
A
V
I
II
III
A
V
25 mm/s
25 mm/s

Tracing 3 ↘ Triggered modes

Patient

Same patient as in tracing 1.

Tracing

Programming in AAT mode 40 beats/minute.

① proper sensing of spontaneous atrial activity triggering atrial pacing;

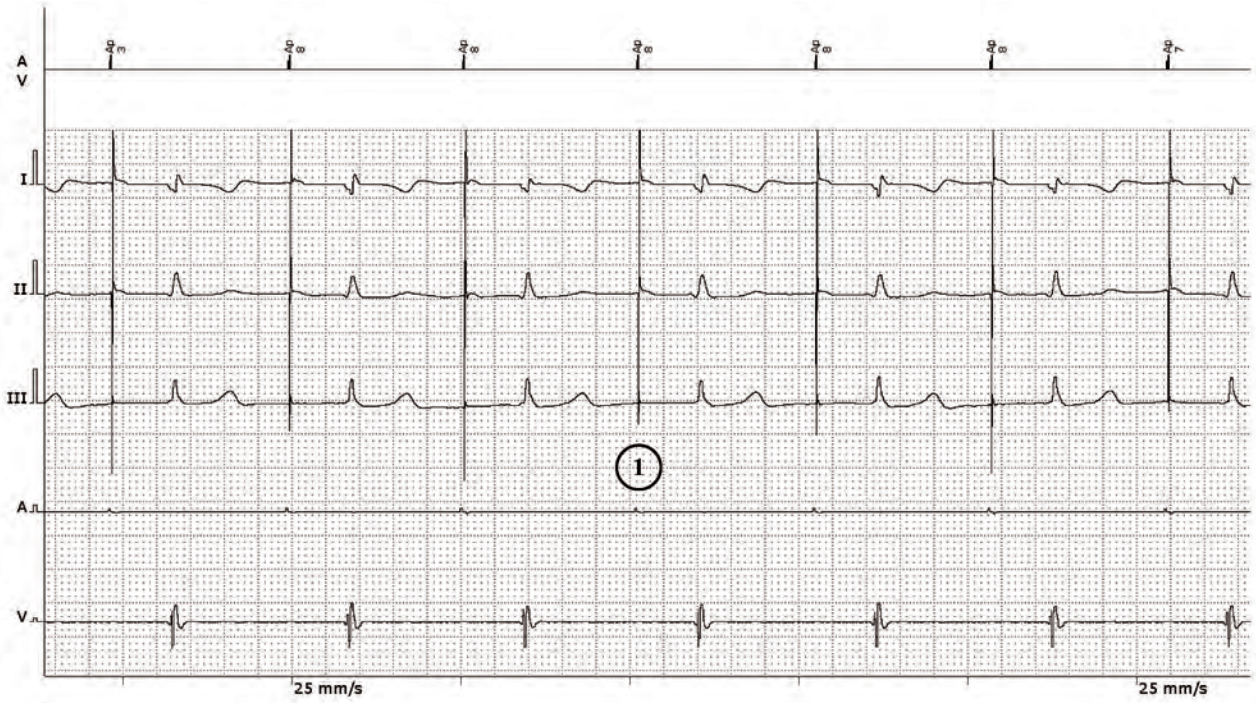
② atrial pacing following sensing of the far-field R wave by the atrial lead.

Comments

When a triggered mode (VVT or AAT) is programmed, the sensing of a non-refractory event triggers an immediate pacing. This functional operation therefore corresponds to the opposite of the VVI-AAI modes where sensing inhibits pacing. This type of pacing mode is nowadays very sparsely programmed. Indeed, pacing during sensing is associated with an unnecessary increase in energy consumption with acceleration of battery wear. The triggered modes can be used in 2 special circumstances:

1) in the case of myopotential detection or electromagnetic interference, a pacemaker programmed in SST mode does not inhibit but induces pacing on each artifact detected outside the refractory period, thus avoiding a pause in pacemaker-dependent patients. This type of mode was of value on older pacemaker models which were more sensitive to external interference given their functioning in unipolar mode only.

2) to evaluate sensing in the chamber under consideration, to verify the absence of far-field oversensing and that the extrasystoles are also correctly sensed. On this tracing, for example, the AAT mode shows that the sensing of sinus activity is appropriate but that there is an oversensing of the far-field R wave.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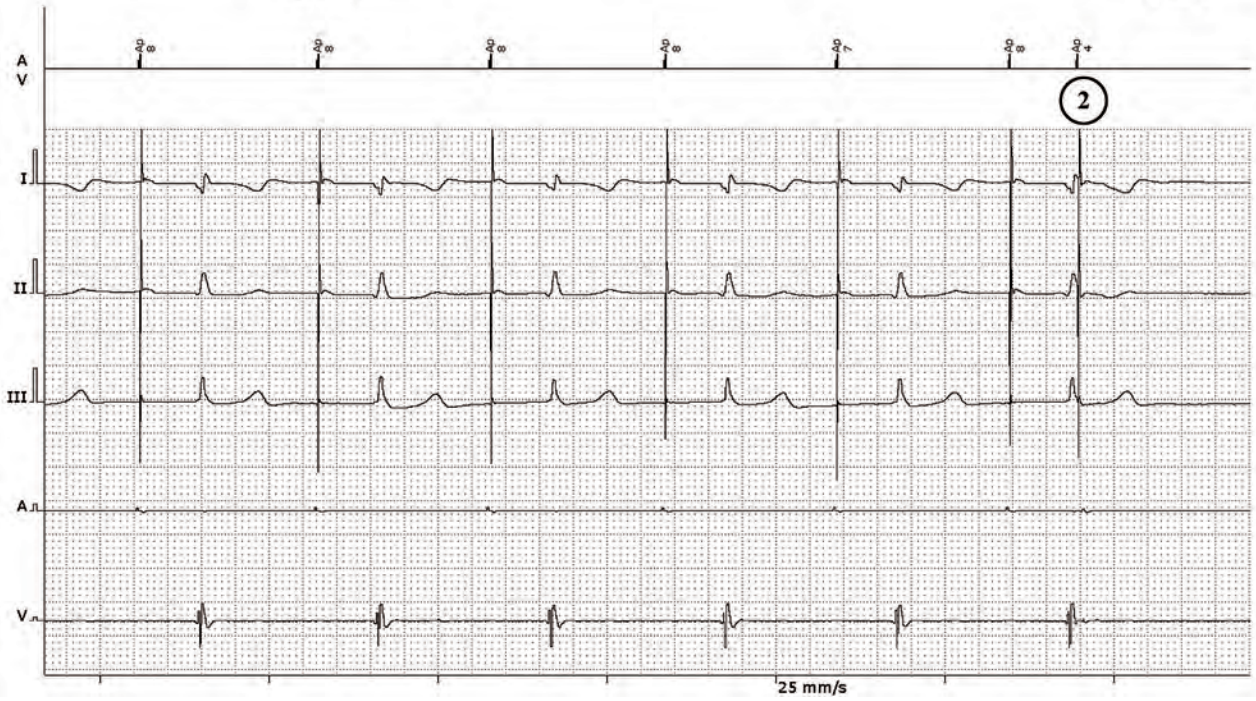
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Tracing 4 ↘ Single-chamber AAI mode

Patient

Same patient as in tracing 1.

Tracing 4a

Programming in AAI mode 50 beats/minute;

① permanent atrial sensing and inhibition of atrial pacing;

Tracing 4b

Programming in AAI mode 60 beats/minute;

② permanent atrial pacing with preserved atrioventricular conduction but relatively long PR interval.

Comments

A single-chamber pacemaker operates in AAI mode when a single lead is positioned in the atrium; the AAI mode can also be programmed in a dual-chamber pacemaker. This tracing allows highlighting the main characteristics of this pacing mode: 1) sensing and pacing of the atrium, inhibition due to a spontaneous atrial event; the preferred indication is therefore a pure sinus node dysfunction without ventricular conduction disorder. An AAI pacemaker allows limiting the number of implanted leads as well as ensuring a physiological rate at rest and during exercise after programming of the rate response while avoiding unnecessary ventricular pacing; 2) absence of ventricular sensing or pacing. AAI single-chamber pacemakers or the programming of the AAI mode in a dual-chamber pacemaker are formally contraindicated in patients with permanent or paroxysmal atrioventricular conduction disorders. They should also be avoided in patients with vagal symptoms or carotid sinus syndrome.

A recent study has reported unfavorable results in the implantation of a single-chamber AAI pacemaker compared to the implantation of a dual-chamber pacemaker in patients with sinus dysfunction. Indeed, the rate of re-intervention is greater in patients implanted with an AAI with the need to add a ventricular lead as a result of the occurrence of an atrioventricular conduction disorder. Hence, the indications for the implantation of a single-chamber AAI pacemaker are nowadays relatively limited.

In this patient, the prolonged post-atrial pacing PR interval is not propitious to the programming of AAI pacing in the long term.


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Pacing Modes

Tracing 5 ↘ Single-chamber VVI mode

Patient

Same patient as in tracing 1.

Tracing

Programming in VVI mode 40 beats/minute;

① spontaneous ventricular sensing and inhibition of ventricular pacing; recycling of the ventricular escape interval on each ventricular sensing; device operating in sentinel mode.

Comments

A single-chamber pacemaker operates in VVI mode when only one lead is positioned in the ventricle; the VVI mode can also be programmed in a dual-chamber pacemaker. Programming of the base rate is essential. Indeed, in patients with sinus dysfunction, if the base rate is too high and above the sinus rate, ventricular pacing becomes permanent with 1) inversion of the physiological atrioventricular activation sequence (retrograde conduction and pacemaker syndrome) if there is no retrograde atrioventricular block; atrial contraction occurs with ventricular contraction in a quasi-synchronous manner, while the atrioventricular valves are closed, causing a retrograde flow towards the pulmonary veins and the vena cava. Pacemaker syndrome results from a complex combination of hemodynamic, neurohumoral and vascular alterations secondary to the loss of atrioventricular synchrony. Symptomatology, which is sometimes very disabling due to increased atrial pressure and venous pressure, includes dyspnea, orthopnea, pulsations in the neck and chest, palpitations, chest pain; 2) loss of atrioventricular synchrony if there is no retrograde conduction.

Conversely, when the minimum pacing rate is below the spontaneous sinus rate (e.g. 40 beats/minute), the patient is not paced when the device is in sentinel mode. This enables: 1) to reduce energy consumption and prolong battery life; 2) to avoid retrograde conduction; 3) to pace effectively only when there is occurrence of a paroxysmal atrioventricular conduction disorder.

Pacing Modes

Tracing 6 ↘ Dual-chamber DDI mode

Patient

Same patient as in tracing 1.

Tracing

Programming in DDI mode 60 beats/minute;

① atrial and ventricular pacing at the base rate (AP-VP);

② acceleration of spontaneous atrial rhythm (probable relatively slow atrial tachycardia) which is sensed (AS) and does not lead to an AV delay; non-synchronized ventricular pacing on atrial activity (pseudo-VVI) at the end of the ventricular pacing interval; inhibition of atrial pacing in the current cardiac cycle;

③ spontaneous atrial rhythm (inhibition of atrial pacing) and ventricular pacing;

④ recovery of sinus rhythm with maintenance of atrioventricular dyssynchrony; ventricular pacing at the base rate;

⑤ atrial and ventricular pacing.

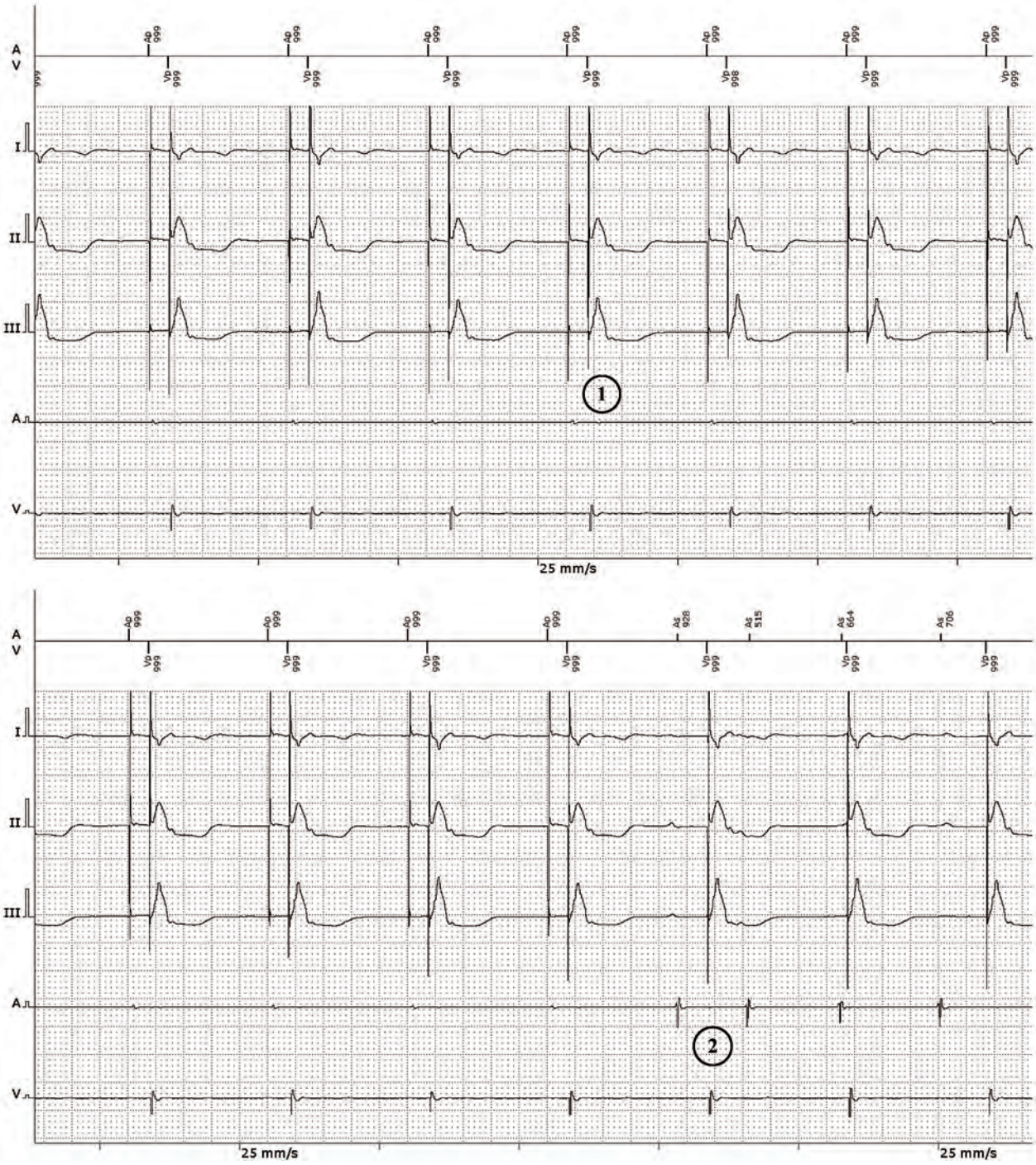
Comments

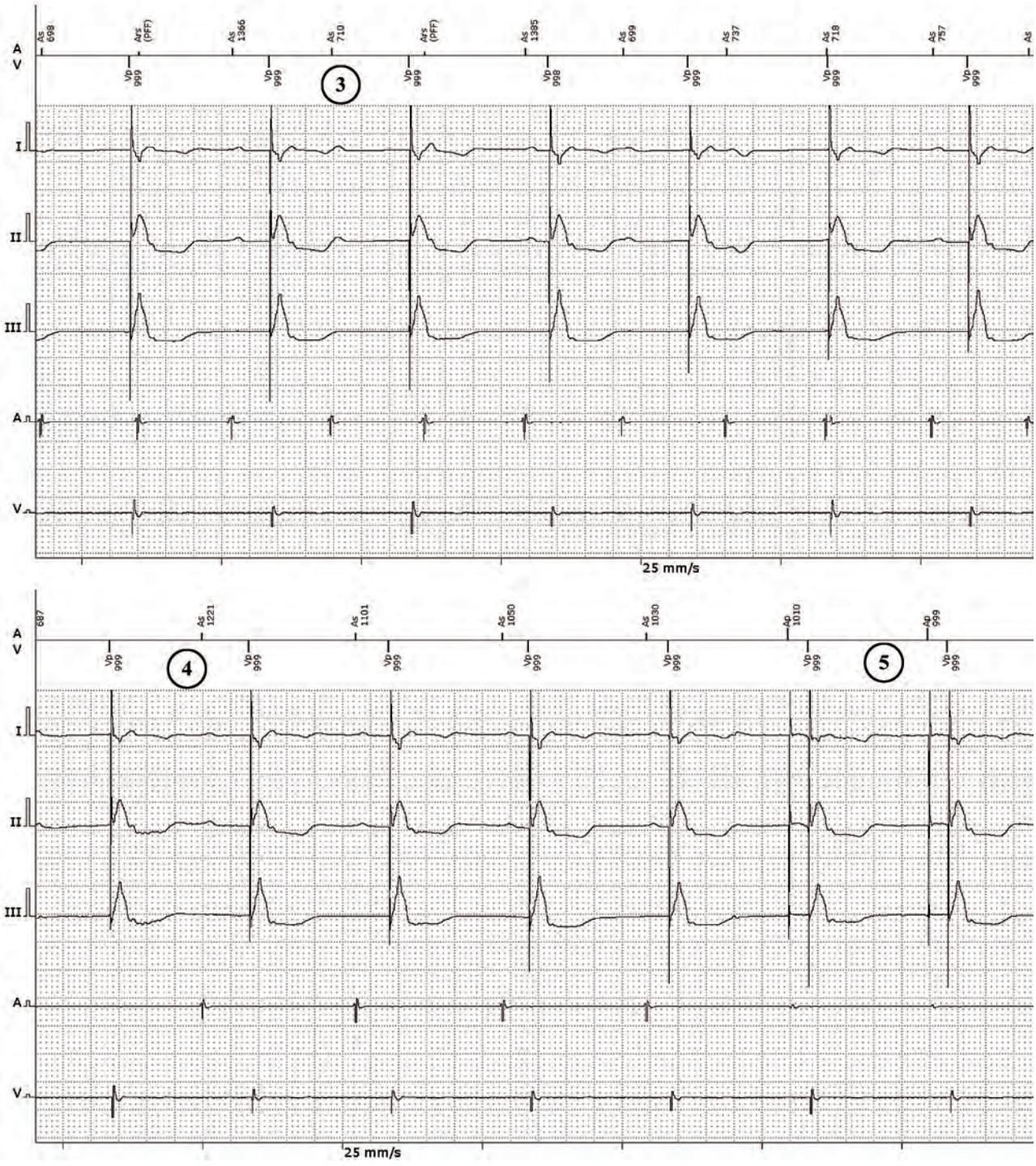
The DDI mode provides dual-chamber sequential AV pacing with dual atrial and ventricular sensing but with no ventricular triggering of the sensed atria. AV synchrony is only provided at the current atrial pacing rate (base rate, rate response or smoothed rate). If the atrial rate is faster than the atrial pacing rate, the latter is inhibited and no AV delay is initiated; when the atria are activated spontaneously, there is no ventricular synchrony.

Thus, in the case of a complete atrioventricular block, spontaneous atrial events do not synchronize with ventricular pacing if their rate is faster than the current atrial pacing rate: functioning is therefore the same as in the VVI mode. This explains the absence of runaway ventricular pacing upon sensing an atrial arrhythmia, hence the use of DDI as a fallback mode. It is also the selected function when the pacemaker does not correctly sense atrial arrhythmias and therefore does not fallback properly, with erratic ventricular pacing. This choice is therefore not appropriate in a patient with atrioventricular block and normal sinus function (lack of P-synchronous pacing), although is conversely completely acceptable if the patient, even with a permanent atrioventricular block, also suffers from sinus dysfunction triggering permanent atrial pacing (since atrial pacing synchronizes ventricular pacing). The setting of the minimum programmed rate is therefore essential. The latter should be high, to prevent the occurrence of spontaneous atrial activation, and programmed in association with the rate response.

The ideal indication of this mode is a patient with atrioventricular block and atrial disease presenting with rapid AF episodes (no risk of runaway) and permanent sinus dysfunction after termination (AP-VP pacing).

Pacing Modes

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Tracing 7 ↘ Vp suppression algorithm

Patient

Same patient as in tracing 1.

Tracing

Programming in DDD mode 60 beats/minute followed by programming of the Vp suppression algorithm;

① atrial pacing and ventricular pacing (AP-VP); DDD mode 60 bpm;

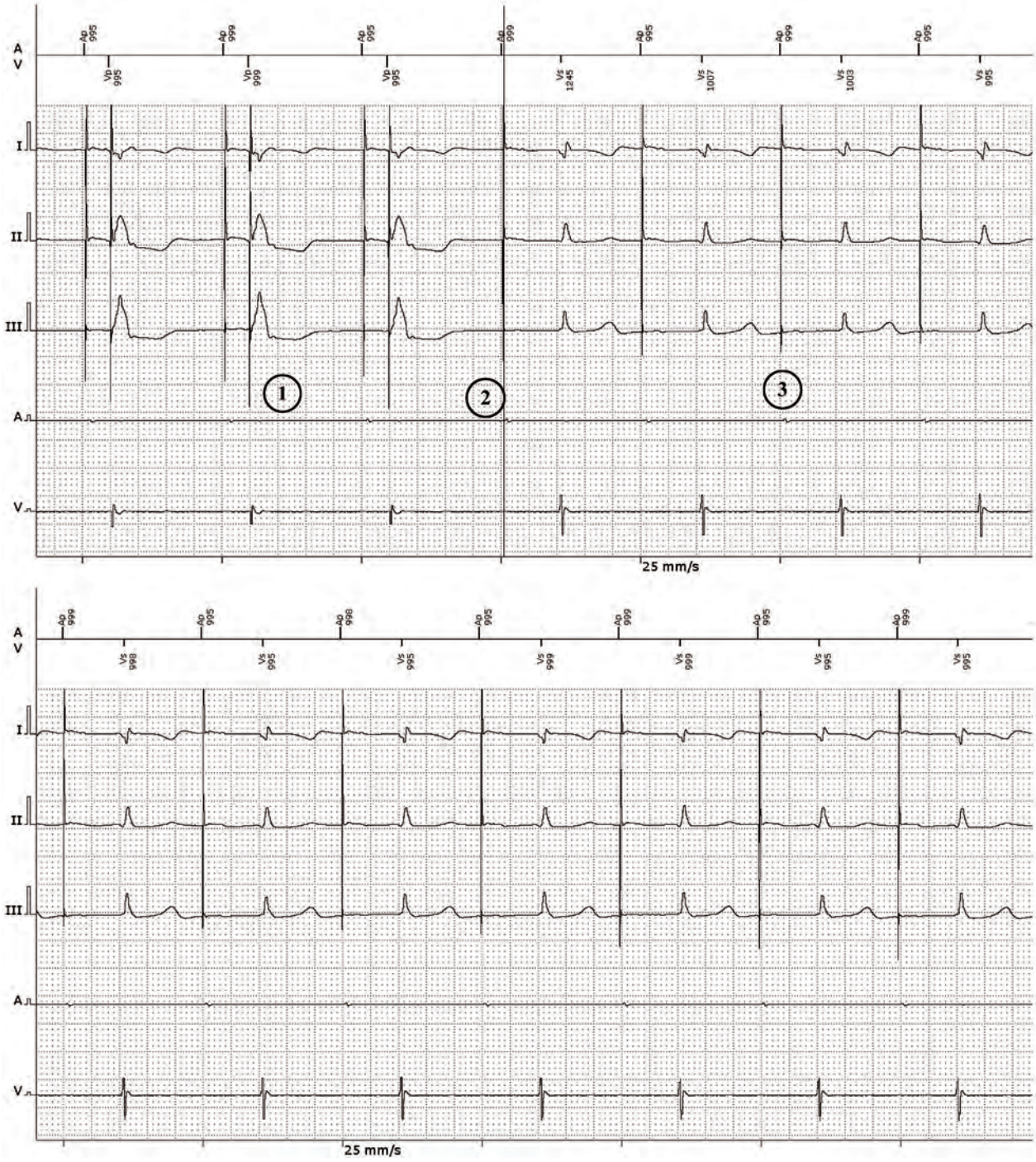
② programming of the Vp suppression algorithm (ADI-DDD mode);

③ atrial pacing and spontaneous ventricular event (long PR pattern).

Comments

There is vast body of literature demonstrating the deleterious effect of prolonged right ventricular pacing. Concomitantly, any reduction in unnecessary ventricular pacing allows battery saving and prolongs the life of the pacemaker. Various modes have been proposed by device manufacturers to reduce the percentage of ventricular pacing without compromising the safety of the patient during the occurrence of an atrioventricular conduction disorder. The preferred indication of this type of mode is therefore the presence of sinus dysfunction with an atrioventricular conduction that is either preserved or altered in a paroxysmal manner. On this tracing, the programming of the ADI-DDD mode can significantly reduce the percentage of pacing pulses compared to permanent DDD mode pacing. In the long term, this should prove beneficial in terms of ventricular remodeling and occurrence of atrial arrhythmia. Analysis of the percentage of ventricular pacing is therefore an important follow-up component in a patient with sinus dysfunction, with the aim of reducing to a minimum the occurrence of any unnecessary ventricular pacing.

When the Vp suppression algorithm is programmed, the pacemaker operates in ADI(R) mode and switches to the DDD(R) pacing mode if atrioventricular conduction is impaired. It should be noted that on this tracing, the PR interval is relatively prolonged (around 400 ms on paced P wave). There is a switching criterion for first-degree AV blocks. The PR interval due to spontaneous or paced atrial activity must exceed 450 ms over 2 consecutive cycles (non-programmable value), which is not the case in this instance.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Tracing 8 ↘ Limitations of the dual-chamber VDD mode

Patient

Young patient, 21 years old, implanted with a VDD pacemaker at the age of 11 for a congenital atrioventricular block; replacement of the pulse generator 3 years ago with implantation of an Evia DR-T pacemaker; programming in VDD mode 60 bpm; transmission of a periodic EGM by remote monitoring.

Tracing

Normal: programming in VDD mode 60 bpm;

① ventricular pacing at 60 bpm and sensing of sinus rhythm in the post-ventricular atrial "blanking" period (far-field protection, PFF);

② sinus activity sensed in the PVARP;

Encouraged sensing: automatic slowing of the base rate;

③ sensing of sinus activity and ventricular synchrony (AS-VP);

Encouraged pacing: VDD mode at 60 bpm;

④ new loss of atrioventricular synchrony, the sinus rhythm being slower than the minimum rate.

Comments

The VDD mode can be programmed on a traditional dual-chamber pacemaker but can also be obtained from a single-lead VDD dual-chamber device with two pairs of electrodes, one floating atrial pair providing atrial sensing, and one ventricular pair for ventricular pacing and sensing. On the other hand, atrial pacing is not possible. This mode is therefore acceptable in the absence of sinus dysfunction, and a low base rate should be programmed, possibly with rate hysteresis, in order to avoid VVI behavior. Indeed, on this tracing, the programming at 60 beats/minute is associated with a loss of atrioventricular synchrony.

The advantages of single-lead VDD systems are that 1) only one lead is required, allowing for a sometimes shorter implantation procedure while reducing the amount of required endovascular material; 2) the absence of trauma to the atrial wall thereby preventing the development of atrial fibrosis; 3) in patients without sinus dysfunction, the physiological atrioventricular activation sequence is preserved.

The disadvantages of single-lead VDD systems are that 1) atrial sensing is sometimes not as effective as that obtained with a separate atrial lead, since the atrial dipole can move away from the wall, especially during deep inspiration and cardiac movements; 2) similarly, the sensing of atrial arrhythmias is sometimes not as effective, for the same reasons, rendering the memory banks less reliable; 3) in the event of loss of paroxysmal atrial sensing on exertion and presence of atrioventricular block, the pacing rate returns to the base rate with a possible sudden drop in rate, along with possible pacemaker syndrome and risk of PMT; 4) this mode should be avoided in the presence of sinus dysfunction.

The preferred indication of the VDD mode is therefore complete atrioventricular block with normal sinus function.

In this patient, the recording of this periodic EGM led to a reduction of the minimum rate in order to promote atrial sensing.

Status report - Mar 15, 2016

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Last message: Mar 15, 2016
Last clinic follow-up: Feb 16, 2016

Recordings

Recordings - Episode 30:

General	
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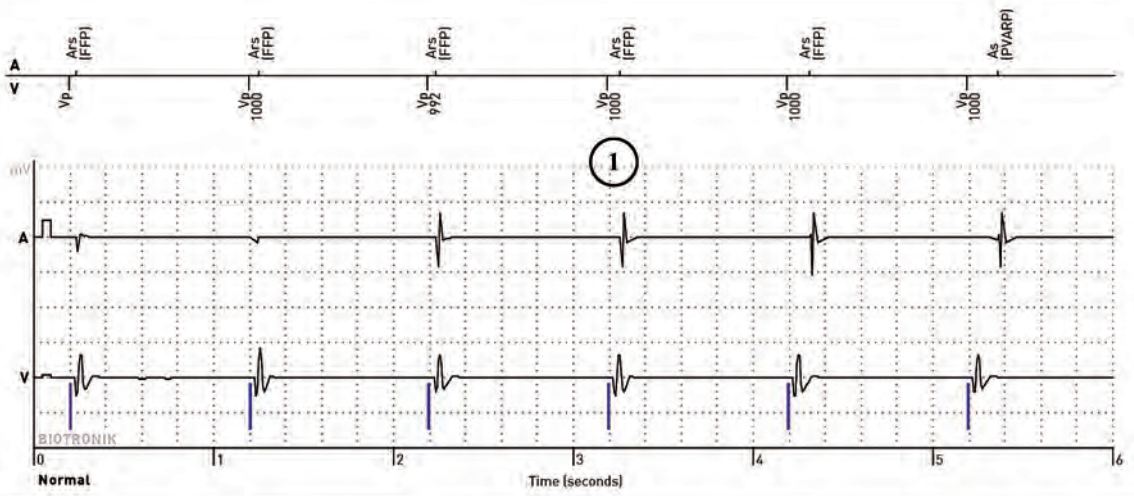
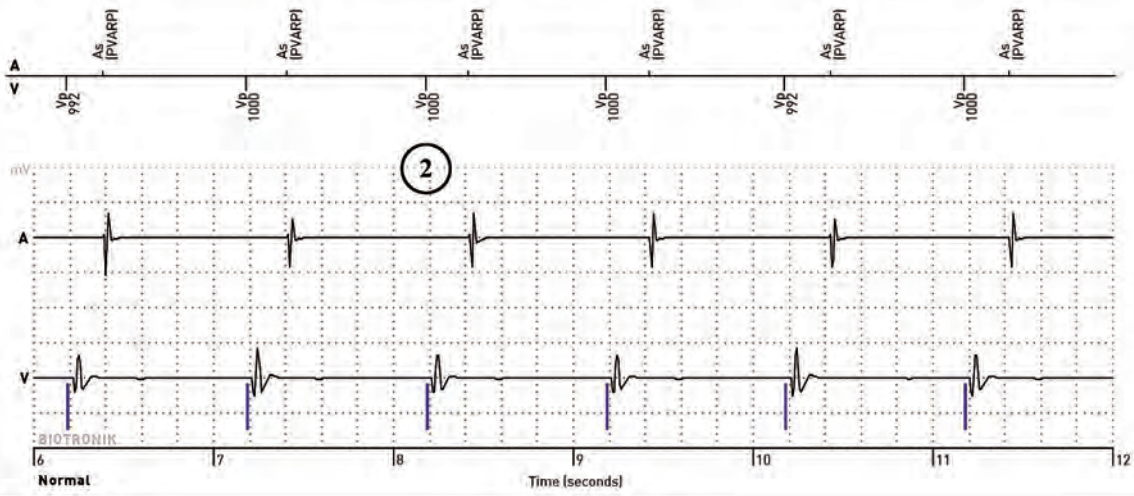
Episode type	Periodic IEGM
Recorded on	Mar 2, 2015 1:21:00 AM

IEGM





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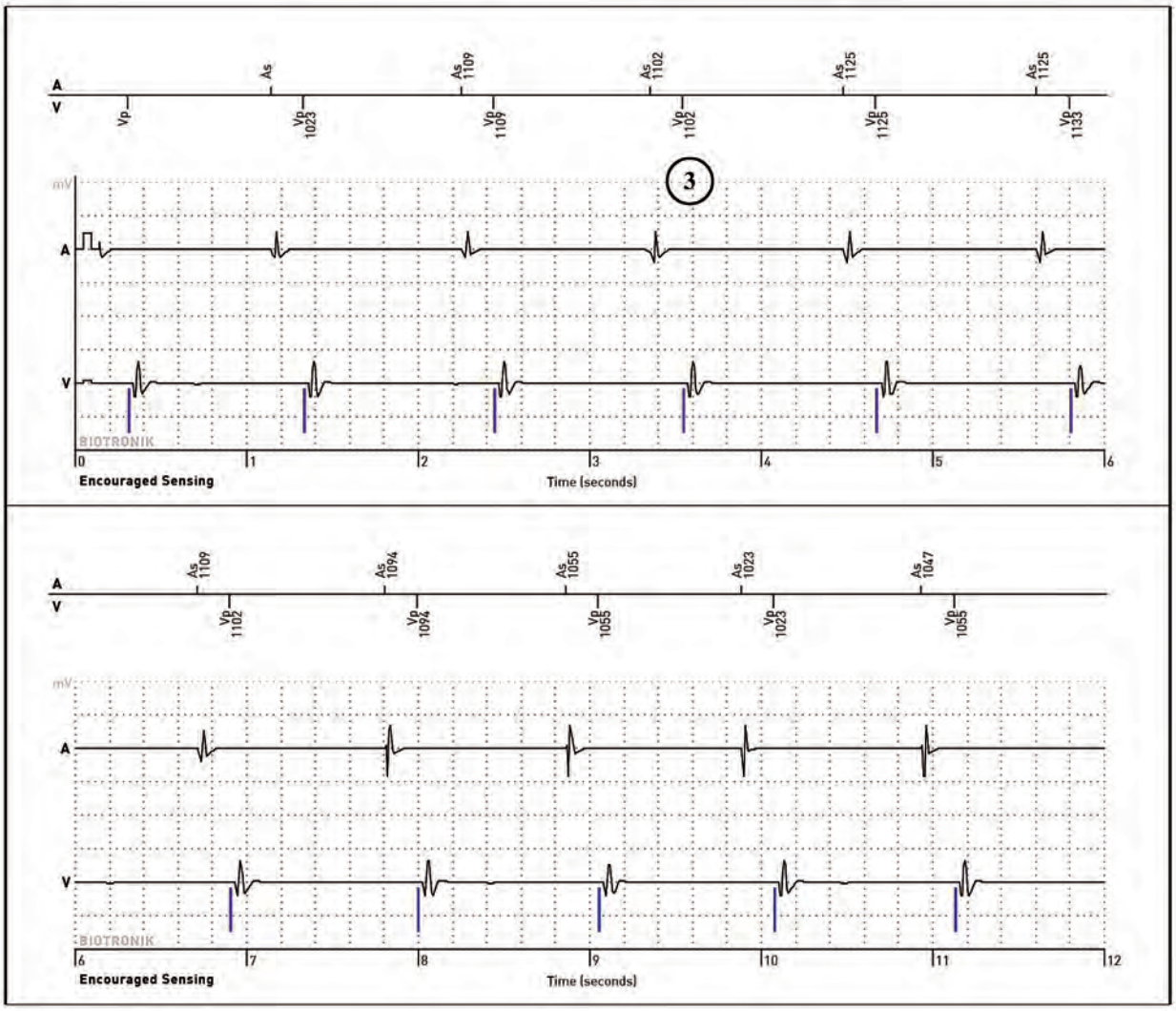
Last message: Mar 15, 2016
Last clinic follow-up: Feb 16, 2016



Status report - Mar 15, 2016

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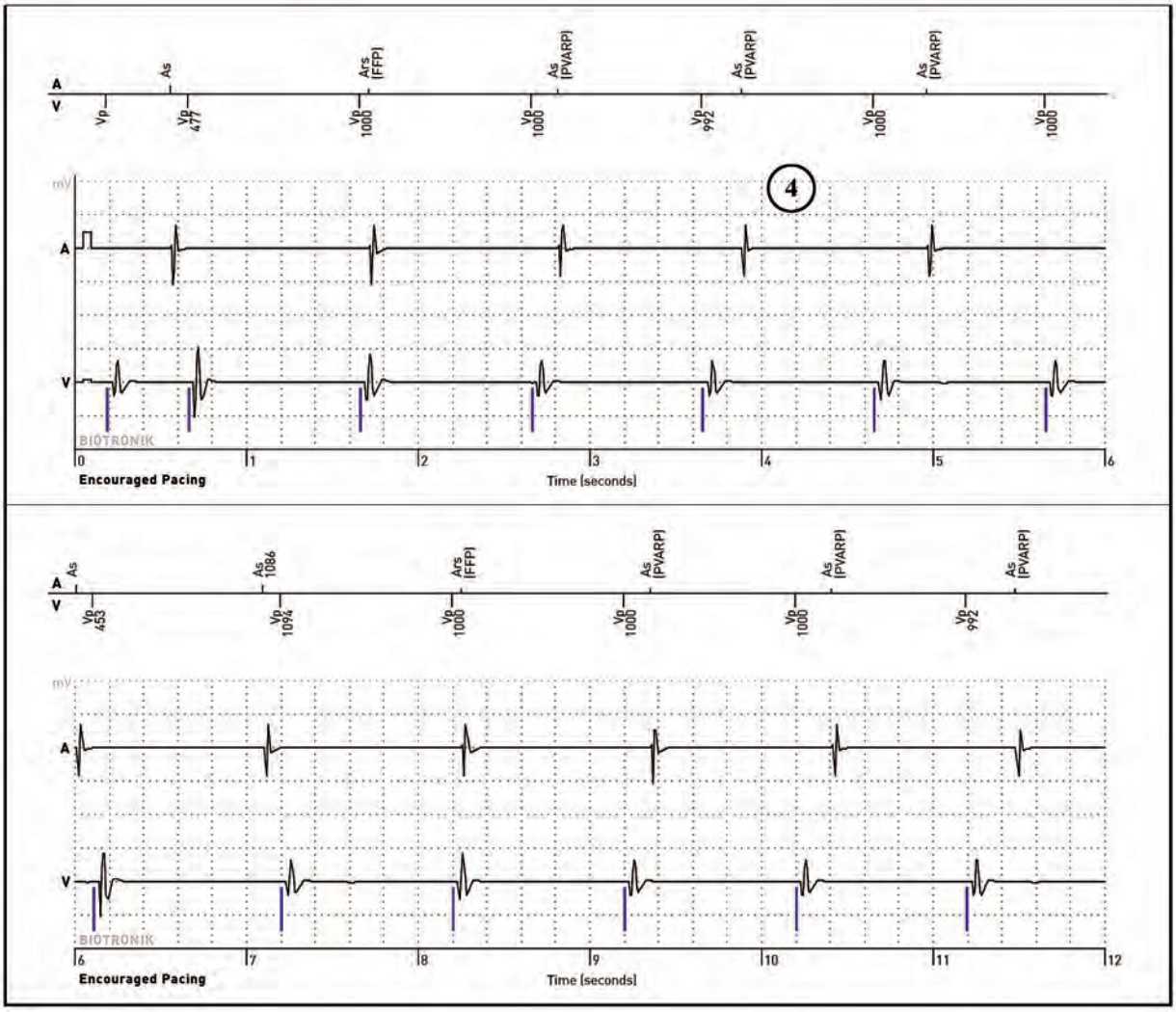


Tracing 9 ↘ Operation of the Vp suppression algorithm

Patient

64-year-old man implanted with an Evia DR-T pacemaker for symptomatic sinus dysfunction (programmed Vp suppression algorithm); interrogation of the pacemaker and conducting of an exercise test (repeated leg flexions).

Tracing 9a

① ADIR pacing mode; atrial rate response pacing with atrioventricular conduction and spontaneous QRS (AP-VS);

② blocked premature atrial contraction (classified as AS since falling outside the refractory periods);

③ absence of switching on a single blocked atrial activity, no ventricular pacing; continuation of the ADIR mode.

Patient

72-year-old man implanted with an Evia DR-T pacemaker for paroxysmal atrioventricular block (programmed Vp suppression algorithm); interrogation of the pacemaker.

Tracing 9a

① spontaneous atrial and ventricular rhythm;

② blocked P wave;

③ second blocked P wave;

④ third blocked P wave;

⑤ switching to DDD mode.

Comments

The AAI-DDD (Vp suppression) mode has been designed to allow pacing in ADI mode with permanent monitoring of atrioventricular conduction and switching to DDD mode when the pacemaker detects an alteration in conduction. There are 4 switching criteria corresponding to the different degrees of atrioventricular block (first-degree AV block, second-degree AV block, third-degree AV block and ventricular pause).

1) first-degree AV block criterion: the pacemaker switches to DDD mode when 2 consecutive atrial events (spontaneous or paced) are conducted with an AS-VS or AP-VS delay exceeding 450 ms (identical value whether the atrium is sensed or paced). This value cannot be changed. In this first tracing, the AP-VS delay is initially relatively prolonged (to the order of 350 ms) but remains below the threshold value, the pacemaker therefore continues to operate in ADIR mode. It is not possible to program this parameter solely in response to exertion. On the other hand, it should be noted that the threshold value required for switching decreases during exertion and during an increase in heart rate.

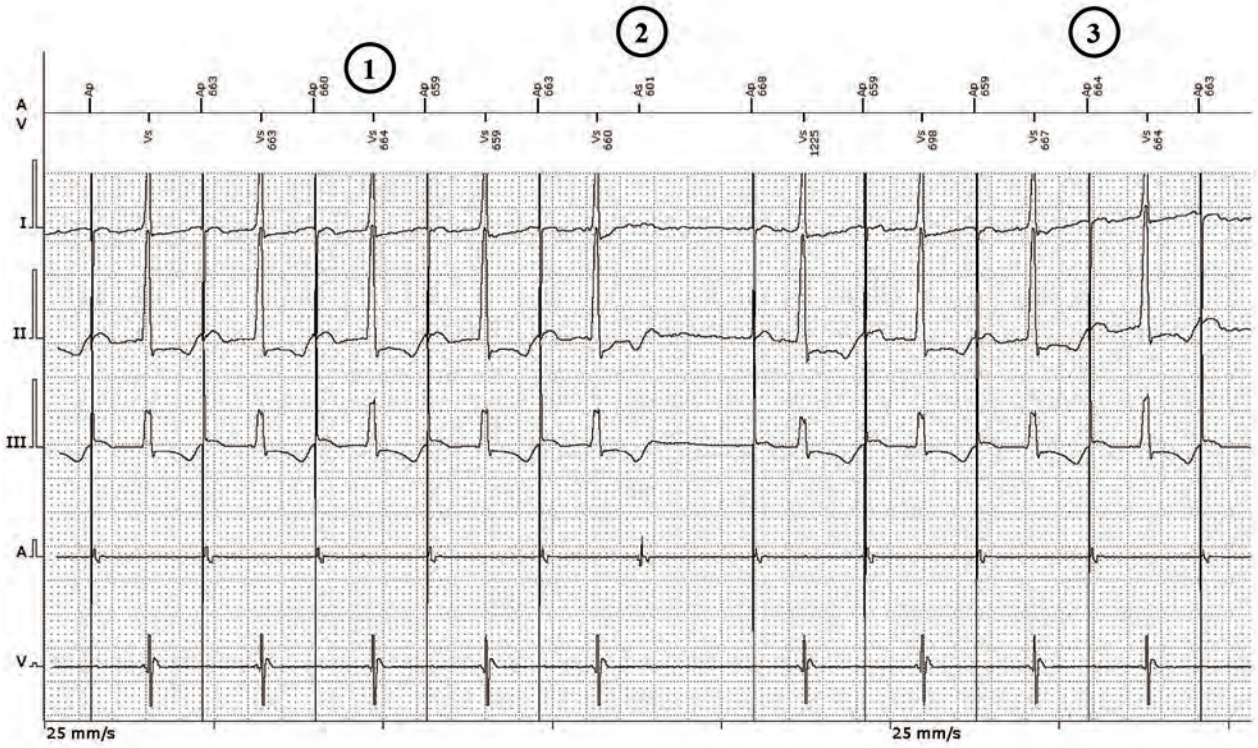
2) second-degree AV block criterion: the pacemaker switches to DDD mode when 3 (nominal) out of 8 atrial (spontaneous or paced) events are blocked (not followed by a spontaneous QRS). This latter value is modifiable: the more the value is decreased, the more frequent the switches; if this value is programmed to 5, this implies that there are at least 2 consecutive blocked atrial activities and the third-degree AV block is also fulfilled. A single blocked atrial activity as that observed in the first tracing therefore does not induce switching when the programming is set to nominal.

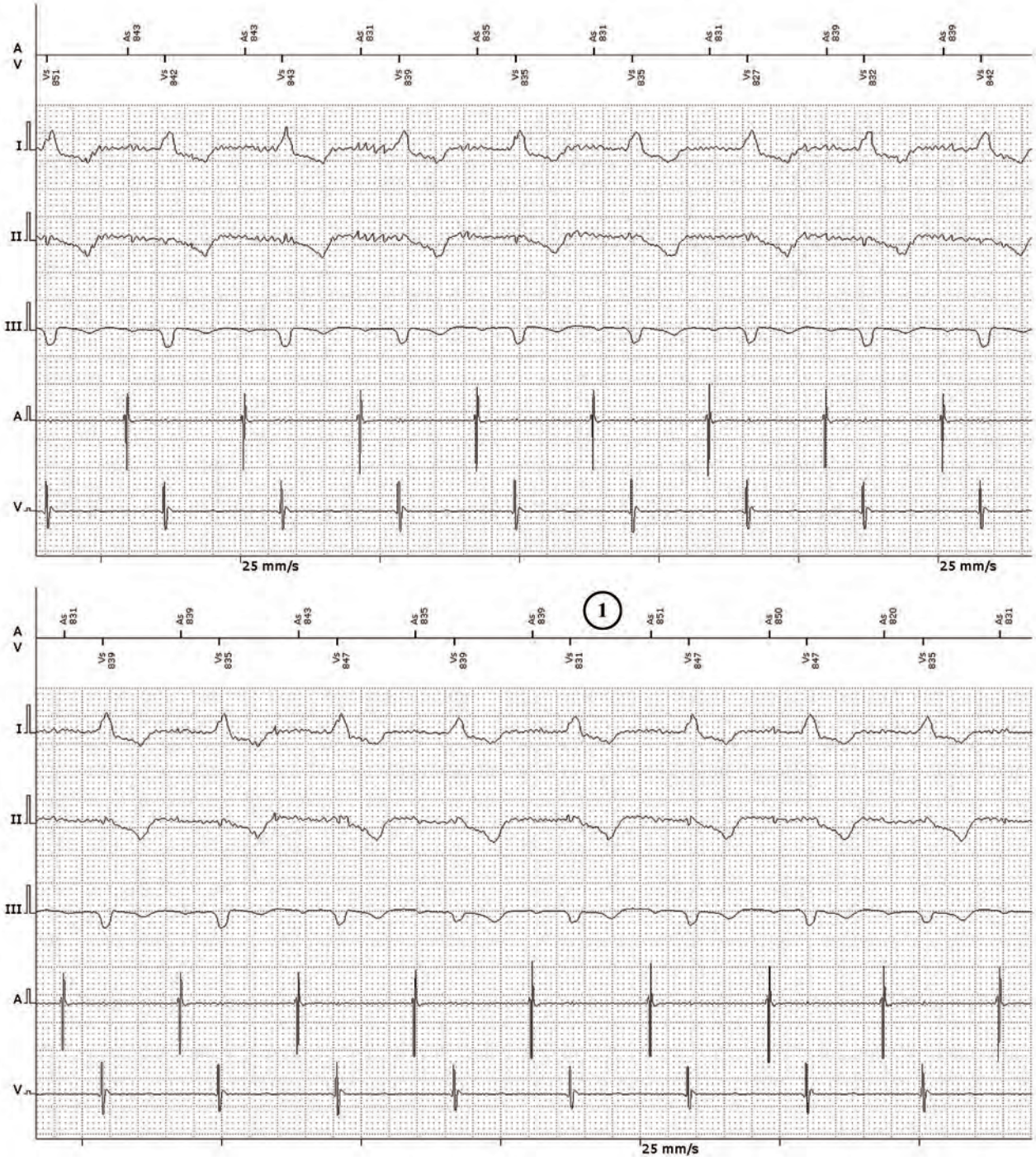
3) third-degree AV block criterion: the pacemaker switches to DDD mode when 2 consecutive spontaneous or paced atrial activities are blocked (not followed by a spontaneous QRS). This parameter cannot be changed.

4) pause criterion: the pacemaker switches to DDD mode when the interval between 2 sensed ventricular activations exceeds 2 seconds. This parameter is also non-modifiable (the duration of the pause cannot be prolonged).

No EGM is automatically recorded as a result of switching from ADI mode to DDD mode, thereby limiting the possibilities of assessing the quality of the algorithm.

Pacing Modes

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Pacing Modes

Tracing 10 ↘ Operation of the Vp suppression algorithm

Patient

72-year-old man implanted with an Evia DR-T pacemaker for complete atrioventricular block; interrogation of the pacemaker; Vp suppression algorithm On.

Tracing 10a

① atrial sensing and ventricular pacing with programmed AV delay;
② prolongation of the AV delay (450 ms) for 8 consecutive cycles with no observed spontaneous conduction;
③ return to ventricular pacing with programmed AV delay.

Patient

72-year-old man implanted with an Evia DR-T pacemaker for complete paroxysmal atrioventricular block; interrogation of the pacemaker.

Tracing 10b

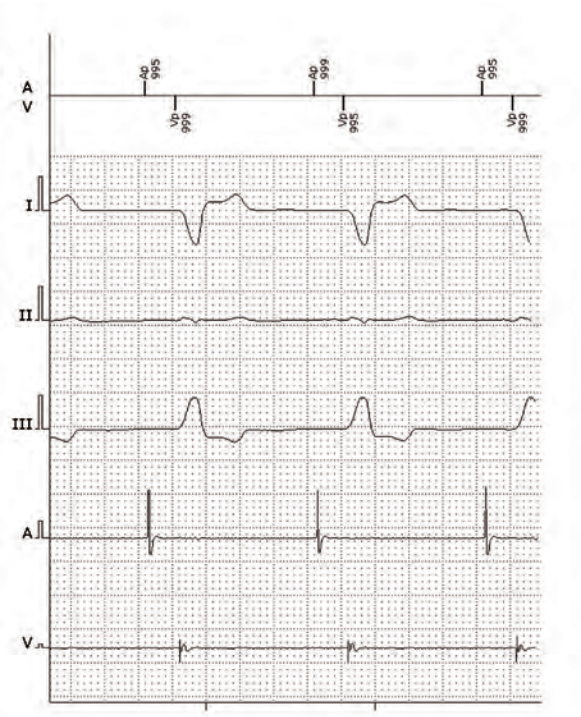
① spontaneous atrial and ventricular rhythm;
② 3 out of 5 P waves blocked;
③ switch to DDD mode;
④ after 30 seconds, search for a spontaneous conduction with a prolongation of the AV delay to a value of 450 ms; spontaneous conduction;
⑤ 6 consecutive intervals with spontaneous conduction; switch to ADI mode;
⑥ 3 out of 5 P waves blocked;
⑦ switch to DDD mode;
⑧ pacing in DDD mode for 30 seconds;
⑨ prolongation of the AV delay to a value of 450 ms for 8 cycles; for the first 3 cycles, appearance of spontaneous conduction;
⑩ on the following cycles, ventricular pacing since absence of spontaneous conduction after 450 ms;
⑪ continuation in DDD mode with programmed AV delay since absence of 6 consecutive cycles with spontaneous conduction.

Comments

The various algorithms for avoiding right ventricular pacing differ in terms of criteria for switching from ADI mode to DDD mode but also in terms of criteria for re-switching to ADI mode. For Biotronik™ pacemakers, when the device is operating in DDD mode, it searches for the presence of an underlying self-paced rhythm every 30 seconds and subsequently spaces the latter (1, 2, 4, 8, 16 ... 128 minutes, up to 20 hours) if the search is inconclusive (persistence of impaired atrioventricular conduction). To achieve the latter, the pacemaker prolongs its AV delay to 450 ms for 8 cycles (identical duration for spontaneous or paced atrial activity). The pacemaker switches to ADI mode if 1 spontaneous ventricular event is sensed during this prolonged AV delay over 6 consecutive cycles (changeable nominal value). During this search, there can thus be no blocked P wave (if absence of spontaneous conduction, ventricular pacing after 450 ms). The episodic prolongation of the AV delay may, however, lead to the occurrence of PMT and can be problematic if it occurs during exercise

with a risk of reaching the 2:1 point over a few cycles (depending on the sum of the AV delay + PVARP).

To avoid iterative alternations between DDD and ADI mode, the Vp suppression function is halted for 20 hours if more than 15 switches/hour are observed.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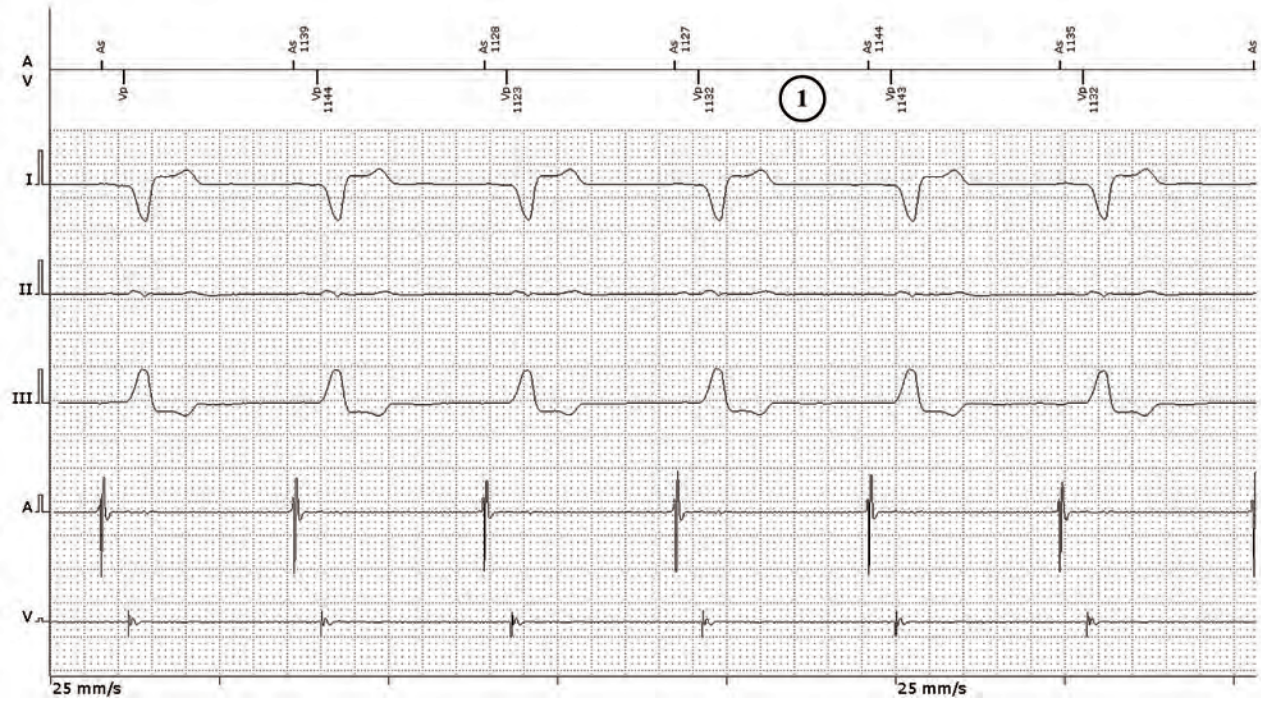
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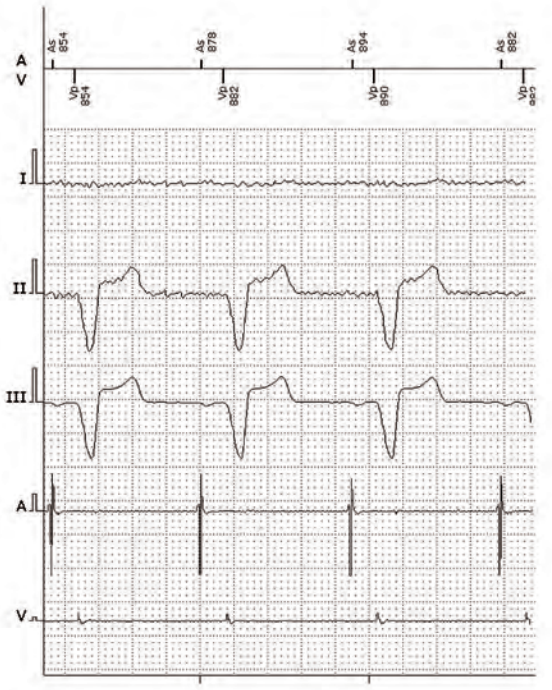
Pacing Modes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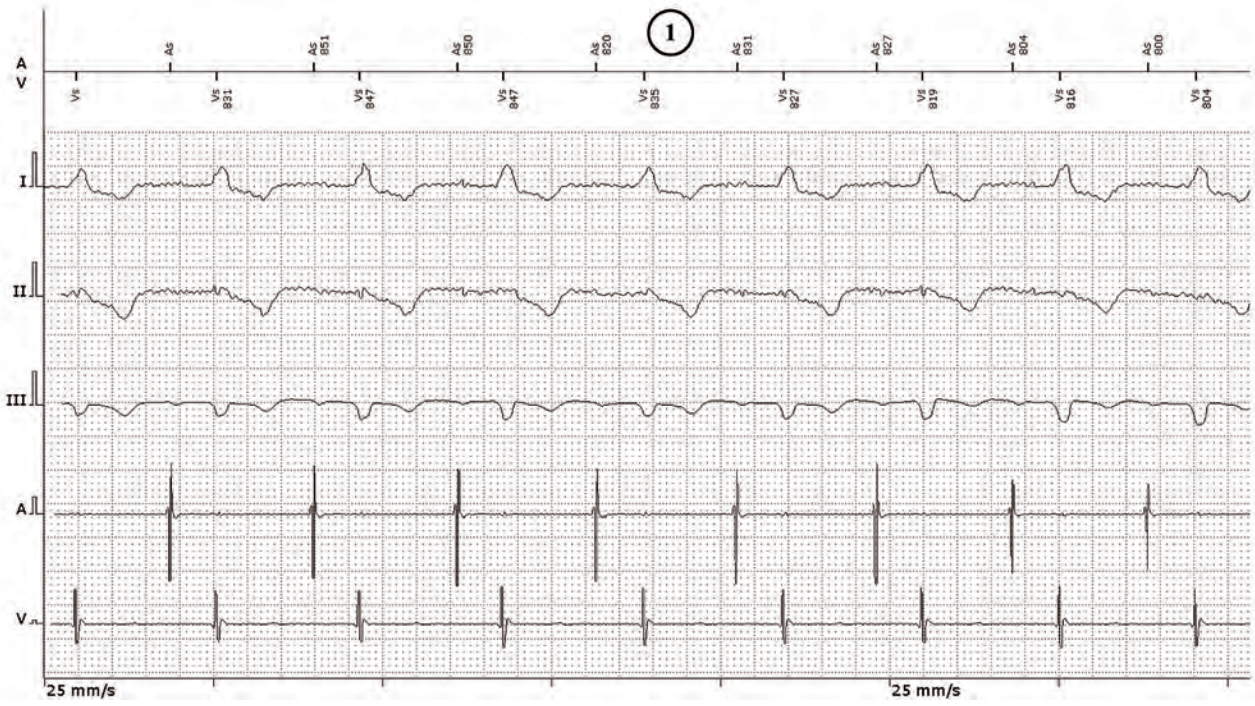
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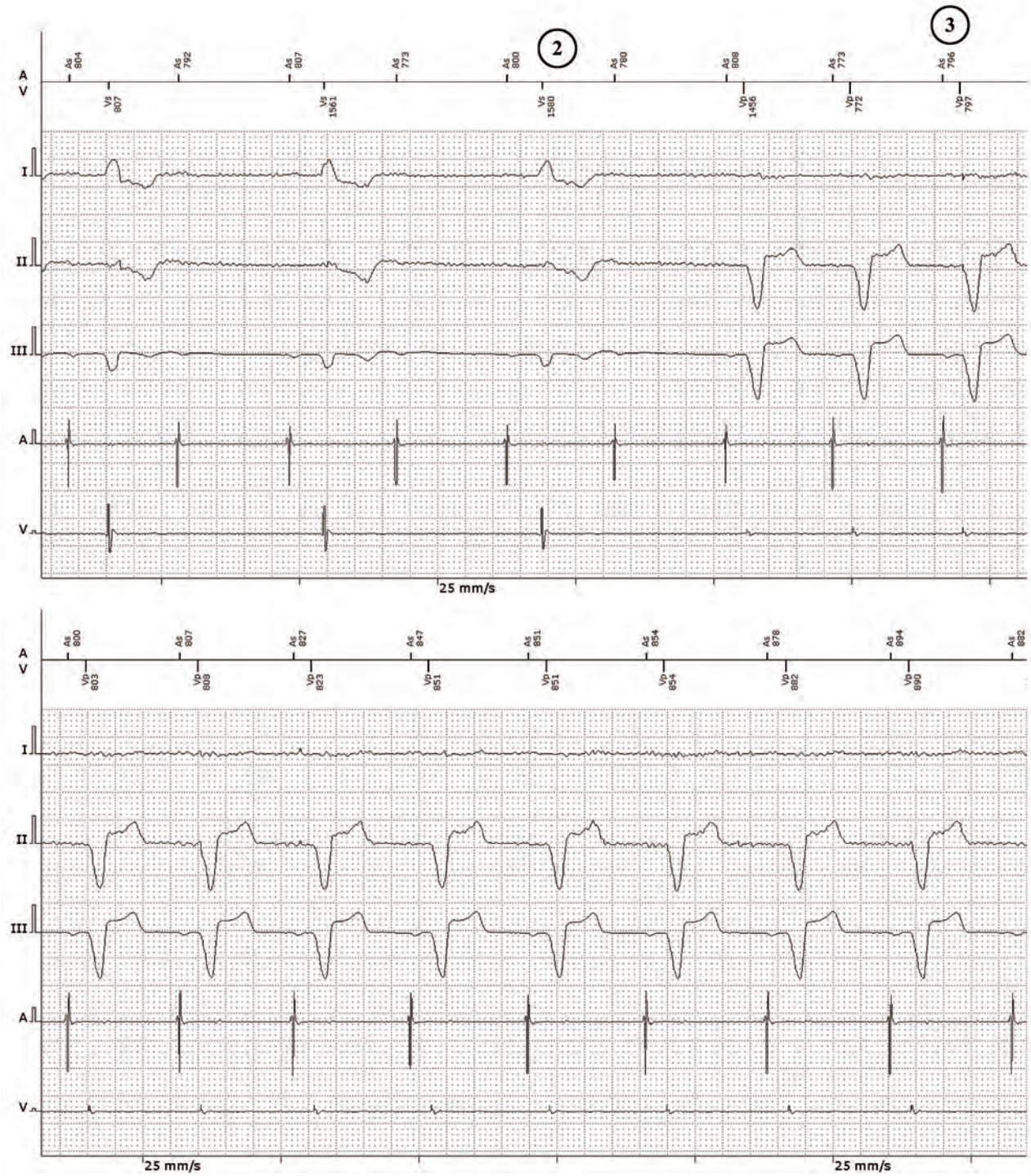

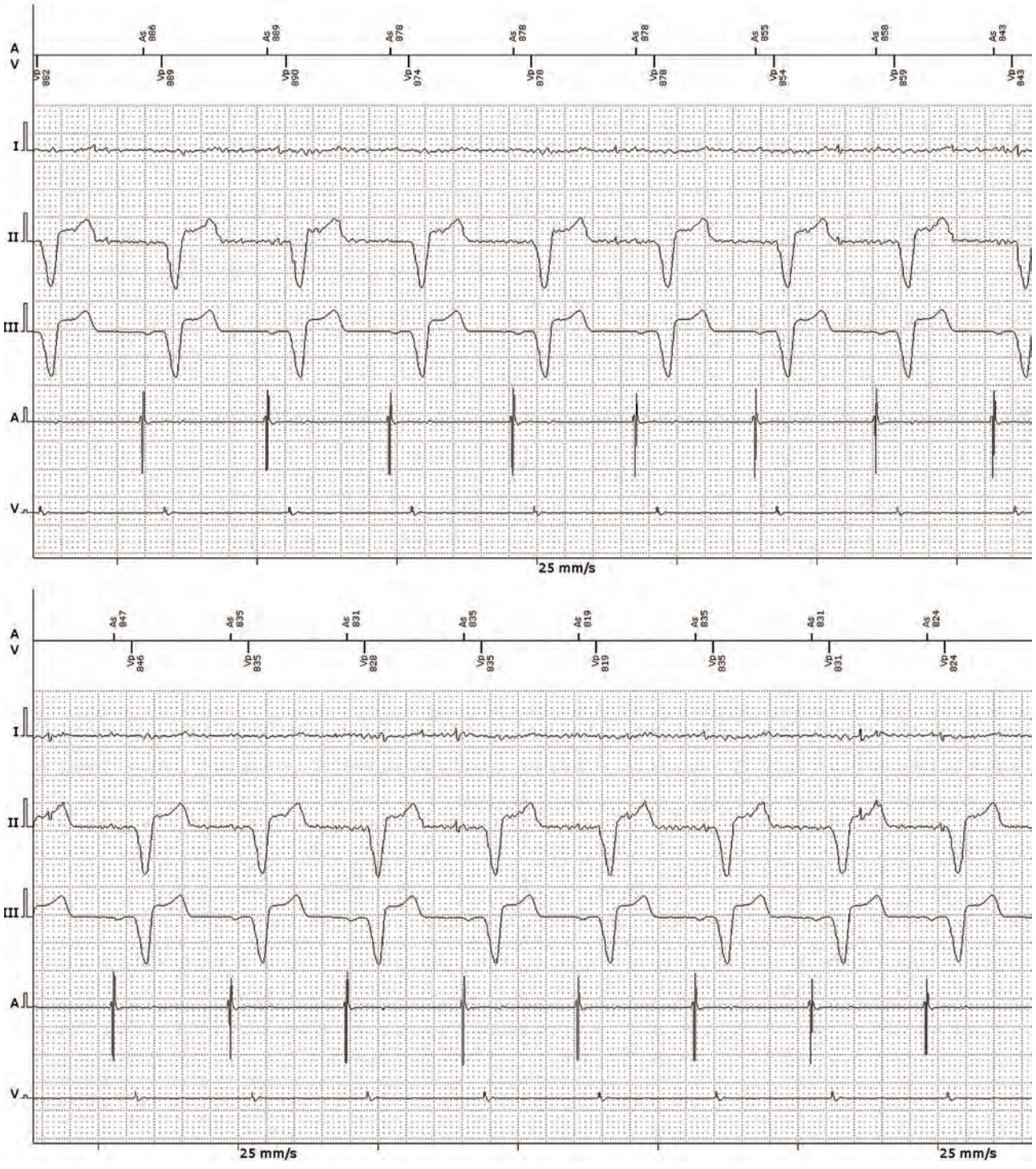
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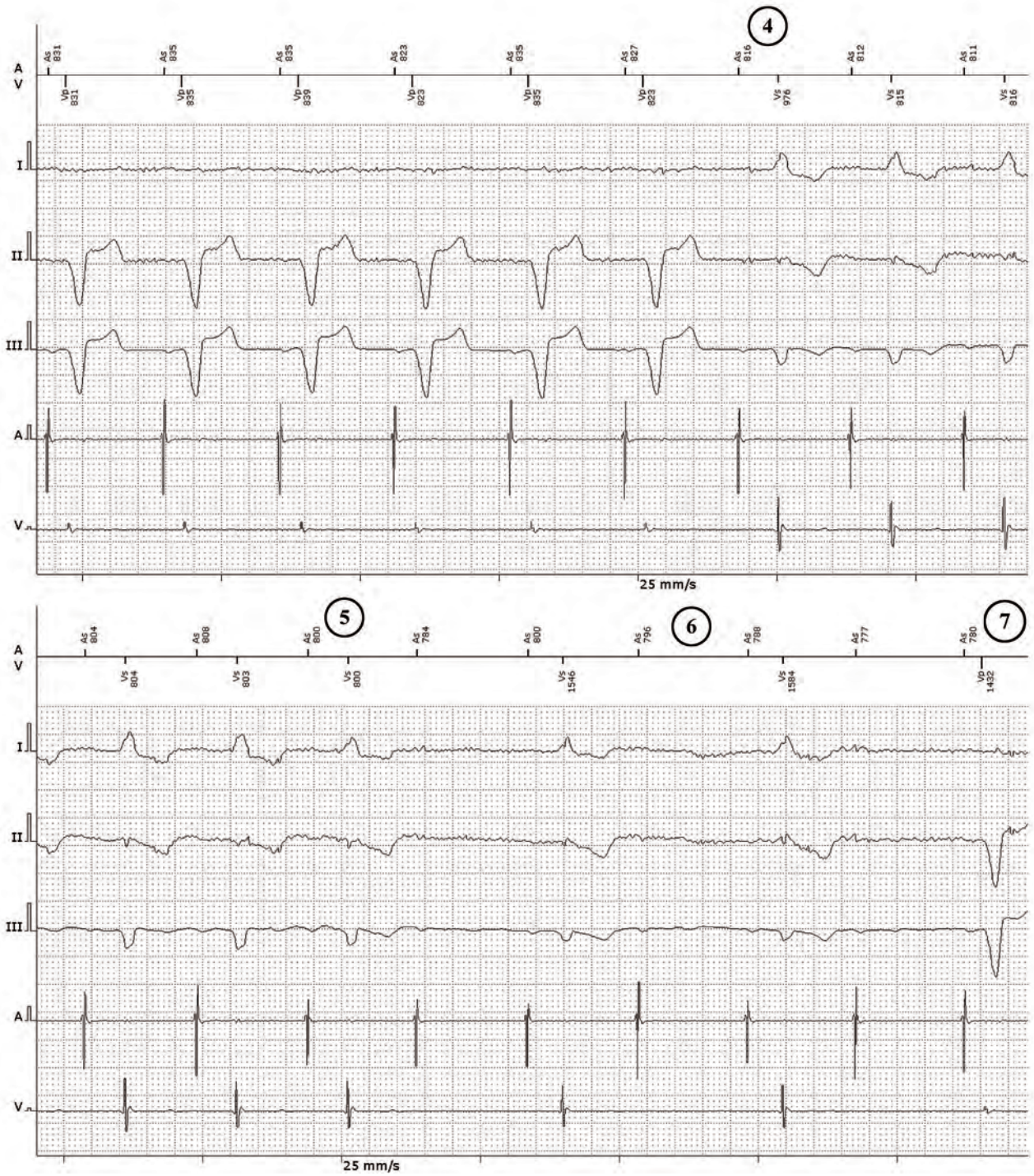


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Implantable Cardiac Pacemaker - chapter 2

Refractory Periods

Tracing 11 ↘ Ventricular crosstalk sensed in the atrial channel

Patient

78-year-old woman implanted with an Evia DR-T pacemaker for syncope and paroxysmal AV block; follow-up control of the pacemaker.

Tracing 11a

① atrial sensing and ventricular pacing; crosstalk with a signal corresponding to ventricular depolarization sensed during the PVARP by the atrial channel;

Tracing 11b

② change in programming with prolongation of the far-field protection (FFP) period; identical signal now oversensed during the FFP;

Tracing 11c

③ decrease in atrial sensitivity enabling to suppress oversensing;

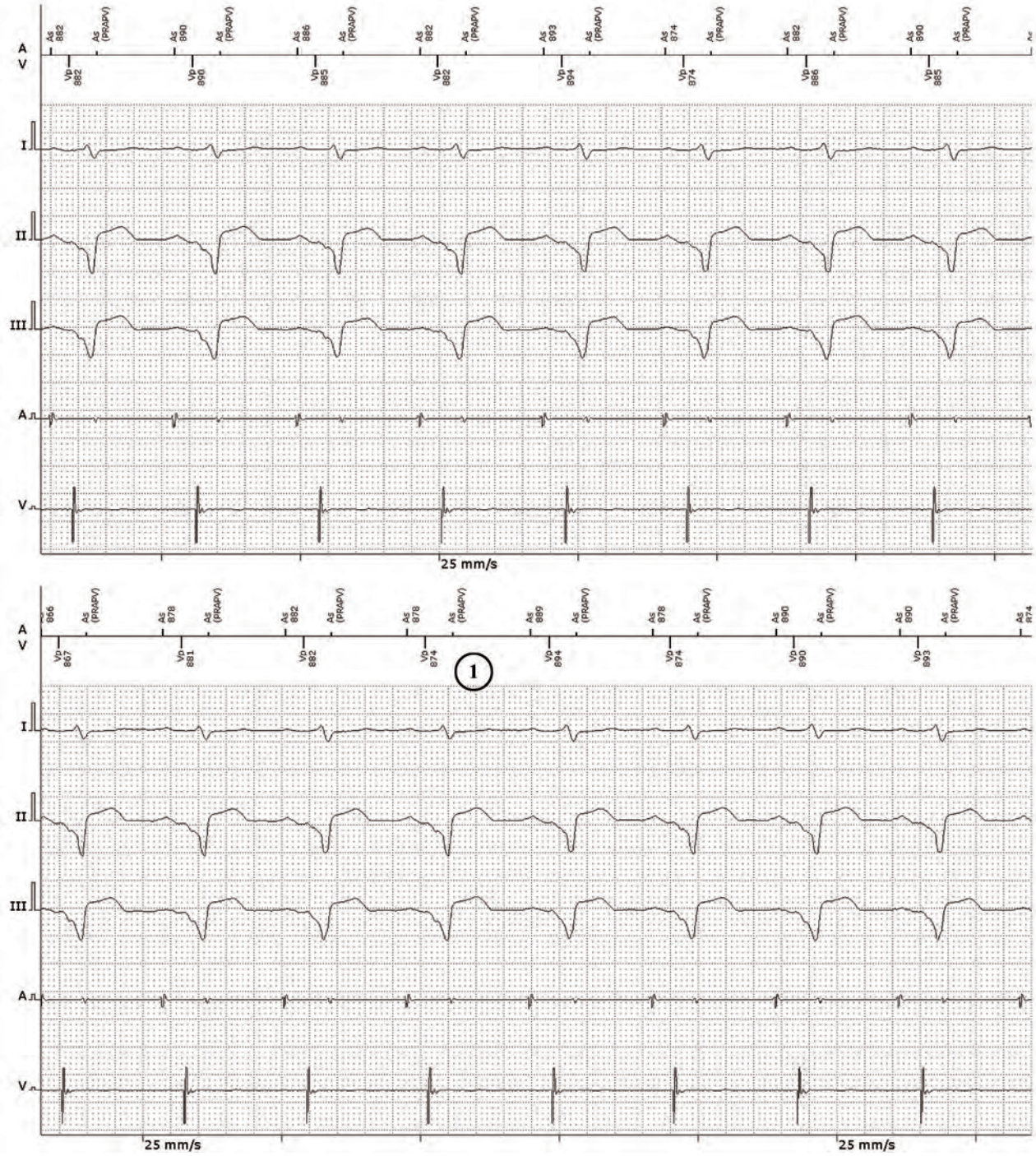
Tracing 11d

④ programming of the Vp suppression mode favoring the occurrence of spontaneous ventricular activity.

Comments

In this patient, the diagnosis of crosstalk is obvious. The sensed ancillary atrial signal is of low amplitude and very precocious in relation to ventricular pacing. This tracing allows highlighting the peculiarities of post-ventricular atrial refractory periods. On the first tracing, oversensing of ventricular depolarization occurs during the PVARP. If the patient's atrial rhythm accelerates (upon exertion, for example), the atrial rate measured by the pacemaker (which includes the cycles during the PVARP) exceeds the fallback rate, which causes inappropriate mode switching. The first option is to prolong the far-field protection period. This is a refractory period applied in the atrium after ventricular sensing and pacing in order to avoid crosstalk. It is not truly absolute since a sensed signal is highlighted on the chain of markers and is denoted as Ars (FFP). On the other hand, this signal does not trigger an AV delay and is not integrated in the counter used for the diagnosis of atrial arrhythmias, thus avoiding inappropriate switching. The nominal value is 100 ms (programmable between 100 and 220 ms) after a spontaneous ventricular event and 150 ms (programmable between 100 and 220 ms) after a paced ventricular event.

When the crosstalk cannot be corrected by a suitable adjustment of the refractory periods, it is possible to modify atrial sensitivity while attempting to maintain a sufficient margin for the sensing of atrial signals in both sinus rhythm and arrhythmia. In this patient, the simplest approach is to program the Vp suppression mode that allows the recovery of a spontaneous conduction and thus avoids crosstalk.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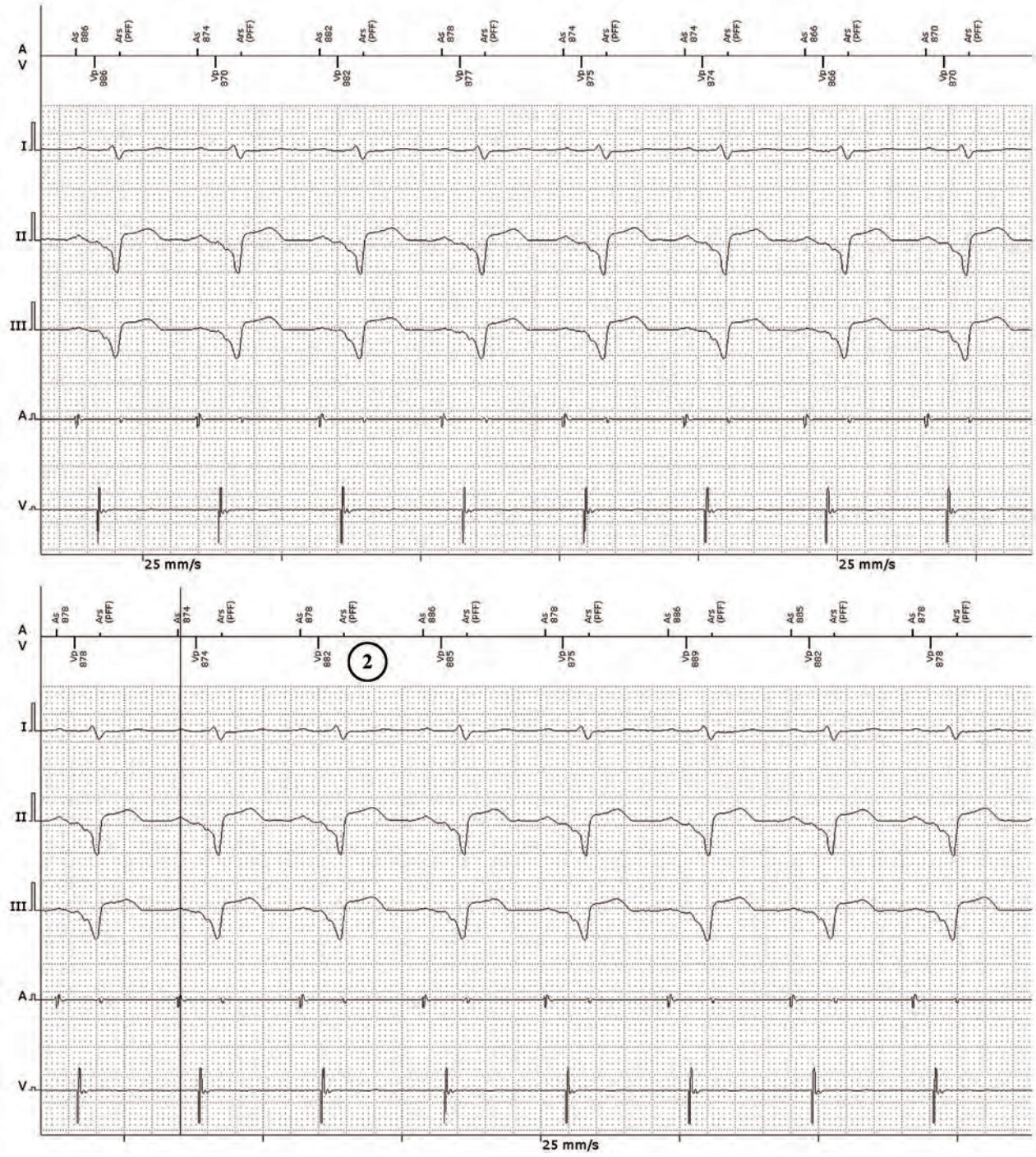
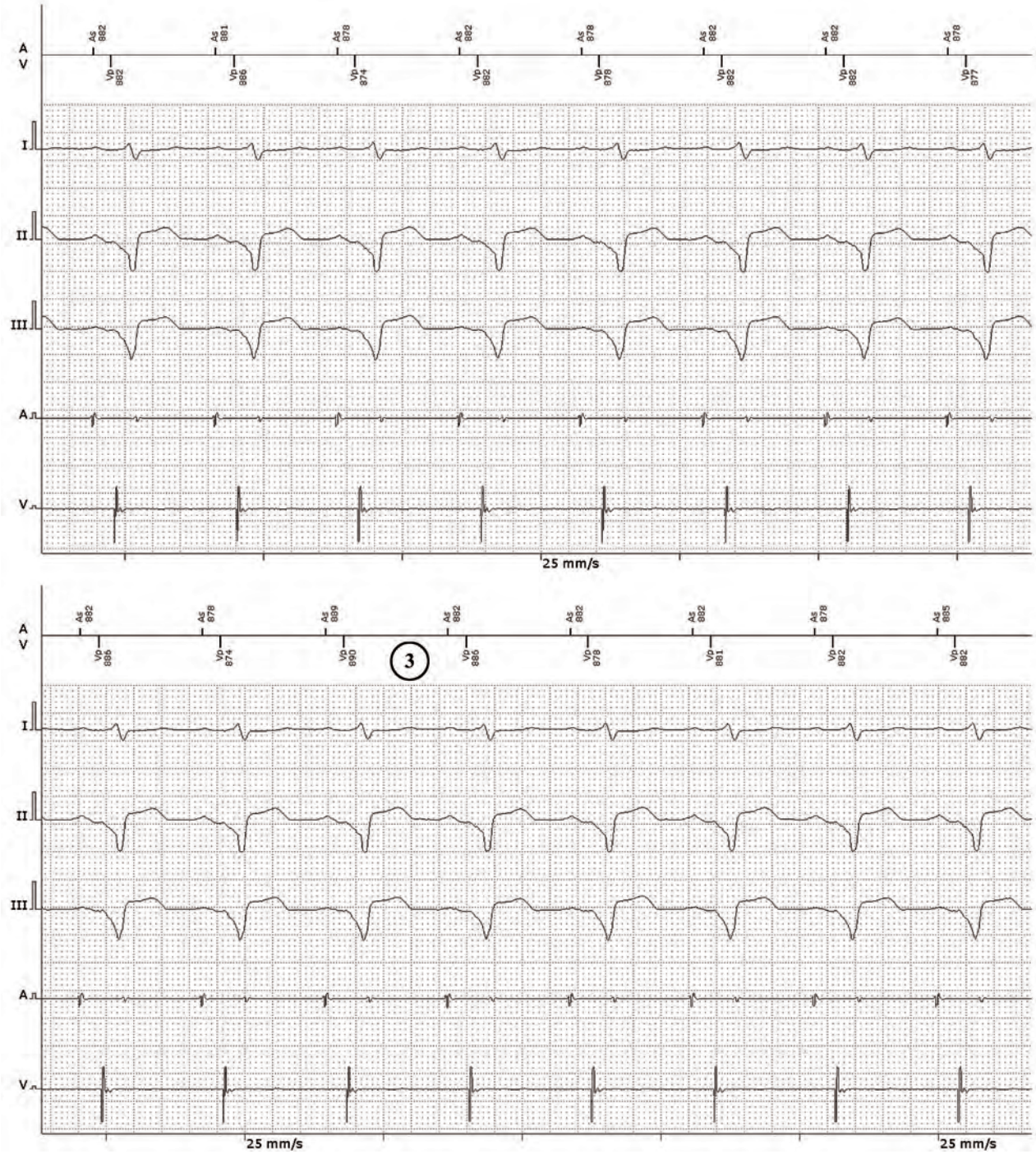
Refractory Periods

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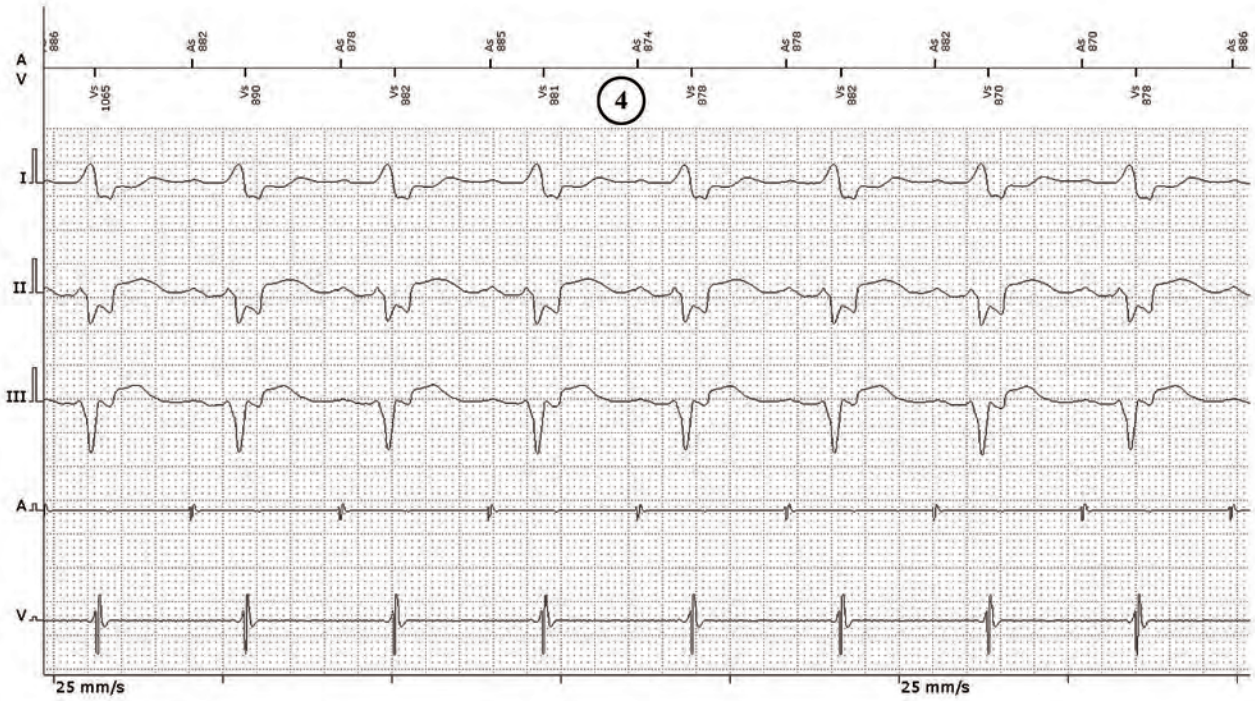
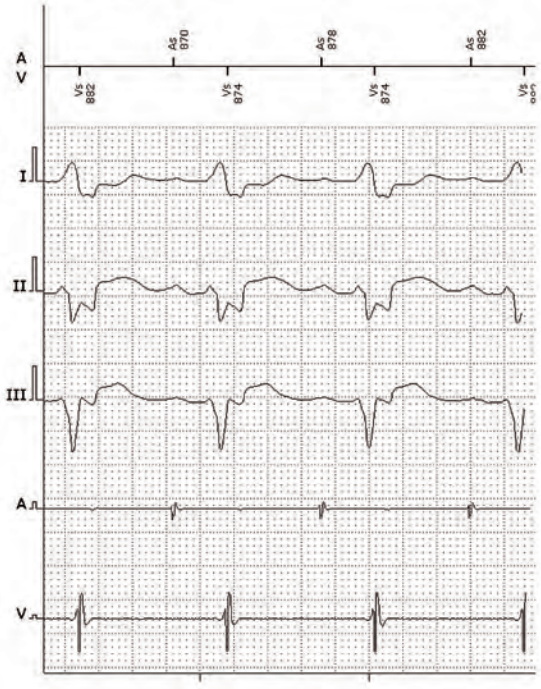
Refractory Periods





Tracing 12 ↘ Crosstalk and ventricular sensitivity

Patient

67-year-old man implanted with an Evia DR-T dual-chamber pacemaker for a syncopal paroxysmal atrioventricular block; programming in DDD mode; routine consultation and recording of the tracing.

Tracing 12a

① AS-VS event properly sensed; AS-VS interval of 180 ms;

② T wave oversensing by the ventricular channel over 2 consecutive intervals;

Tracing 12b

③ ventricular pacing with pseudo-fusion pattern (stimulus but no change in ventriculogram pattern);

④ slowing of the sinus rate and unipolar atrial pacing; crosstalk with signal sensed by the ventricular channel and pacing at the end of the safety window with ventricular capture; T wave oversensing;

Tracing 12c

⑤ change in chart speed for better visualization of the crosstalk; it is possible to visualize a signal of small amplitude on the ventricular channel following atrial capture; this signal is sensed after the post-atrial ventricular blanking, in the safety window and triggers ventricular pacing with capture 100 ms after the atrial pacing.

Comments

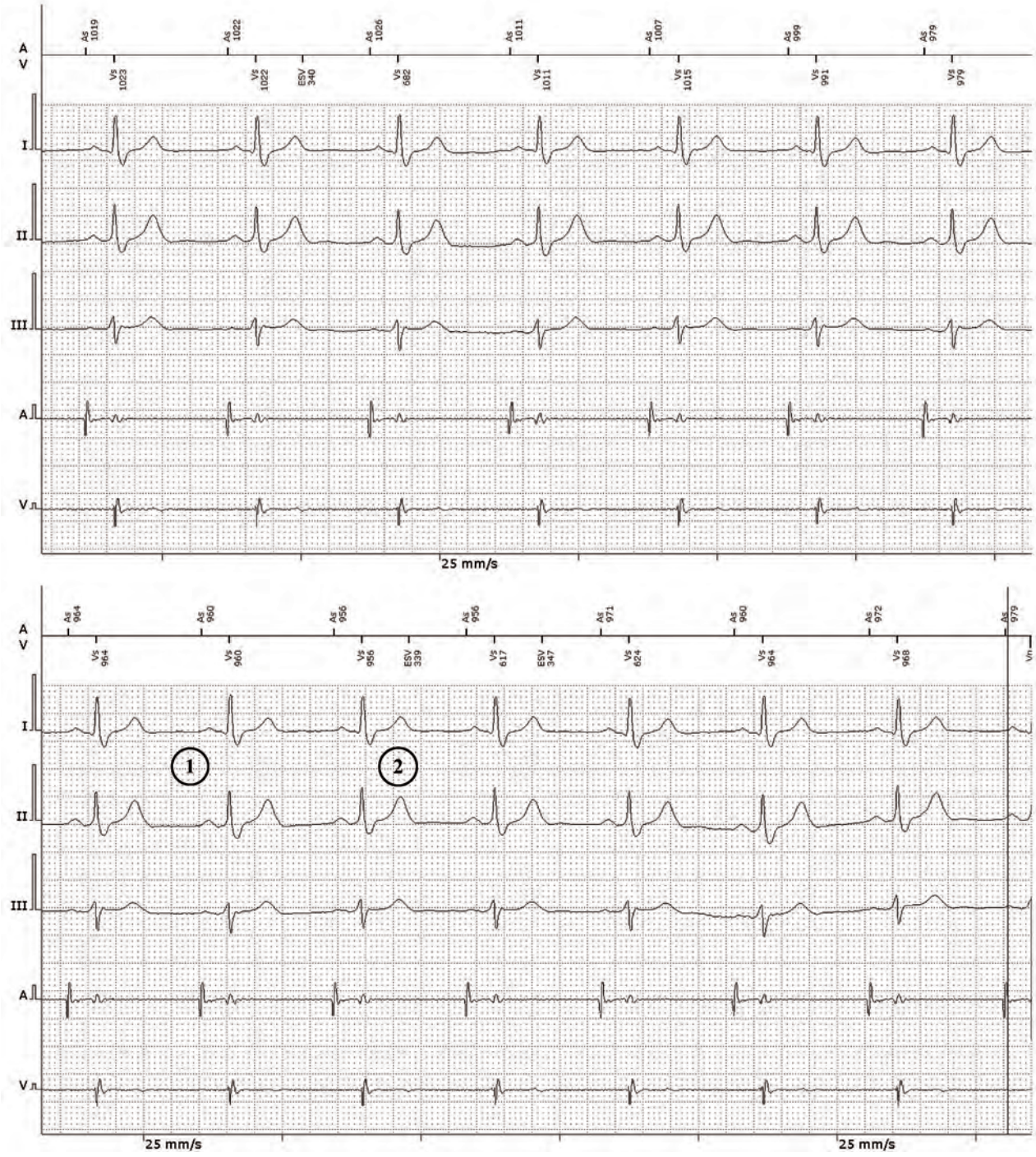
The sensing of atrial activity does not trigger refractory periods in the ventricle, the risk of oversensing being relatively limited (spontaneous atrial signals of low amplitude). In contrast, following an atrial pacing, it is imperative to protect the ventricular chamber, the risk of crosstalk being high (pacing in Volts, sensing in mV with a ratio of 1 per 1000).

A programmable ventricular blanking period (between 30 and 70 ms with a nominal value of 30 ms) is therefore triggered after an atrial stimulus. This period is intended to avoid sensing of the atrial stimulus by the ventricular sensing chain which would result in ventricular inhibition. A ventricular signal occurring during post-atrial ventricular blanking is not sensed and therefore does not inhibit ventricular pacing occurring at the end of the programmed AV delay.

The safety window is a ventricular sensing period as an adjunct to post-atrial ventricular blanking. It is only initiated after atrial pacing and is designed to prevent ventricular asystole due to inappropriate inhibition of ventricular pacing by the sensing of atrial stimulus or depolarization. Ventricular sensing occurring after post-atrial ventricular blanking but before the end of the safety window is considered non-physiological and triggers ventricular pacing at the end of the safety window. The short AV delay feature allows the recognition of a safety window pacing on the electrocardiogram. If the event sensed in the safety window is the result of crosstalk or oversensed noise, the pacing pulse allows effective ventricular capture at the end of the safety window. If the event sensed in the safety window corresponds to a late PVC or to atrioventricular conduction, the pacing at the end of the safety window occurs sufficiently early during the absolute myocardial ventricular refractory period to avoid pacing at the peak of the T wave. The safety window extends up to 100 ms after the atrial pacing (immutable value).

In this asymptomatic patient, this crosstalk associated with T wave oversensing on both the spontaneous ventricular event and the paced ventricular event indicates that the device is too sensitive at the ventricular level. A reduction in sensitivity (increase in the programmed value) allowed resolving both problems.

Refractory Periods

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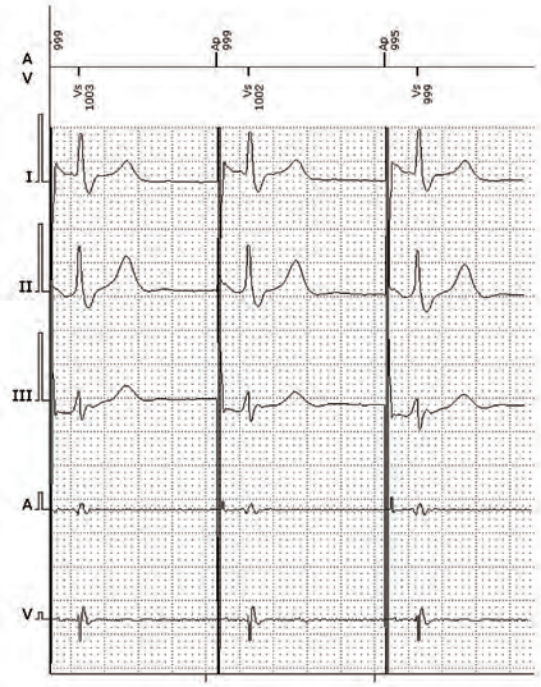
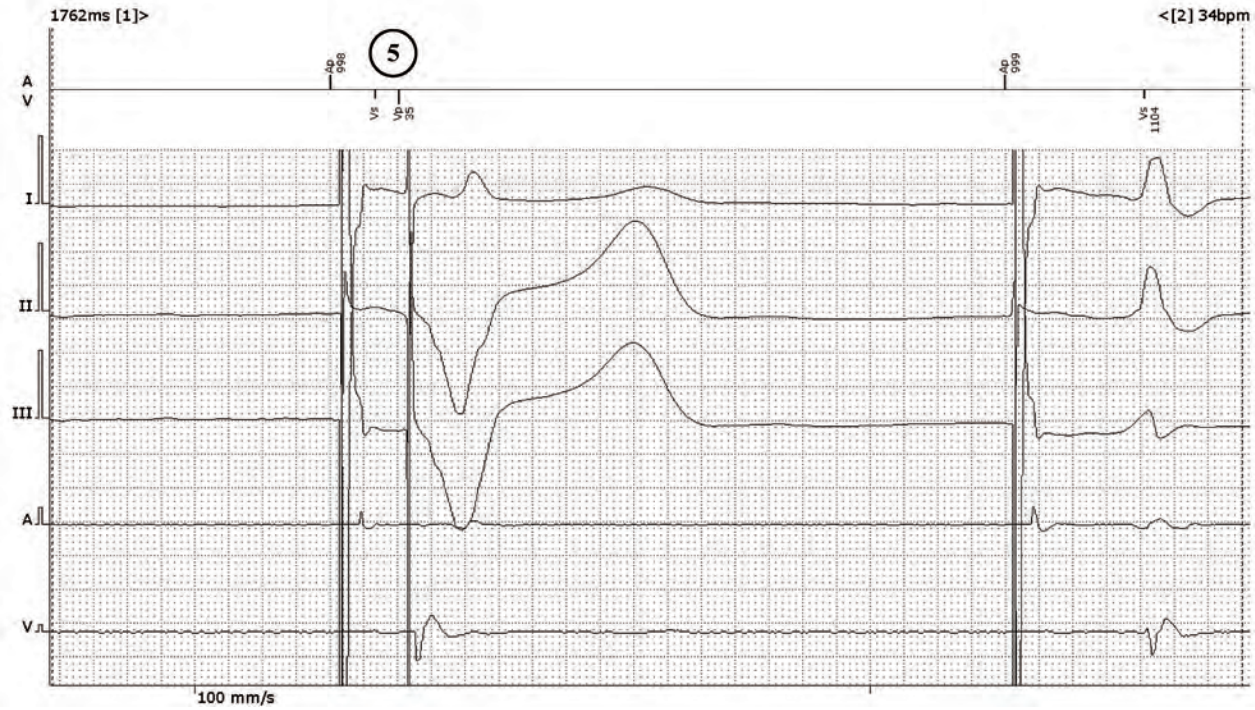
Refractory Periods





Tracing 13 ↘ Repetitive PMT due to crosstalk; diagnosis by remote monitoring

Patient

78-year-old woman with an Evia DR-T dual-chamber pacemaker; telemedicine alert message (yellow) for high ventricular rate; summoning of the patient presenting signs of heart failure on arrival.

Tracing 13a

① yellow alert for mean ventricular rate higher than the programmed limit (> 100 bpm);

② the telemedicine report shows a sudden increase in the percentage of ventricular pacing (from 0 to 100%) and a sudden increase in atrial and ventricular rate (rate equal to 116 bpm);

Tracing 13b

At arrival, recording of the tracing with 3 electrocardiographic leads, the atrial channel and the ventricular channel;

③ atrial pacing and ventricular pacing with probable atrial and ventricular capture;

④ probable crosstalk; the atrial EGM shows a signal sensed in the atrium outside of the refractory periods (AS) likely corresponding to ventricular depolarization subsequent to the pacing;

⑤ the signal is classified as AS and is followed by an AV delay and ventricular pacing;

⑥ new crosstalk although the signal is now sensed in the far-field period (no AV delay synchronized to this signal);

⑦ probable retrograde conduction with atrial interval classified as AS generating an AV delay;

⑧ probable PMT with succession of AS-VP cycles and constant VP-AS intervals; the atrial lead is positioned in the atrium (upper portion of the atrium), which explains the late sensing of atrial activity (depolarization from the lower portion of the atrium); the actual delay between the atrium and ventricular pacing is longer than that suggested by the short AV delay, thus explaining the possibility of a retrograde conduction (low atrial rhythm outside its refractory periods) and a PMT;

⑨ after 8 consecutive cycles, suspicion of PMT; the device prolongs the AV delay by 50 ms;

⑩ despite this change in AV delay, the VA interval remains constant: diagnosis of PMT;

⑪ prolongation of the PVARP over one cycle; the retrograde conduction is sensed in the PVARP; no AV delay and termination of the tachycardia;

⑫ identical perpetual reproduction of the same sequence.

Tracing 13c

⑬ retrograde conduction test carried out in VDI mode at 90 bpm; presence of retrograde conduction with atrial activity sensed in the PVARP; relatively constant VA intervals.

Comments

The initiation of a pacemaker-mediated tachycardia involves the programming of an atrial (DDD or VDD) monitoring mode, the permeability of retrograde conduction, a PVARP programmed shorter than the retrograde conduction and a momentary or permanent loss of atrioventricular synchrony. Indeed, if ventricular activity is correctly synchronized with that of the atrium, retrograde conduction is blocked. The

Refractory Periods

maintenance of the PMT results from the sensing of a retrograde P' wave outside the refractory periods, which leads to the triggering of an often prolonged AV delay, which again fosters retrograde conduction after ventricular pacing. A PMT is therefore a repetitive sequence in which the pacemaker reacts to each retrograde P wave by pacing the ventricle at a high rate which in turn generates a retrograde P wave.

The cycle is thus repeated indefinitely unless there is appearance of a retrograde block or intervention of a specific algorithm. A PMT of prolonged duration may be poorly supported with symptoms ranging from a mild feeling of malaise or palpitations to cardiac decompensation in patients with an underlying heart disease. The rate of a PMT is contingent on the retrograde conduction time, the programmed maximum rate and the ongoing AV delay.

This tracing shows the specificities of the Biotronik™ devices in the management of PMTs:

1) one of the specificities of Biotronik™ pacemakers is to propose the measurement of the retrograde conduction time in order to adapt the programming of the PVARP. The retrograde conduction test is performed in VDI mode (programmable rate which must exceed the patient's spontaneous rate, nominal 90 bpm). The first 5 intervals are not analyzed. The device confirms the presence of a retrograde conduction when there is a 1:1 ratio between spontaneous atrial events and paced ventricles and when the VA interval is deemed constant. Three retrograde conduction values are provided: minimum VA interval value, maximum value and mean value. If these 3 values do not differ by more than 25 ms (as in this patient), the presence of a retrograde conduction is suspected.

2) the device suspects a PMT if the heart rate exceeds 100 beats per minute, the VA interval (VP-AS) is shorter than the programmed VA interval (nominal value of 350 ms, programmable between 250 and 500 ms) for 8 consecutive cycles, and the VA intervals are stable (+/- 25 ms).

3) the device confirms the diagnosis of PMT by modifying the AV delay on a single interval (prolongation of 50 ms on this tracing) and by analyzing the duration of the next VA interval; if the duration of the VA interval is shortened, this implies that the AA interval has not been impacted by the change in AV delay which is suggestive of a diagnosis of sinus tachycardia; conversely, if this VA interval is not modified, this implies that atrial activity is dependent on the preceding ventricular pacing which suggests the diagnosis of PMT.

4) the device prolongs the PVARP (programmed VA criterion + 50 ms) over one interval; the following atrial activity falls within the PVARP, does not trigger an AV delay which interrupts the PMT.

This tracing also highlights the fact that if the triggering factor of the PMT is not corrected, the tachycardias can become incessant. In the present instance, remote monitoring has enabled a rapid diagnosis with a warning alert of increased mean ventricular rate. Upon arrival, the patient showed signs of heart failure, which were rapidly corrected after the change in programming and diuretic treatment. Atrial sensitivity was decreased (value was increased) in order to avoid crosstalk. Prolonging the PVARP beyond the retrograde conduction time (380 ms) was also possible in this patient with very limited exercise capacities (relatively low 2:1 point).

Status report

BIOTRONIK
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Evia DR-T
PM implanted Jul 6, 2011

Status: YELLOW

Status - Summary:

1

Status summary for patient ID

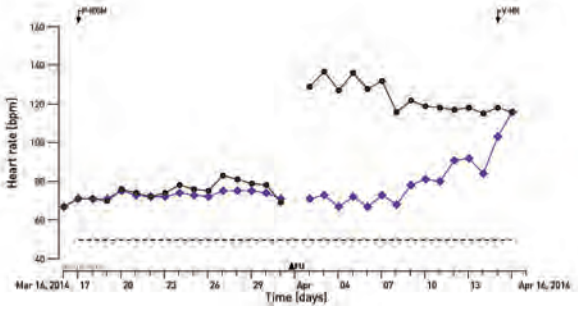
Category	Status	Finding	Info
HF monitor	YELLOW	**Mean ven. heart rate above limit (> 100 bpm)** Above limit since Apr 15, 2014 1:11:00 AM - Last value 116 bpm measured on Apr 16, 2014 1:11:00 AM	Acknowledged Apr 15, 2014 10:31 AM.
Automatic remark: none			

Status - Physiologic. param.:

Heart rate	24 h	Since Apr 1, 2014 12:22:34 AM Mean values
Mean atrial heart rate [bpm]	116	123
Mean ven. heart rate [bpm]	116	81
Activity		
Patient activity [% of day]	2	2

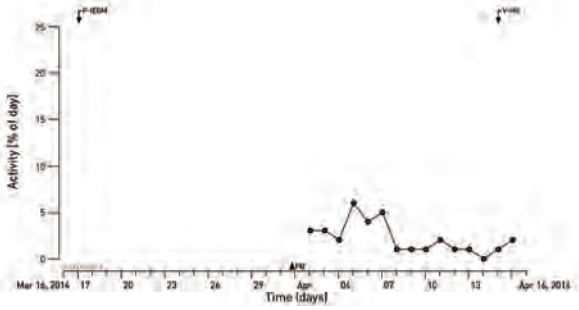
Mean heart rate

• Mean atrial heart rate [bpm] ◆ Mean ven. heart rate [bpm] ▬ Progr. basic rate [bpm]



Patient activity

• Patient activity [% of day]



Status report

BIOTRONIK
excellence for life

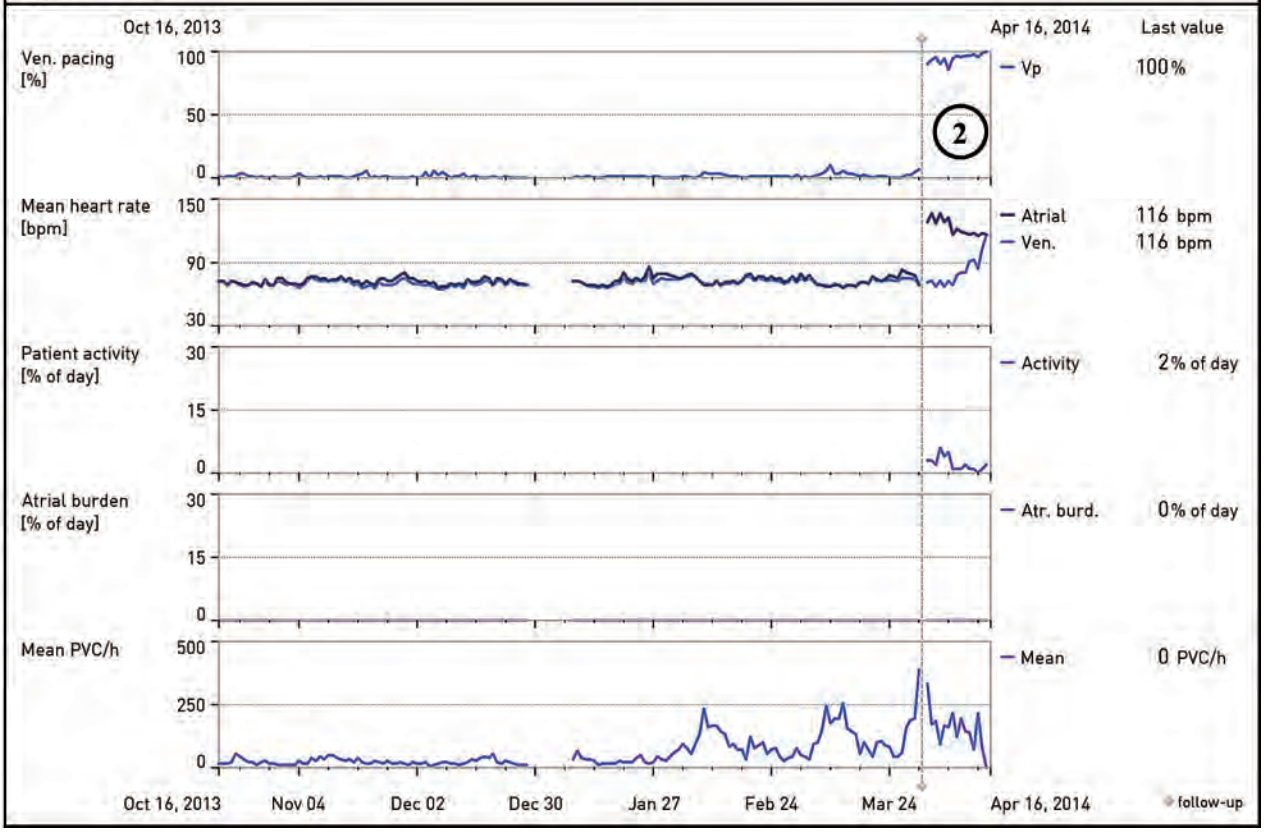
Evia DR-T
PM implanted Jul 6, 2011

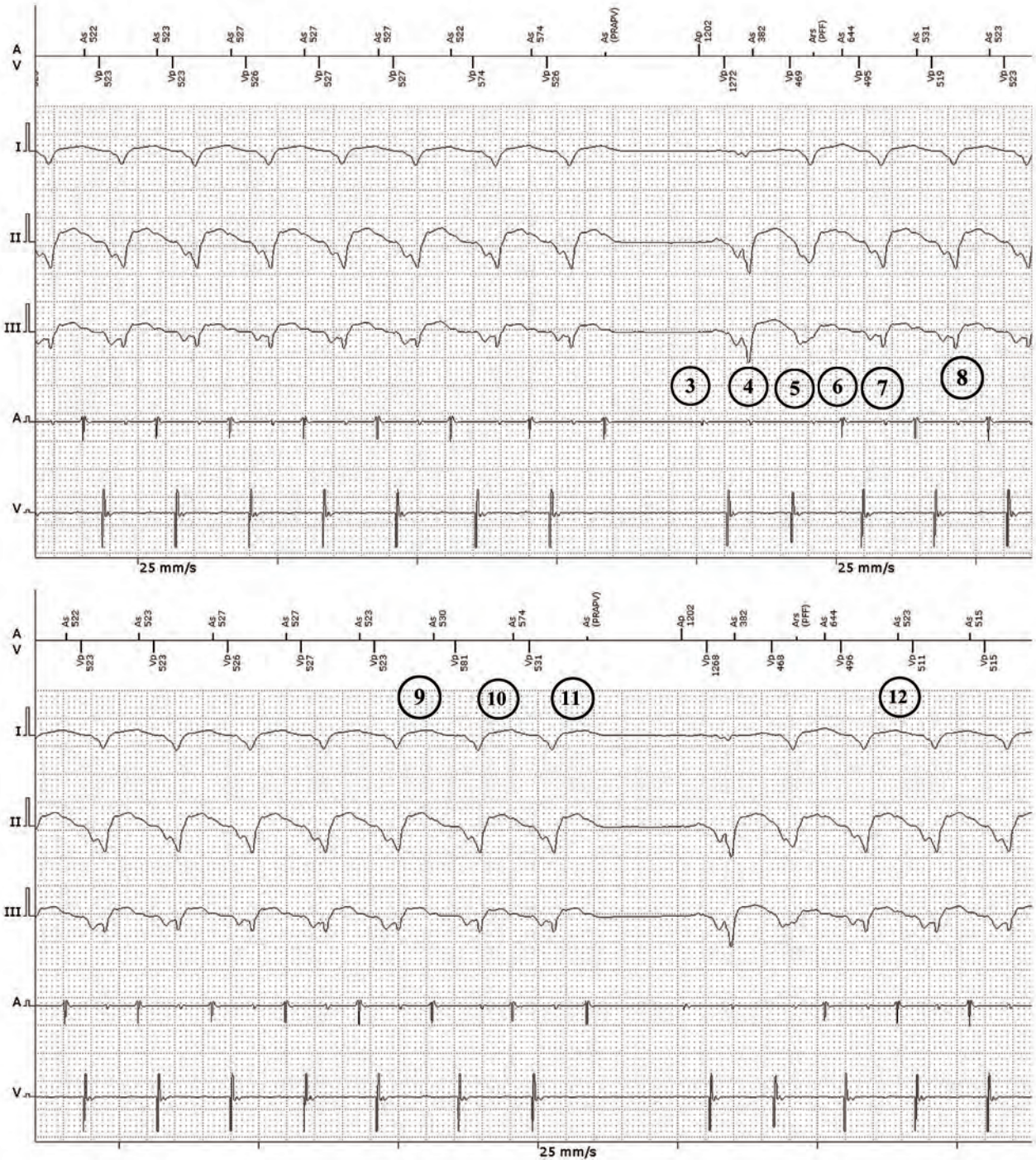
Status - HF monitor:

Device status Apr 16, 2014	
Battery status	OK
Pacing mode	DDD

Arrhythmias since Apr 1, 2014 (mean values)	
Atrial arrhythmia episodes per day	0
High ven. rate episodes per day	0

Long term trends

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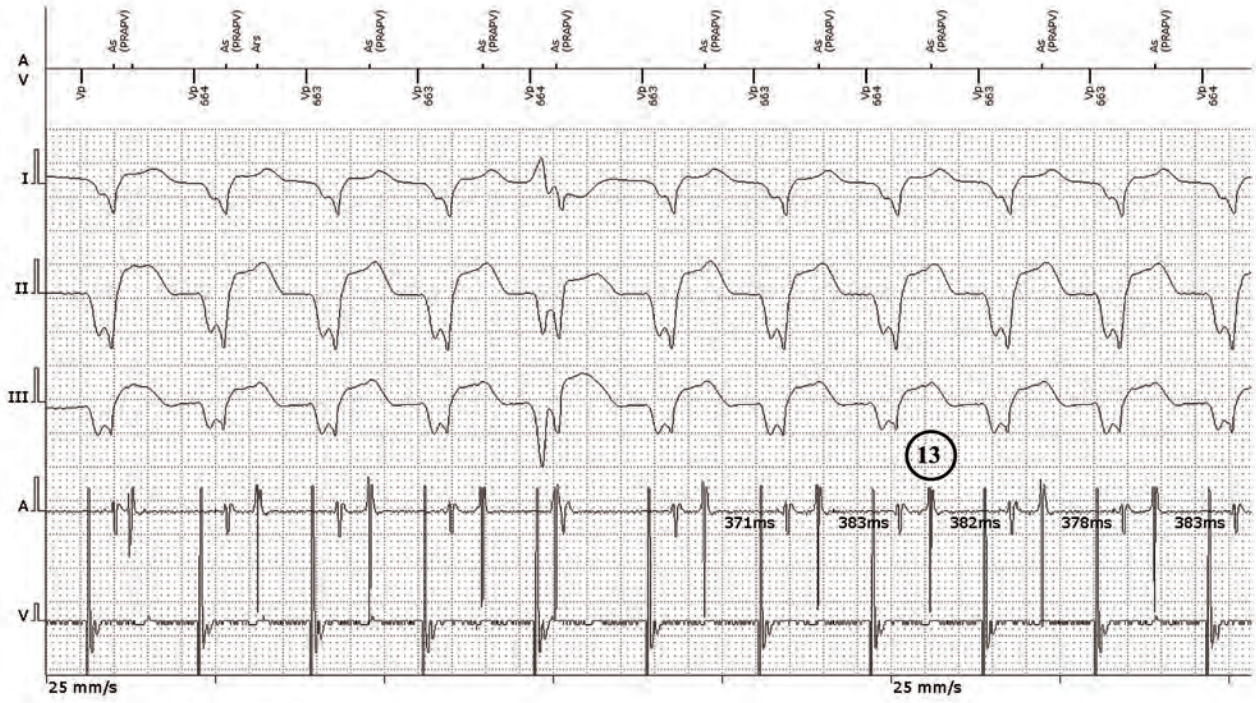
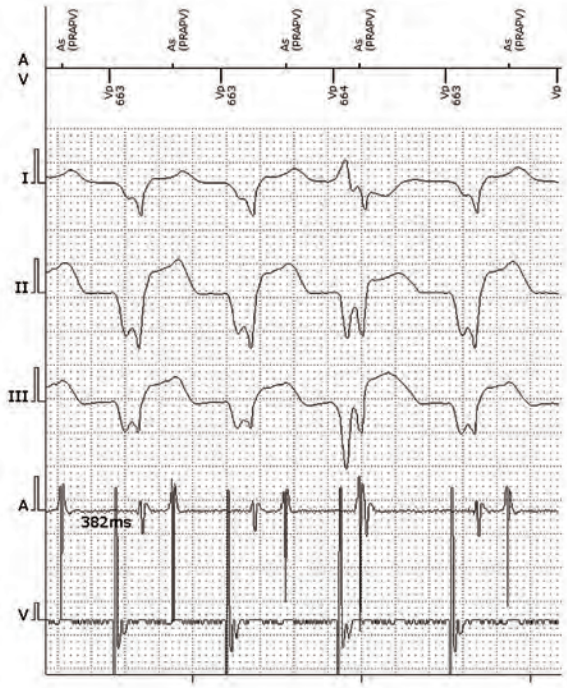
Refractory Periods





Tracing 14 ↘ Incessant PMT

Patient

81-year-old man implanted with an Evia DR-T pacemaker for sinus dysfunction; hospitalization for cardiac decompensation; recording of this EGM tracing on arrival.

Tracing 14a

① permanent tachycardia at the programmed maximum rate (120 bpm) with succession of AS-VP cycles;

Tracing 14b

The PMT termination algorithm had been deprogrammed. Programming of this algorithm and recording of this EGM;

② new PMT;

③ operation of the algorithm with confirmation phase; prolongation of the AV delay for one cycle (+ 50 ms);

④ retrograde conduction time remains constant confirming the PMT;

⑤ prolonging of the PVARP over one cycle (programmed VA criterion + 50 ms);

⑥ PMT termination and atrial pacing; inefficient pacing since occurring during the refractory period of the atrial myocardium;

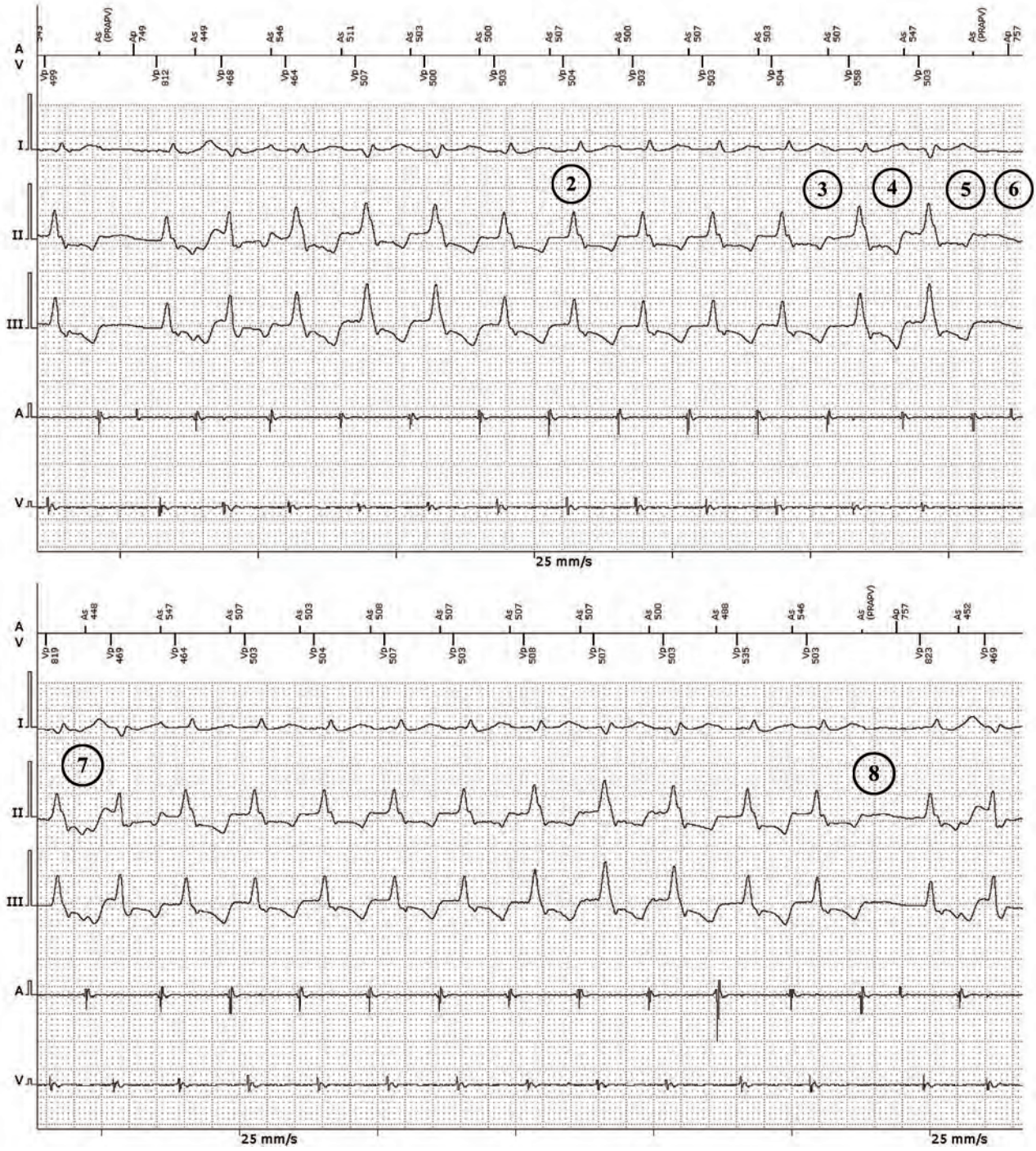
⑦ this inefficient pacing favors retrograde conduction and the resumption of PMT;

⑧ the sequence repeats itself.

Comments

These tracings illustrate 2 causes of incessant PMT. On the first tracing, the PMT detection and termination algorithm was deprogrammed, thus explaining the persisting tachycardia. On the second tracing, the algorithm was reprogrammed, the device diagnoses the PMT, terminates it efficiently although the PMT immediately resumes. Indeed, atrial pacing occurs in the myocardial refractory period and is therefore ineffective and favors the occurrence of retrograde conduction. In this patient, it is necessary to diagnose the initial triggering mechanism of the PMT. Consideration should also be given to programming a PVARP that is longer than the retrograde conduction time, even if it appears relatively long (in the order of 400 ms) and that such prolongation may limit 1:1 tracking upon exertion. However, the exercise capacity of this 81-year-old patient is considerably reduced.

Refractory Periods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Tracing 15 ↘ PMT and ADI-DDD mode

Patient

83-year-old man implanted with an Evia DR-T pacemaker for complete paroxysmal atrioventricular block; programming of the DDD-ADI mode; feeling of palpitations; interrogation of the pulse generator.

Tracing

Programming in DDD mode;

① atrial pacing and ventricular pacing (AP-VP);
② programming of the DDD-ADI mode (vertical line);
③ search for spontaneous conduction with prolongation of the AV delay to 450 ms;
④ crosstalk with sensing in the far-field protection (FFP) period;
⑤ ventricular pacing with long AV delay;
⑥ probable retrograde conduction sensed outside the refractory periods (AS);
⑦ ventricular pacing with long AV delay;
⑧ new retrograde conduction;
⑨ eighth cycle with AV delay at 450 ms; the search for atrioventricular conduction failed;
⑩ AV delay shorter than previous delay but longer than that programmed so as not to exceed the synchronous maximum tracking rate;
⑪ due to this long AV delay, retrograde conduction;
⑫ PMT with adjustment of the AV delay so as not to exceed the maximum rate, which favors the occurrence of retrograde conduction;
⑬ after 8 VP-AS cycles > 100 beats per minute, with stable VP-AS intervals and a VP-AS interval duration less than the programmed value, suspicion of PMT; prolongation of the AV delay over one cycle;
⑭ the prolongation of the AV delay leads to a prolongation of the AS-AS interval (the time of occurrence of the atrial activity is contingent on when the ventricle is paced): suggestive of a PMT;
⑮ prolongation of the PVARP for one cycle; the ensuing atrial activity falls within the PVARP and does not trigger an AV delay;
⑯ termination of the tachycardia.

Comments

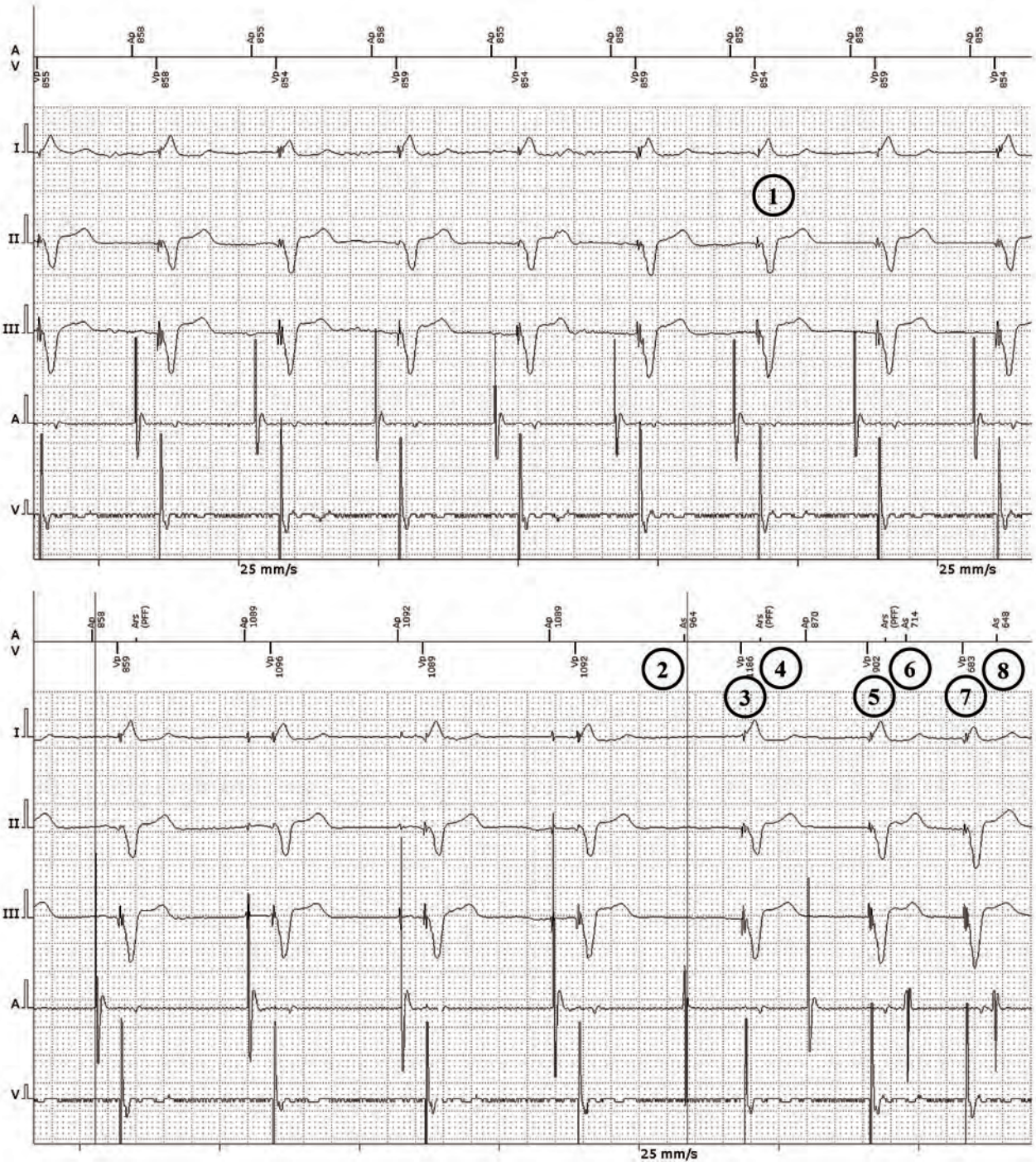
As explained previously, when the pacemaker operates in DDD-ADI mode, the search for spontaneous conduction is based on an atrioventricular delay hysteresis with an AV delay of 450 ms during 8 cycles. Therefore, there can be no blocked P waves during this search, which allows preventing potentially symptomatic ventricular pauses that may, in a few patients, favor the occurrence of ventricular arrhythmias.

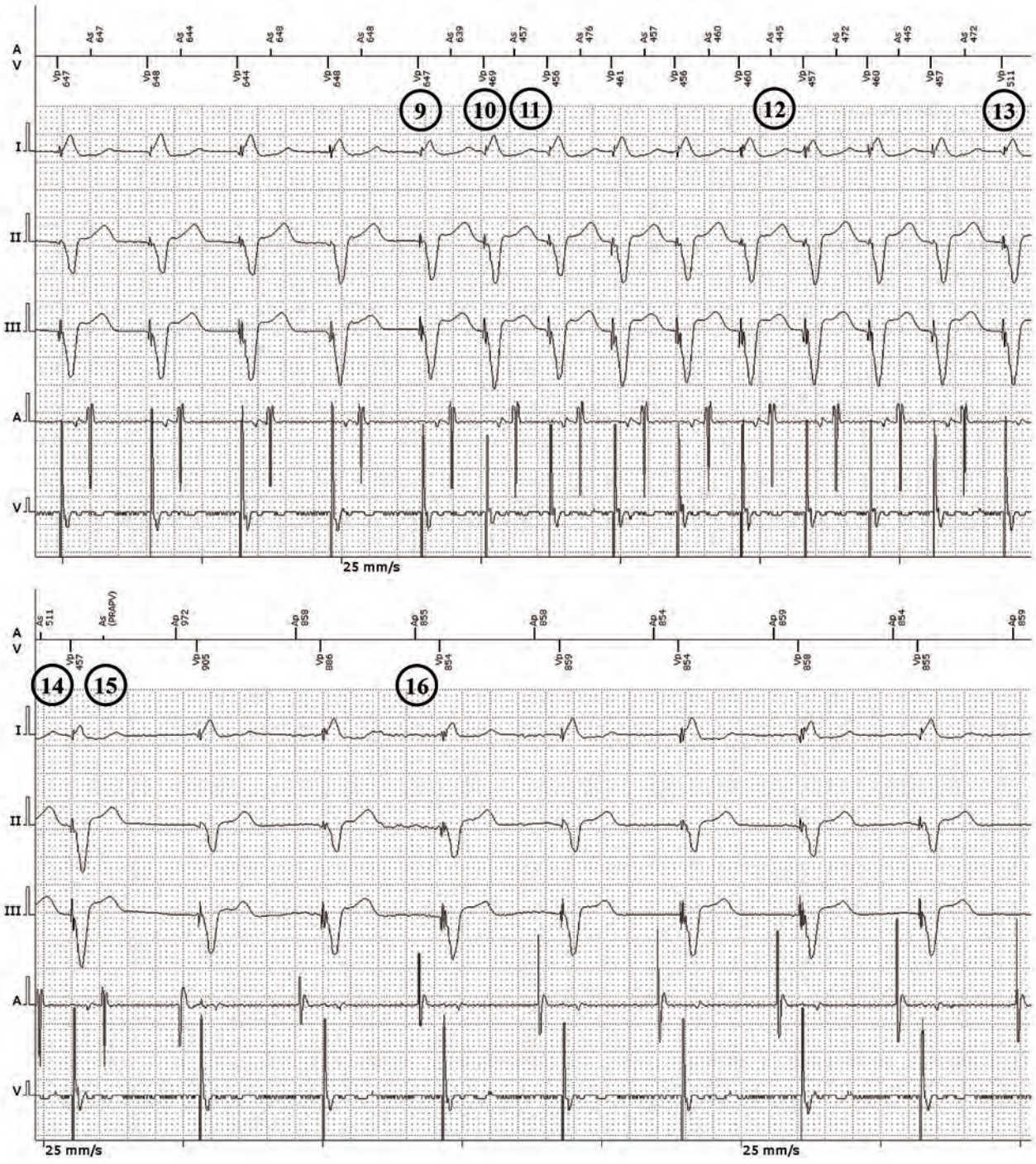
When there is a permanent or paroxysmal atrioventricular conduction disorder, as observed in this patient, this search results in failure and leads to a return to the DDD mode at the programmed AV delay. One of the limitations of this option is that in patients with altered anterograde conduction but preserved retrograde conduction, prolonging the AV delay favors the occurrence of retrograde conduction which can generate a pacemaker-mediated tachycardia without the need for other triggering factors (atrial or ventricular extrasystole, loss of atrial capture, etc.). The number of PMTs can thus be very substantial. The simplest and most logical approach in the presence of a permanent complete atrioventricular block is not to program the Vp suppression algorithm. When the conduction disorder is paroxysmal and when it is deemed desirable

to preserve the spontaneous conduction, it is therefore essential to verify that the PVARP is appropriately programmed longer than the retrograde conduction time.

Note that it is possible to program an automatic PVARP. Its operation differs completely from that of other manufacturers. Indeed, for Medtronic™ devices, for example, the duration of an automatic PVARP decreases with the increase in heart rate. For Biotronik™ devices, when the PVARP is programmed to Auto, the nominal PVARP is 250 ms without modification during exercise. The PVARP is prolonged by 50 ms when a PMT episode is diagnosed and treated by the device.

Refractory Periods

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Tracing 16 ↘ Repetitive nonreentrant ventriculoatrial synchrony

Patient

75-year-old man implanted with an Evia DR-T pacemaker for sinus dysfunction; hospitalization for palpitations and dyspnea; recording of this EGM tracing on arrival.

Tracing

① effective ventricular pacing;

② retrograde conduction and detection of atrial activity in the PVARP;

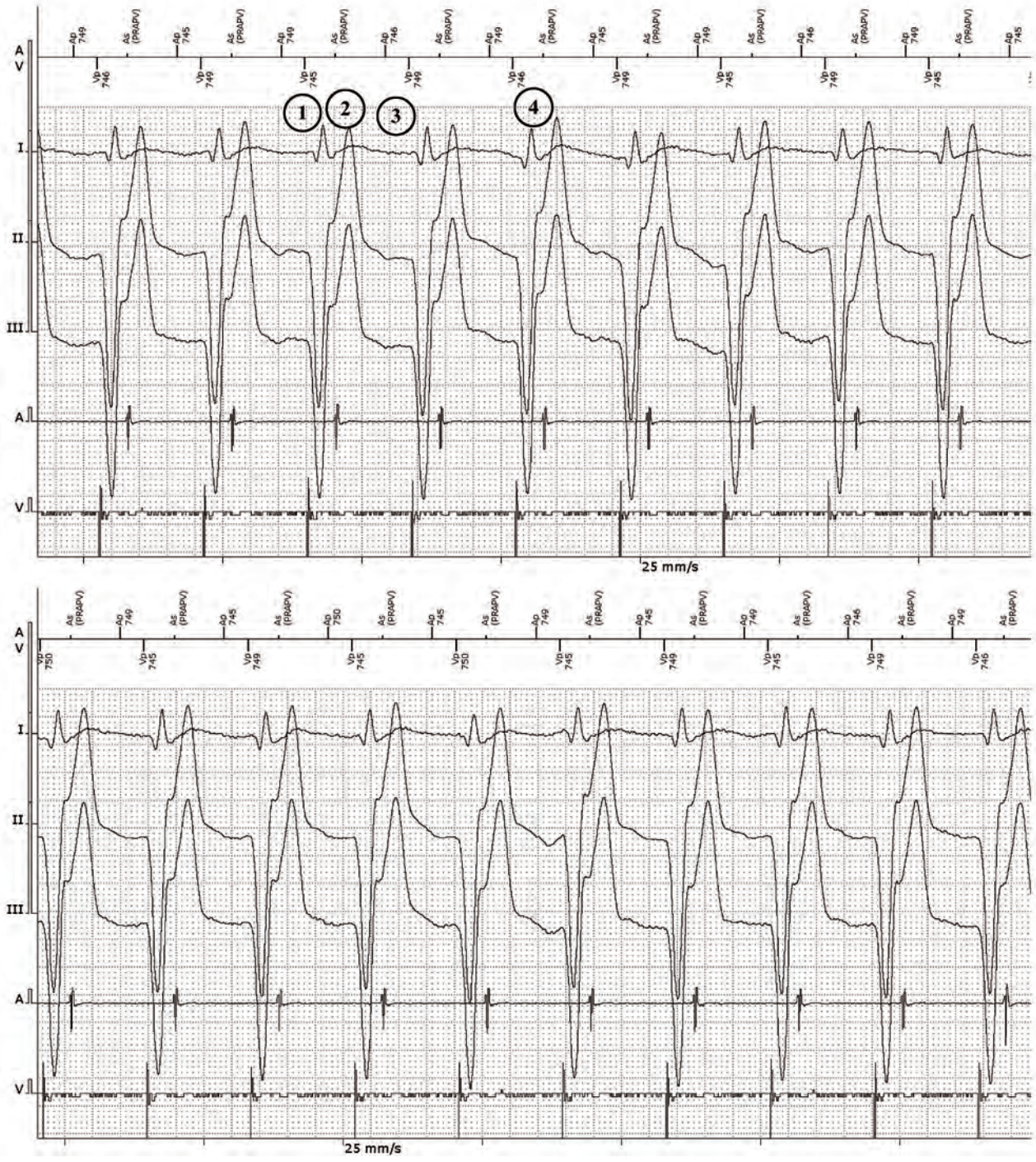
③ ineffective atrial pacing since falling in the refractory period following the previous atrial depolarization;

④ the cycle repeats itself with retrograde conduction in the PVARP and ineffective atrial pacing favoring retrograde conduction.

Comments

This tracing illustrates a particular form of "PMT" in conjunction with the detection of retrograde conduction in the PVARP (functional undersensing) and an inefficient atrial pacing (loss of functional capture) since delivered in the physiological refractory period. This patient presented a normal atrial threshold (<1V for 0.5 ms) with an adjusted programming margin (2.5V for 0.4 ms). This type of repetitive sequences can 1) be generated by all of the causes associated with loss of atrioventricular synchrony (same as those for a PMT). This loss of synchrony results in a PMT or NRVAS (non-reentrant ventriculoatrial synchrony) as a function of the retrograde conduction time and the various pacemaker settings (PVARP, minimum rate, programming of different specific algorithms, etc); 2) be associated with a symptomatology similar to that of a conventional PMT in conjunction with the loss of the active atrial component and with retrograde conduction (dyspnea, palpitations, pacemaker syndrome, etc.); 3) occur for the DDD mode but also for the DDI mode (possible atrial pacing) but not for the VDD mode (atrial pacing needed).

Atrial pacing occurs at the end of the escape interval. If atrial pacing is effective, the cycle is interrupted. The higher the rate (minimum rate or rate response), the greater the risk that atrial pacing falls within the atrial myocardial refractory period and that the pacing is ineffective. To avoid this type of problem, one must therefore 1) avoid all causes associated with a dissociation (PVC, PAC, myopotential oversensing, loss of atrial capture, etc.); 2) decrease the pacing rate (minimum rate and rate response) and reduce the AV delay in order to allow the atrial myocardium more time to exit its refractory period; 3) deprogram the prolongation of post-PVC PVARP if it is not accompanied by an automatic prolongation of the atrial escape interval.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Implantable Cardiac Pacemaker - chapter 3

Pacing

Tracing 17 ↘ Displacement of the atrial lead into the ventricle

Patient

74-year-old man implanted with an Evia DR-T dual-chamber pacemaker for atrioventricular block; interrogation of the pacemaker the day after implantation.

Tracing 17a

① atrial pacing and ventricular pacing; sensing of a signal in the atrial channel in the far-field protection (FFP) period;

② atrial pacing and probable ventricular capture (identical pattern to the previous QRS); ventricular depolarization is detected by the ventricular channel in the safety window; pacing at the end of the safety window without capture;

Tracing 17b

Reprogramming in DDI mode 50 bpm;

③ no sensing of sinus activity; sensing of spontaneous ventricular activity by the atrial channel and the ventricular channel (quasi-simultaneous sensing).

Patient

60-year-old man implanted with an Evia DR-T pacemaker for paroxysmal atrioventricular block; 3 months after implantation, transmission of a periodic EGM by telemedicine.

Tracing 17c

Normal

① ventricular sensing classified as PVC (not preceded by atrial activity classified as AS); sensing of a signal concurrent with ventricular sensing in the atrial channel (in the far-field protection period);

Encouraged sensing

② no modification of the tracing;

Encouraged pacing

③ atrial pacing with probable ventricular capture; ventricular sensing and pacing at the end of the safety window (100 ms after atrial pacing) without capture;

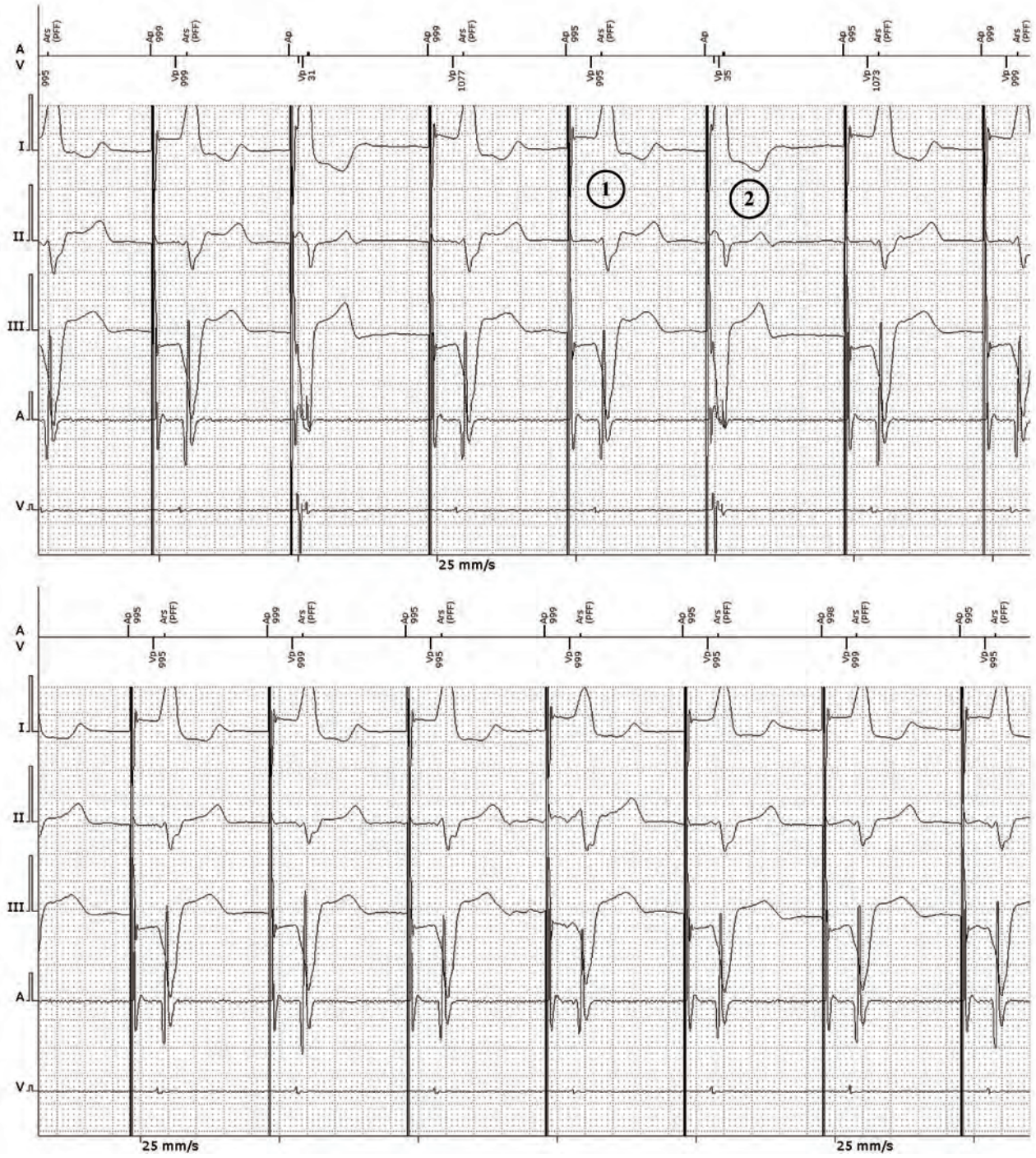
Pulmonary radiography reveals a displacement of the atrial lead in the ventricular chamber.

Comments

These different tracings correspond to an early dislodgement of the atrial lead that has fallen into the ventricle. On the first tracing, the atrial lead drives the ventricle intermittently. On the second tracing, a slowing of the minimum rate allows highlighting the sensing of ventricular depolarization by the atrial lead. A repositioning of the atrial lead enabled the resumption of normal operation. The third tracing illustrates the value of the transmission of a periodic EGM enabling to make the diagnosis in this asymptomatic patient. One of the interesting features of the Biotronik™ devices is to approximate, during this periodic EGM, what is actually

performed during the consultation, with transmission of a real-time EGM without modification of the programming (Normal), followed by transmission of an EGM with reduction in pacing rate in order to favor spontaneous activation and verify the quality of the sensing (Encouraged sensing), and lastly, transmission with an increase in pacing rate in order to favor pacing and verify the effective capture.

When an abnormal tracing is revealed in the immediate aftermath of implantation of a dual-chamber pacemaker, the diagnosis of lead dislodgement should be evoked when the functioning of a single lead appears abnormal. Inverting the 2 leads seems more likely when the lead connected to the atrial channel senses and/or paces the ventricle and the lead connected to the ventricular canal senses and/or paces the atrium.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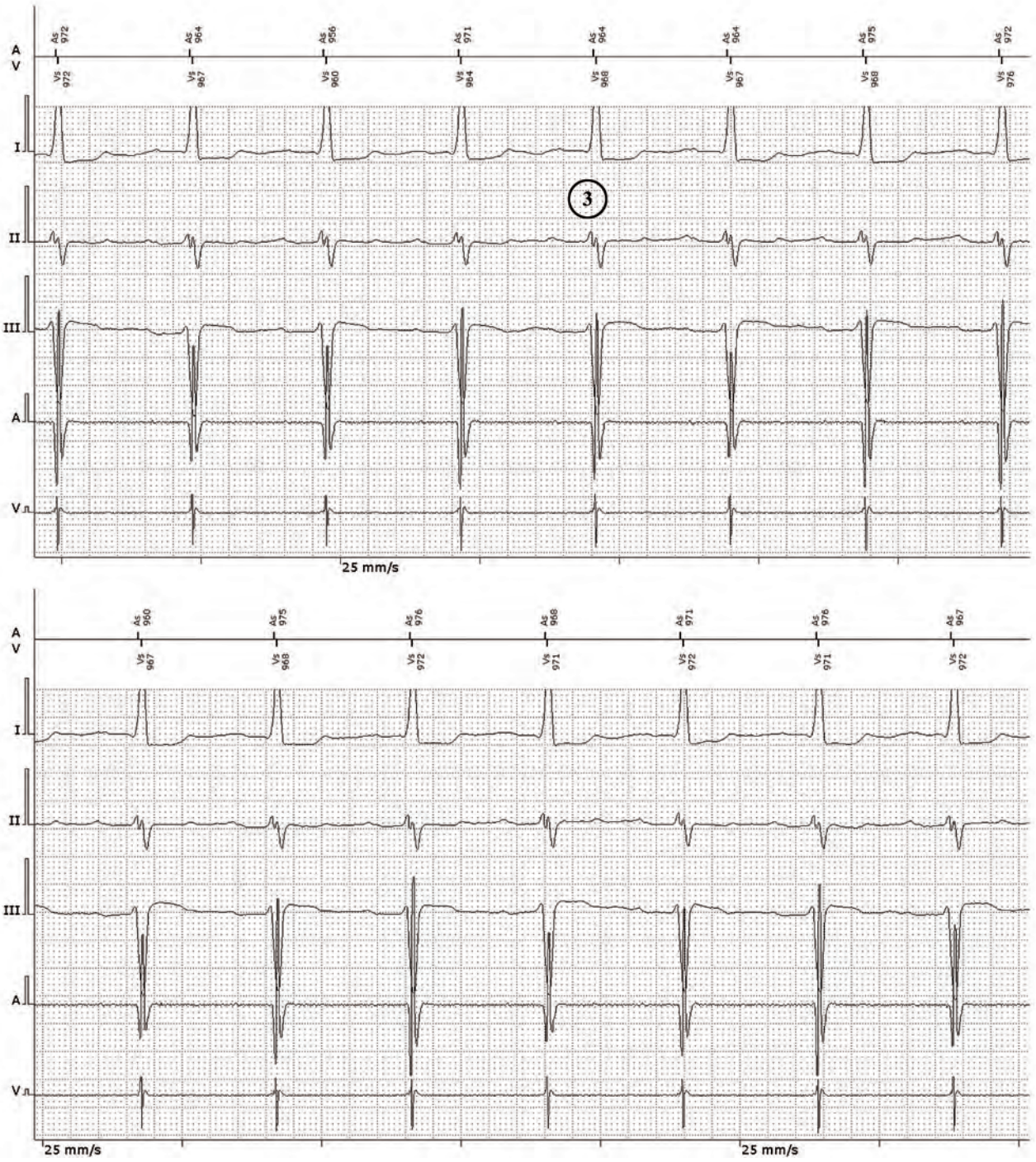
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Status report - Mar 14, 2016

BIOTRONIK excellence for life

Last message: Mar 15, 2016
Last clinic follow-up: Nov 13, 2015

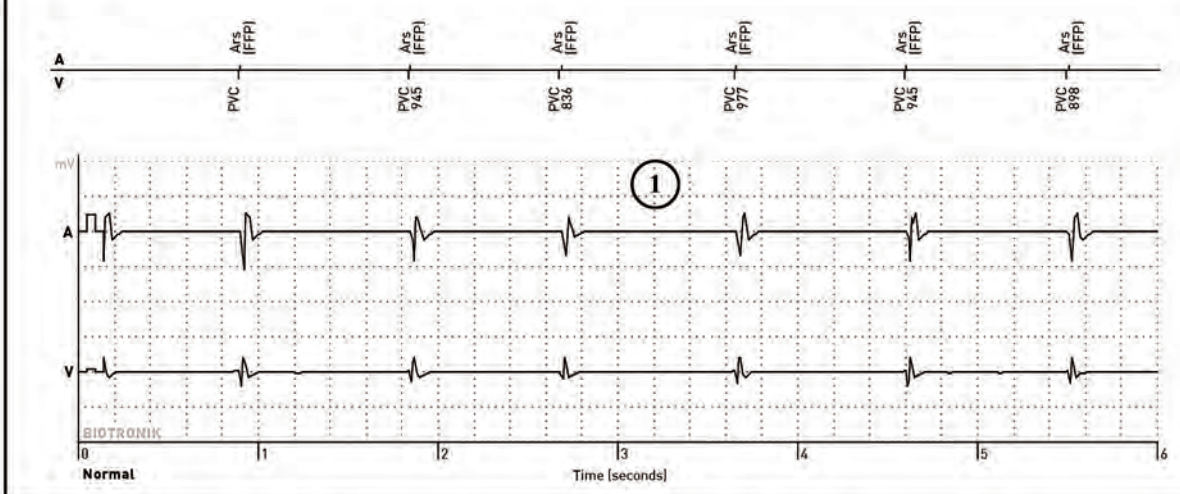
Phone: -

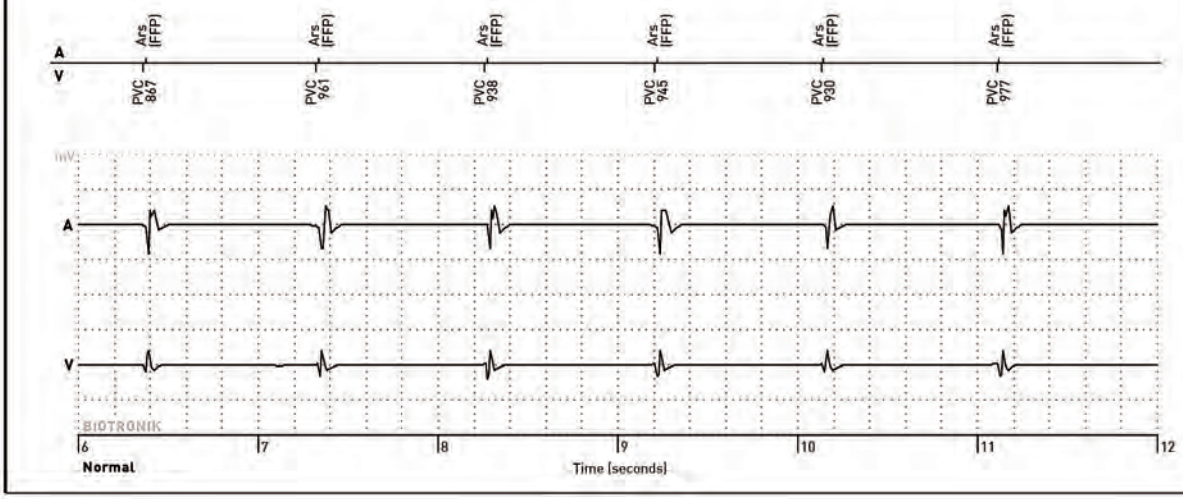
Recordings

Recordings - Episode 2:

General	
Episode number	2
Episode type	Periodic IEGM
Recorded on	Dec 21, 2014 12:40:00 AM

IEGM



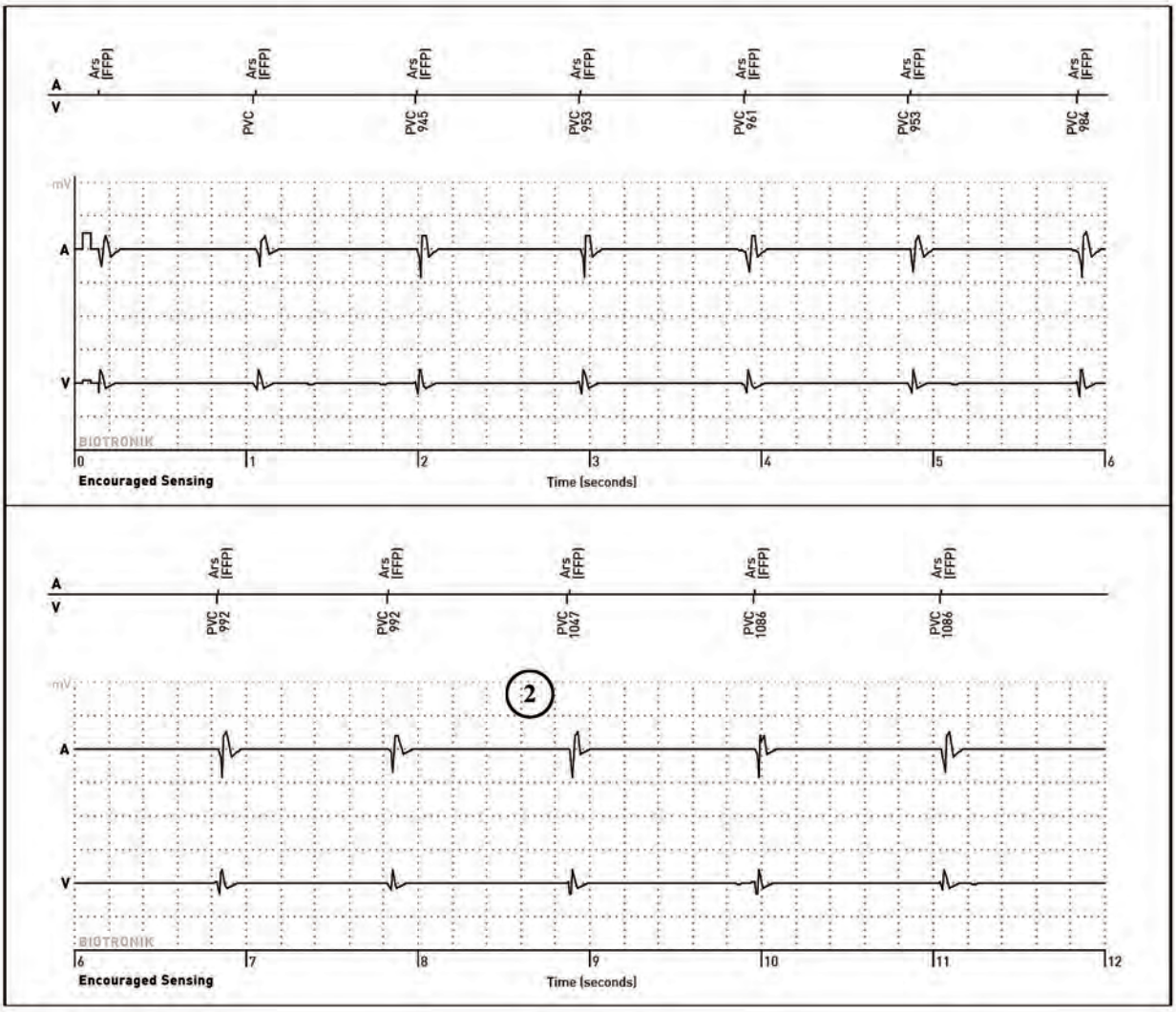


Status report - Mar 14, 2016

BIOTRONIK
excellence for life

Last message: Mar 15, 2016
Last clinic follow-up: Nov 13, 2015

Phone: -



Status report - Mar 14, 2016

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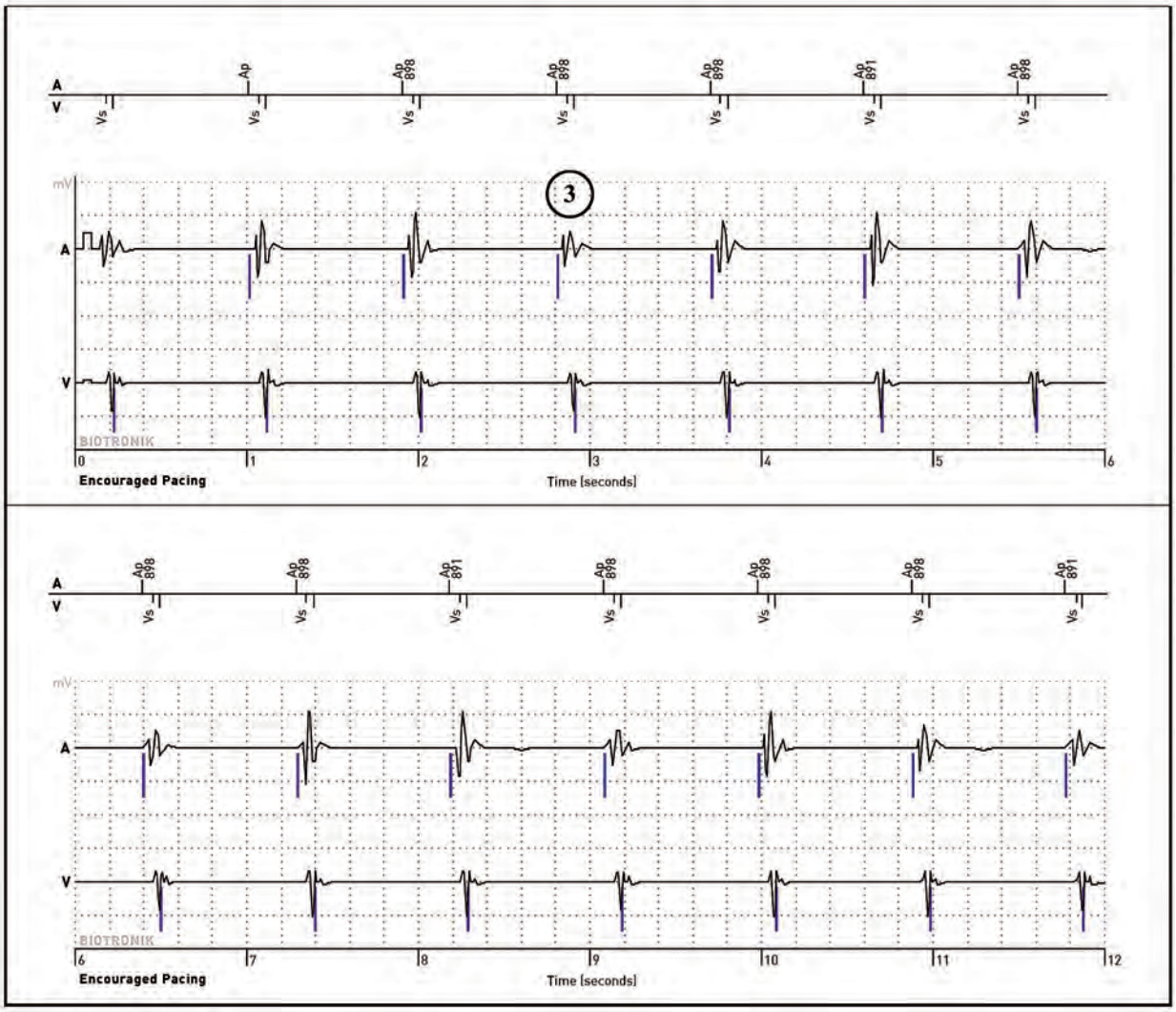
Phone: -

Last message: Mar 15, 2016
Last clinic follow-up: Nov 13, 2015



Tracing 18 ↘ Atrial pacing failure

Patient

81-year-old man implanted with an Evia DR-T dual-chamber pacemaker for complete atrioventricular block; interrogation of the pacemaker 1 year after implantation.

Tracing

① ineffective atrial pacing with effective ventricular pacing;

② sensing of spontaneous sinus activity outside of the refractory periods leading to an AV delay and ventricular pacing;

③ ineffective atrial pacing and sinus activity falling within the post-atrial atrial blanking, therefore unsensed;

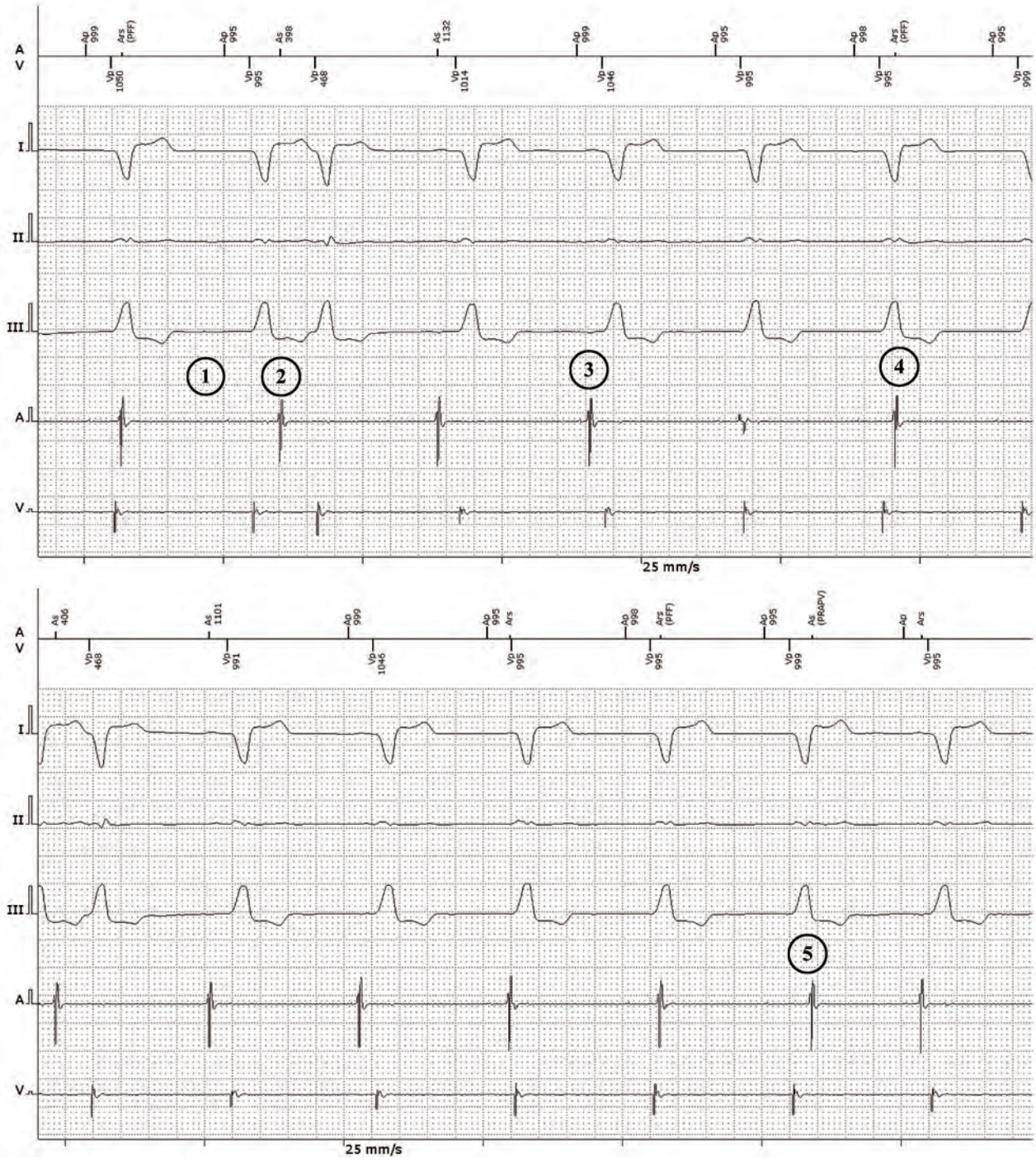
④ ineffective atrial pacing and sinus activity falling within the far-field protection period;

⑤ ineffective atrial pacing and sinus activity falling within the PVARP.

Comments

The pacing threshold corresponds to the smallest electrical pulse, delivered outside of all the natural refractory periods, capable of generating the propagation of a depolarization wave. It can be measured in voltage (Volts) or in pulse width (milliseconds). The determination of the pacing threshold is of major importance since the programming of the voltage and duration of the pulse ultimately conditions the safety margin and determines the energy consumption of the prosthesis and therefore the speed of battery wear. It is generally recommended to set a safety margin of 100% which corresponds to a double threshold voltage. This margin of safety is intended to take into account the circadian variations of the pacing threshold, the latter of which are variably influenced, from one subject to another, by sleep, meal intake, physical activity, fever, etc.

This tracing reveals atrial capture failure. The atrial output amplitude was programmed in this patient at 3 Volts for a pulse duration of 0.4 ms. Without any obvious identifiable cause (no lead macro-dislodgement, no metabolic disorder), the pacing threshold had passed beyond this value (threshold at 3.5 Volts for 0.4 ms). Sensing remained appropriate (> 1.5 mV) and pacing impedance normal (470 Ohms). The temporary increase in output amplitude at 4 volts for 0.4 ms solved the problem. In a second phase, the pacing threshold stabilized around 2 Volts for 0.4 ms allowing long-term programming at 3 Volts for 0.4 ms thereby ensuring an acceptable safety margin and energy consumption.


A
V
I
II
III
A
V
1
2
3
4
25 mm/s
5
25 mm/s

Tracing 19 ↘ Ventricular pacing failure

Patient

78-year-old man implanted with a Philos II DR-T dual-chamber pacemaker for syncopal complete atrioventricular block; chronic renal failure patient on dialysis; consulting for several episodes of syncope.

Tracing 19a

① atrial sensing and ventricular pacing with capture;

② atrial sensing and ineffective ventricular pacing.

Patient

59-year-old man implanted with an Evia DR-T dual-chamber pacemaker for syncope due to sinus dysfunction; routine follow-up control.

Tracing 19b

③ effective atrial pacing and ineffective ventricular pacing without capture; unsensed spontaneous ventricular activity since falling within the post-ventricular ventricular refractory period (no possibility of assessing the quality of ventricular sensing on this tracing).

Patient

61-year-old man, implanted with an Evia DR-T dual-chamber pacemaker for syncope due to paroxysmal atrioventricular block; consulting for repeated lipothymias.

Tracing 19c

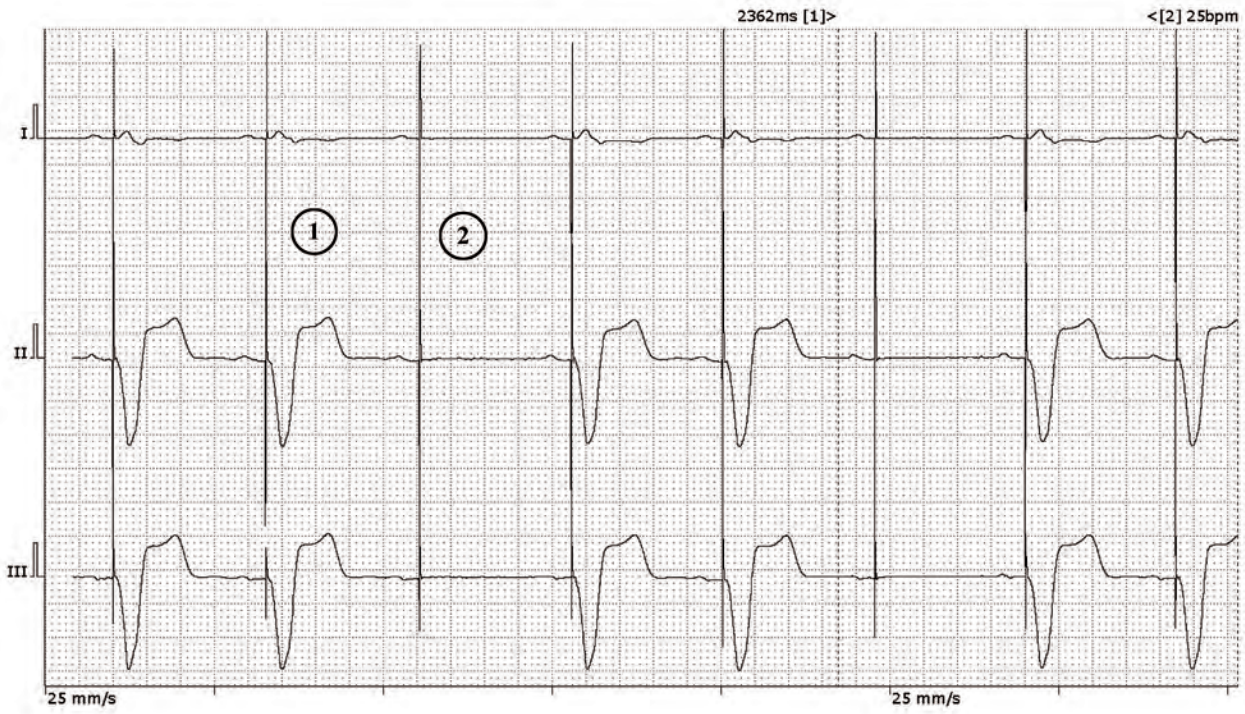
④ atrial sensing and ventricular sensing (AS-VS);

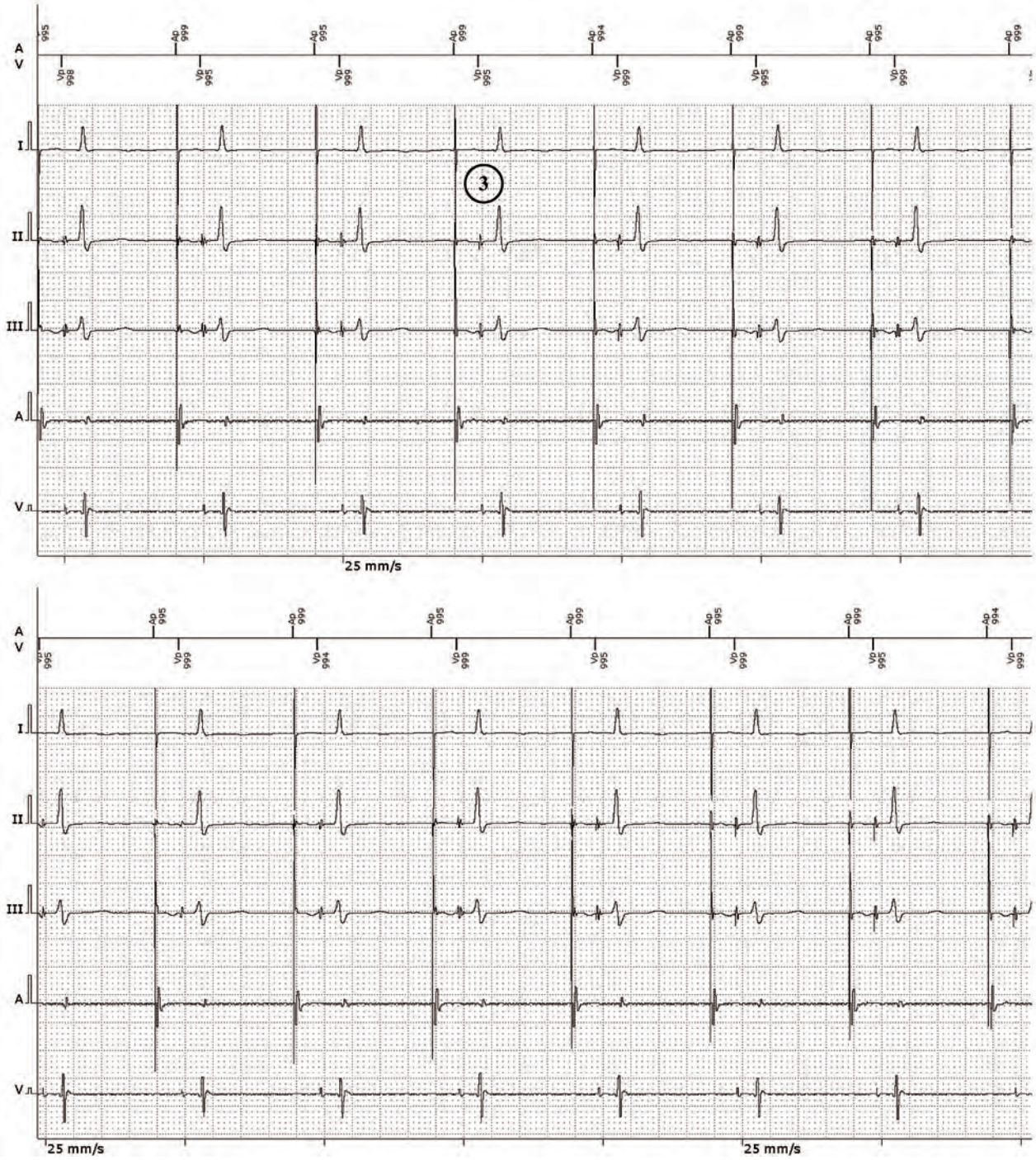
⑤ blocked P wave, ineffective ventricular pacing without capture.

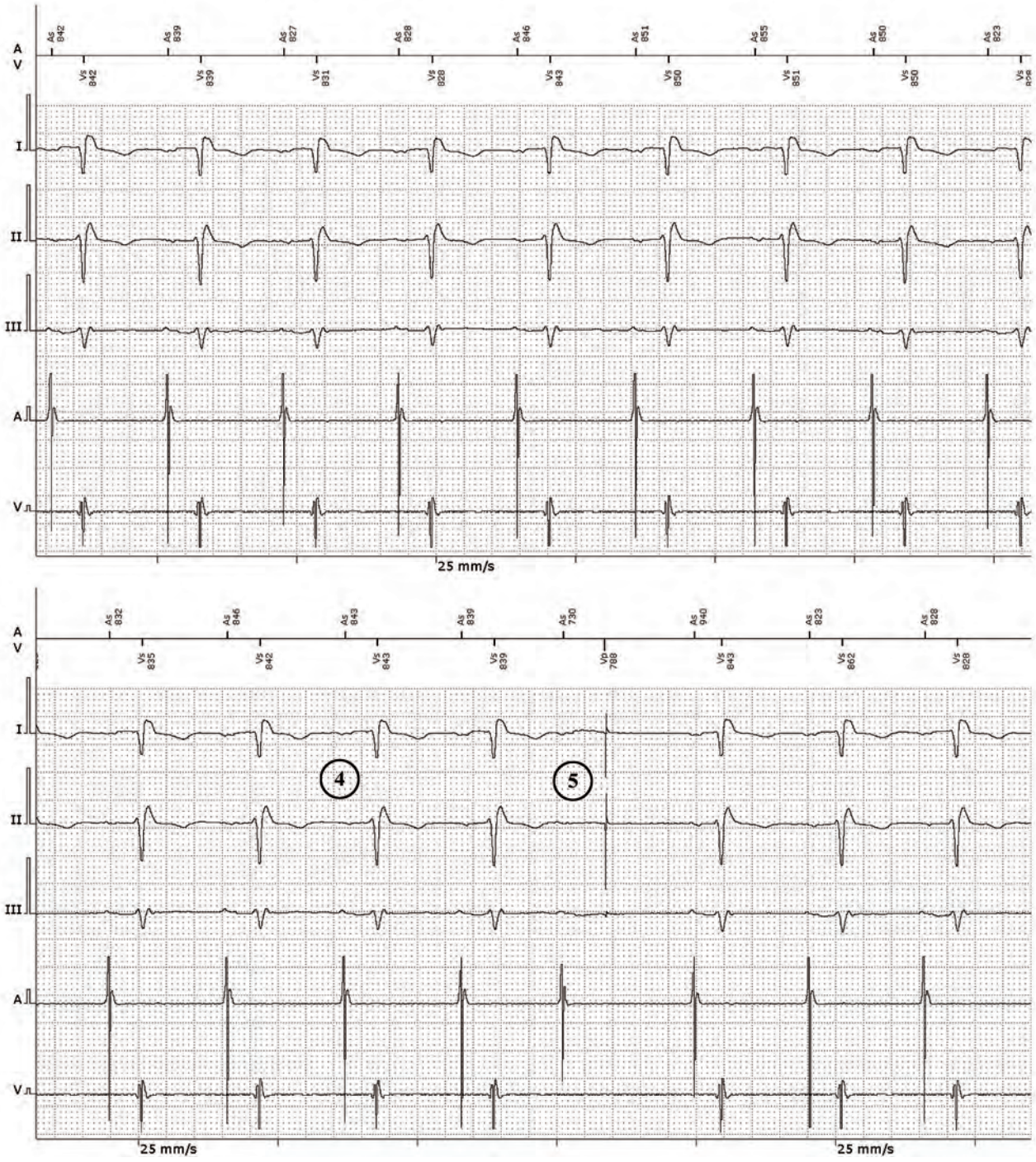
Comments

These tracings highlight a loss of permanent or intermittent ventricular capture in patients implanted with a dual-chamber pacemaker. Consequences vary according to the underlying rhythm of the patient. In the first pacemaker-dependent patient with complete atrioventricular block, an intermittent loss of capture (rise in threshold in a dialyzed patient) is associated with the occurrence of syncope and a high risk of sudden death. In the second patient with preserved atrioventricular conduction (implanted for sinus dysfunction), a permanent loss of capture does not cause symptoms. Finally, in the last patient with paroxysmal second-degree atrioventricular block, the loss of ventricular capture is associated with the occurrence of 1- to 2-second pauses due to blocked P wave and responsible for the described lipothymias.

In the presence of a rise in threshold, the question of whether to program the automatic adjustment of pacing output arises. It is therefore important to be completely familiar with the operation of this algorithm and in particular the maximum amplitude that can be delivered in this setting. Indeed, there is a delivered upper limit that does not correspond to the maximum capacities of the device so as to avoid a premature wear of the batteries in the event of algorithm dysfunction. The programming of the automatic amplitude adjustment is therefore not adjusted when the threshold is very high.


2362ms [1]>
<[2] 25bpm
I
II
III
1
2
25 mm/s
25 mm/s


A
V
I
II
III
A
V
3
25 mm/s
25 mm/s
25 mm/s


A
V
I
II
III
A
V
25 mm/s
4
5
25 mm/s
25 mm/s

Tracing 20 ↘ Automatic right ventricular threshold measurement

Patient

69-year-old man implanted with an Evia DR-T dual-chamber pacemaker for paroxysmal atrioventricular block; during the consultation, automatic right ventricular threshold measurement.

Tracing 20a

① first phase of the signal quality check with capture assessment; for 5 consecutive cycles, a single ventricular pulse is delivered (an emergency pacing is delivered only in the absence of capture); the AV delay is shortened (15 ms for spontaneous atrial activity as in this patient or 50 ms for paced atrial activity) to ensure complete ventricular capture; the starting amplitude of this test is programmable; the first of these cycles is ignored to allow stabilization of the signal at the new pacing amplitude; the evoked control response of the capture is assessed over the next 4 cycles;

② second phase of the signal quality check; for 5 consecutive cycles, 2 consecutive ventricular pulses with a 100 ms delay are delivered; the first allows an effective capture, the second is delivered in the absolute refractory period to assess the polarization artifact in the absence of capture; these two successive phases allow differentiating between capture and non-capture, an imperative prerequisite for carrying out an automatic threshold measurement; if a single non-capture is found during the first phase or if the polarization signal is too strong, the validation step of signal quality is not verified and the automatic threshold measurement cannot be performed;

③ once the quality of the signal is verified, the threshold measurement begins with a successive decrease in pacing amplitude in decremental 0.6 V steps as long as no loss of capture is diagnosed; the AV delay remains short to ensure complete capture;

④ if no loss of capture is diagnosed at 0.6 V, the pacing amplitude is decreased with a 0.1 V step;

⑤ the tracing shows a loss of capture on the first pulse at 0.5 V; a second pacing is delivered 100 ms after the first pulse at an amplitude of 0.6 V (0.1 V above the tested amplitude with a pulse duration of 1 ms); in this patient, both pulses at 0.5 V are ineffective, the threshold is therefore determined at 0.6 V and the threshold measurement stops.

Patient

74-year-old woman implanted with an Evia DR-T dual-chamber pacemaker for complete atrioventricular block; during the consultation, automatic right ventricular threshold measurement.

Tracing 20b

① first phase of the signal quality check with capture assessment; for 5 consecutive cycles, a single ventricular pulse is delivered (the first of which is not visualized on this tracing); the AV delay is shortened to 50 ms since atrial activity is paced; the starting amplitude of this test is programmed to 3 V (nominal value);

② second phase of the signal quality check (5 cycles with double ventricular pacing);

③ once the quality of the signal is verified, the threshold measurement begins with a successive decrease in pacing amplitude in decremental 0.6 V steps as long as no loss of capture is diagnosed;

④ loss of capture diagnosed at 0.6 V over 2 consecutive cycles;

⑤ the pacing amplitude thus returns to the last value allowing a capture (1.2 V in this instance);

⑥ the pacing amplitude is decreased with a 0.1 V step;

⑦ in this patient, both pulses at 0.9 V are ineffective, the threshold is therefore determined at 1 V and the threshold measurement stops.

Comments

In all modern pacemakers, it is now possible to program an automatic ventricular threshold measurement function more or less associated with an automatic adjustment of the pacing amplitude.

When the ventricular capture control is programmed to OFF, the thresholds are not automatically measured by the device. When the ventricular capture control is programmed to ON, automatic measurement of the ventricular pacing threshold is followed by an adjustment of the pacing amplitude with cycle-to-cycle control of capture efficiency. The principle of the threshold measurement is to determine the minimum amplitude allowing an effective capture with an accuracy of 0.1 V. When the ventricular capture control is programmed to ATM, the device automatically measures the threshold value but without any possible adjustment of the pacing amplitude which remains fixed regardless of the measured value.

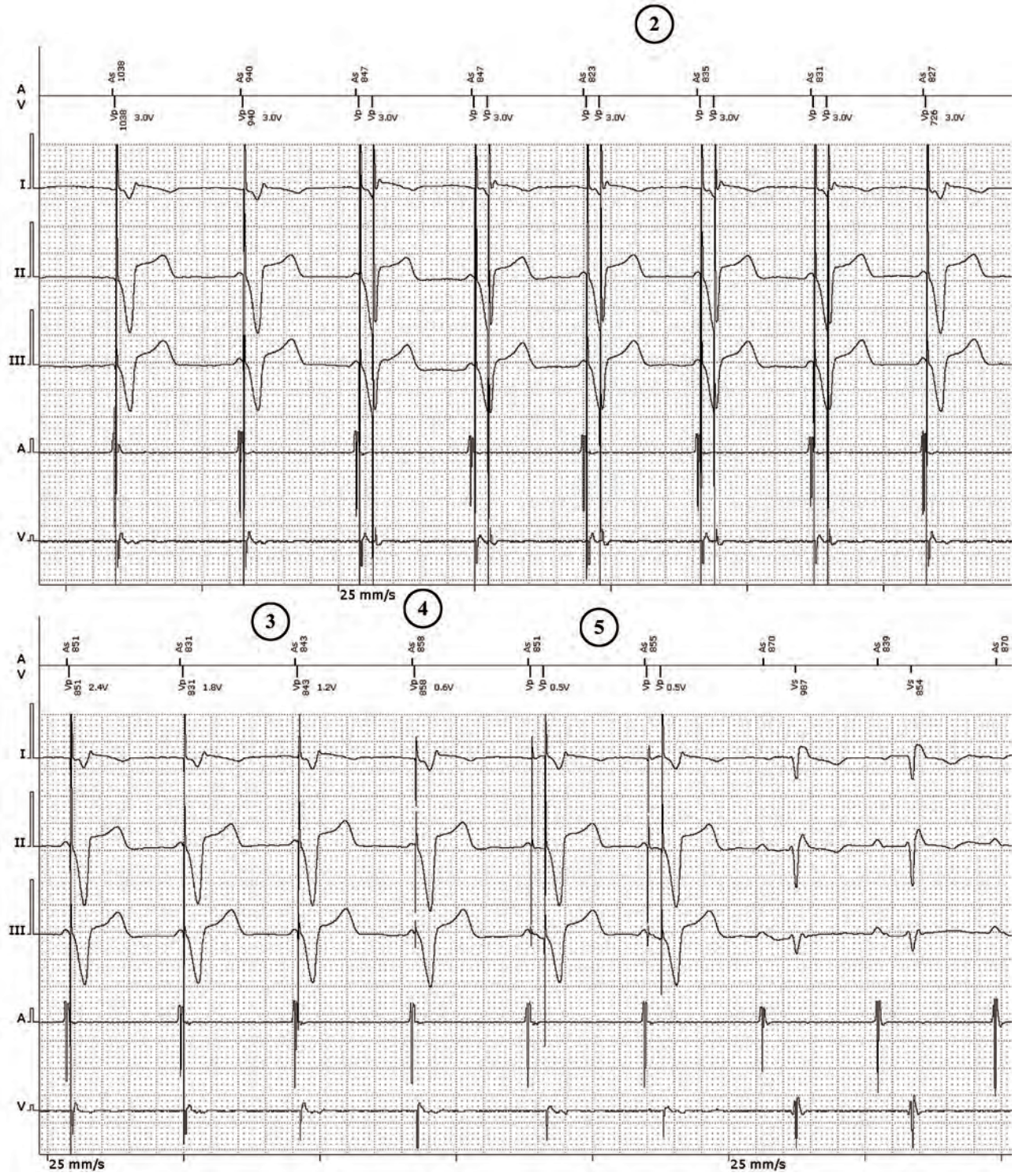
The scheduling of the automatic measurement and the frequency of the measurements are programmable.

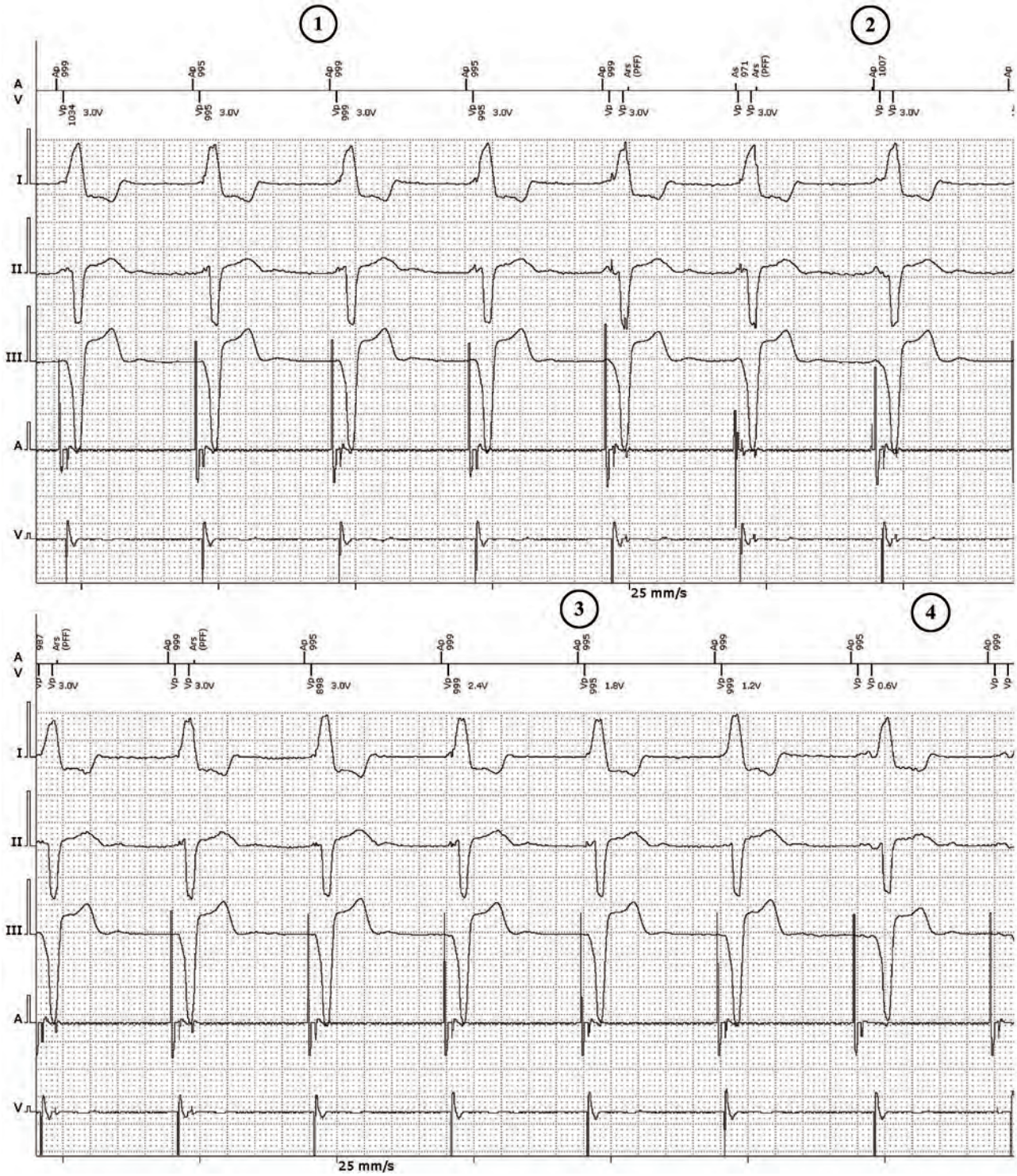
When the ventricular capture control is programmed to ON, there is therefore a cycle-to-cycle verification of the capture based on the analysis of the evoked response. A safety margin with respect to the threshold measurement is programmable (nominal value 0.5 V). This programming option is only possible if the pulse duration is programmed to 0.4 ms or less; indeed, if a loss of capture is found, a safety pulse is delivered by increasing the pulse duration; hence, a sufficient margin is required.

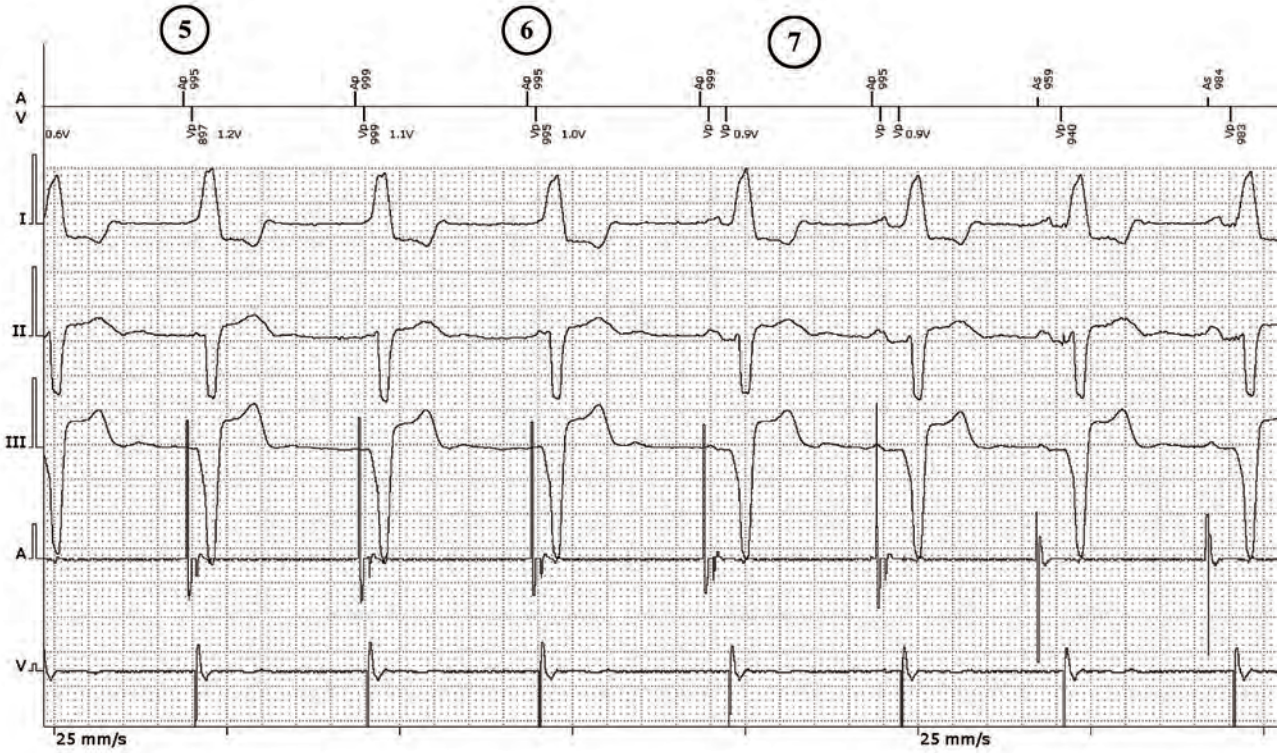
Another key element to be aware of is that the maximum amplitude that can be delivered is 4.8 V for 0.4 ms, thus well below the maximum capacities. This programming option must therefore be avoided when the pacing threshold is very high.

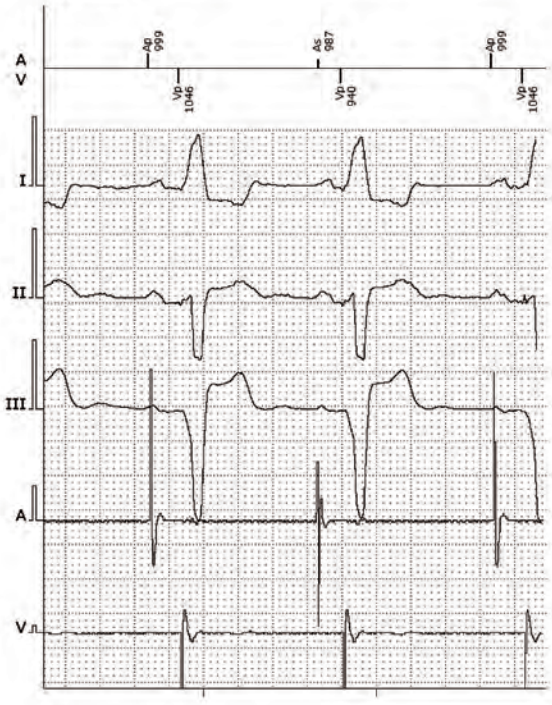
Various parameters are thus programmable: 1) the starting amplitude which corresponds to the starting value of the threshold measurement; the nominal value is 3 V (programmable from 2.4 to 4.8 V); 2) the safety margin which corresponds to the amplitude value added to the threshold measurement; the nominal value is 0.5 V (programmable from 0.3 to 1.2 V); it should be noted that irrespective of the threshold value and the safety margin, the pacing amplitude cannot fall below 0.7 V; 3) the timing of the search and search interval, which correspond to the time when the threshold is systematically measured, even in the absence of loss of capture detection by the device, and the interval between each minimum search.


A
V
I
II
III
A
V
25 mm/s
25 mm/s
1
3.0V
3.0V
3.0V
25 mm/s


2
A
V
I
II
III
A
V
25 mm/s
3
4
5
25 mm/s
25 mm/s


1
2
3
4
A
V
I
II
III
A
V
25 mm/s
25 mm/s


5
6
7
A
V
I
II
III
A
V
25 mm/s
25 mm/s


A
V
I
II
III
A
V

Tracing 21 ↘ Automatic atrial threshold measurement

Patient

77-year-old man implanted with an Evia DR-T dual-chamber pacemaker for syncope with left bundle branch block; during the consultation, automatic right atrial threshold measurement.

Tracing 21a: manual measurement of the right atrial threshold

① pacing in the AAI mode with capture verification by the presence of ventricular conduction; 0.1 V step over 2 cycles; effective capture;

② loss of capture at 0.3 V (threshold measured at 0.4 V);

Tracing 21b: automatic measurement of the right atrial threshold

① the threshold measurement is carried out in DDI mode (no ventricular trigger of spontaneous atrial activities and therefore no risk of PMT) at a rate 20% higher than the spontaneous rate (in order to favor atrial pacing) with a short AV delay of 50 ms and a post-ventricular atrial blanking of 150 ms (compromise in order to avoid crosstalk and to favor atrial sensing indicating loss of atrial capture); for each tested value, 5 pulses are delivered; the starting value is programmable (in this instance 3 V, nominal value); in the absence of atrial sensing, diagnosis of effective atrial capture;

② reduction of pacing amplitude in decremental 0.6 V steps (in each instance, 5 pulse tests);

③ for an amplitude of 0.6 V, persistence of the capture (absence of sensing of spontaneous atrial activity);

④ prior to decreasing the amplitude, atrial synchronous pacing delivered at the end of each series of 5 pulses; this atrial pacing is of an amplitude greater than 0.5 V relative to the previous tested amplitude;

⑤ reduction of amplitude in decremental 0.1 V steps with capture at 0.3 V;

⑥ new atrial synchronous pacing;

⑦ loss of capture diagnosed upon the presence of spontaneous atrial activity (traced line on the atrial markers line);

⑧ after 2 consecutive losses of capture, synchronous pacing;

⑨ to verify this threshold measurement: first step, 5 pulses at an amplitude above 0.3 V relative to the threshold value; in this instance, 0.7 V since threshold measured at 0.4 V (last effective value); with this margin, capture is effective;

⑩ second step, 5 pulses at an amplitude under 0.3 V relative to the threshold value; in this instance, 0.1 V since threshold measured at 0.4 V (last effective value); with this margin, the absence of capture is verified;

⑪ last synchronization pacing (the objective is to avoid the occurrence of a PMT).

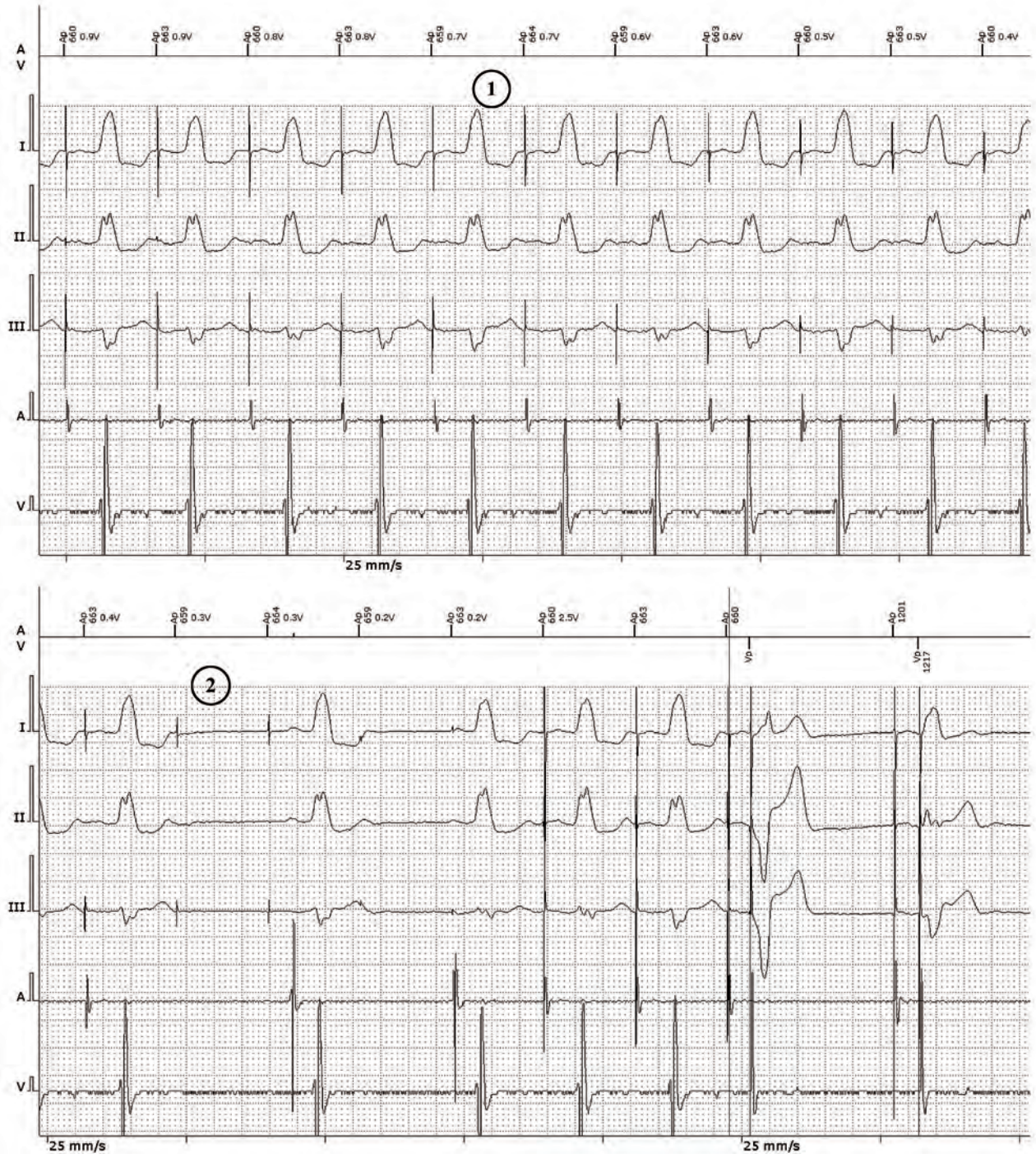
Comments

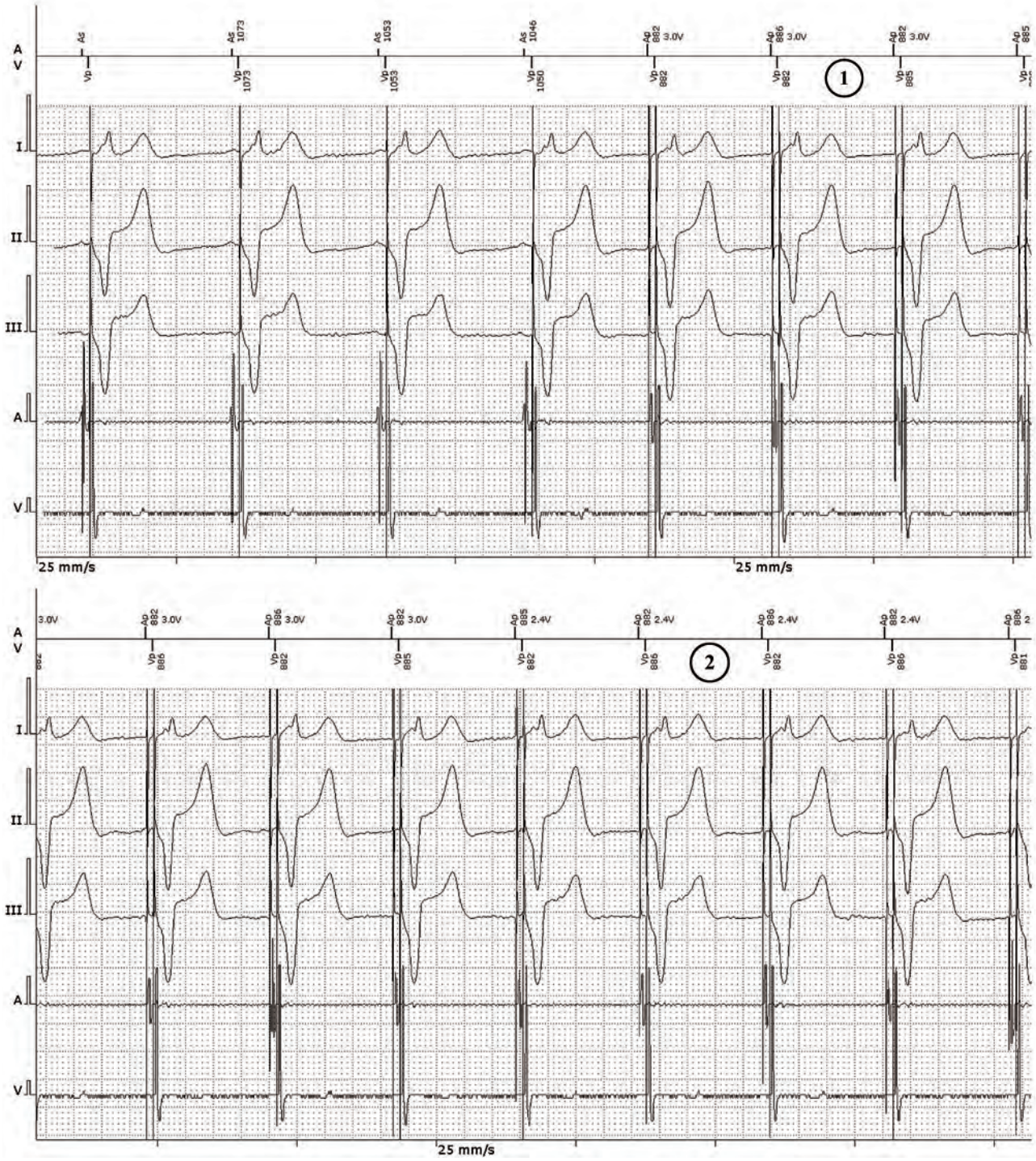
In this patient, the measurement of the automatic atrial threshold reveals the same value as that performed by the physician, thus validating the proper functioning of the automatic threshold measurement algorithm. The functioning of the automatic atrial threshold measurement and the ensuing amplitude adjustment have many similarities with the control of ventricular capture but also certain differences. The automatic control of atrial capture is not based on the analysis of the evoked atrial response but on the presence of sensed atrial signals indicative of loss of capture: resumption of intrinsic rhythm or retrograde conduction if the patient is dependent on the atrium (sinus dysfunction). This measurement cannot therefore be performed in patients with major sinus dysfunction and with no retrograde conduction. The combination of a short AV delay and a short post-ventricular atrial blanking allows optimizing the atrial sensing window while reducing the risk

of crosstalk which can distort the measurement. The atrial threshold test procedure generally lasts longer (for an equal threshold value) than the ventricular threshold measurement.

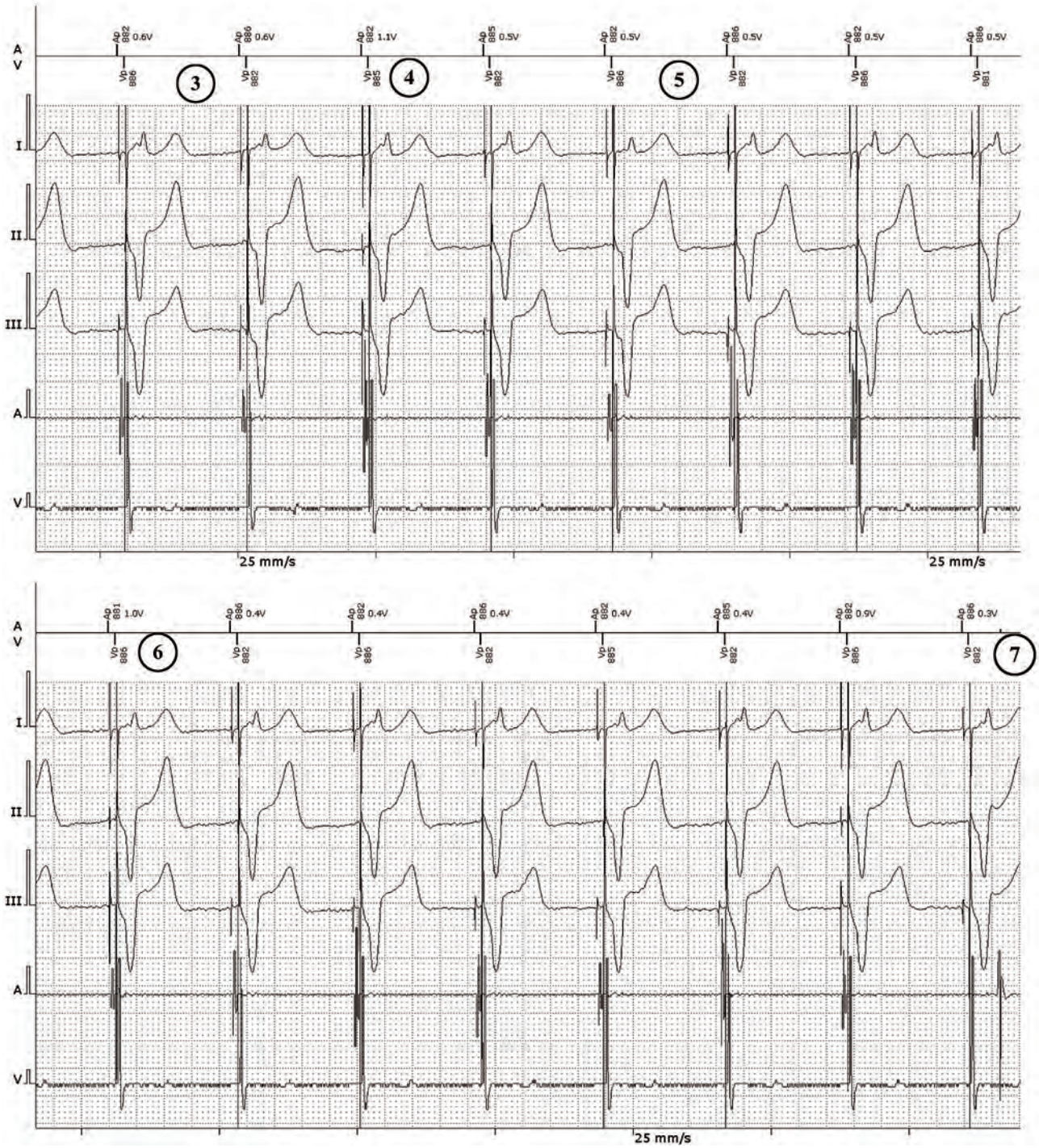
The programmable parameters remain the same (possibilities of ON, OFF and ATM) although certain nominal values differ: minimum amplitude (nominal value of 1 V), safety margin (nominal value of 1 V).

The principle of amplitude adjustment once the threshold is measured is fundamentally different since it is based on the Auto-threshold concept. The atrial threshold is measured one or several times a day (time of measurement and number of measurements per day are programmable). There is then no cycle-to-cycle verification of capture efficiency although the amplitude is adjusted until the next measurement (fixed amplitude between 2 threshold measurements). This explains why the programmed safety margin is greater (adjustment to circadian threshold variations) than the automatic ventricular adjustment.


1
2
I
II
III
A
V
25 mm/s
25 mm/s
25 mm/s


A
V
I
II
III
A
V
25 mm/s
25 mm/s
1
2
25 mm/s


A
V
I
II
III
A
V
25 mm/s
25 mm/s
25 mm/s


A
V
Ap 882 0.6V
Vp 886
3
Ap 886 0.6V
Vp 882
Ap 882 1.1V
Vp 885
4
Ap 885 0.5V
Vp 882
Ap 882 0.5V
Vp 886
5
Ap 886 0.5V
Vp 882
Ap 882 0.5V
Vp 886
Ap 886 0.5V
Vp 881
I
II
III
A
V
25 mm/s
25 mm/s
Ap 881 1.0V
Vp 886
6
Ap 886 0.4V
Vp 882
Ap 882 0.4V
Vp 886
Ap 886 0.4V
Vp 882
Ap 882 0.4V
Vp 885
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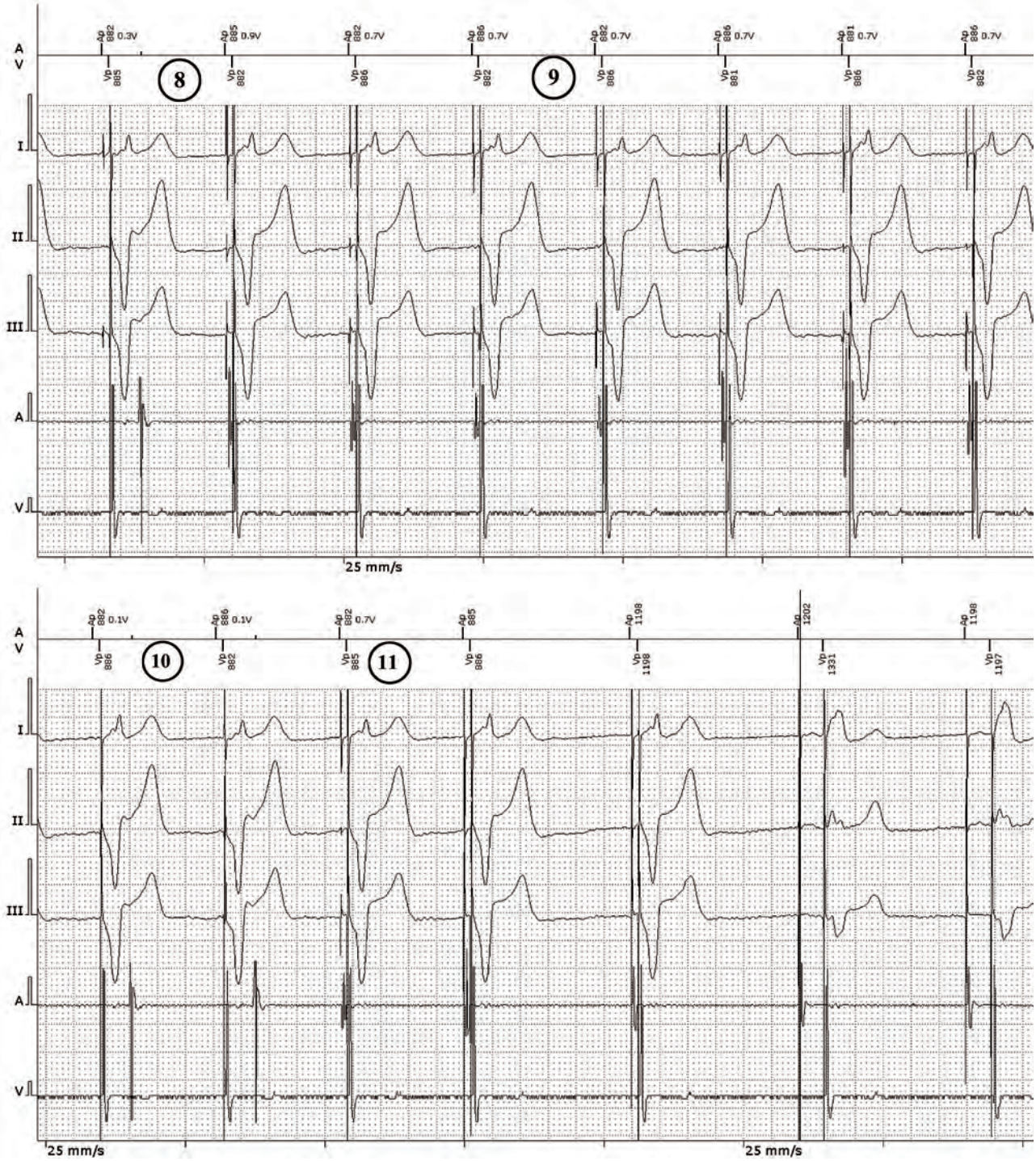
Vp 882
Ap 882 0.9V
Vp 886
Ap 886 0.3V
Vp 882
7
25 mm/s


A
V
I
II
III
A
V
8
9
10
11
25 mm/s
25 mm/s
25 mm/s

Implantable Cardiac Pacemaker - chapter 4

Sensing

Tracing 22 ↘ Ventricular sensing failure

Patient

84-year-old man implanted with a Biotronik Cyclos DR pacemaker for atrial disease; asymptomatic, routine visit.

Tracing 22a

① atrial sensing and ventricular pacing with possible fusion with spontaneous rhythm;
② unsensed PVC (no marker);
③ atrial sensing and ventricular pacing in the post-PVC T wave (vulnerable period) without effective capture;
④ atrial sensing and ventricular pacing with possible fusion with spontaneous rhythm;
⑤ unsensed PVC (no marker);
⑥ atrial sensing and ventricular pacing in the post-PVC T wave (vulnerable period) with effective ventricular capture and arrhythmogenic risk;

Tracing 22b

Ventricular sensing test (VVI 40 bpm);

⑦ proper ventricular sensing of the conducted ventricular activity (pattern confirming the preceding fusion pattern);
⑧ sensed PVC;
⑨ unsensed PVC;

Tracing 22c

Programming change in ventricular sensitivity (pacemaker rendered more sensitive, lowering of the programmed sensitivity value);

⑩ proper sensing of PVC.

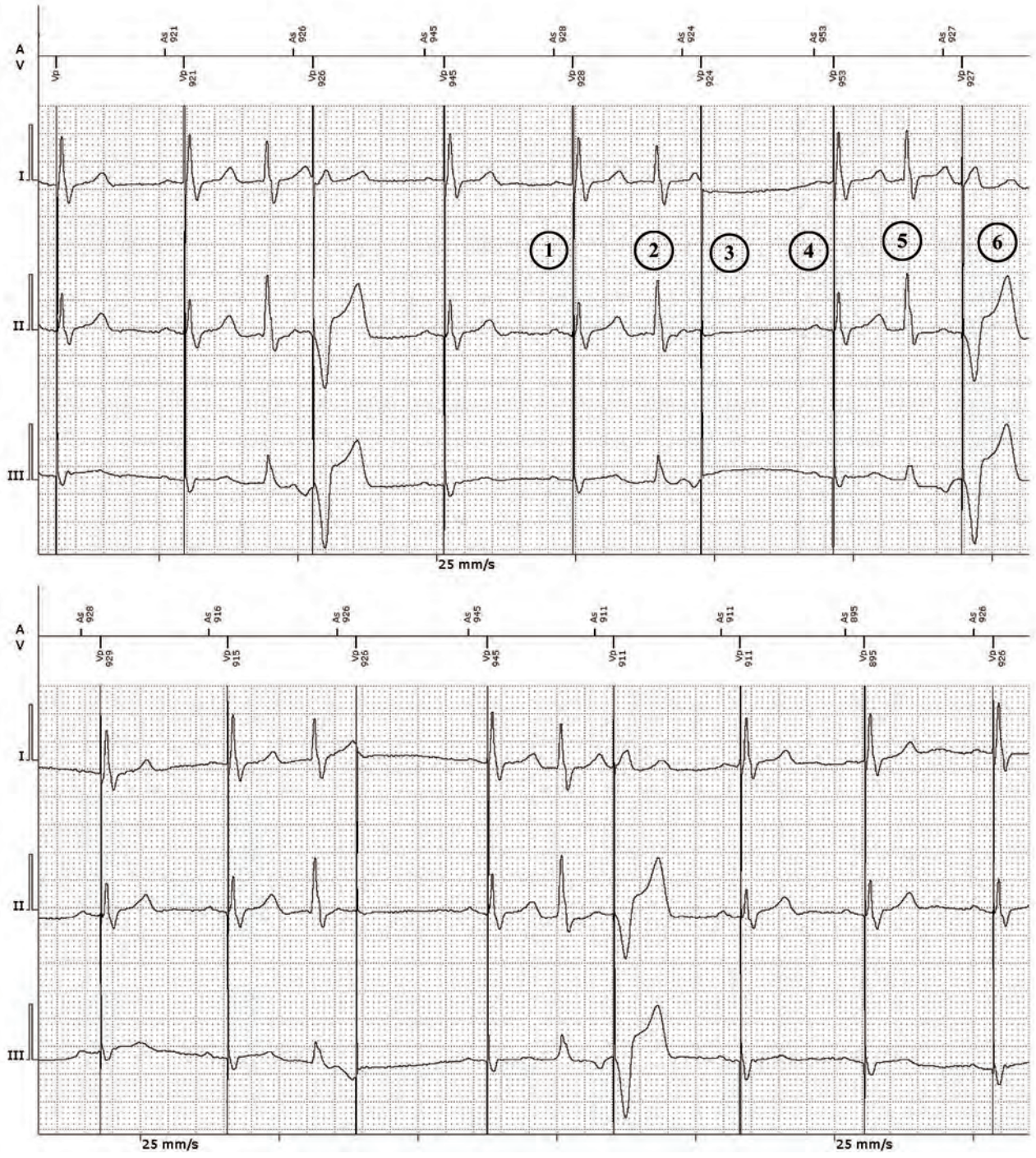
Comments

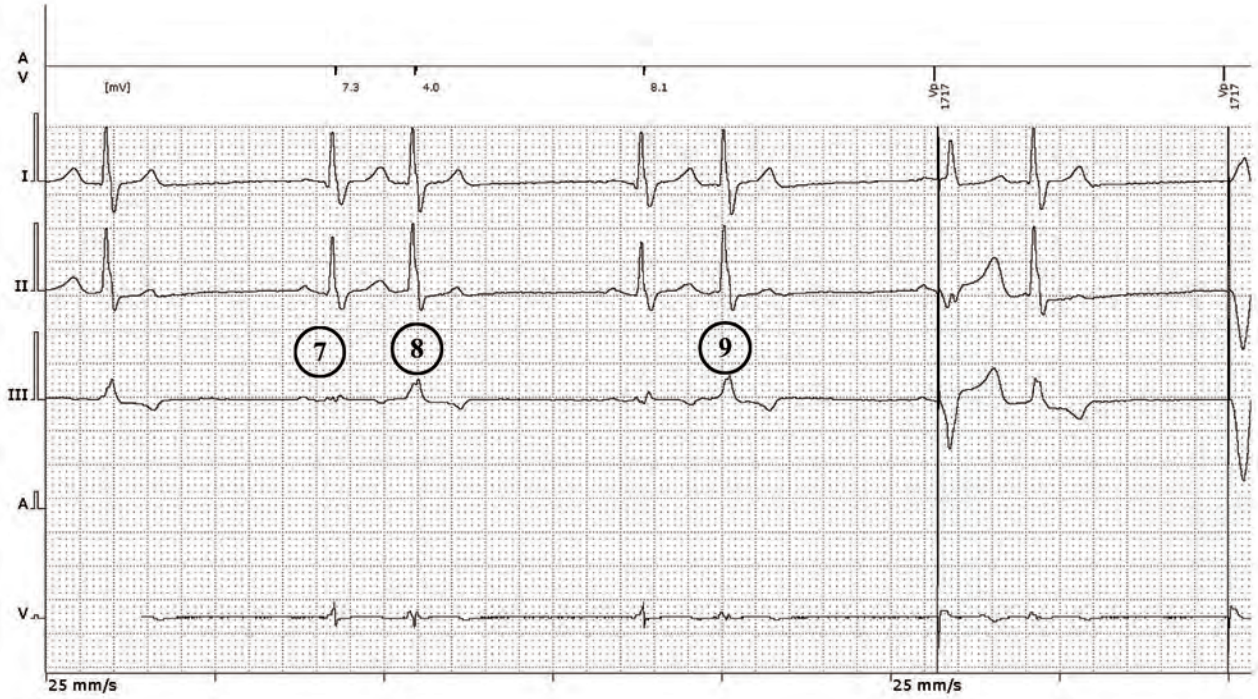
Device sensitivity expressed in millivolts (mV) qualifies the ability of the pacemaker to correctly sense spontaneous cardiac events. An adequate programming of the sensitivity level should detect all spontaneous cardiac events occurring in the implanted chamber while not detecting other events (crosstalk with sensing of cardiac signals from the other chamber, myopotentials, interference, etc). The programming of bipolar sensing allows increasing the specificity of the sensing relative to unipolar sensing by limiting the risk of sensing extracardiac signals or crosstalk while enabling the programming of high sensitivity values. Conversely, in the unipolar configuration, the risk of sensing extracardiac signals or crosstalk requires the programming of a lower sensitivity level with an increased risk of undersensing.

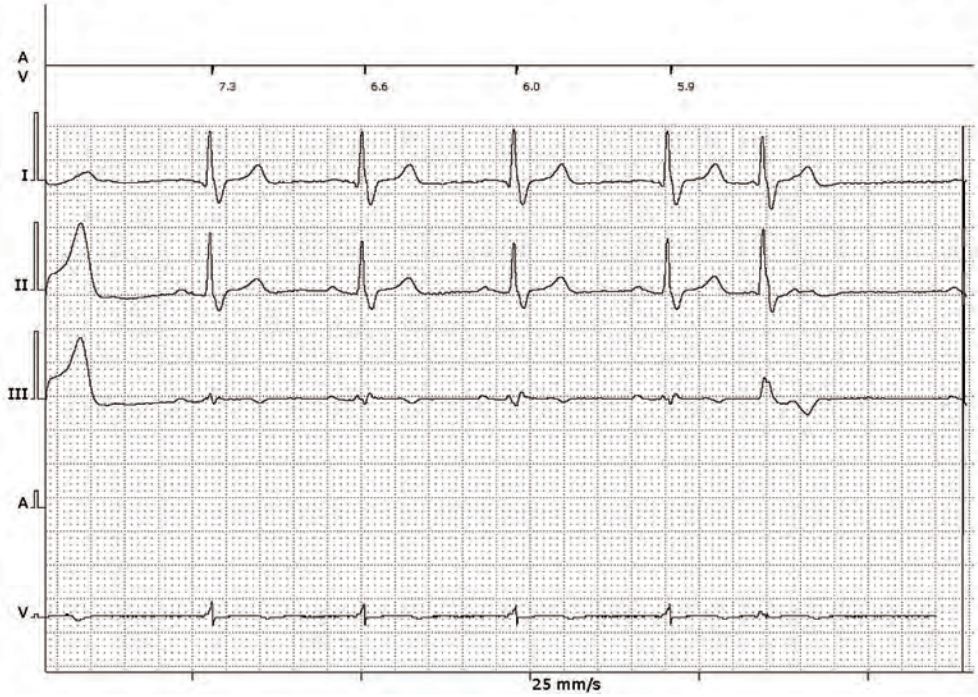
Traditionally, unlike implantable defibrillators, pacemakers operated with a stable and fixed sensitivity over the entire cardiac cycle. Nowadays, the various manufacturers offer in their range of devices a fusion between the operating platforms of both pacemakers and defibrillators. Although the sensing constraints differ (crucial need for a defibrillator to detect and treat very rapid, polymorphic and low-amplitude ventricular rhythm disorders), modern pacemakers allow the programming of an adaptive sensitivity (variable sensitivity level according to the amplitude of the sensed R wave or P wave) with a progressive increase in sensitivity during the cardiac cycle (possibility of detecting small amplitude signals without oversensing the T wave).

For Biotronik™ pacemakers, atrial and ventricular sensitivity can be programmed to either a fixed value or with automatic adjustment (automatic sensitivity control). The maximum automatic sensitivity is 2 mV for the ventricle (higher value than for a defibrillator), 0.2 mV for atrial bipolar sensing and 0.5 mV for atrial unipolar sensing. Following a pacing pulse, the maximum sensitivity is achieved after 360 ms in the atrium and 575 ms in the ventricle. When ventricular sensitivity is programmed to automatic, the maximum sensitivity value is therefore not programmable (2 mV non-modifiable value).

These tracings reveal an undersensing of PVC leading to pacing in the vulnerable period. The depolarization signal of an extrasystole is often fragmented, the slopes of its various components often being slower, with an increased risk of undersensing. In the absence of proper sensing, the pacemaker operates in asynchronous mode with no possible inhibition on spontaneous ventricular activities. There is a small but non-zero theoretical risk of inducing a malignant polymorphic ventricular arrhythmia compromising patient survival. In addition, this unnecessary and dangerous pacing leads to energy consumption detrimental to the lifespan of the device. Programming a more suitable fixed ventricular sensitivity allowed correcting the problem. The choice between automatic sensitivity and fixed sensitivity is sometimes difficult. Programming a fixed ventricular sensitivity of 1 or 2 mV renders the device more sensitive than programming to automatic sensitivity. In the presence of an oversensing or undersensing problem, the choice of the sensing method (fixed or adaptive) will primarily depend on the amplitude of the signals and the variability in amplitude of these signals.


A
V
I
II
III
1
2
3
4
5
6
25 mm/s
25 mm/s
25 mm/s


A
V
[mV]
7.3
4.0
8.1
Vp
1717
Vp
1717
I
II
III
A
V
7
8
9
25 mm/s
25 mm/s


A
V
7.3
6.6
6.0
5.9
I
II
III
A
V
25 mm/s


A
V
I
II
III
10
25 mm/s
25 mm/s
25 mm/s

Tracing 23 ↘ Ventricular sensing failure

Patient

54-year-old man, implanted with an Evia DR pacemaker for atrial disease; recording of a periodic EGM.

Tracing

① atrial sensing and ventricular sensing;

② ventricular sensing failure; operation in Vp suppression mode, no switching to DDD mode following a single blocked P wave;

③ second undersensed ventricular event;

④ no switching to DDD mode, the switching criterion having not been reached (3 blocked P waves out of 8).

Comments

This tracing also reveals one of the limitations of automatic sensing on Biotronik™ pacemakers. The maximum sensitivity value (2 mV) is not programmable and is not adjusted when ventricular events are of small amplitude, as in this patient (between 1.5 and 2.5 mV). It may therefore be necessary to program a fixed sensitivity with a higher sensitivity level (programmed sensitivity fixed at 1 mV for example). The recording of a periodic EGM can enable the diagnosis of dysfunctions that are not identifiable by the pacemaker such as an undersensing problem. The proper functioning of the various algorithms for preserving spontaneous conduction requires good quality atrial and ventricular sensing. This patient presented numerous inappropriate switching episodes related to this ventricular undersensing problem (false diagnosis of second-degree AV block, third-degree AV block or ventricular pause).

Status report - Mar 15, 2016

BIOTRONIK
excellence for life

Phone: 0607396217

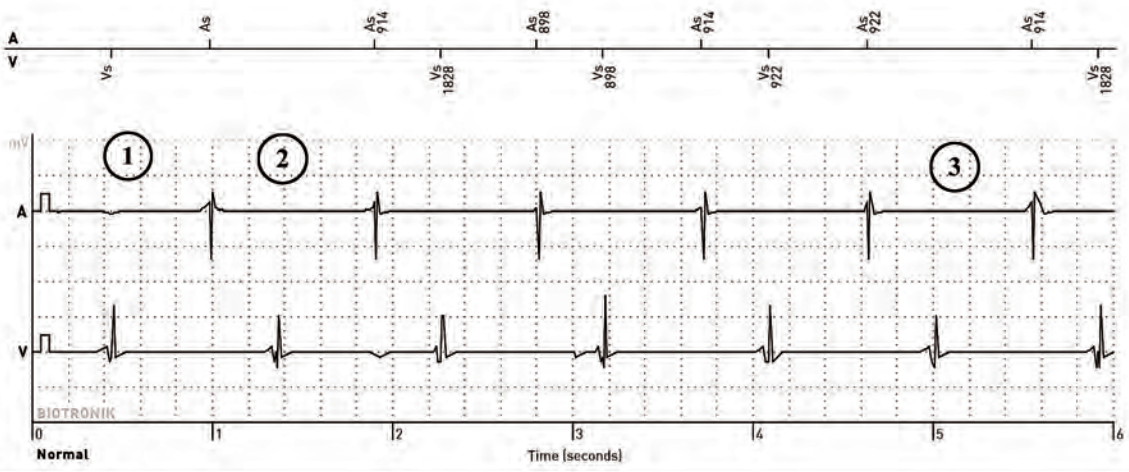
Last message: Mar 15, 2016
Last clinic follow-up: Nov 26, 2015

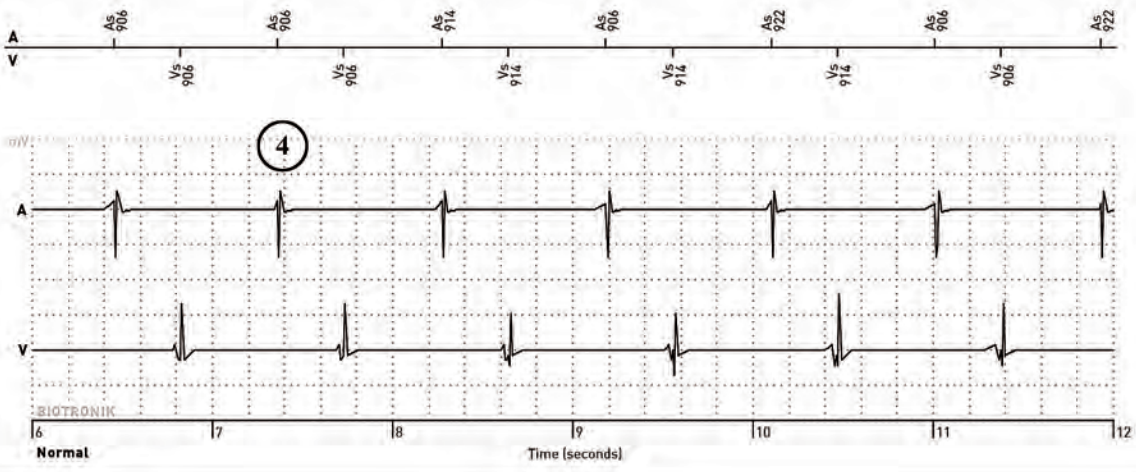
Recordings

Recordings - Episode 10:

General	
Episode number	10
Episode type	Periodic IEGM
Recorded on	Apr 17, 2014 12:39:00 AM

IEGM





Status report - Mar 15, 2016

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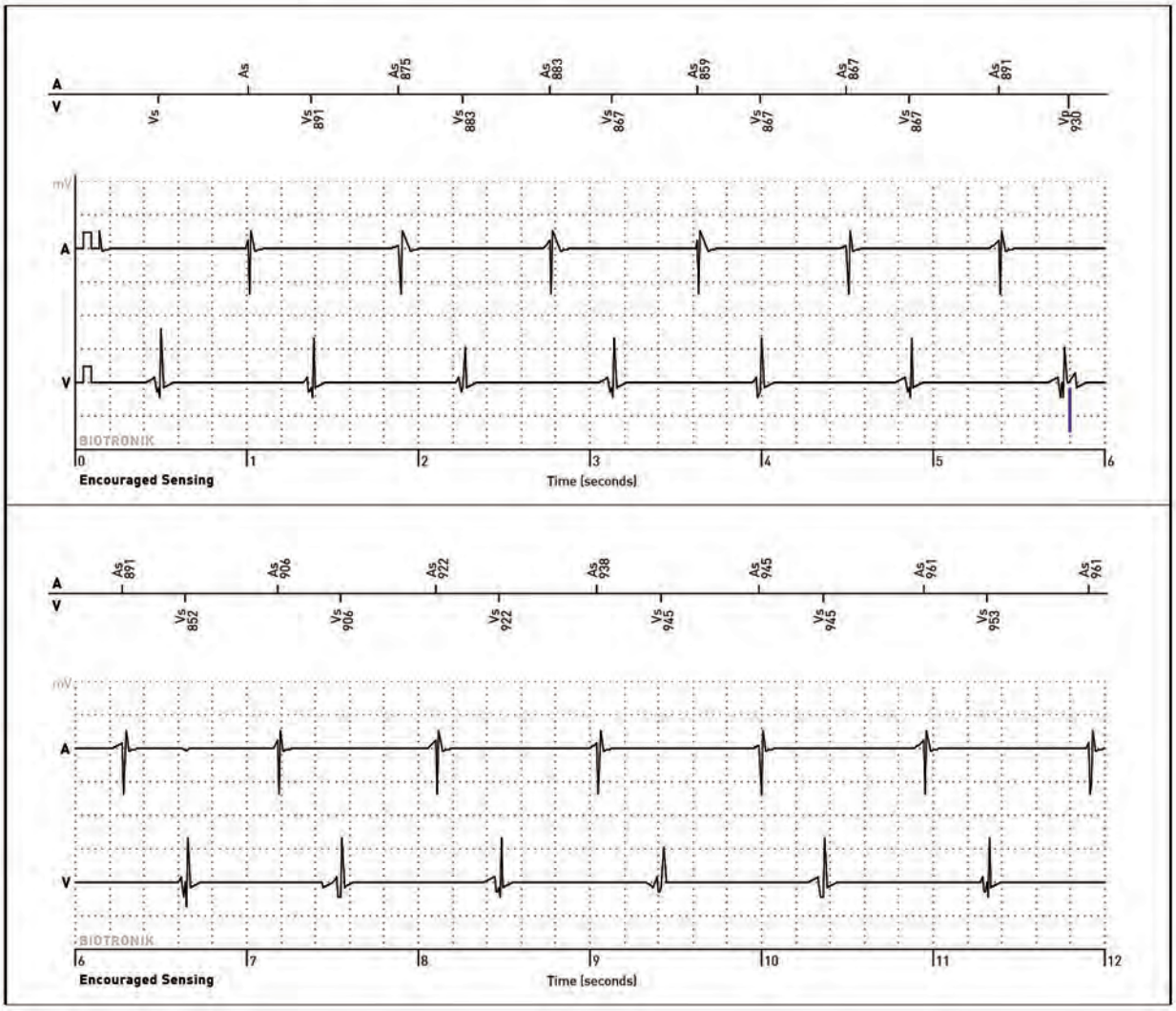
Phone: 0607396217

Last message: Mar 15, 2016
Last clinic follow-up: Nov 26, 2015



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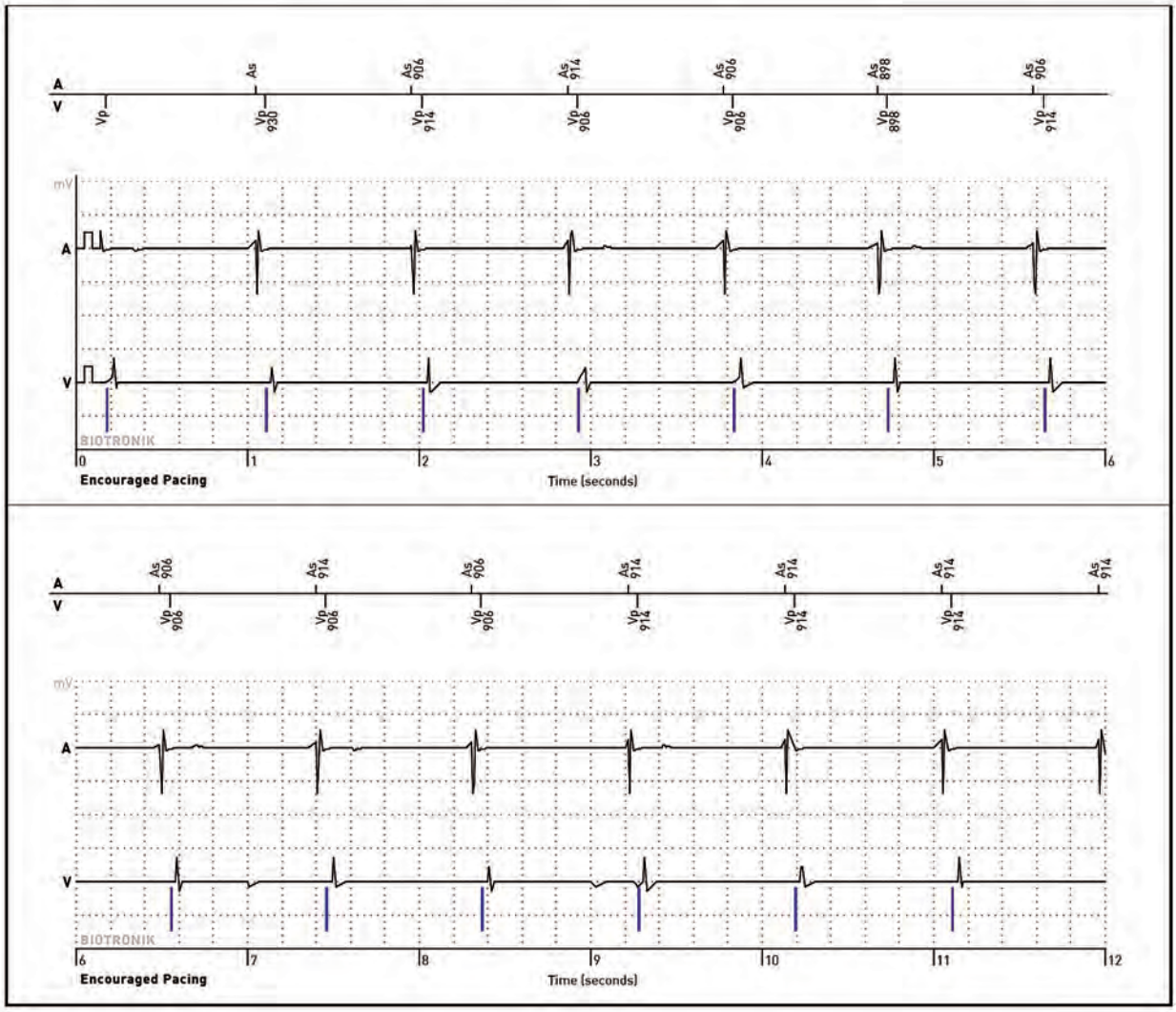


Tracing 24 ↘ T wave oversensing

Patient

71-year-old man, implanted with a Biotronik Evia DR-T dual-chamber pacemaker for syncopal complete atrioventricular block; routine control; numerous PVCs recorded in the device's memory.

Tracing

① atrial sensing and ventricular pacing;

② ventricular pacing and T wave oversensing; sinus P wave sensed in the PVARP (prolongation of the post-PVC PVARP);

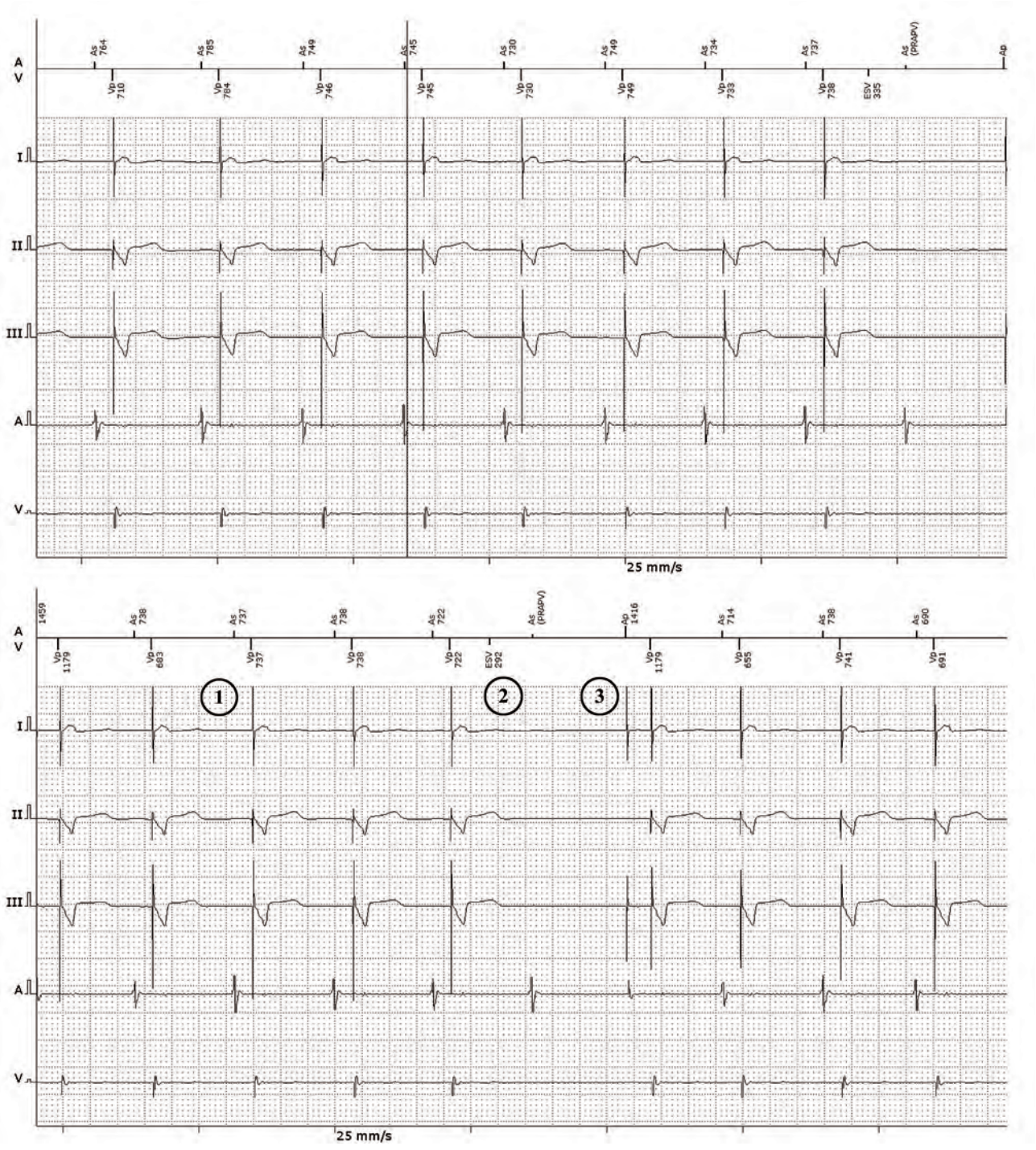
③ atrial pacing and ventricular pacing.

Comments

The quality of the sensing of a signal is dependent on a certain number of its physical characteristics: 1) its frequency spectrum: the frequency of a signal is expressed in hertz (Hz), and is the inverse of its period. A pacemaker amplifies incoming signals in a frequency range, on average, between 10 and 70 Hz corresponding to the cardiac depolarization signals. The signals located below and above this zone are filtered and are therefore rendered less or non-detectable by the system. In the ventricular channel, the R waves have a frequency spectrum between 10 and 30 Hz and are amplified. On the other hand, the T waves whose spectrum is less than 5 Hz are filtered. Similarly, signals of atrial origin collected in the ventricle usually have a very low frequency, and are most often filtered. The frequency spectrum of signals of muscular origin, such as the pectoral muscle (myopotentials), is superimposed on that of P waves and R waves. In the unipolar configuration, the sensing field extends from the distal electrode of the pacing lead to the pulse generator which is placed on or under the pectoral muscle with an increased risk of interference by the sensing of signals of muscular origin during certain physical exertions; 2) its slope: this parameter describes the amplitude variation of the cardiac signal as a function of time, expressed in mV/ms. The pacemaker senses the fastest portion of the signal corresponding to the passage of the depolarization wave facing the electrode. If the depolarization signal is fragmented as is sometimes the case for an extrasystole, the slopes of its various components are often slower, with an increased risk of undersensing. At implantation, the pacing leads should ideally be positioned at a site where the depolarization slope is at least 1mV/ms in the ventricle and at least 0.5mV/ms in the atrium. The measurement of the slope of the signal is contingent on its processing, and in particular on the filters used. The latter differ depending on the measuring system, the external device for determining the thresholds or the prosthesis that will be permanently connected. The observed differences can be very significant. However, direct recording of the signal at implantation may be useful in searching for the site that yields the largest intrinsic deflection. The intrinsic deflection of an endocardial signal almost never occurs at the beginning of the corresponding signal on the surface ECG. For example, sensing of ventricular depolarization in a patient with complete right bundle branch block is very late. Similarly in the atrium, atrial sensing may occur at the end of the P wave of the surface ECG; 3) its amplitude: the amplitude of the signal measured by the pacemaker corresponds to the amplitude of the signal which remains detectable by the pacing system after analysis of its frequency and the determination of the slope. It is expressed in mV. This is the parameter used at the end of the signal processing chain to determine the sensitivity level of the system. At implantation of a pacing lead, attention must be given to obtaining a signal corresponding to the band pass of the pacemaker, the intrinsic deflection of which is the fastest possible and of high amplitude. Amplitude levels of at least 5 mV in the ventricle and at least 2 mV in the atrium are typically targeted.

This tracing reveals an oversensing of the T wave, the ventricular channel being too sensitive. Automatic and adaptive cycle-to-cycle sensing, which is absolutely essential for the proper functioning of a defibrillator, is now available in pacemaker platforms. Pacemaker constraints in terms of sensing of

fast low-amplitude signals are less than those of a defibrillator (necessity to sense and treat ventricular fibrillation). On the other hand, the oversensing of a cardiac (T wave, P wave) or extracardiac (myopotential, interference, etc) signal can be extremely problematic in pacemaker-dependent patients. In the presence of T wave oversensing, as observed in this patient, programming of a fixed rather than automatic sensitivity may be preferred.


A
V
I
II
III
A
V
25 mm/s
1
2
3
25 mm/s

Tracing 25 ↘ atrial sensing failure

Patient

50-year-old man, implanted with an Evia VR pacemaker for sinus dysfunction; recording of a periodic EGM.

Tracing

① atrial pacing;

② atrial sensing failure with pacing in the atrial vulnerable period.

Comments

This tracing reveals an intermittent atrial undersensing. P wave sensing has certain peculiarities. Indeed, the amplitude of the sensed atrial signal can vary according to the position of the patient and as a function of the respiratory cycle. It is therefore necessary to set a sufficient margin to avoid atrial undersensing issues during exertion which, in a patient with atrioventricular block, can cause a sudden decrease in the ventricular pacing rate. In addition to the lack of proper monitoring of P waves during exertion, atrial undersensing may have a pro-arrhythmogenic effect if atrial pacing occurs in vulnerable atrial periods with a risk of atrial arrhythmia induction.

Status report - Mar 15, 2016

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Phone: -

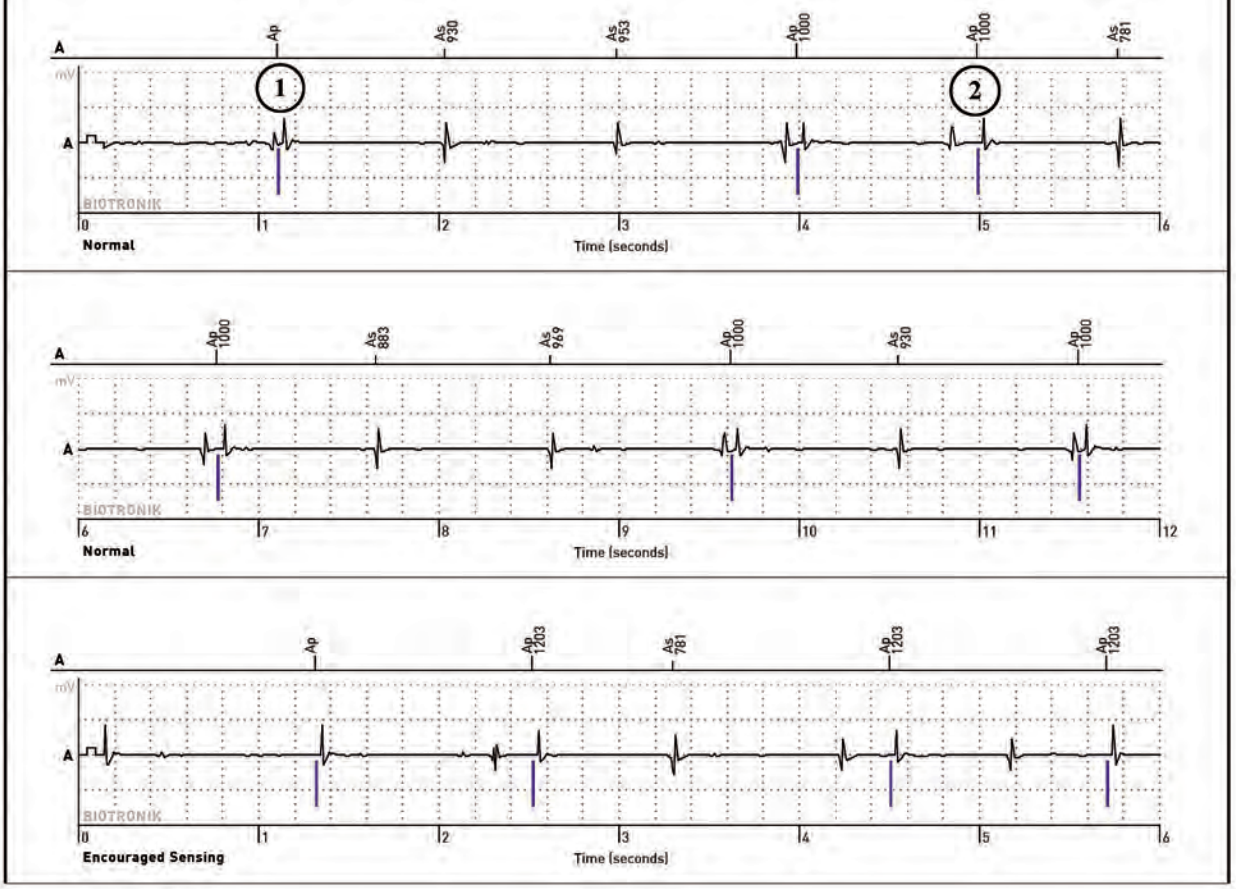
Last message: Mar 15, 2016
Last clinic follow-up: May 4, 2015

Recordings

Recordings - Episode 19:

General	
Episode number	19
Episode type	Periodic IEGM
Recorded on	Jan 12, 2015 12:59:00 AM

IEGM

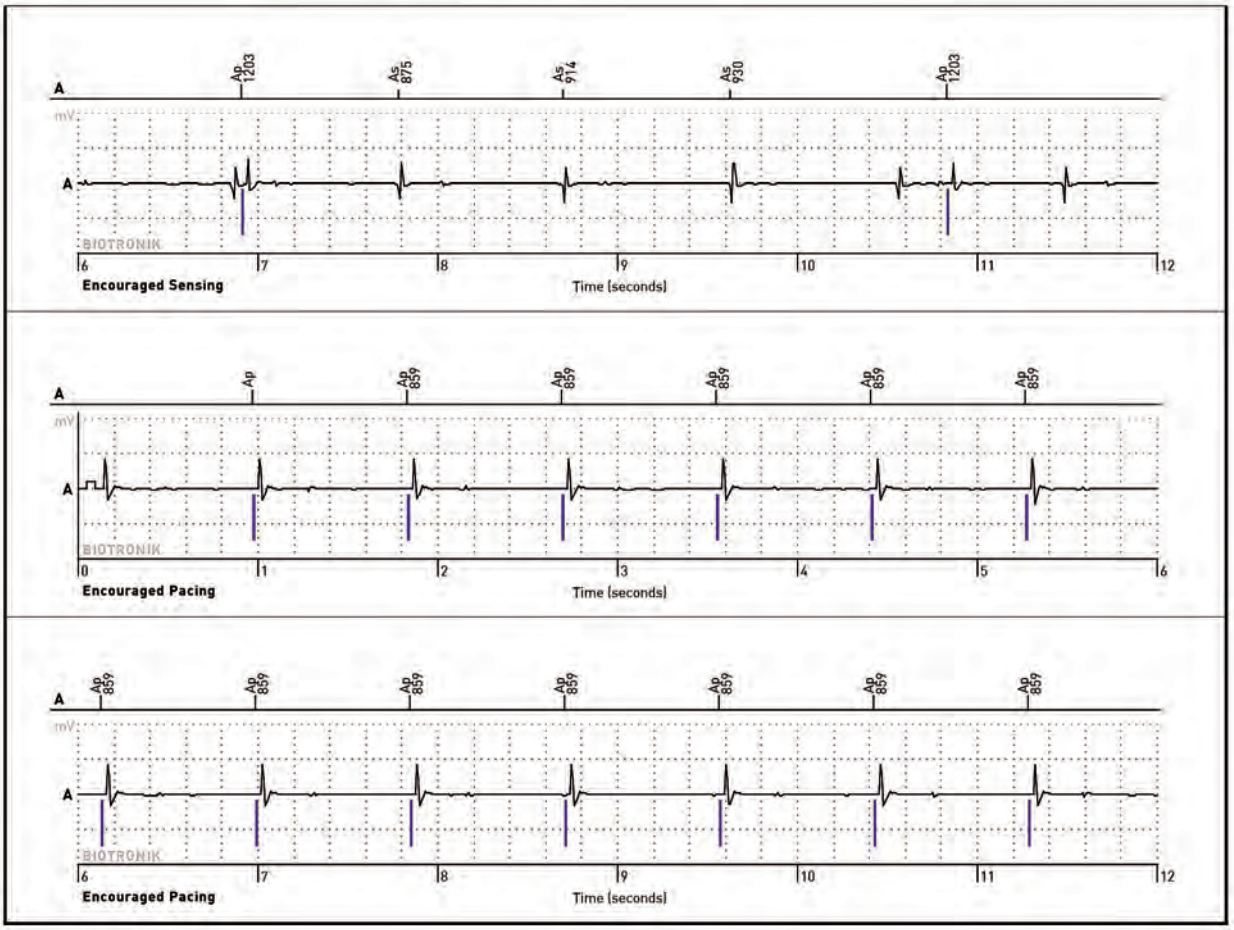


Status report - Mar 15, 2016

BIOTRONIK
excellence for life

Phone: -

Last message: Mar 15, 2016
Last clinic follow-up: May 4, 2015



Implantable Cardiac Pacemaker - chapter 5

Exercise

Tracing 26 ↘ Ventricular arrhythmias on exertion

Patient

A 67-year-old male coronary patient implanted with an Evia DR-T dual-chamber pacemaker for complete atrioventricular block; highlighting of episodes diagnosed as non-sustained ventricular tachycardia stored in the device's memory.

Tracing 26a

VT episode recorded in memory;

① AS-VP cycle likely occurring during exertion (rate above 100 bpm);

② non sustained ventricular tachycardia burst (atrioventricular dissociation);

③ spontaneous termination;

Tracing 26b

An exercise test (repeated flexions) is performed during the consultation with recording of a tracing and atrial and ventricular EGMs;

① rest; rate <60 bpm with AS-VP cycles;

② after a few flexions, acceleration of the rate (95 bpm);

③ first ventricular extrasystole;

④ ventricular bigeminism;

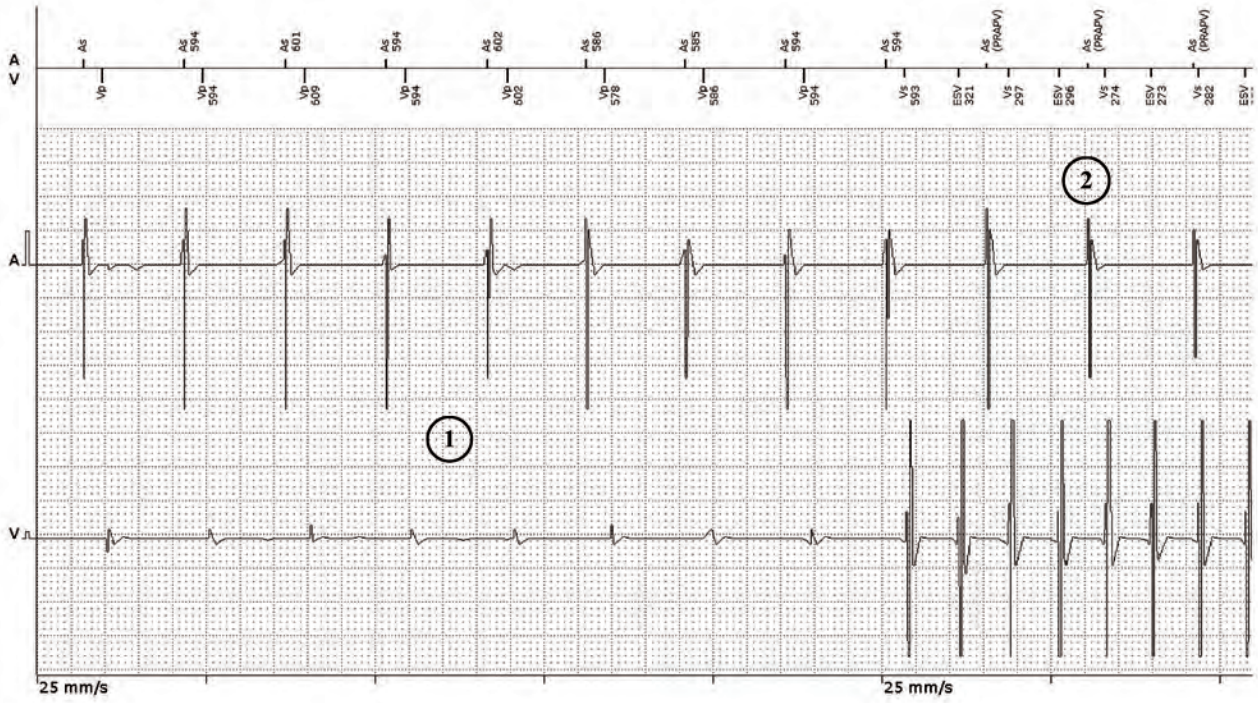
⑤ P wave blocked in the PVARP; on the previous cycle, the P wave following the PVC falls within the far-field protection period and is therefore not counted in the calculation of atrial rate; the ensuing P wave falls within the PVARP;

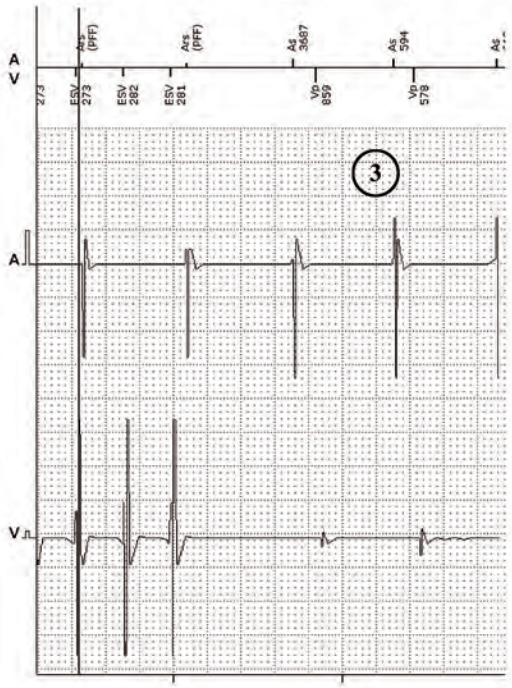
⑥ chest discomfort experienced by the patient; polymorphic ventricular triplet.

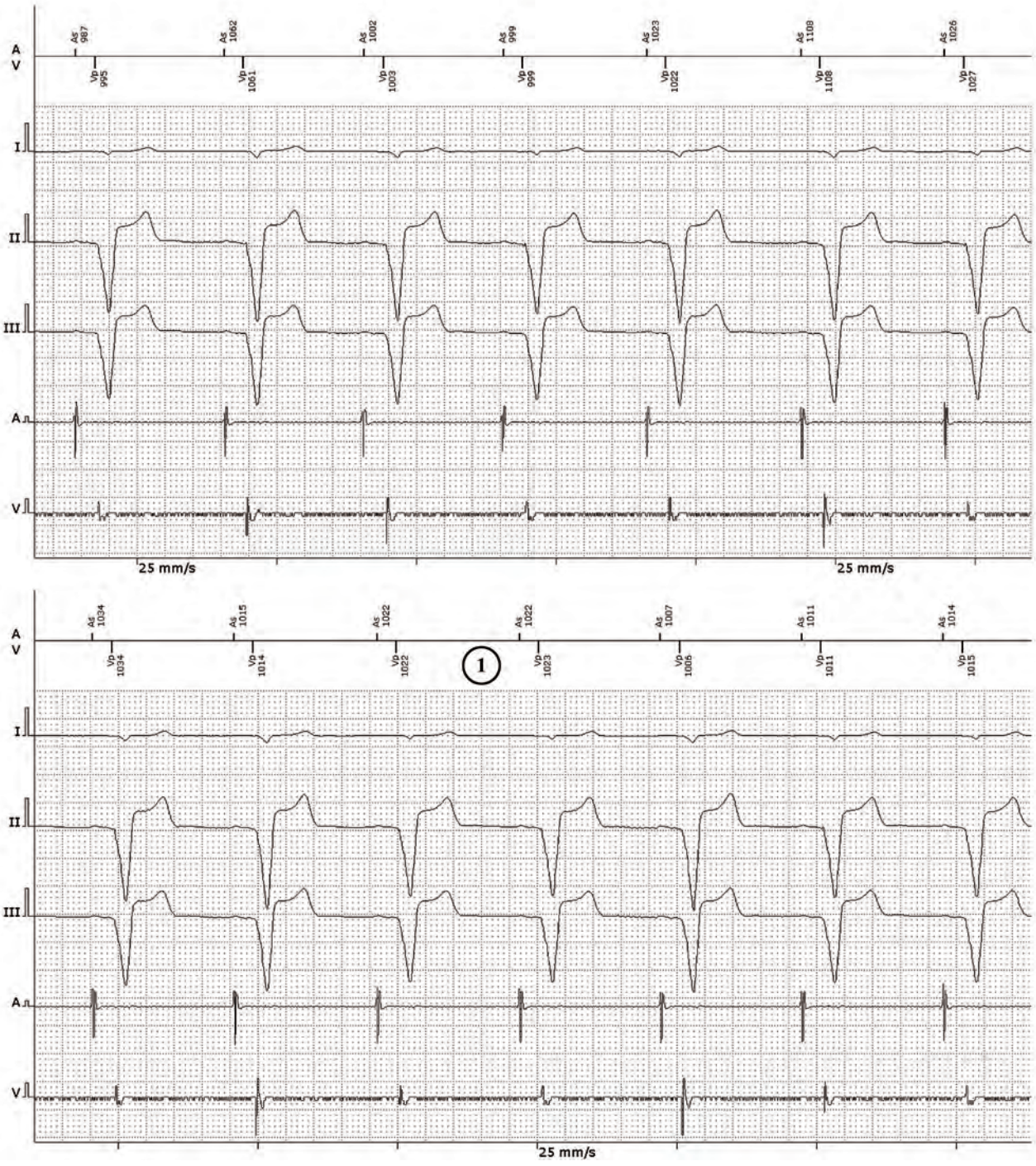
Comments

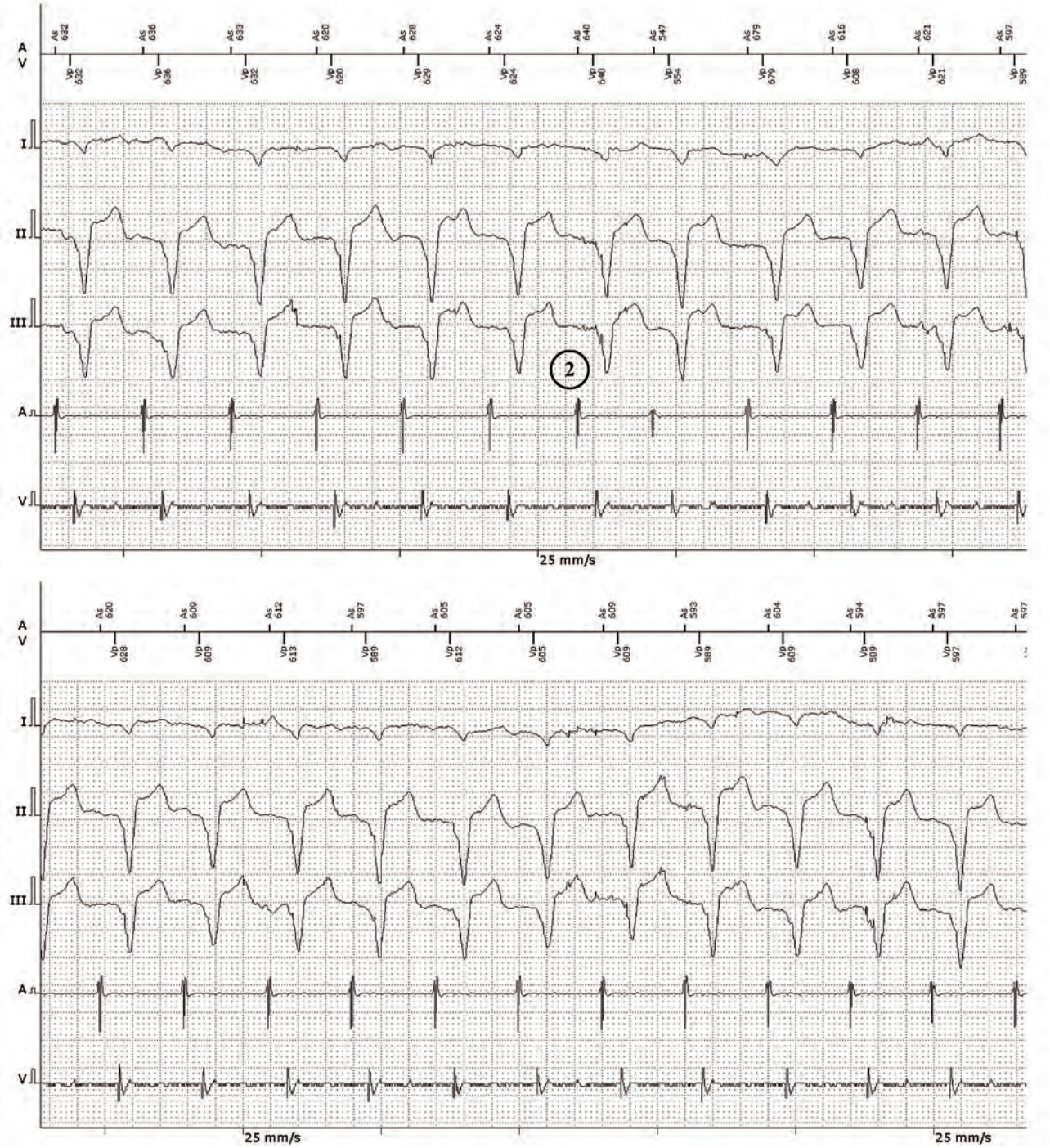
The demonstration of ventricular extrasystoles during this exercise test led to the conducting of a new coronary angiography in this known and treated coronary patient which showed the presence of a severe stenosis of the anterior interventricular branch. An angioplasty with stent placement was performed in this setting with good angiographic results. The combination of chest discomfort and the occurrence of a polymorphic ventricular extrasystole at the peak of exertion led to suspect the presence of myocardial ischemia which was confirmed by the demonstration of a significant stenosis.

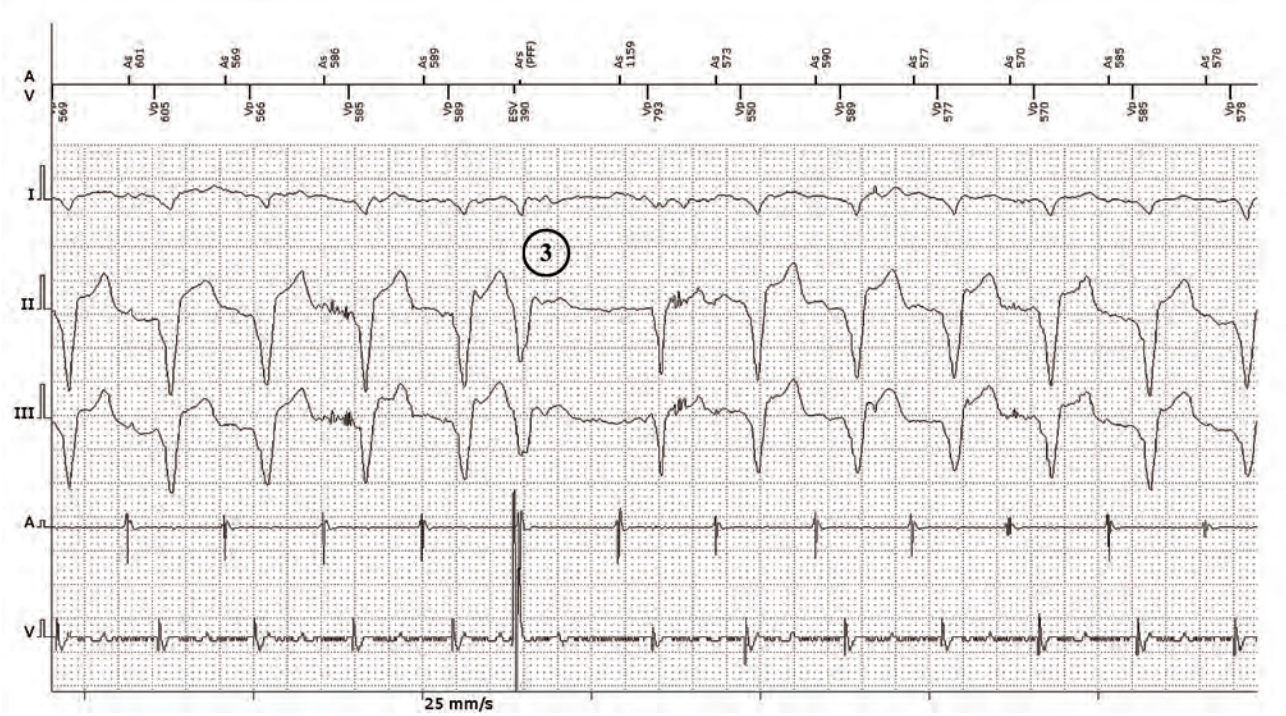
In this coronary patient, the choice was initially made to program a low maximum synchronous rate (110 bpm), which appears unwise in this active patient with complete atrioventricular block. Indeed, the patient's chronotropic status is relatively preserved in spite of a well-monitored beta-blocker treatment. If the sinus rate of the patient exceeds the maximum synchronous rate at exertion, a physiologically-poor Wenckebach phenomenon occurs with the presence of blocked P waves. Just as it is legitimate to limit the response rate in a coronary patient with chronotropic incompetence, it would appear just as inappropriate to limit the increase in ventricular rate in a patient with complete atrioventricular block by a low-programmed maximum synchronous rate.

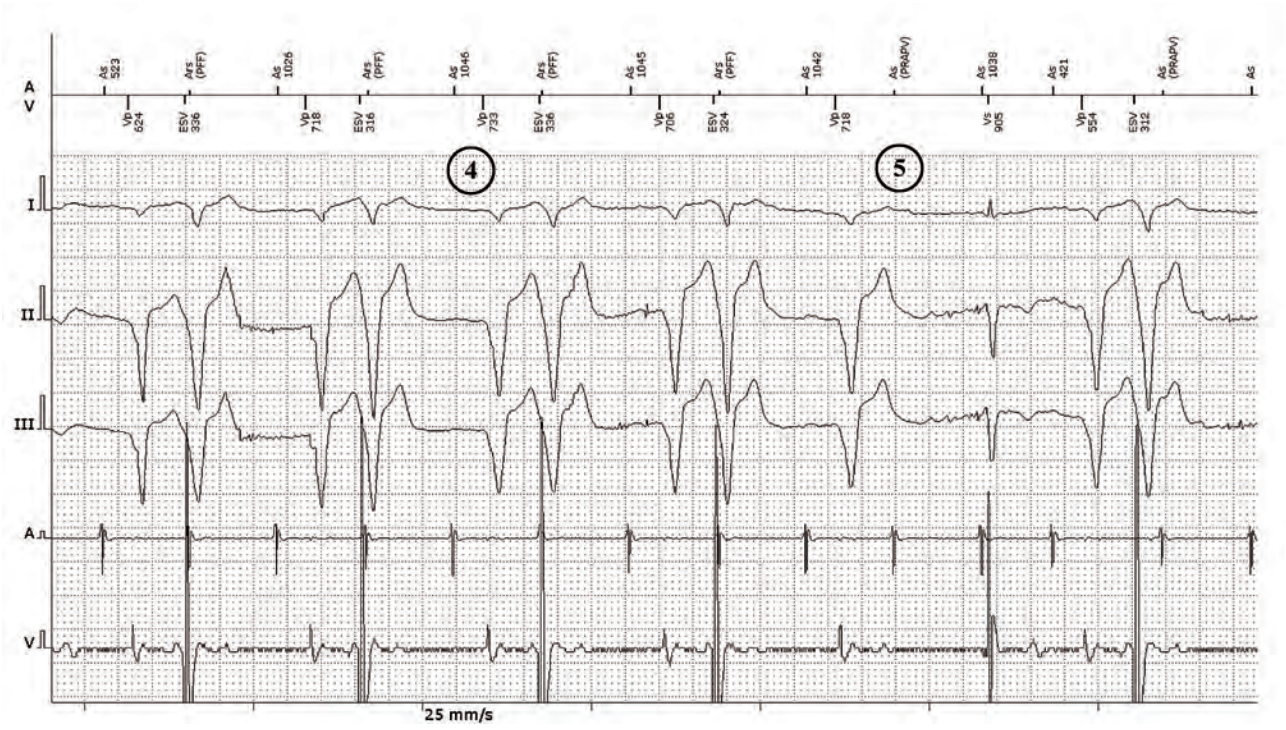

A
V
As
Vp
Vs
ESV
(PRAPV)
2
1
25 mm/s
25 mm/s

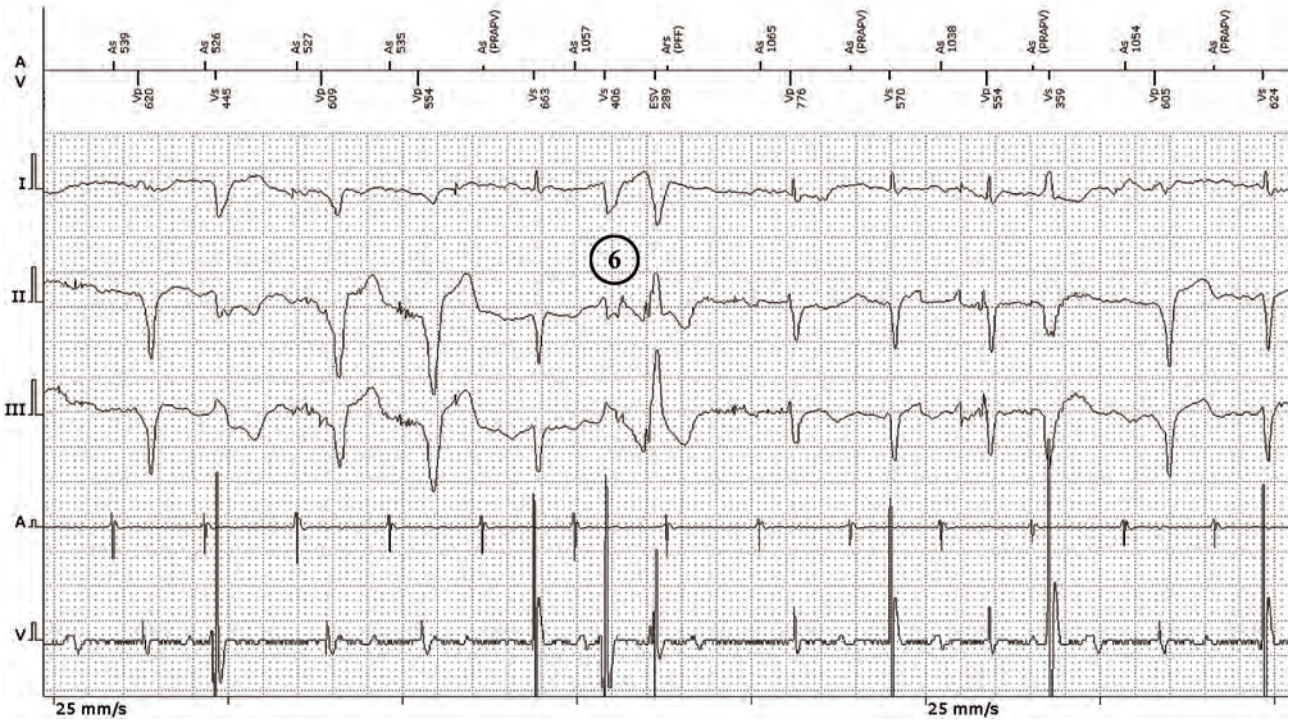

A
V
(PFF)
ESV
3
25 mm/s


A
V
As 987
Vp 995
As 1062
Vp 1061
As 1002
Vp 1003
As 999
Vp 999
As 1023
Vp 1022
As 1108
Vp 1108
As 1026
Vp 1027
I
II
III
A
V
25 mm/s
25 mm/s
A
V
As 1034
Vp 1034
As 1015
Vp 1014
As 1022
Vp 1022
1
As 1022
Vp 1023
As 1007
Vp 1006
As 1011
Vp 1011
As 1014
Vp 1015
I
II
III
A
V
25 mm/s


A
V
I
II
III
A
V
2
25 mm/s
25 mm/s
25 mm/s


A
V
I
II
III
A
V
3
25 mm/s


A
V
As 523
Vp 624
Ars (PFF)
ESV 336
As 1026
Vp 718
Ars (PFF)
ESV 316
As 1046
Vp 733
Ars (PFF)
ESV 336
As 1045
Vp 706
Ars (PFF)
ESV 324
As 1042
Vp 718
As (PRAPV)
As 1038
Vs 905
As 421
Vp 554
As (PRAPV)
ESV 312
As
4
5
I
II
III
A
V
25 mm/s


A
V
I
II
III
A
V
6
25 mm/s
25 mm/s

Tracing 27 ↘ Heart rate drop during exercise

Patient

53-year-old man implanted with an Evia DR-T dual-chamber pacemaker for complete atrioventricular block; feeling of lipothymia on exertion; performance of an exercise test at consultation (repeated flexions).

Tracing 27a

① onset of exertion; atrial sensing and ventricular pacing; analysis of the pattern of the atrial electrograms reveals a variable amplitude, even if all P waves are sensed;

② discomfort experienced by the patient; atrial undersensing (P wave not sensed); low amplitude signal; in the absence of atrial sensing, no ventricular pacing and pause (ventricular rate divided by 2) explaining the discomfort felt by the patient;

③ respiratory cycle of the atrial signal amplitude; P waves properly sensed;

④ new atrial undersensing due to a low-amplitude signal and sudden decrease in ventricular rate;

⑤ continuation of exertion; marked lipothymia; improvement in the quality of atrial sensing (signals of greater amplitude); atrial sensing and ventricular pacing;

⑥ P wave sensed in the PVARP; absence of ventricular pacing;

⑦ 2:1 point; repetitive sequences with every second P wave falling within the PVARP;

⑧ change in programming: shortening of the PVARP;

⑨ resumption of atrioventricular 1:1 synchrony and of a physiological and adjusted rate; disappearance of symptoms;

Tracing 27b

Atrial sensing test (VDI 30 bpm)

⑩ this test shows the variability in the measurement of the atrial signal amplitude (between 1 and 2.7 mV).

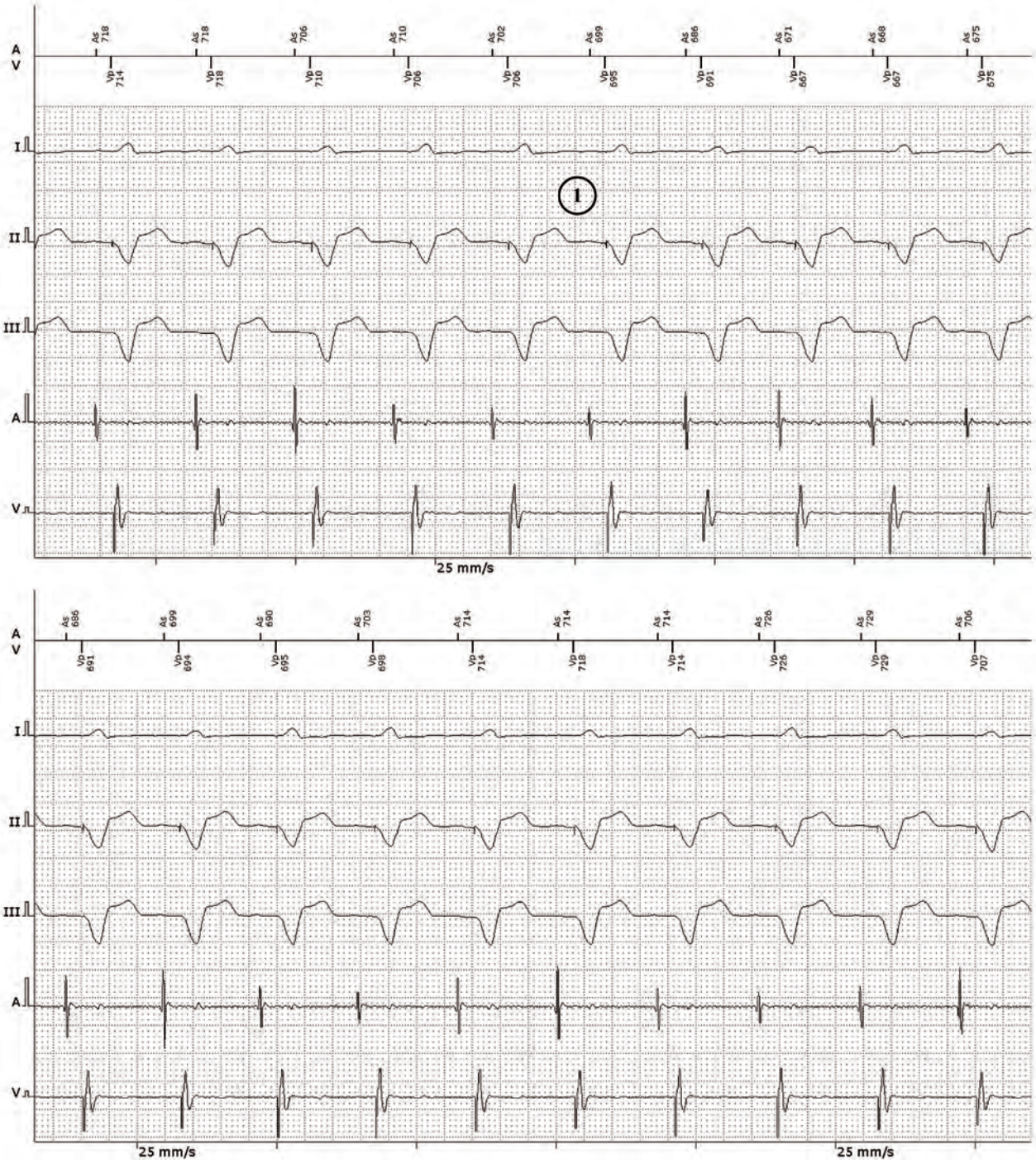
Comments

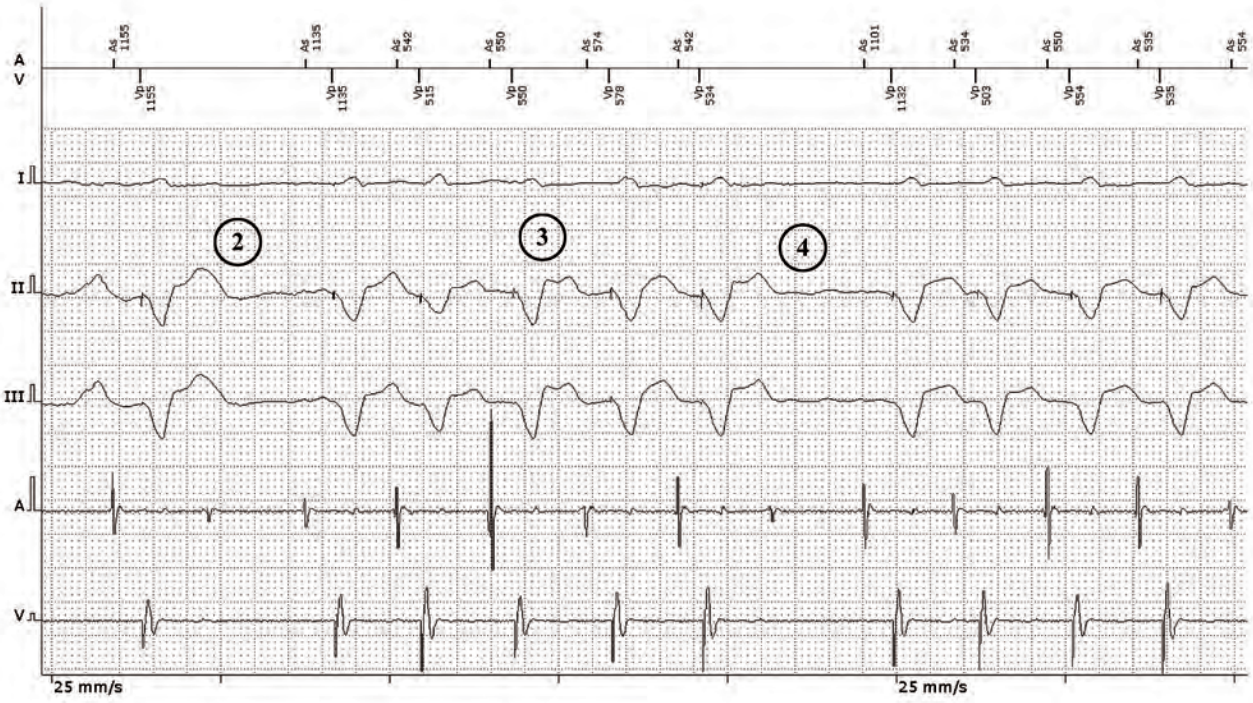
This patient presented significant symptomatology on exertion with the presence of lipothymias and marked limitation of his exercise capacity. Several mechanisms can be involved in this setting. The particular interest of this tracing is that the exercise revealed both an atrial undersensing and a 2:1 block.

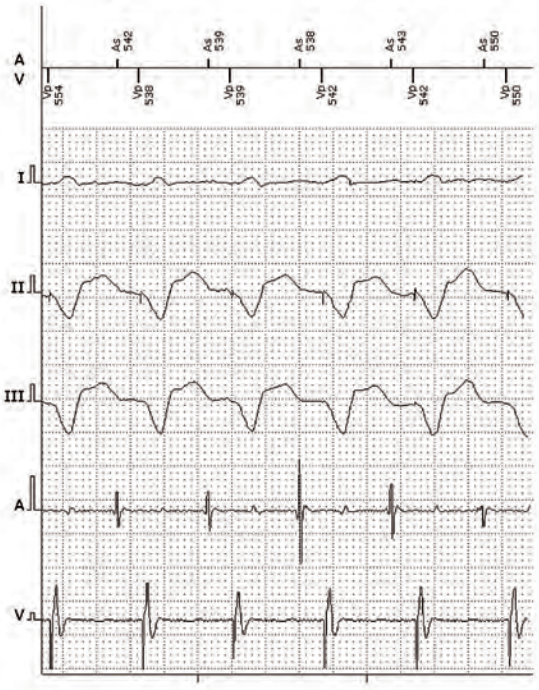
This patient presented an intermittent atrial undersensing. Atrial EGM analysis revealed a wide variability in the amplitude of atrial signals as a function of the respiratory rhythm. In a patient with preserved atrioventricular conduction, an atrial undersensing on exertion is associated with a reappearance of spontaneous ventricular activity without a sudden fall in rate and therefore without significant symptomatology. Conversely, in a patient with complete atrioventricular block (as on this tracing), atrial undersensing results in a sudden drop in rate, which is often symptomatic. Atrial undersensing is much more frequent than a 2:1 block or ventricular oversensing or loss of capture of the 2 leads, which constitute the other causes of a sudden drop in rate on exertion and should therefore be searched in priority in this setting. For a recent Biotronik™ dual-chamber pacemaker, atrial sensitivity can be programmed to a fixed value or with automatic adjustment (automatic sensitivity control). The automatic sensitivity control measures the amplitude of the P wave and adjusts the cycle to the sensitivity threshold. The maximum automatic sensitivity is 0.2 mV for atrial bipolar sensing and 0.5 mV for atrial

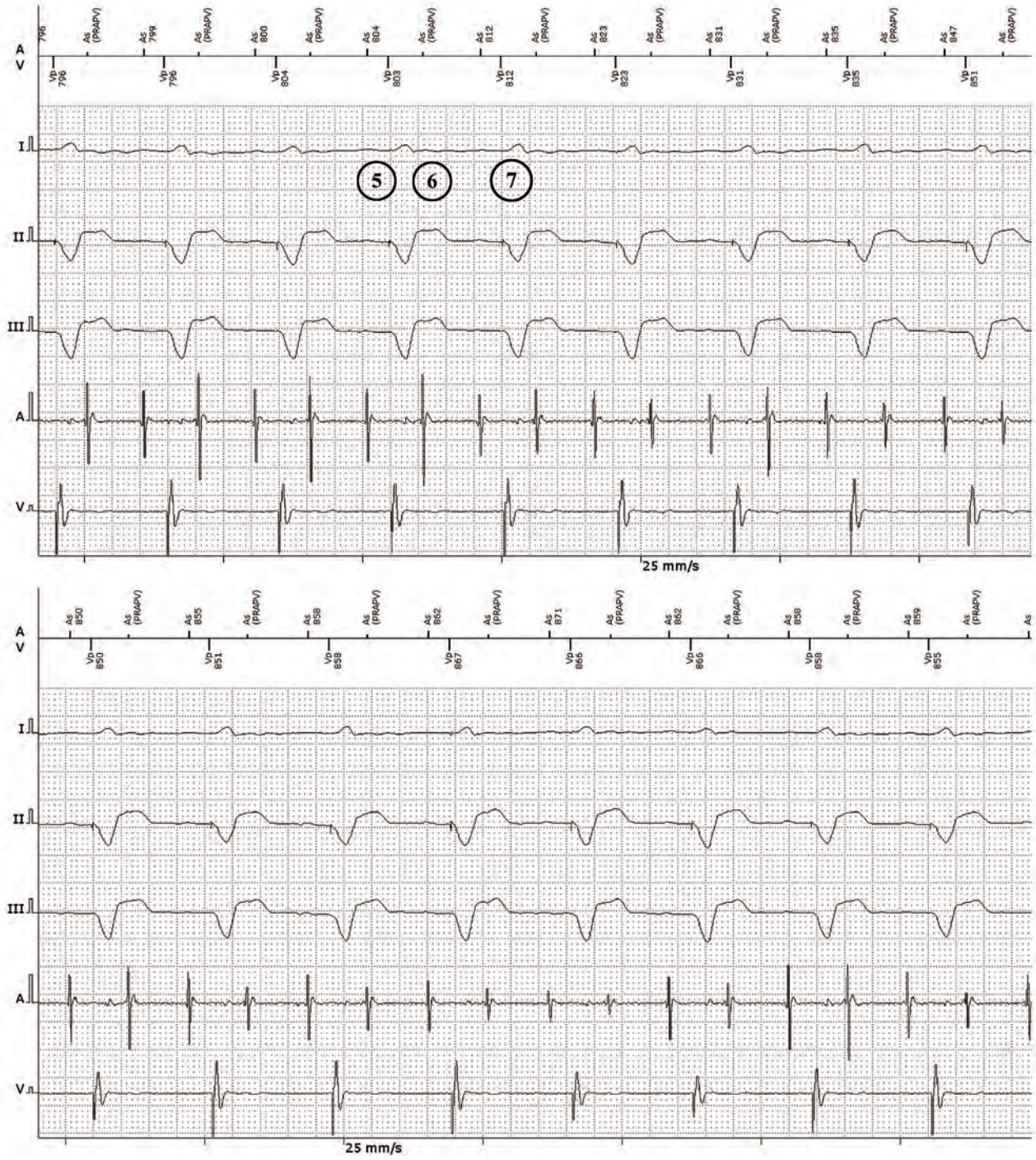
unipolar sensing (non-modifiable). In this patient, atrial sensing was programmed to a fixed value of 0.5 mV. A programming change to an adaptive sensitivity corrected the problem.

This tracing also allows emphasizing the specifics of the settings in patients with preserved exercise capacity and complete atrioventricular block. An adjusted setting should avoid the occurrence of the 2:1 point, which often leads to disabling symptoms. In this patient, the 2:1 point was set too low (150 bpm). The total atrial refractory period that defines the 2:1 point corresponds to the sum of the AV delay + PVARP. In young patients, it is essential to push this 2:1 point beyond the sinus acceleration capacities during exercise. To achieve this, it is possible to program a dynamic AV delay with automatic shortening upon exertion. In this complete anterograde atrioventricular patient, a 90-bpm VDD test did not demonstrate retrograde conduction during 3 successive consultations making the occurrence of a PMT highly hypothetical (possible but very unlikely resumption of a prior retrograde conduction essential for the occurrence of a PMT). It therefore appears possible to program an extremely short PVARP, which allows to considerably increase the 2:1 point and thus restore a preserved exercise capacity.

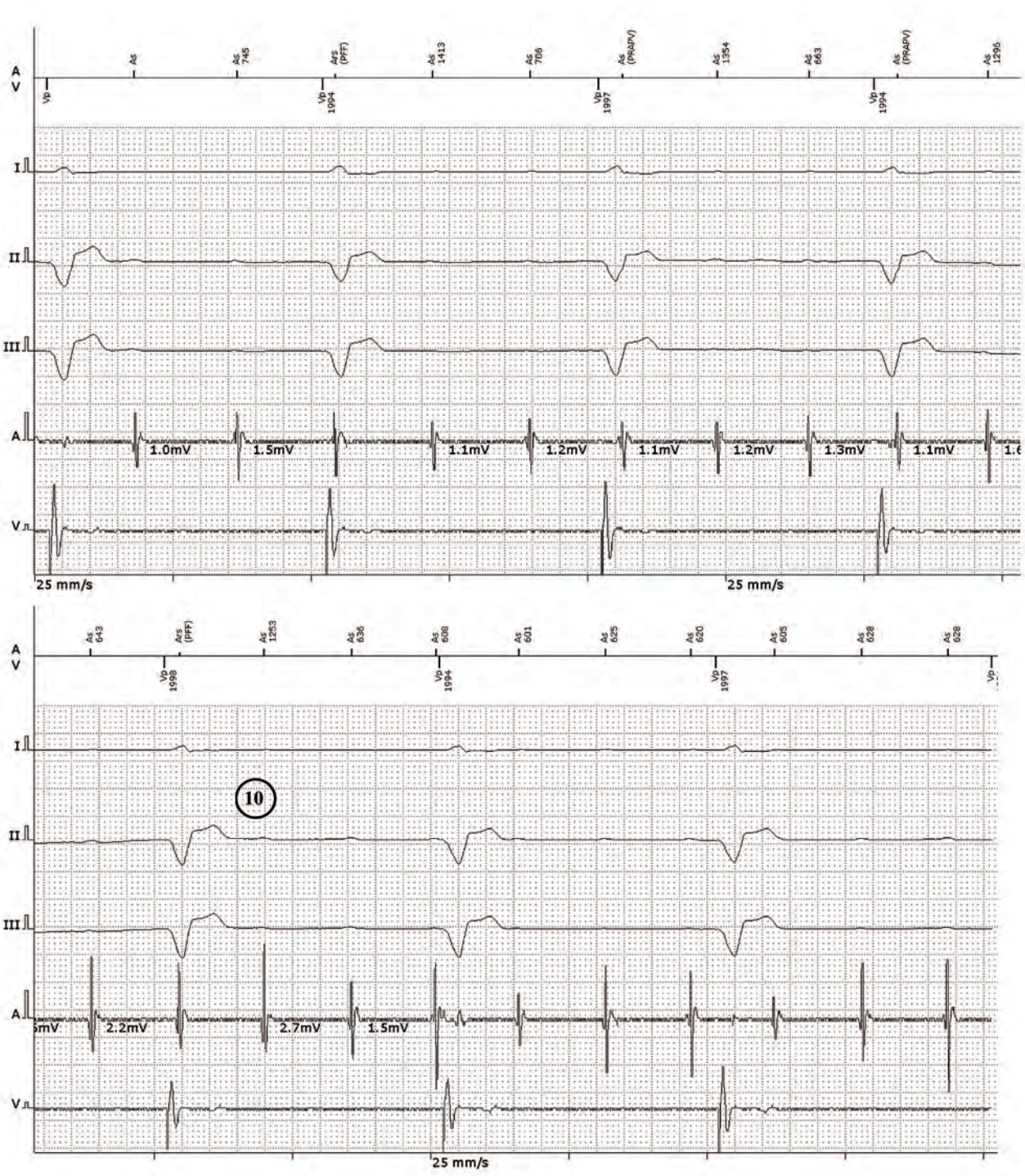

A
V
I
II
III
A
V
1
25 mm/s
25 mm/s
25 mm/s


A
V
I
II
III
A
V
2
3
4
25 mm/s
25 mm/s


A
V
I
II
III
A
V


A
V
I
II
III
A
V
5
6
7
25 mm/s
25 mm/s


A
V
I
II
III
A
V
25 mm/s
8
9
25 mm/s
25 mm/s


A
V
I
II
III
A
V
1.0mV
1.5mV
1.1mV
1.2mV
1.1mV
1.2mV
1.3mV
1.1mV
25 mm/s
25 mm/s
10
2.2mV
2.7mV
1.5mV
25 mm/s

Implantable Cardiac Pacemaker - chapter 6

Management of Arrhythmias

Tracing 28 ↘ Diagnosis of atrial fibrillation by remote monitoring

Patient

88-year-old man implanted with an Evia DR pacemaker for sinus dysfunction with prolonged PR interval; programming in DDD mode; asymptomatic; telemedicine yellow alert message for occurrence of an atrial arrhythmia.

Tracing

① yellow alert in the setting of an atrial load above the set limit and of a classified long atrial episode;

② the atrial arrhythmia status shows that the atrial arrhythmia appears permanent over the past 24 hours;

③ this plot shows that the atrial arrhythmia is permanent since the outset of this episode with mode switching;

④ the HF Monitor status shows that once the atrial arrhythmia had started, the percentage of ventricular pacing had decreased while the ventricular rate had slightly increased and that the patient's activity had decreased indicating a possible poor tolerance to the arrhythmia;

⑤ on this type of platform, the diagnosis of AF is not accompanied by the systematic telemedicine transmission of a recorded EGM at the time of the episode; on the other hand, the sending of an alert message can be accompanied by the sending of a periodic EGM; 3 channels are available: the markers with intervals, the atrial sensing channel and the right ventricular sensing channel; the arrhythmia being prolonged on this tracing, it is possible to confirm the presence of an actual atrial arrhythmia with spontaneous conduction confirming the diagnosis made by the pacemaker;

⑥ the periodic EGM performed 3 months earlier revealed a sinus rhythm with atrial extrasystoles (trigger for the induction of an atrial arrhythmia) with ventricular pacing.

Comments

AF is the most common form of arrhythmia in pacemaker-implanted patients and is associated with increased morbidity and mortality. One of the major interests of remote monitoring is optimizing the management of patients with AF episodes. AF is associated with 2 principal risks: poor hemodynamic tolerance and increased thromboembolic risk. Telemedicine allows an early diagnosis of arrhythmia, particularly asymptomatic episodes, and allows the adjustment of antiarrhythmic medical treatment and the rapid introduction of anticoagulant therapy. In a patient with atrial arrhythmia, irrespective of the chosen therapeutic strategy, telemedicine allows an optimization of the follow-up with 1) regular analysis of the mean rate and the maximum rate for the rate control strategy, or 2) evidence of possible recurrences for the rhythm control strategy.

The telemedicine report reveals the AF load, the number of episodes and mode switches, as well as provides histograms, atrial and ventricular rate curves, and pacing percentages. On the other hand, the atrial fibrillation alert was not accompanied by the transmission of an EGM recorded during the episode, which limited the ability to confirm the diagnosis and eliminate any differential diagnoses (crosstalk, oversensing of noise by the atrial lead, etc). This drawback has been addressed in the latest platforms.

Status report

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Evia DR-T
PM implanted Oct 17, 2013

Status: YELLOW

Status - Summary:

(1)

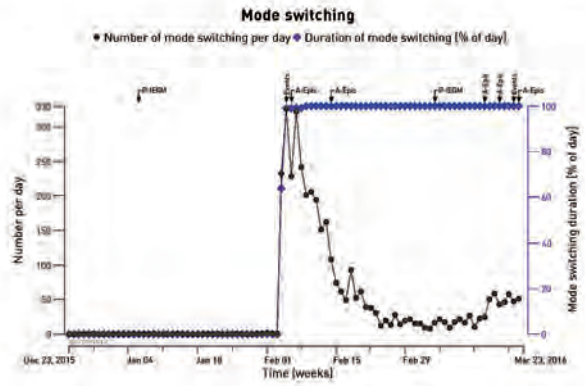
Status summary for patient ID "35789"

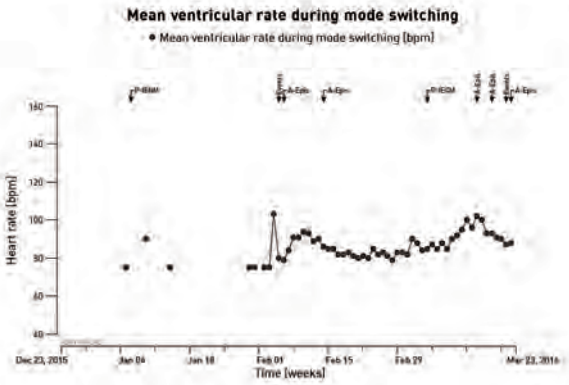
Category	Status	Finding	Info
Atr. arrhythmia	YELLOW	**Atrial burden above limit (> 25% of day)** Above limit since Feb 4, 2016 1:09:00 AM - Last value 100% of day measured on Mar 23, 2016 1:09:00 AM	Acknowledged Feb 4, 2016 9:48 AM.
		Long atrial episode detected (ongoing at end of mon. interv.) 1 episode(s) detected between Mar 22, 2016 1:09:00 AM and Mar 23, 2016 1:09:00 AM - The programmed episode duration limit was 12h 0min	Acknowledged today.
Automatic remark:	none		

Status - Atr. arrhythmia:

(2)

Atrial burden	24 h	Since Oct 29, 2013 1:09:00 AM Mean values
Atrial burden [% of day]	100	6
Atrial arrhythmia episodes per day	1	0
New long atrial episode detected (ongoing at end of mon. interv.)	YES	
Start of ongoing atrial episode	Mar 22, 2016 10:54:48 AM	
Mode switching		
Number of mode switching per day	51	5
Duration of mode switching [% of day]	100	6
Mean ventricular rate during mode switching [bpm]	88	79
New long mode switching episode detected (ongoing at end of mon. interv.)	---	
Start of ongoing mode switching episode	---	





(3)

Status report

BIOTRONIK
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Evia DR-T
PM implanted Oct 17, 2013

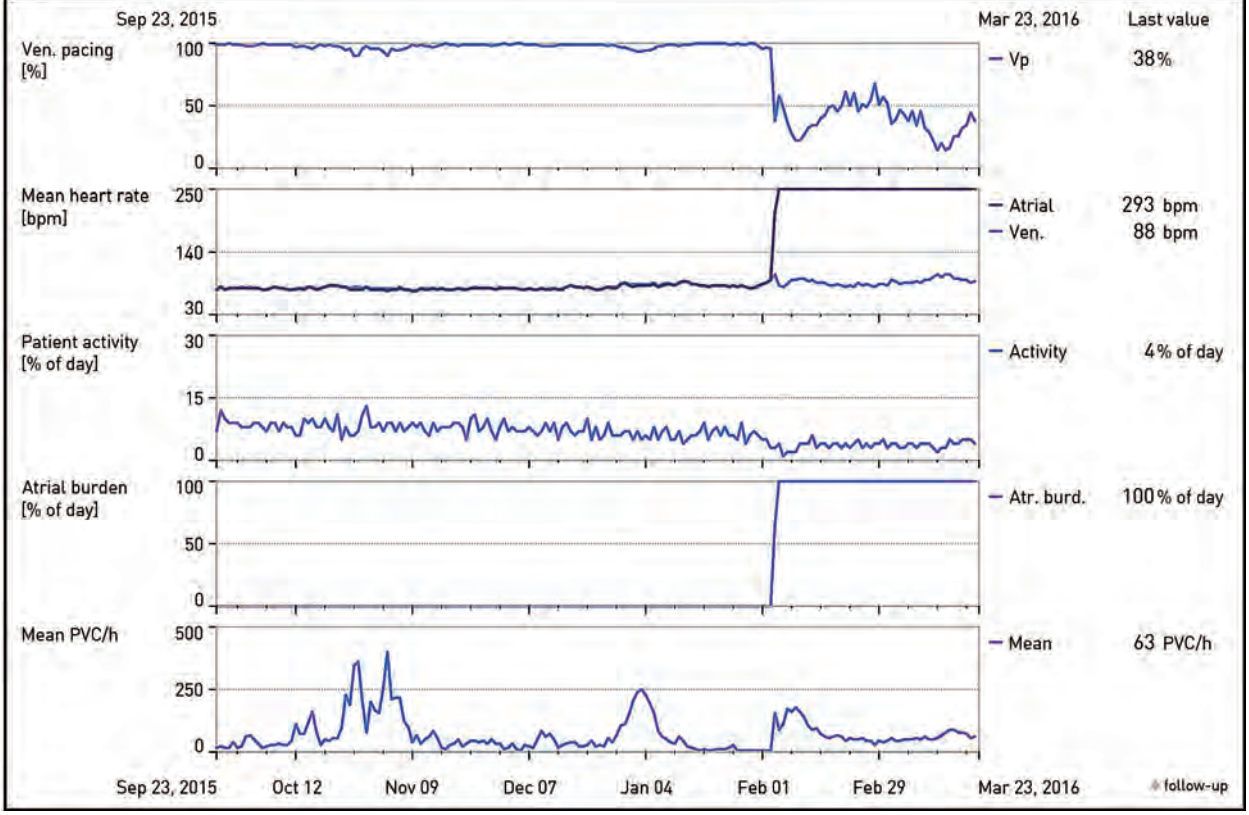
4

Status - HF monitor:

Device status Mar 23, 2016	
Battery status	OK
Pacing mode	DDD

Arrhythmias since Oct 29, 2013 (mean values)	
Atrial arrhythmia episodes per day	0
High ven. rate episodes per day	0

Long term trends



Status report

BIOTRONIK
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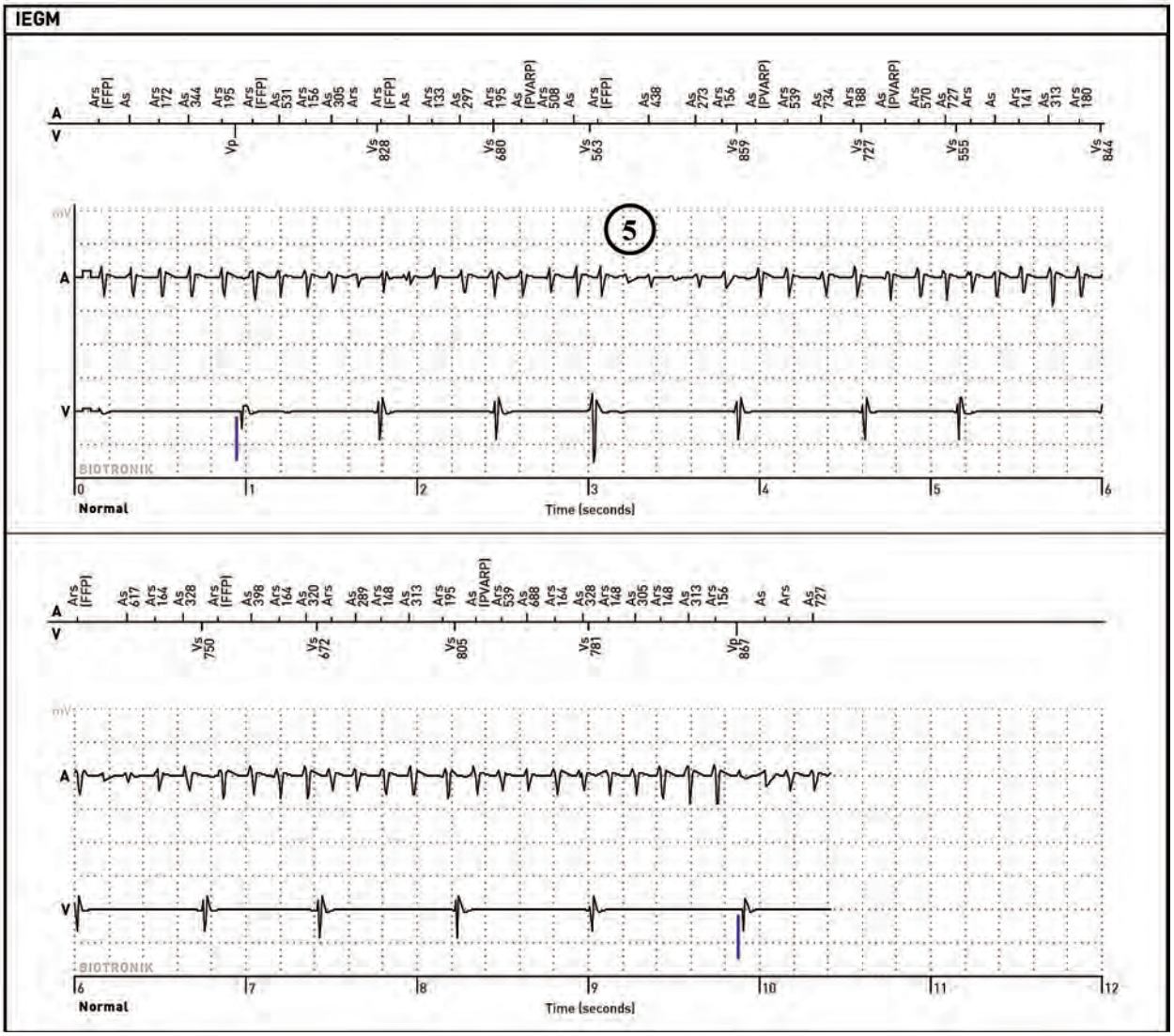
Evia DR-T
PM implanted Oct 17, 2013

Recordings

Recordings - Episode 29:

General	
Episode number	29
Episode type	Periodic IEGM
Recorded on	Mar 6, 2016 12:39:00 AM

IEGM



Status report

BIOTRONIK
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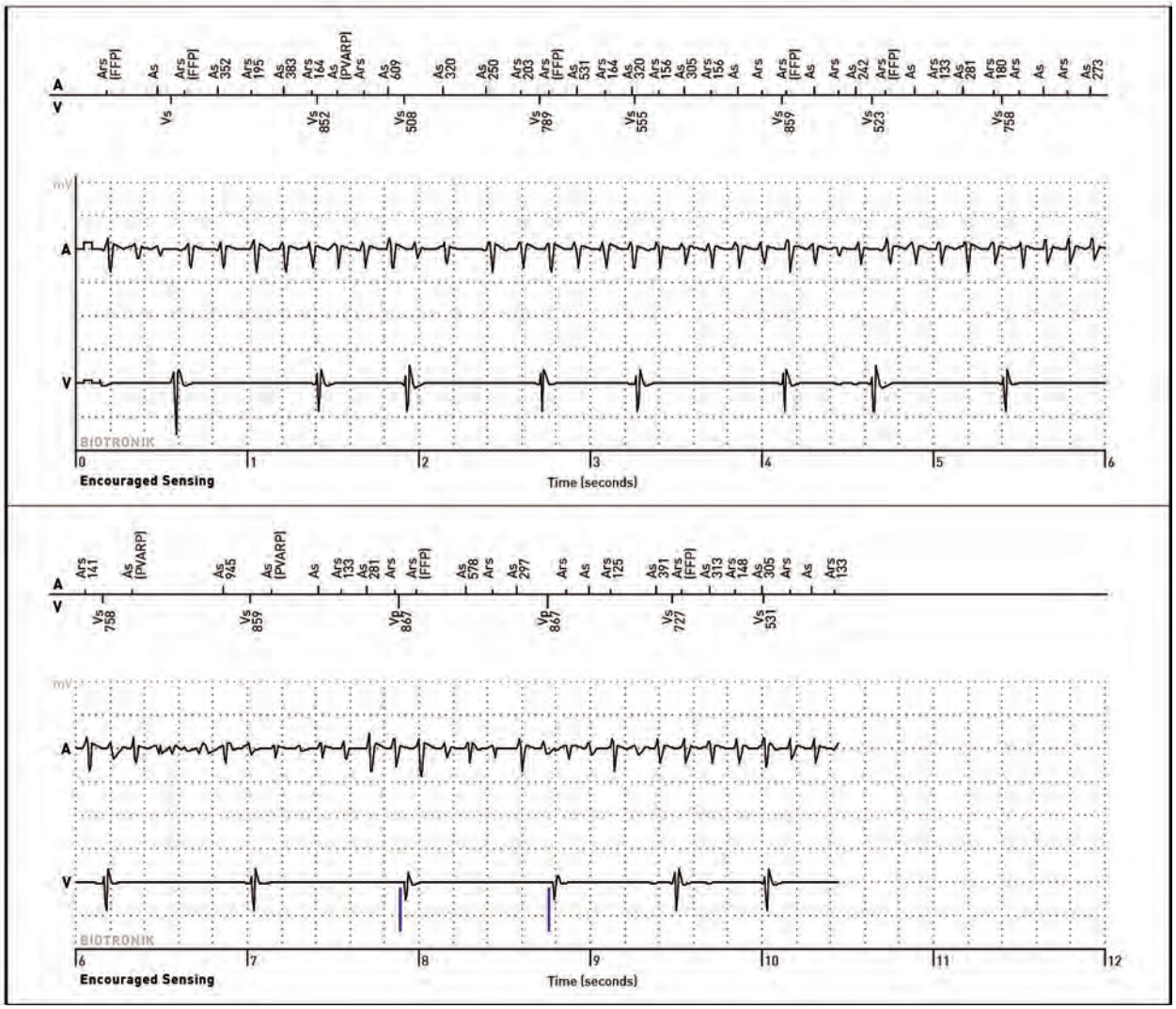
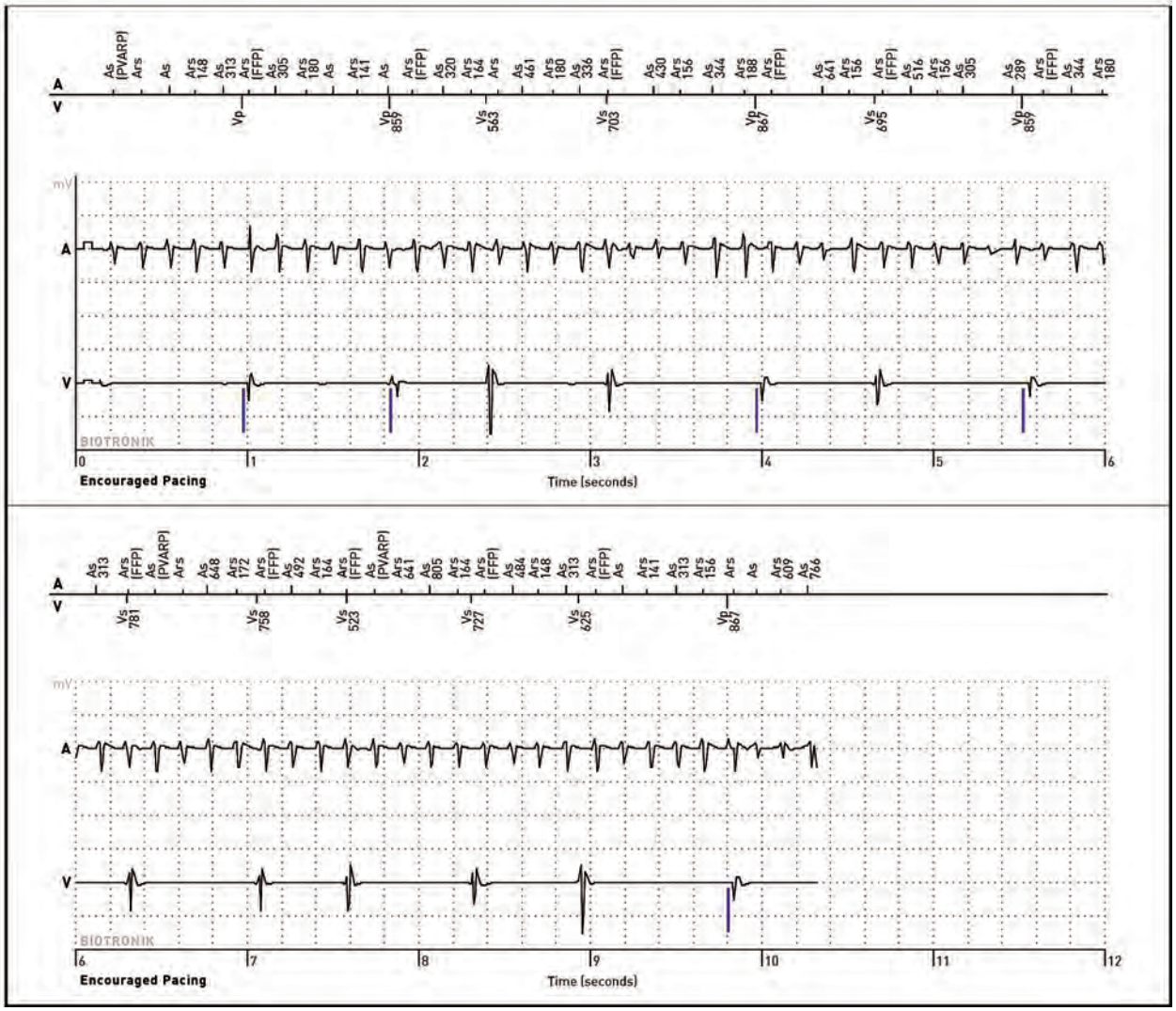
Evia DR-T
PM implanted Oct 17, 2013



Status report

BIOTRONIK
excellence for life

Evia DR-T
PM implanted Oct 17, 2013



Status report

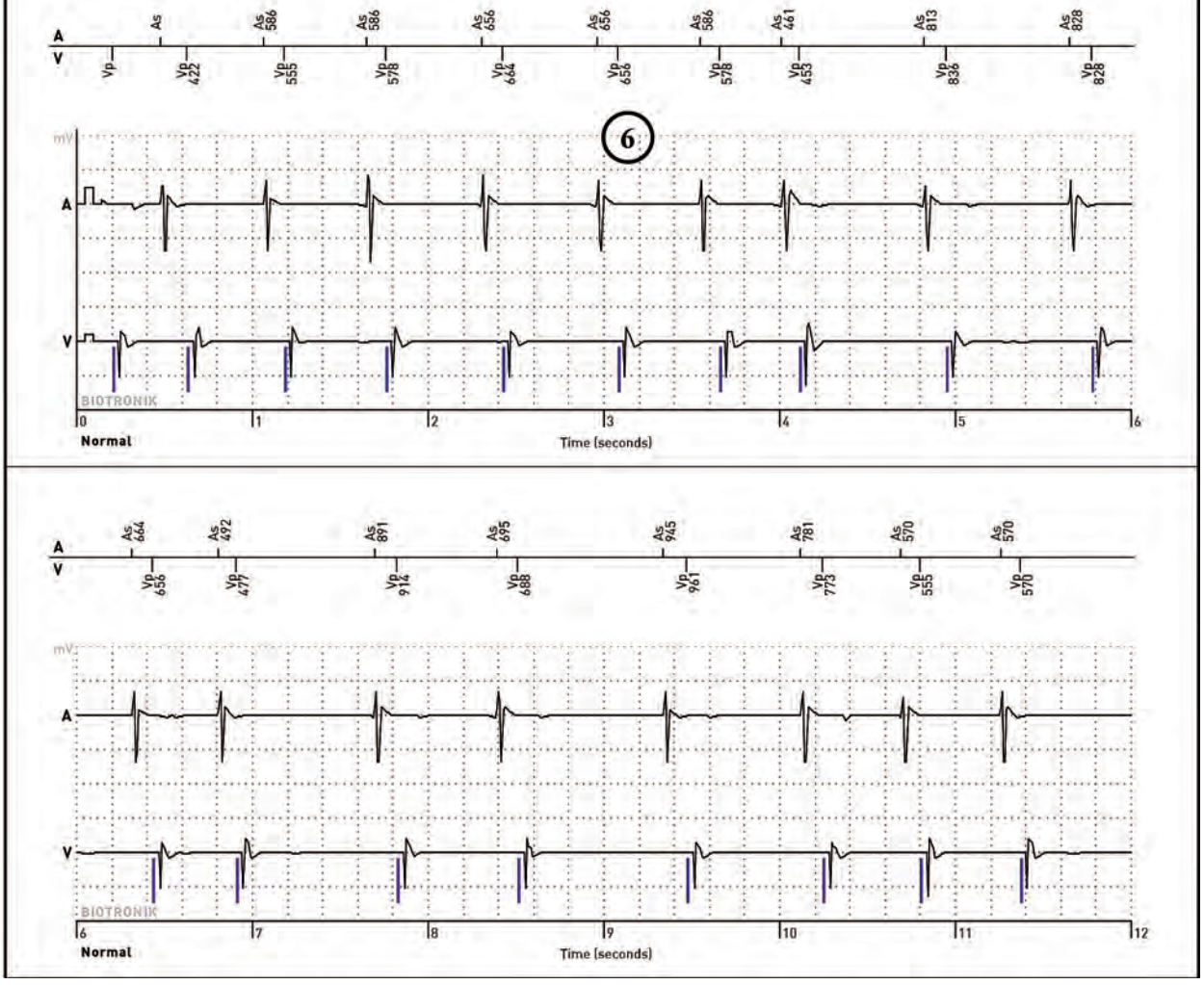
BIOTRONIK
excellence for life

Evia DR-T
PM implanted Oct 17, 2013

Recordings - Episode 27:

General	
Episode number	27
Episode type	Periodic IEGM
Recorded on	Jan 6, 2016 12:39:00 AM

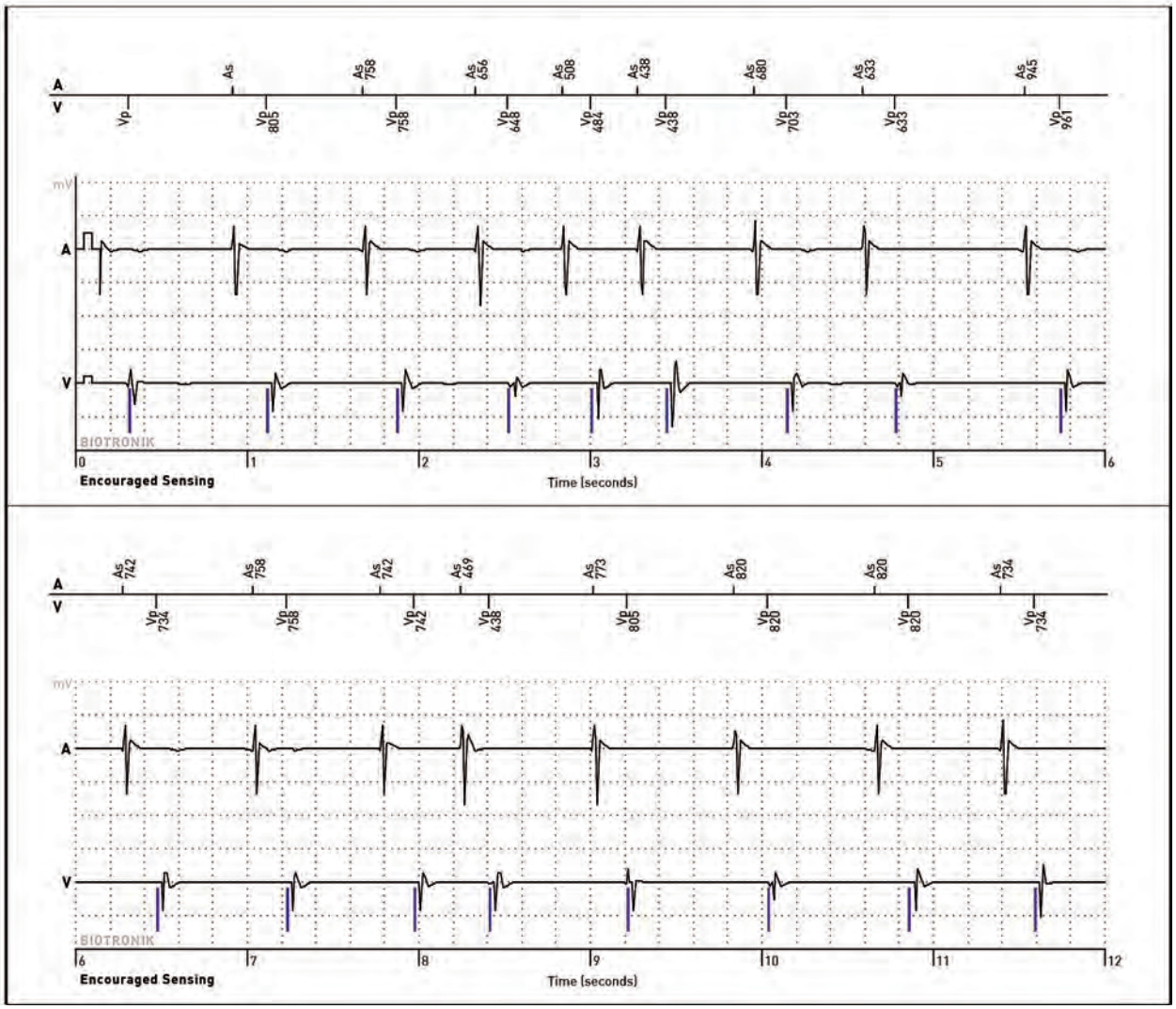
IEGM



Status report

BIOTRONIK
excellence for life

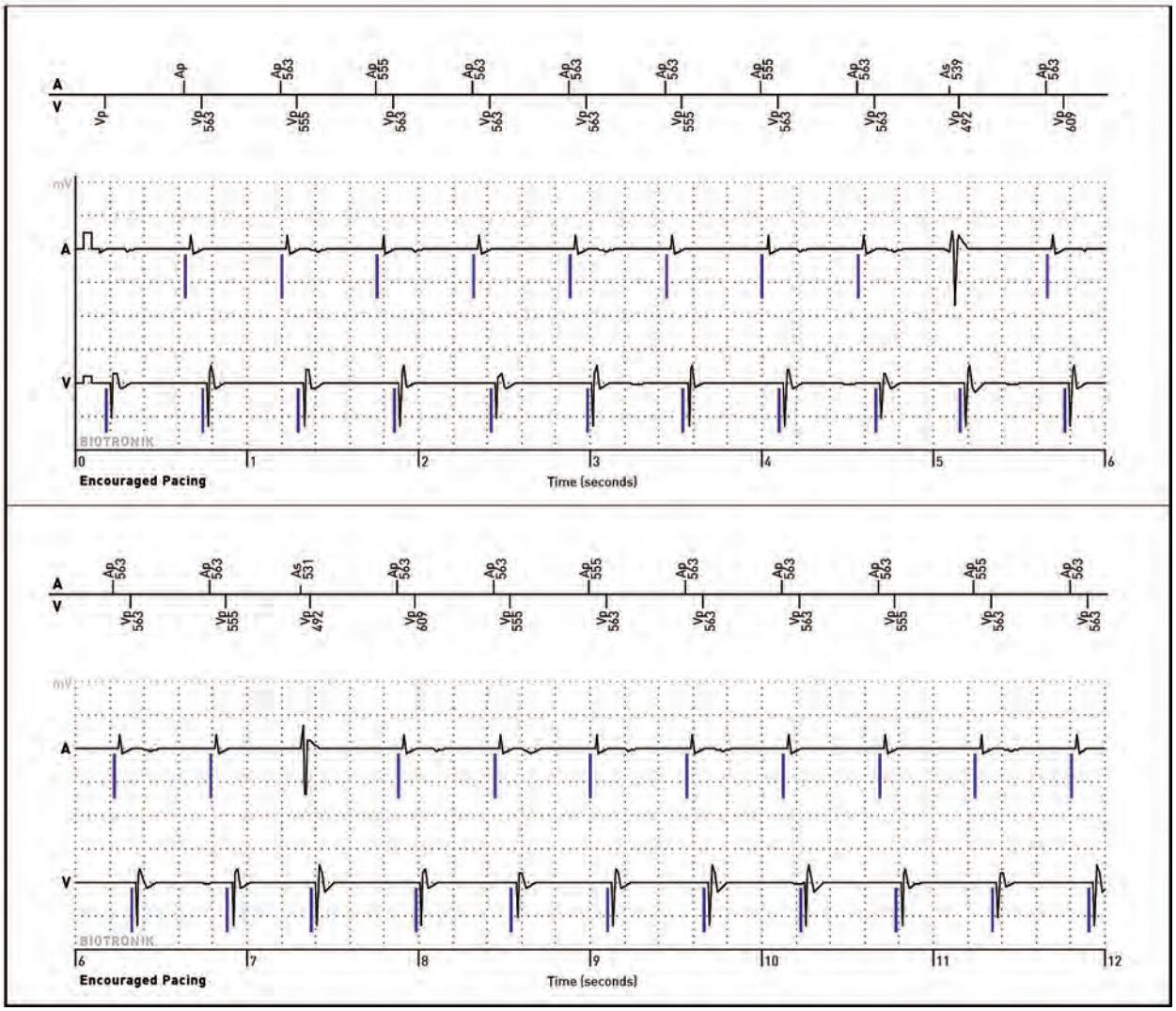
Evia DR-T
PM implanted Oct 17, 2013



Status report

BIOTRONIK
excellence for life

Evia DR-T
PM implanted Oct 17, 2013



Tracing 29 ↘ Diagnosis of atrial fibrillation by remote monitoring on the new platforms

Patient

76-year-old man, implanted with an Eluna Evia DR pacemaker for paroxysmal atrioventricular block; programming in DDD mode; asymptomatic; telemedicine yellow alert message for occurrence of an atrial arrhythmia.

Tracing

① yellow alert in the setting an atrial load above the set limit and of a classified long atrial episode;

② in the new platforms, a telecardiology alert for atrial fibrillation is accompanied by the transmission of an EGM recorded during the episode;

③ this EGM confirms the diagnosis of atrial arrhythmia with permanent ventricular pacing.

Commentaires

In this patient with impaired atrioventricular conduction, the atrial arrhythmia episodes were asymptomatic, with the ventricular rate remaining normal. The presence of subclinical atrial arrhythmia episodes increases the risk of stroke and systemic embolism. Telemedicine enabled an early diagnosis and the rapid introduction of anticoagulant and antiarrhythmic therapy, whereas in a classical face-to-face follow-up, this would only have been initiated weeks or even months later.

This example illustrates the need to confirm the accuracy of the diagnoses made by the pacemaker. A false diagnosis of AF may lead to an unnecessary introduction of anticoagulant therapy. The systematic sending of an EGM during the atrial arrhythmia episode on the newer platforms is thus an invaluable advance in the remote management of pacemaker-implanted patients.

Status report

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Eluna 8 DR-T
PM implanted Jun 9, 2015

Status: YELLOW

Status - Summary:

1

Status summary for patient ID "34909"

Category	Status	Finding	Info
Atr. arrhythmia	WHITE	**Long atrial episode detected (ongoing at end of mon. interv.)** 1 episode(s) detected between Jun 21, 2015 1:29:00 AM and Jun 22, 2015 1:29:00 AM - The programmed episode duration limit was 12h 0min	Acknowledged Jun 22, 2015 10:57 AM.
HF monitor	YELLOW	**Atrial burden above limit (> 25% of day)** Above limit since Jun 21, 2015 1:29:00 AM - Last value 100% of day measured on Jun 22, 2015 1:29:00 AM	Acknowledged Jun 22, 2015 10:57 AM.
Recordings / Episode	WHITE	**Episode details received** Details were received for 2 episodes, which were detected between Jun 19, 2015 8:55:48 PM and Jun 20, 2015 5:11:32 PM	Acknowledged Jun 22, 2015 10:57 AM.
Automatic remark: none			

Status - Atr. arrhythmia:

Atrial burden	24 h	Since Jun 11, 2015 1:29:00 AM Mean values, * Max values
Atrial burden [% of day]	100	34
Atrial arrhythmia episodes per day	0	2
New long atrial episode detected (ongoing at end of mon. interv.)	YES	
Start of atrial episode (ongoing at end of mon. interv.)	Jun 20, 2015 5:11:32 PM	
Duration of longest atrial episode	---	1d 5h 25min*
End of last atrial episode	Jun 20, 2015 5:10:06 PM	
Mode switching		
Number of mode switching per day	---	---
Duration of mode switching [% of day]	---	---
Mean ventricular rate during mode switching [bpm]	---	---
New long mode switching episode detected (ongoing at end of mon. interv.)	---	
Start of mode switching episode (ongoing at end of mon. interv.)	---	

Status report

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Eluna 8 DR-T
PM implanted Jun 9, 2015

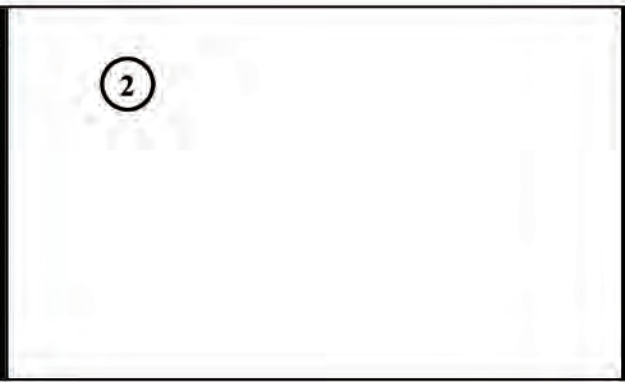
Recordings

Recordings - Episode list:

No.	Detection time	Type	Details	Predetection PP/RR [ms]
4	Jun 20, 2015 5:11:32 PM	AT	Monitoring only; ongoing on Jun 21, 2015 1:29:00 AM	--- / 773
3	Jun 19, 2015 8:55:48 PM	AT	Monitoring only; Duration: 6min 14s	--- / 977
2	Jun 13, 2015 12:33:12 AM	AT	Monitoring only; Duration: 22min 50s	--- / 973
1	Jun 11, 2015 4:54:42 PM	AT	Monitoring only; ongoing on Jun 12, 2015 1:29:00 AM	--- / 766
	Jun 10, 2015 10:59:54 AM	Follow-up		

Recordings - Episode 4:

General	
Number	4
Type	AT
Detection	Jun 20, 2015 5:11:32 PM
Termination	---
Duration	---
Device settings no.	8
Mean atrial rate/PP interval at initial detection [ms]	---
Mean ven. rate/RR interval at initial detection [ms]	773



Status report

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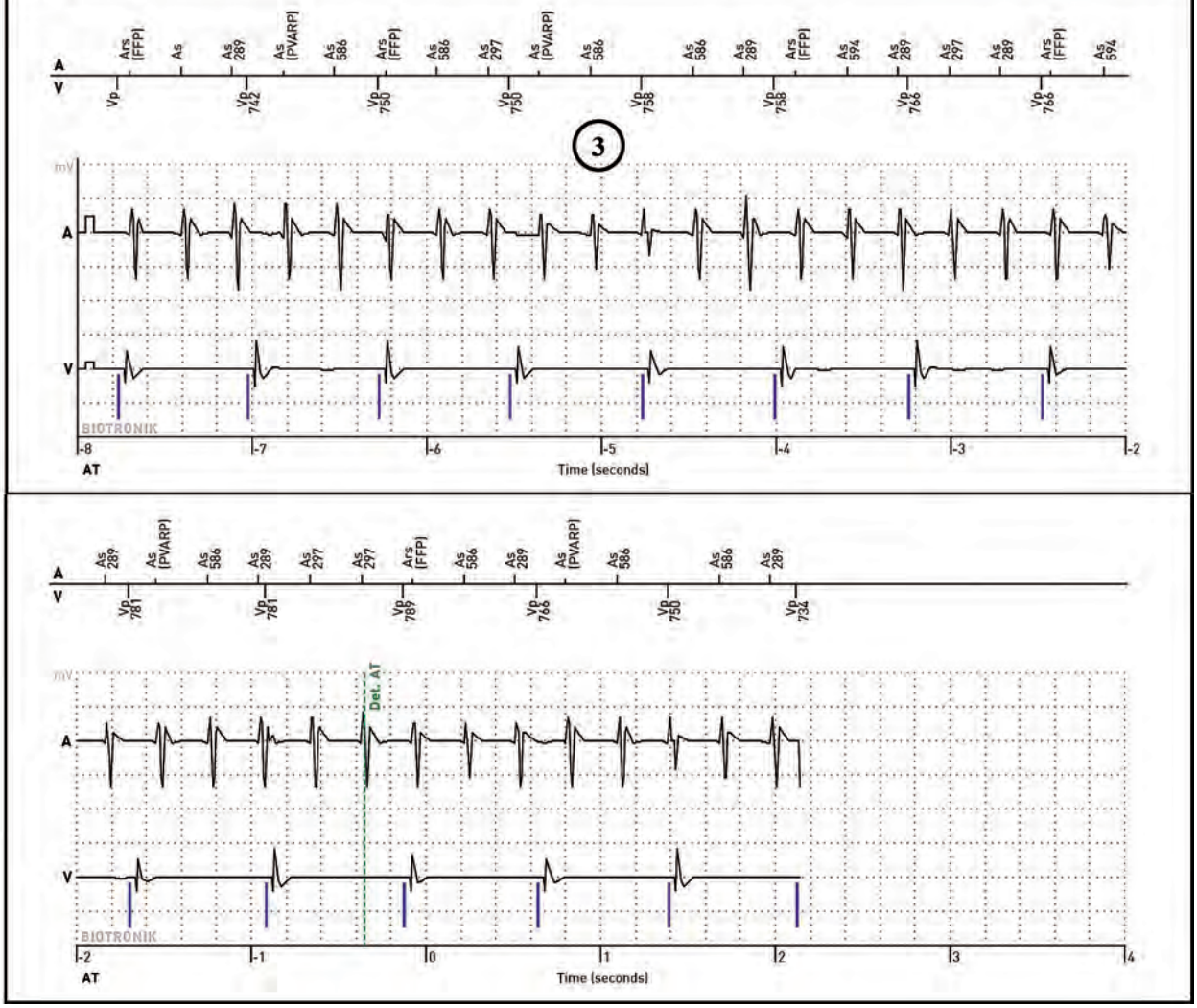
Eluna 8 DR-T
PM implanted Jun 9, 2015

IEGM



Implantable Cardioverter Defibrillator

Case studies based
on **Biotronik™** tracings

Implatable Cardioverter Defibrillator - chapter 1

Counters

Tracing 1 ↘ VF counter

Patient

A 43-year-old man implanted with a Lumax 340 VR-T single-chamber ICD for severe ischemic cardiomyopathy.

Telemedicine tracing

3 channels are available; the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the right ventricular sensing channel (V).

① sinus rhythm;

② polymorphic ventricular arrhythmia with extremely wide QRS complexes; short interval sensed in the VF zone;

③ undersensing of a ventricular interval explaining that the ensuing interval is classified as VS;

④ interval classified as VS in the absence of undersensing, the ventricular interval being slower than the programmed VF zone;

⑤ the VF counter is full (programmed at 12/16); start of the capacitor charge;

⑥ no therapy was delivered;

⑦ end of the episode;

Programmer tracing

The 3 channels are the same as for the telecardiology tracing.

⑧ start of the capacitor charge (black line);

⑨ ventricular undersensing explaining the intervals classified as VS;

⑩ double counting of the QRS complex;

⑪ interruption of the capacitor charge following the sensing of 3 out of 4 intervals classified as VS; spontaneous interruption of the arrhythmia explaining the absence of delivered therapy.

Comments

This first tracing allows detailing the operation of the VF counter used in Biotronik™ ICDs. It is a probabilistic counter (fast X/Y intervals) with various programming options depending on the age of the device (for the Iperia 6/8, 8/12, 10/14, 12/16, 16/20, 18/24, 20/26, 22/30, 24/30, 30/40 ICD platforms). Ventricular fibrillation is, by definition, a rapid, disorganized, chaotic arrhythmia, with low and/or variable amplitude ventricular signals. All of these characteristics favor the risk of undersensing with sometimes amplitude signals below the sensing threshold (nominal value of 0.8 mV) and often a high beat-to-beat variability in amplitude which may detract the sensing circuit given the use by the ICD of a sensitivity level which adapts according to the amplitude of the preceding signal. The different counter values were chosen so as to obtain an optimal balance between the accurate sensing of ventricular fibrillation (necessary tolerance of a certain number of long pseudo-intervals generated by undersensing) and the need not to fill the counters in the presence of T wave, P wave or R wave oversensing (frequently associated with a 50% short interval ratio).

In this patient, the VF counter was programmed at 18/24 (75% ratio) and the tracing showed 2 intervals classified as VS during the initial sensing without any significant impact on the sensing of the episode, the probabilistic counter tolerating a maximum ratio of 25% of long intervals. The first VS interval was

related to an intermittent undersensing, the second with a slower interval than the limit of the lower zone of the programmed VF zone. The detection quality of a ventricular arrhythmia is multiparametric and is contingent on: 1) the filters and the amplification which vary according to the manufacturers; 2) the amplitude of the ventricular signals with a limit set by the programmed sensitivity (nominal value 0.8 mV for Biotronik™ devices); 3) the variability in signal amplitude: certain characteristics of the adjustment of the sensitivity level during the cardiac cycle (adjustment percentage and adjustment delay) are independently programmable; 4) the number of intervals required to fill the counter which is programmable; as seen previously, the percentage of fast intervals (X/Y ratio) also varies slightly depending on the programming (66 to 80%); 5) the limit of the programmed zones and the type of counter used; one of the features of the devices of this manufacturer is that the counting method differs completely between the VT zone and the VF zone.

Status report

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Lumax 340 VR-T (XL)

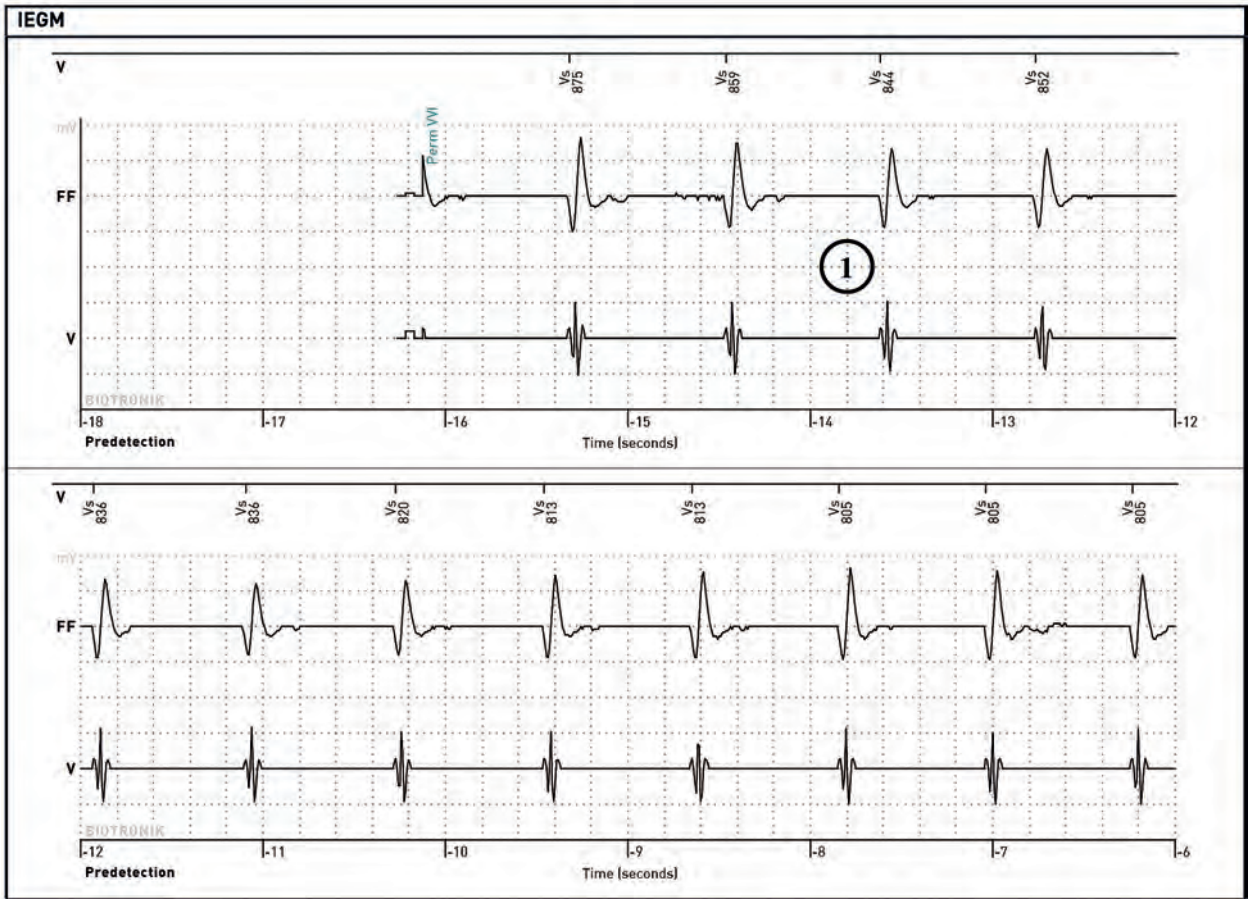
Recordings

Recordings - Episode 31:

General	
Episode number	31
Episode type	VF
Detection	Jan 21, 2014 10:31:21 PM
Termination	Jan 21, 2014 10:31:37 PM
Duration	16s
Device settings no.	11
Detection	
Mean RR at initial detection [ms]	117
Onset [%]	62
Stability [ms]	57
Redetection	---

Therapy	
ATP in VT/VF delivered	0
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	1
Maximum energy [J]	40
Termination	
Mean RR at termination [ms]	626
Remark	
none	

IEGM



Status report

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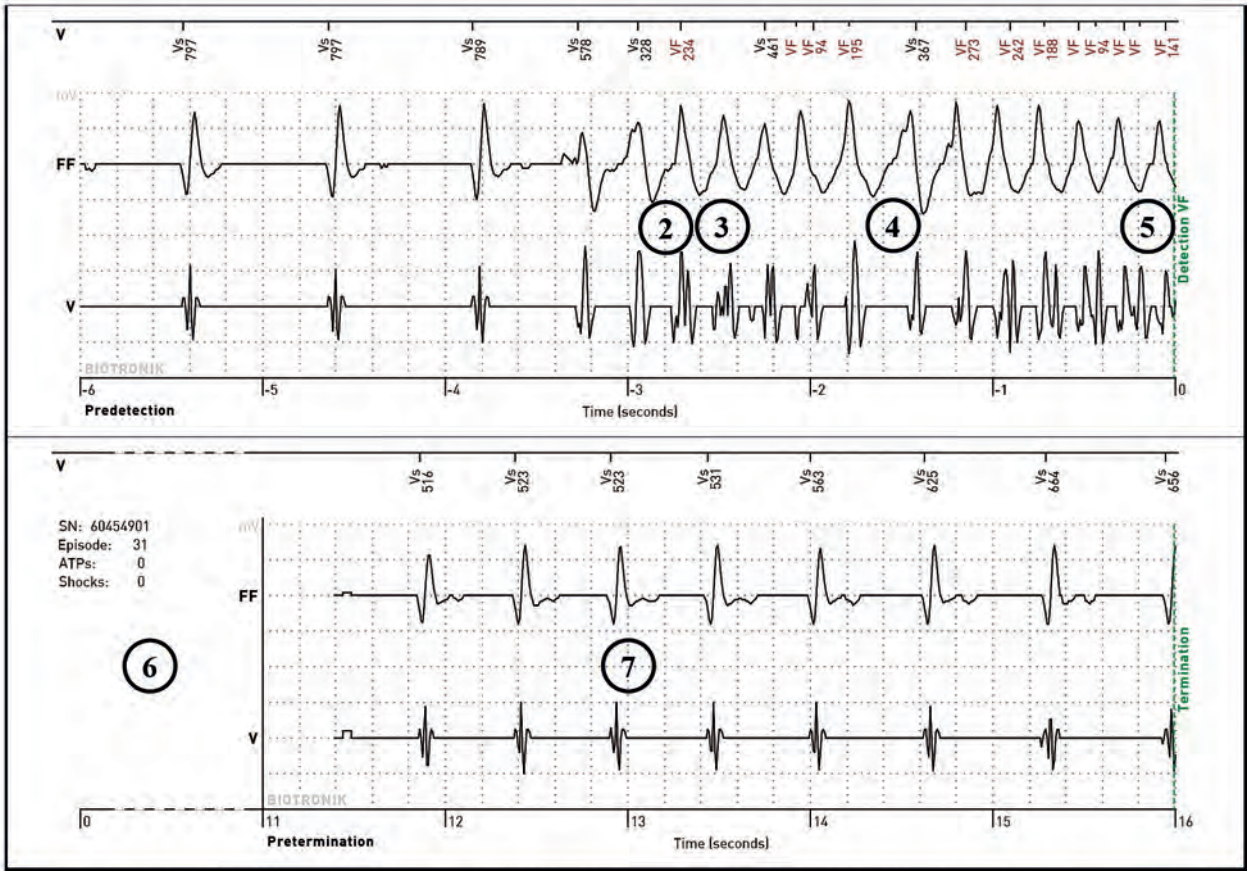
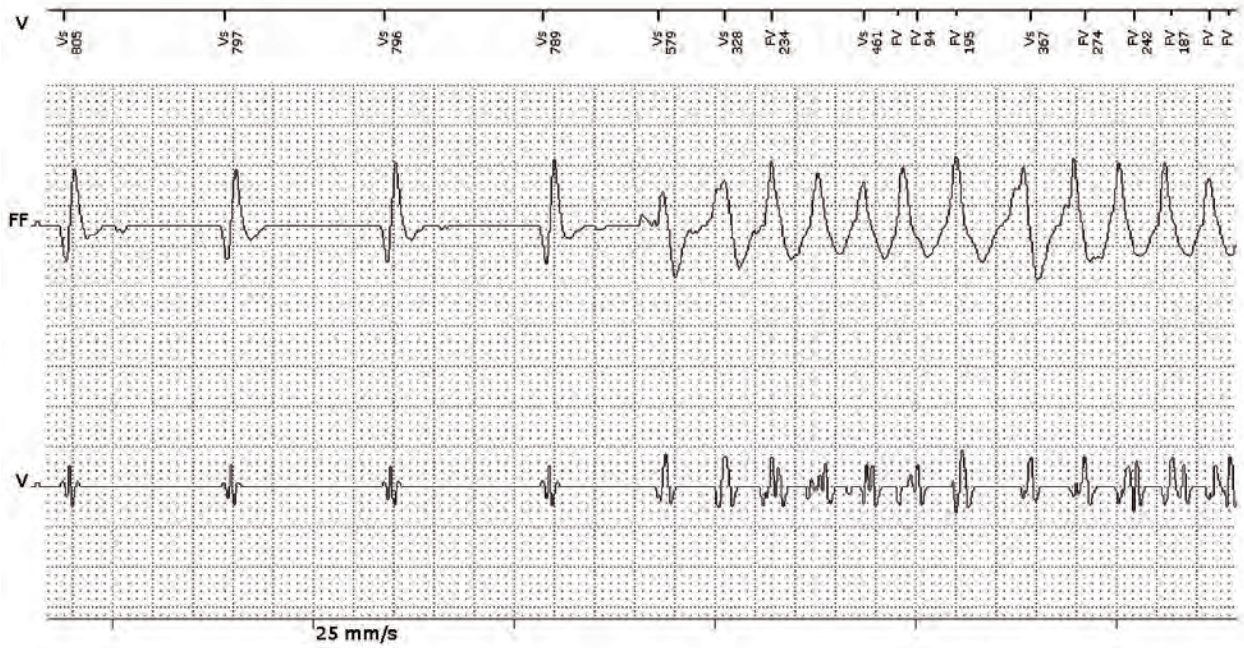
Lumax 340 VR-T (XL)

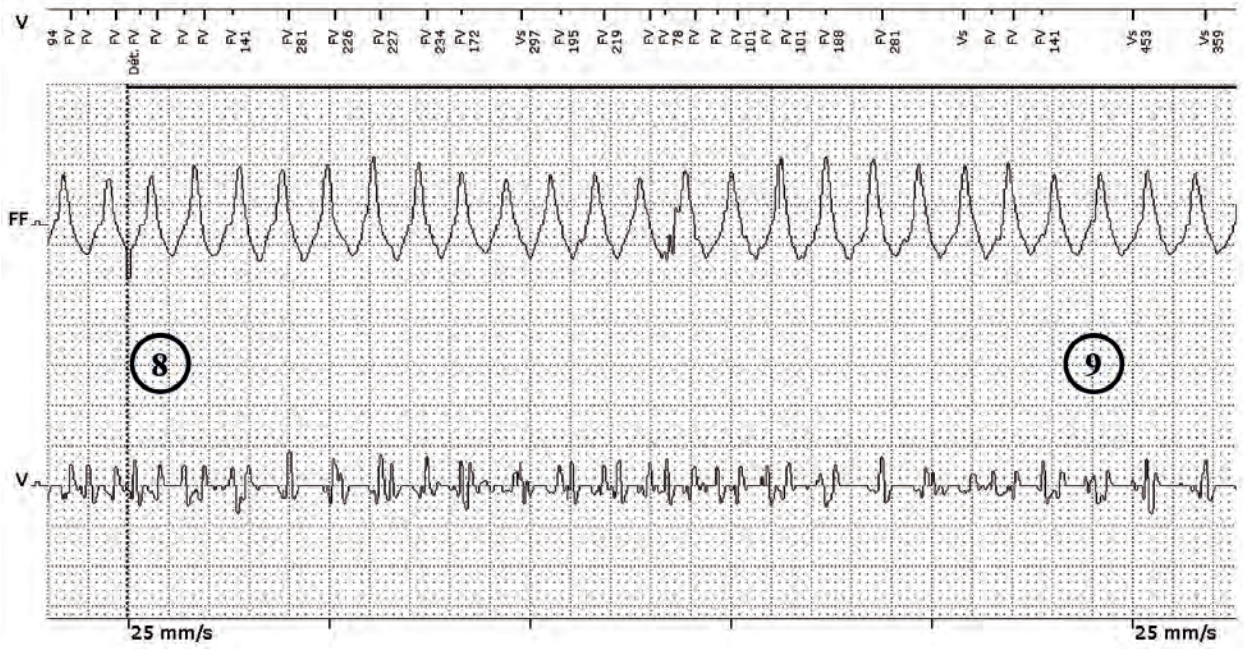


Prothèse Lumax 340 VR-T XL

N/S :

Enregistrements - EGM Episode : 31

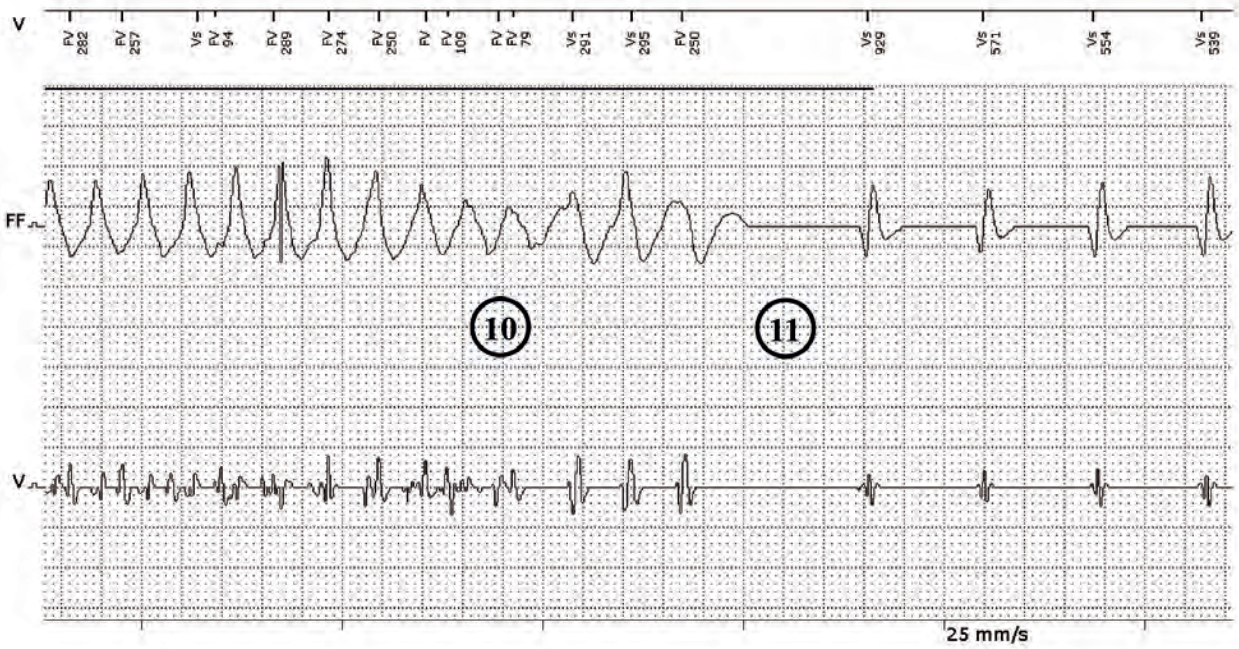


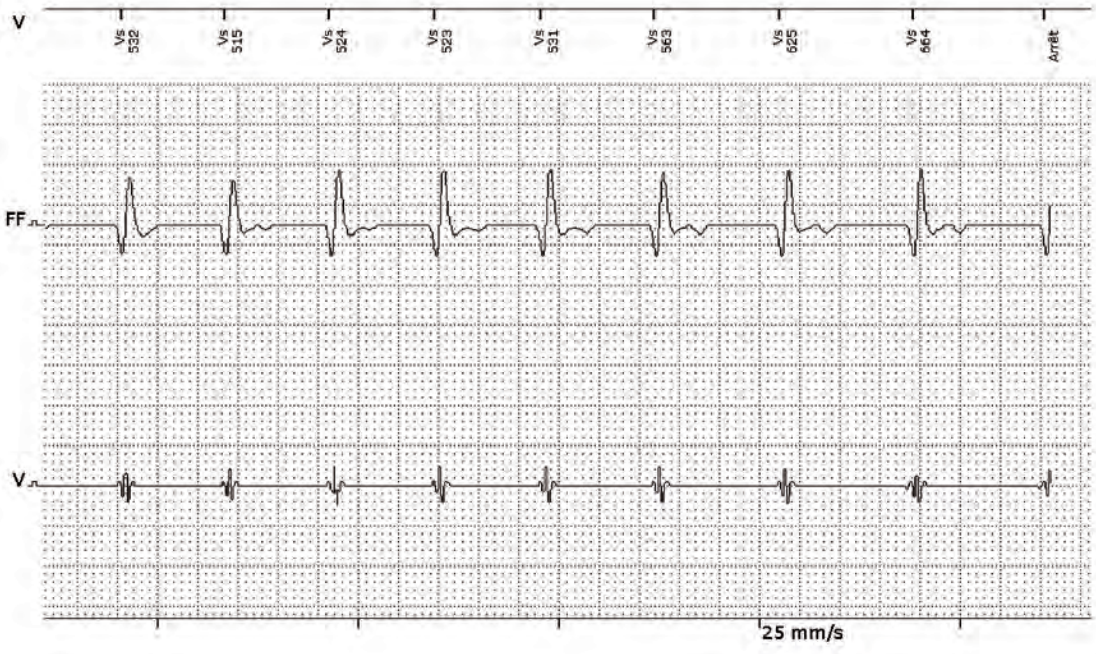


Prothèse Lumax 340 VR-T XL

N/S :

Enregistrements - EGM Episode : 31





Tracing 2 ↘ VT counter

Patient

65-year-old man implanted with an Ilesto 7 340 VR-T single-chamber ICD for severe ischemic cardiomyopathy.

Programmer tracing

3 channels are available; the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the right ventricular sensing channel (V).

① sinus rhythm;

② regular monomorphic tachycardia detected in VT1 zone; change in morphology comparatively to the sinus rhythm QRS complexes;

③ VT1 counter full (30 intervals);

④ antitachycardia pacing sequence;

⑤ termination of the arrhythmia;

⑥ end of episode after 12 intervals classified as VS.

Patient

75-year-old man implanted with an Iperia 7 HF triple-chamber ICD for ischemic cardiomyopathy with left bundle branch block; palpitations; the initial detection counter was programmed to 30 in the VT1 zone, to 28 in the VT2 zone and to 24/30 in the VF zone.

Telemedicine tracing

4 channels are available; the markers with the time intervals, the atrial channel (A), the right ventricular sensing channel (RV) and the left ventricular channel (LV).

① atrial sensing and biventricular pacing;

② onset of a VT with atrioventricular dissociation; first interval classified in the VT1 zone (increments the VT1 counter);

③ interval classified in the VT2 zone which increments the VT2 and VT1 counter;

④ interval classified in the VF zone which increments the VT2 and VT1 counter;

⑤ interval classified in VT1 zone which increments the VT1 counter and decrements the VT2 counter;

⑥ repetition of intervals classified in the VT2 zone which increment the VT2 and VT1 counter;

⑦ the VT1 counter is full (30) but not the VT2 counter (27); classification of the episode in VT1;

⑧ delivery of 2 antitachycardia pacing sequences corresponding to the therapies of the VT1 zone;

⑨ termination of the arrhythmia.

Comments

The specifics of the VT counter must be perfectly integrated in order to allow optimal programming. Indeed, for Biotronik™ devices, the counting method differs completely between the VT zone (up and down counter) and the VF zone (probabilistic counter), which is not the case for the ICDs of other manufacturers (with the exception of Medtronic™ ICDs).

The various ventricular events are classified according to the RR intervals in the paced ventricle (PV), sinus zone (VS), VT1, VT2 or VF. The low frequency of each zone is programmable, the different zones being continuous. It is therefore possible to program a single sensing zone (VF), 2 zones (VF + VT1) or 3 zones (VF + VT2 + VT1). An interval sensed in the VF zone increments the VT2 and VT1 counter (+1) as well as an interval in the VT2 zone for the VT1 zone. Indeed, the sensing of an interval in a tachycardia zone increments the counter of the slower tachycardia zones by 1. Conversely, an interval in the sinus zone decrements the VT1 and VT2 counter(s) (-1) as well as an interval in the VT1 zone for the VT2 zone. It is therefore an "up and down" counter. For the Hyperia platform, the VT1 counter is programmable between 10 and 100 intervals, the VT2 counter between 10 and 80 intervals. A counter reaching the required number of intervals necessitates diagnosis and associated therapies.

The "up and down" counter accurately detects monomorphic and regular ventricular tachycardias between 150 and 200 beats/minute with consecutive intervals sensed in the same tachycardia zone. This counter can also function efficiently for faster tachycardias (between 200 and 230 beats/minute), which are more likely to be polymorphic and therefore at increased risk of undersensing. Indeed, an interval classified as VS in conjunction with an undersensing does not reset the VT counter to 0 (difference with Medtronic™ ICDs) but decrements the latter only by 1; an intermittent undersensing thus delays but does not prevent the detection.

In clinical practice, different questions arise when choosing the number of zones to program and whether or not to program one or two VT zones (in addition to the VF zone):

1. which arrhythmia counter does one wish to use?

This issue is important for Biotronik™ devices. Indeed, the operation of the VT counter and the VF counter differs completely, which is not the case for the Boston Scientific™, Abbott™ or Livanova™ devices (this issue therefore does not intervene in the choice of the number of zones to be programmed on these devices). For a Biotronik™ ICD, in contrast, setting the limit of the VT or VF zone also sets the type of counter used ("up and down" counter or probabilistic counter) which can have an influence on the ability to effectively detect polymorphic ventricular arrhythmia.

2. in which zone is it possible to discriminate the origin of the arrhythmias?

The latest guidelines recommend discriminating the origin of the arrhythmias (VT versus SVT) up to very high rates (230 beats/minute). This issue is therefore central to the choice of the number of zones and zone limits for Biotronik™ devices. Indeed, it is not possible for these devices to discriminate in the VF zone. Programming a relatively low VF zone (in the order of 200 beats/minute) would therefore considerably limit the possibility of discriminating the origin of the arrhythmias.

3. should different therapies be programmed according to the frequency of the tachycardias?

Traditionally, it was customary to program several antitachycardia pacing sequences (between 3 and 6) for tachycardias between 150 and 200 beats/minute before eventually delivering one to several shocks and to deliver electric shocks without delay as first line treatment for faster tachycardias. Today, antitachycardia pacing is considered the first-line therapy for tachycardias up to rates of 230-250 beats/minute. It could thus be useful to program a second VT zone (VT2) between 200 and 230 beats/minute to allow initially treating these tachycardias by one or more antitachycardia pacing sequences.

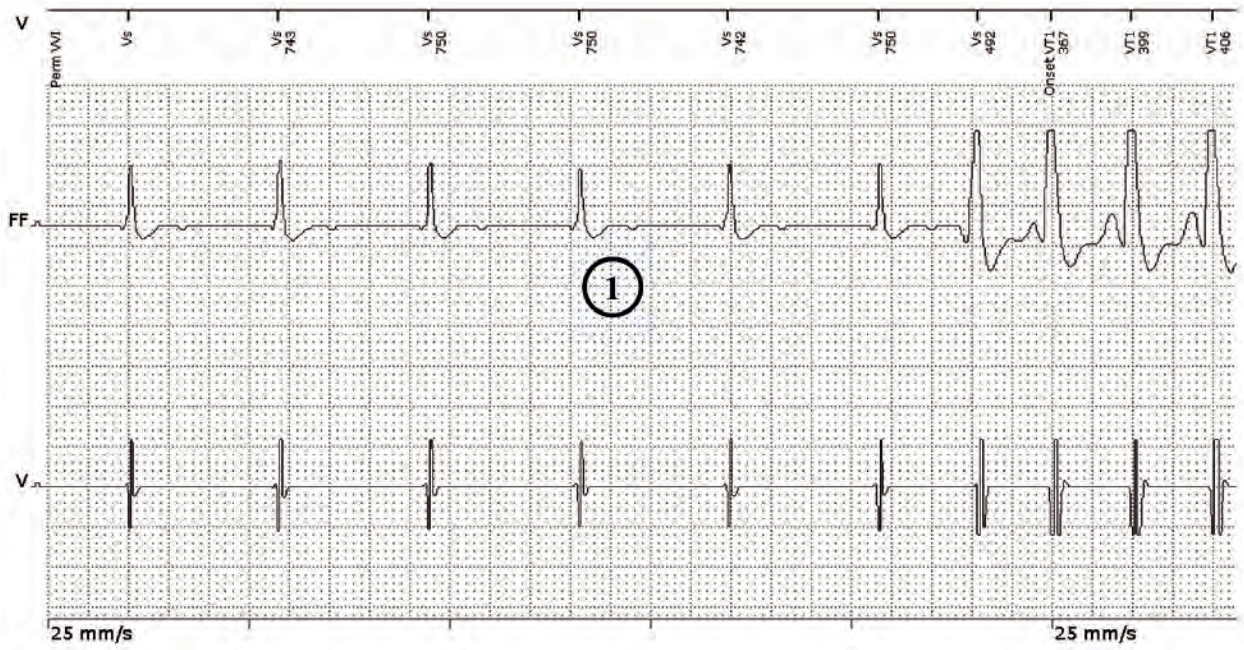
However, the possibility of delivering a one-shot ATP in VF zone has reduced the interest of programming this second intermediate VT zone. Its justification nowadays is limited to being able to program more than one antitachycardia pacing sequence.

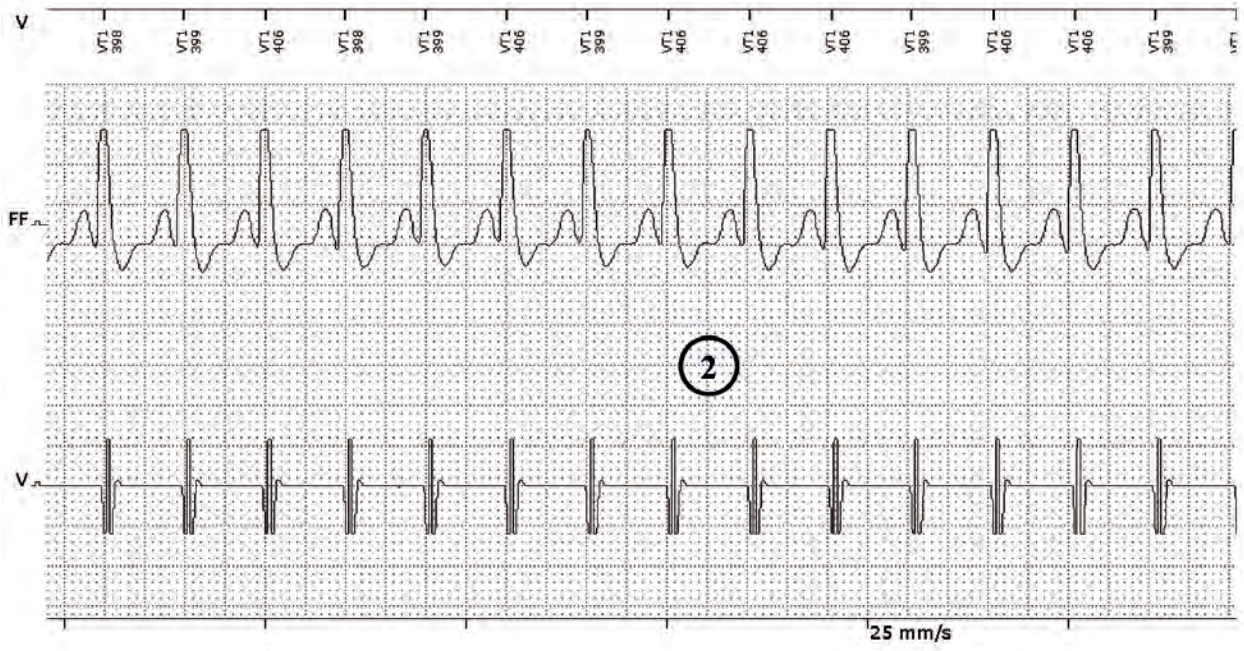
The new international guidelines integrate these elements and advocate programming as primary prevention in Biotronik™ devices a VF zone starting at 231 beats/minute, a VT2 zone starting at 188 beats/minute and possibly a VT1 monitoring zone; in secondary prevention, it is advisable to add a VT1 zone with therapies 10 to 20 beats/minute slower than clinical tachycardia.

Device Ilesto 7 VR-T

S/N:

Recordings - IEGM Episode: **1246**

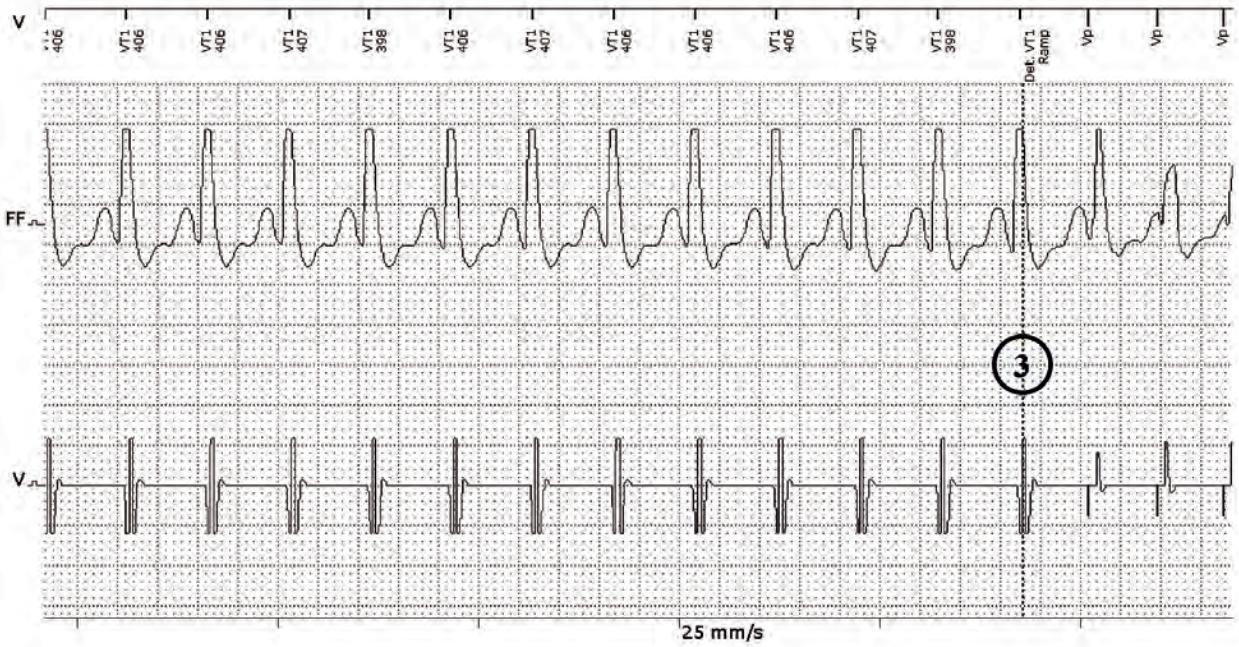


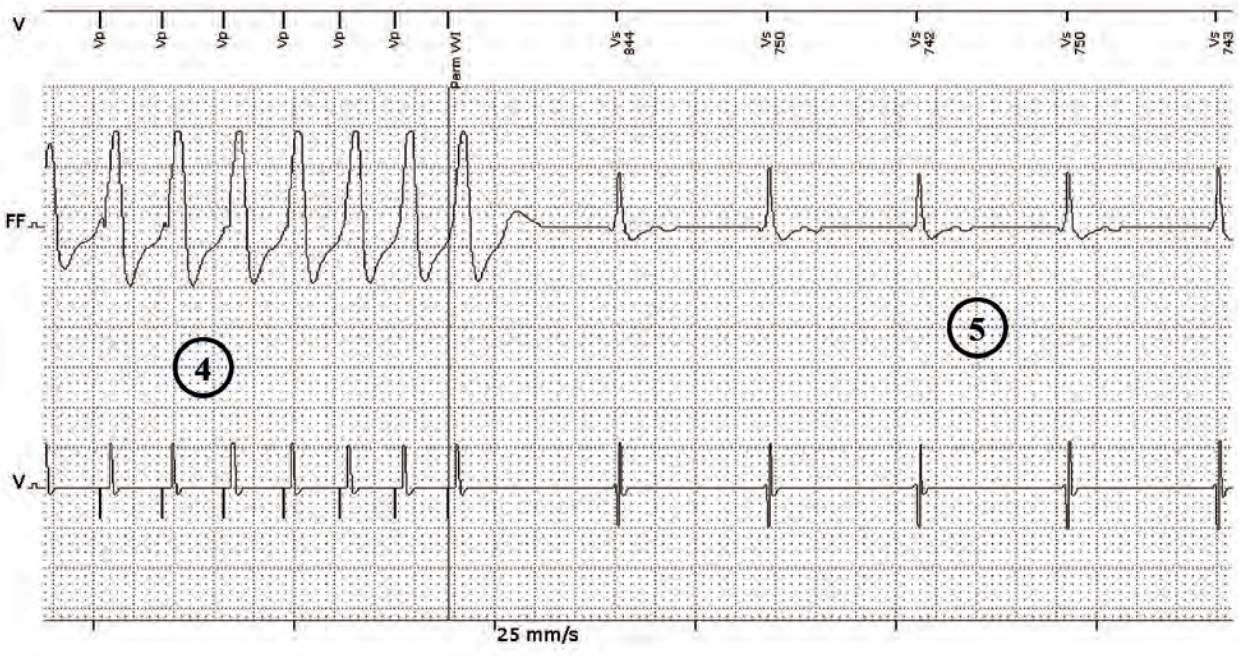


Device Ilesto 7 VR-T

S/N:

Recordings - IEGM Episode: **1246**

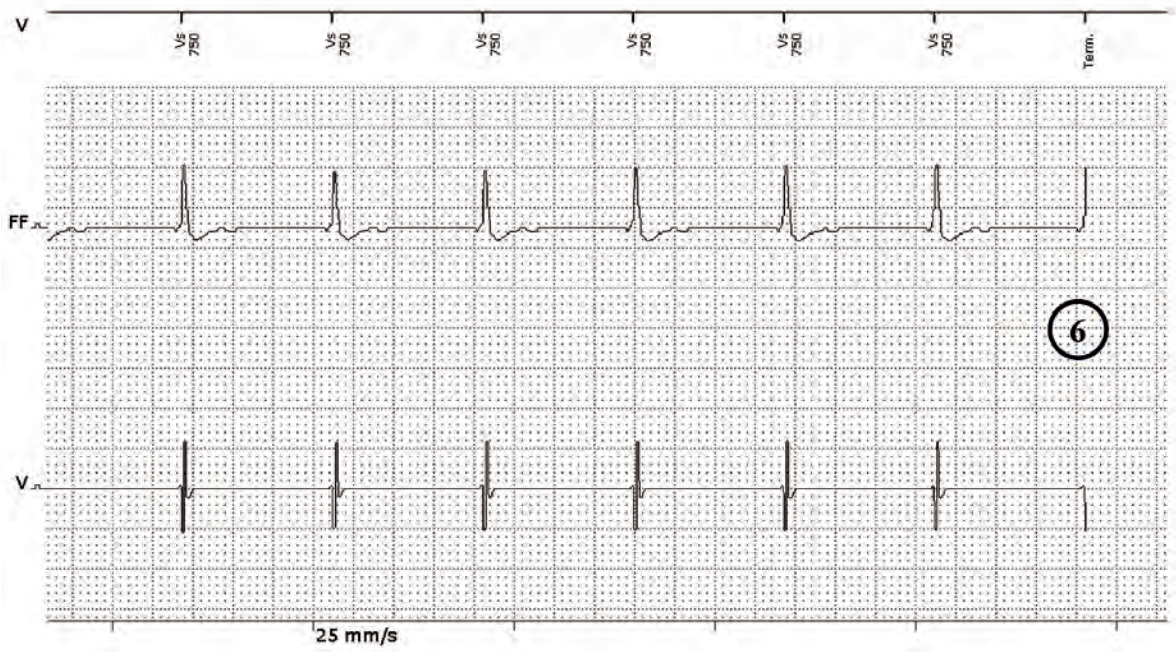




Device Ilesto 7 VR-T

S/N:

Recordings - IEGM Episode: **1246**



Status report

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Iperia 7 HF-T

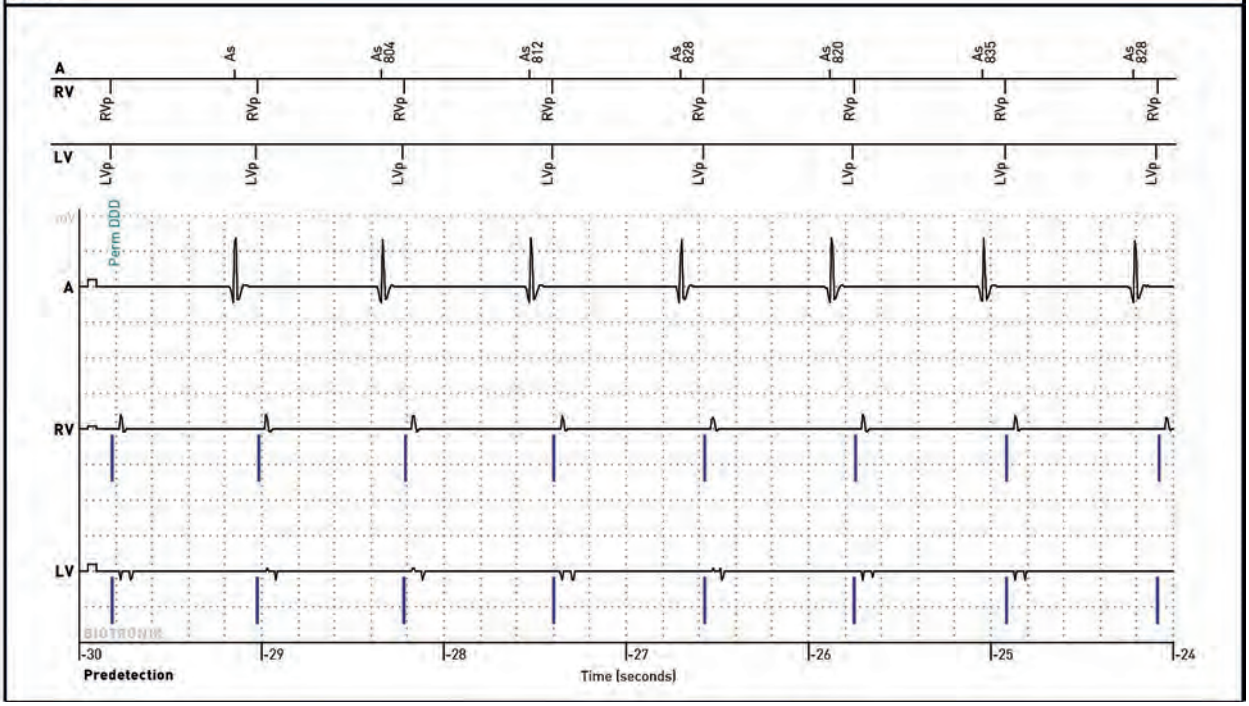
Recordings

Recordings - Episode 5:

General	
Episode number	5
Episode type	VT1
Detection	Mar 30, 2017 4:40:29 PM
Termination	Mar 30, 2017 4:40:46 PM
Duration	17s
Device settings no.	19
Detection	
Mean PP at initial detection [ms]	746
Mean RR at initial detection [ms]	290
Onset [%]	57
Stability [ms]	2
Redetection	VT2: 1

Therapy	
ATP delivered (total)	2
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	0
Maximum energy [J]	---
Termination	
Mean PP at termination [ms]	577
Mean RR at termination [ms]	576
Remark	
Therapy	surge guard applied

IEGM



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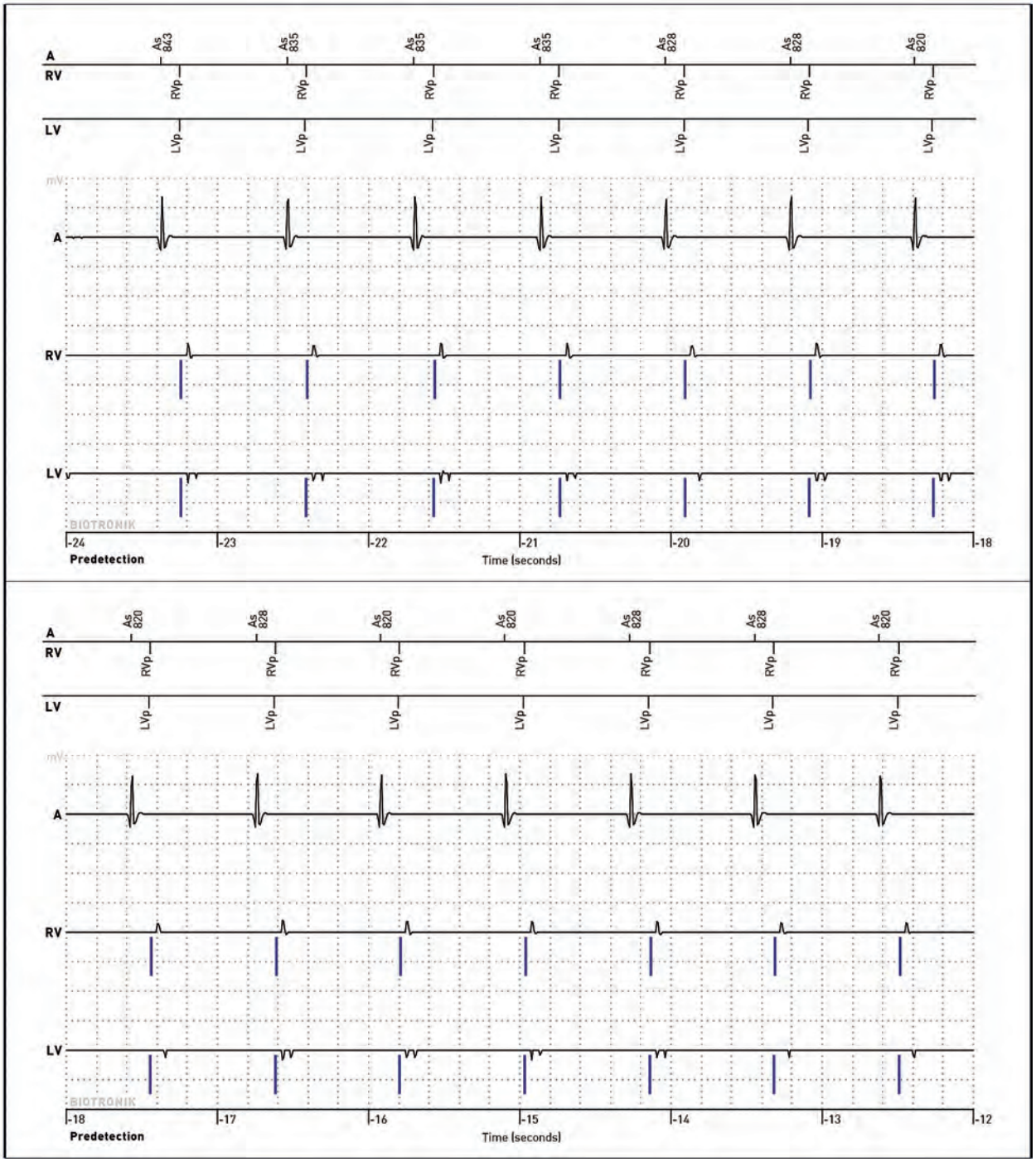
Iperia 7 HF-T



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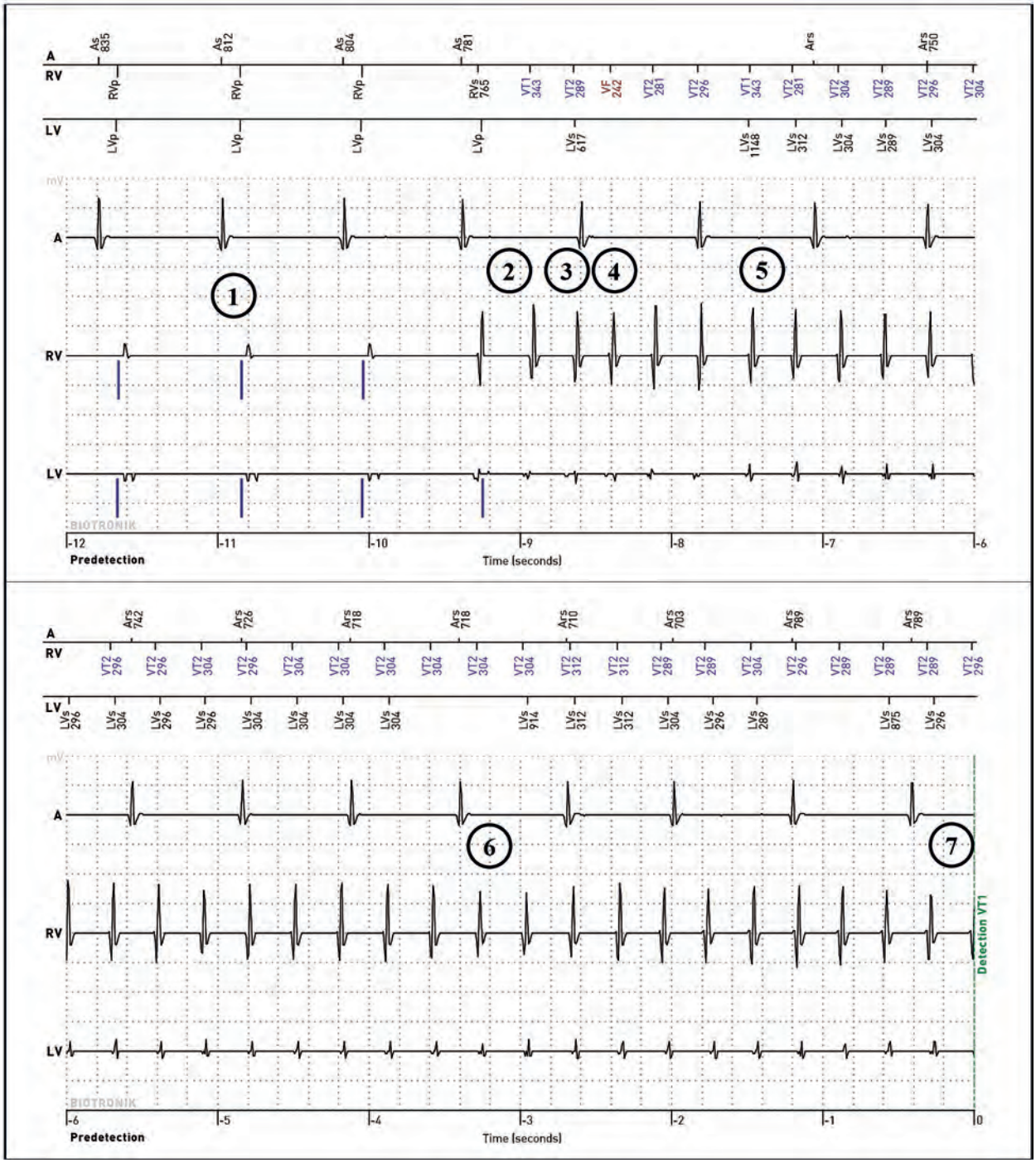
Iperia 7 HF-T



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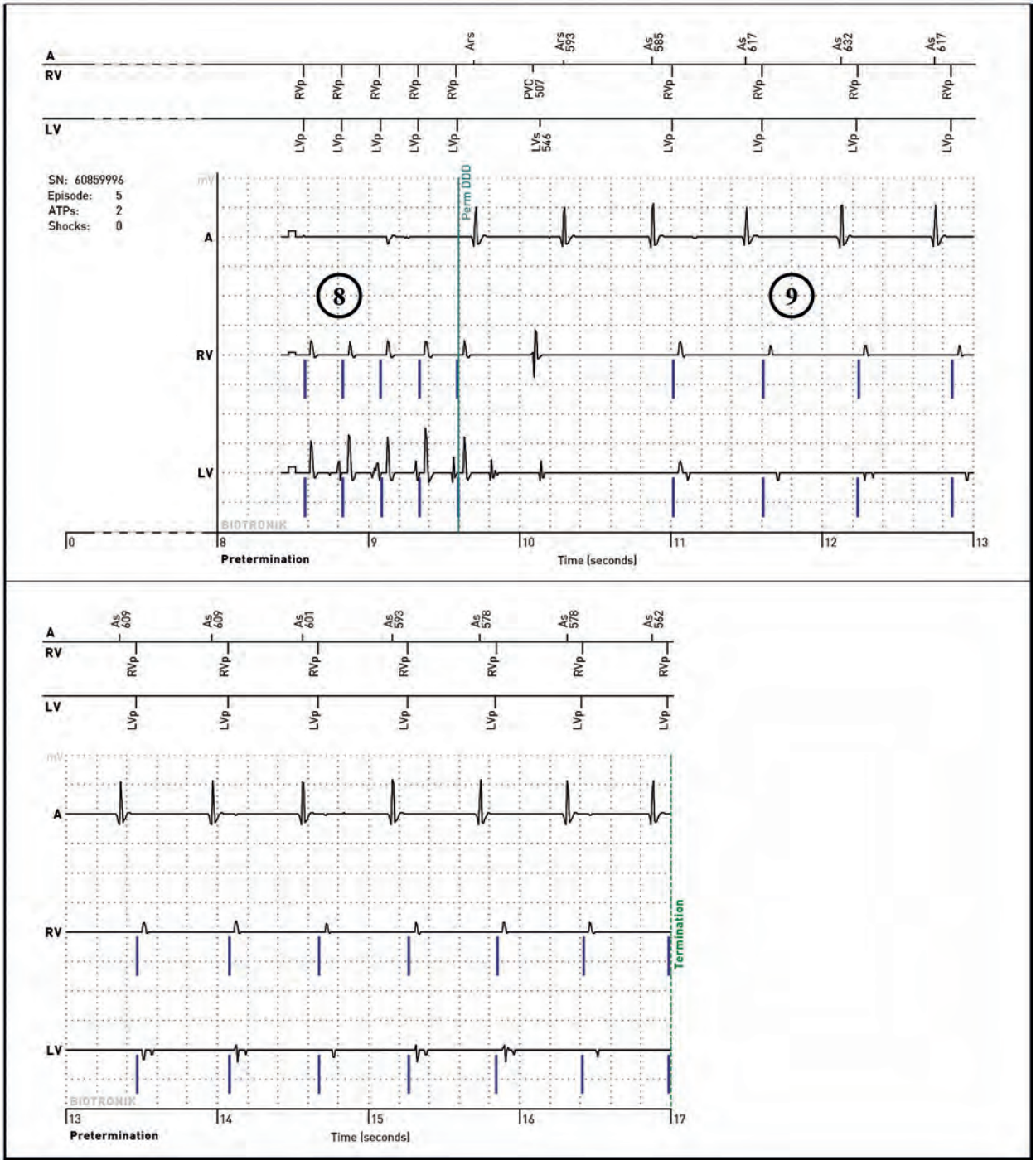
Iperia 7 HF-T



Tracing 3 ↘ Lead fracture and VF counter

Patient

83-year-old man implanted with a Lumax 540 HF-T triple-chamber ICD for heart failure with left bundle branch block; remote monitoring alert for several episodes of VF without delivery of therapy.

Telemedicine tracing

4 channels are available; the markers with the time intervals, the atrial channel (A), the right ventricular sensing channel (RV) and the left ventricular channel (LV).

① biventricular pacing;

② the EGM reveals an oversensing of disorganized, very rapid, non-physiological ventricular signals; certain intervals are at the limit of the programmed blanking;

③ the oversensing is intermittent although the initial VF counter programmed at 18/24 is full;

④ absence of delivered therapy;

Programmer tracing (identical episode)

The 4 channels are the same as for the telecardiology tracing.

⑤ the VF counter is full; start of the capacitor charge;

⑥ charge interrupted after 3 out of 4 intervals classified as RVp (pacing) or RVs (sensing).

Comments

This tracing shows a characteristic pattern of lead dysfunction associated with the occurrence of multiple episodes of charging of the capacitors. The oversensing could be reproduced by thwarted maneuvers favoring the oversensing of pectoral myopotentials which could already be evoked on the tracing given the high frequency of sensed signals. The preponderance of short intervals versus long intervals explains that the 75% ratio required to fill the initial counter is met (18/24). Most commonly, lead dysfunction is initially revealed by short episodes diagnosed as non-sustained VT (a few intervals). The duration of the oversensing episodes generally increases progressively in parallel with the wear of the lead. In order to avoid the occurrence of inappropriate therapies, it is clear that in addition to a rapid diagnosis supported by a remote follow-up, one solution is to extend the number of intervals required for the initial diagnosis of VF. Nowadays, the new guidelines favor the first-line programming of initial counters at 30/40 even without signs of lead dysfunction. Results obtained on large-scale samples showed that this programming significantly reduced the number of inappropriate therapies but also the number of appropriate but avoidable therapies, with the arrhythmia terminating spontaneously without significantly increasing the risk of syncope.

Status report

BIOTRONIK excellence for life

Lumax 540 HF-T

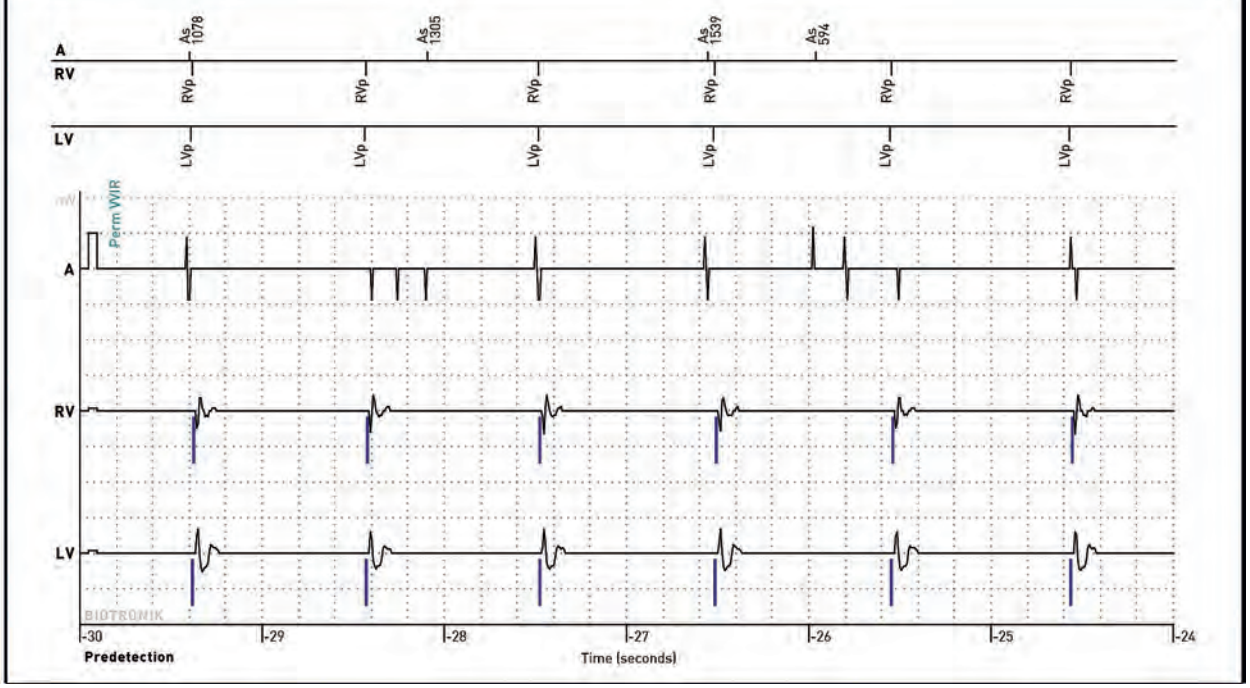
Recordings

Recordings - Episode 1419:

General	
Episode number	1419
Episode type	VF
Detection	Jul 28, 2015 9:17:48 AM
Termination	Jul 28, 2015 9:18:01 AM
Duration	13s
Device settings no.	16
Detection	
Mean PP at initial detection [ms]	> 1998
Mean RR at initial detection [ms]	123
Onset [%]	89
Stability [ms]	74
Redetection	---

Therapy	
ATP in VT/VF delivered	0
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	1
Maximum energy [J]	40
Termination	
Mean PP at termination [ms]	> 1998
Mean RR at termination [ms]	931
Remark	
none	

IEGM



Status report

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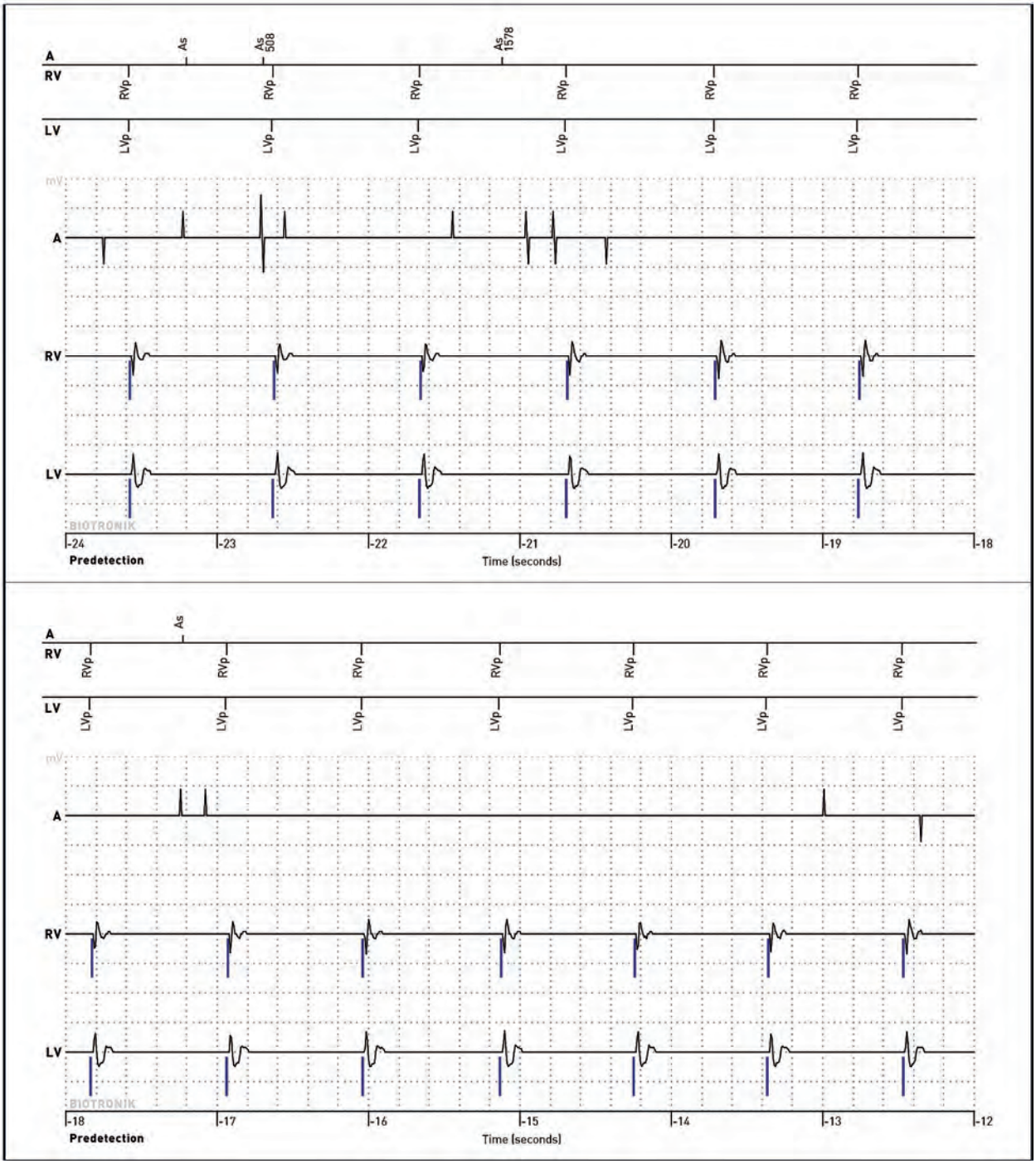
Lumax 540 HF-T



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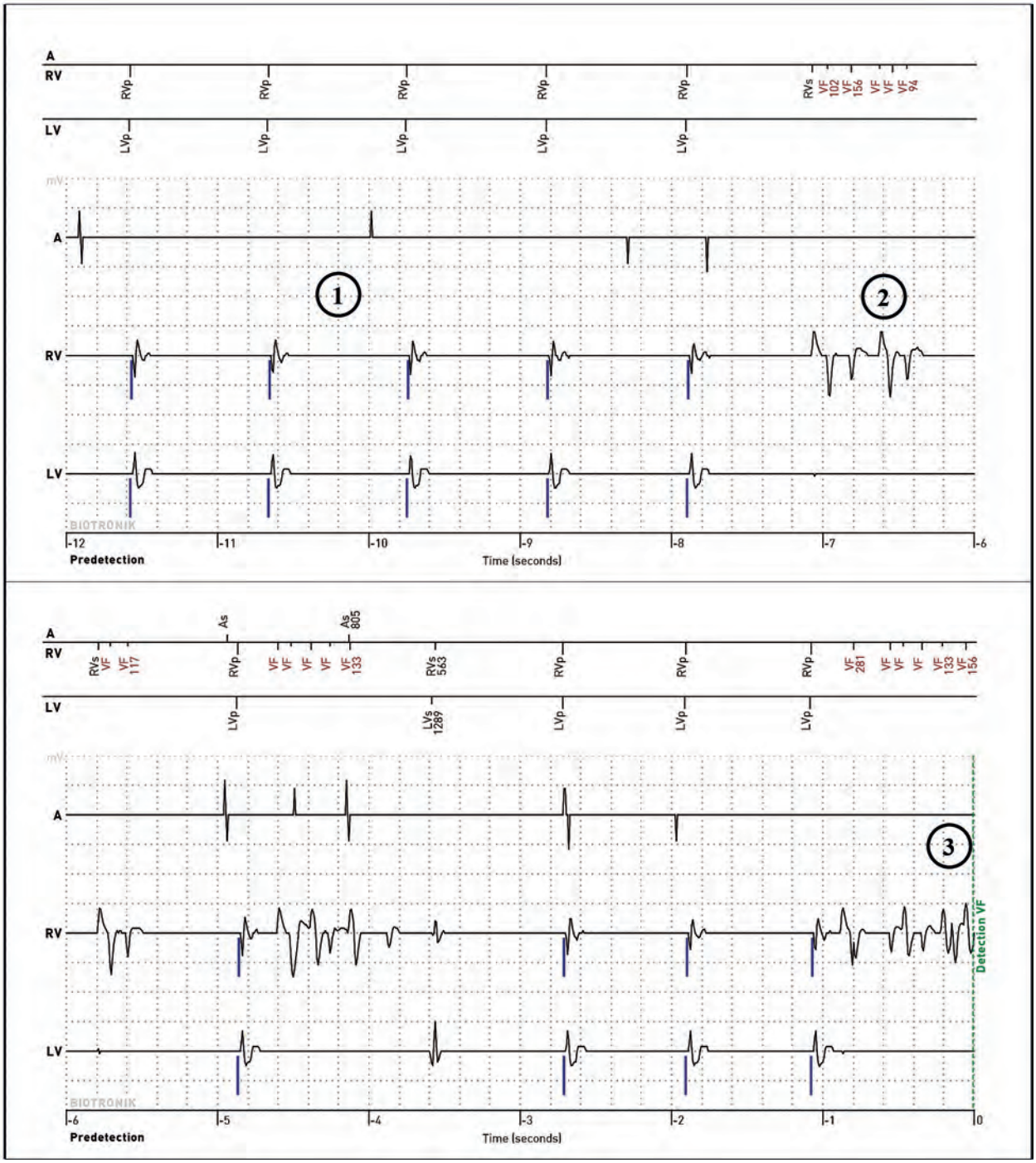
Lumax 540 HF-T



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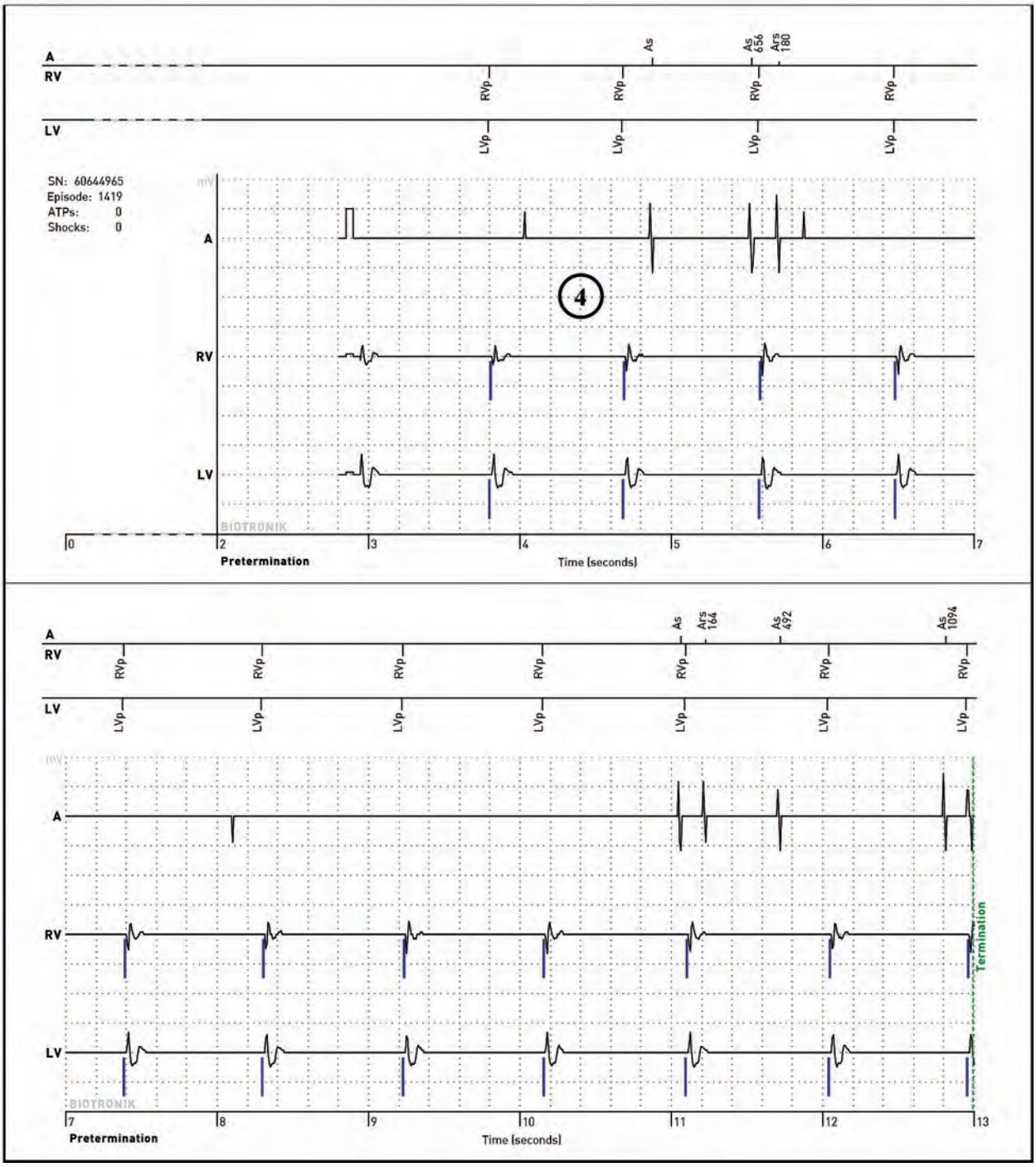
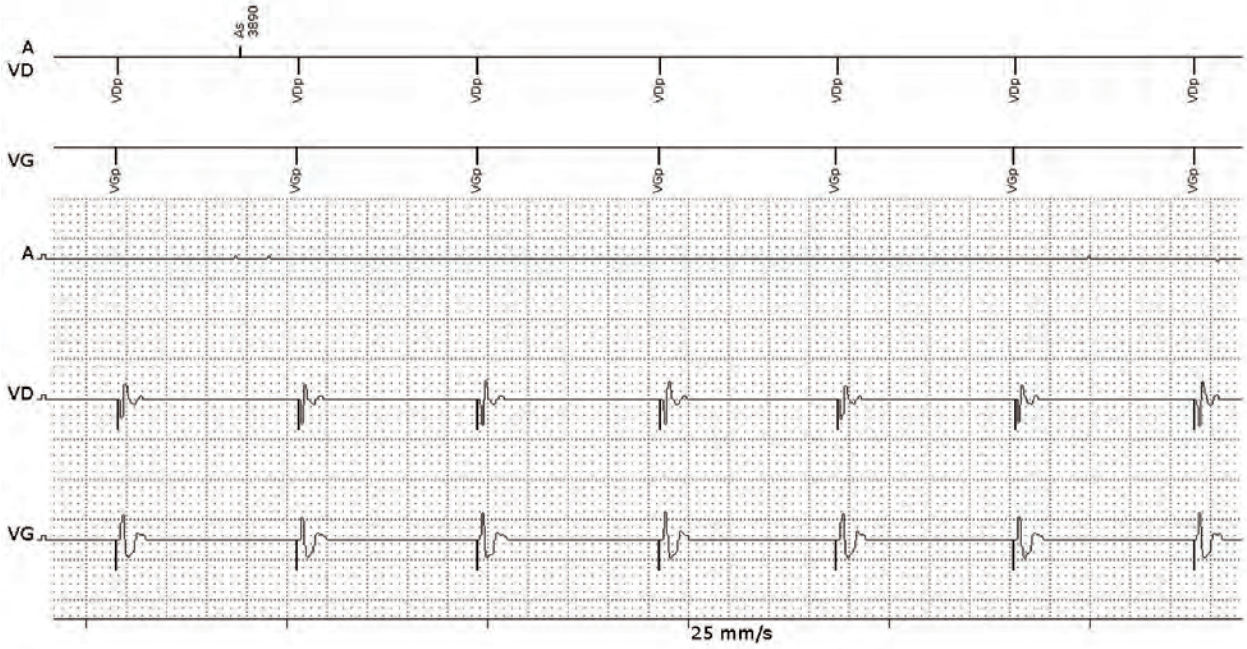
Lumax 540 HF-T

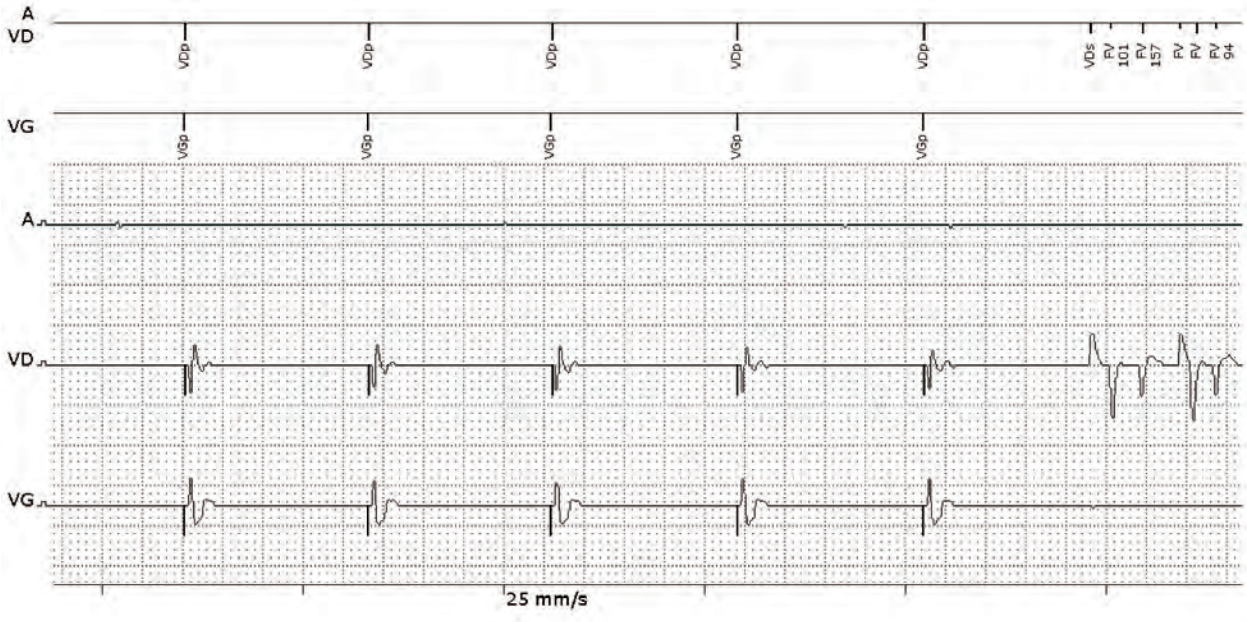


Prothèse Lumax 540 HF-T

N/S :

Enregistrements - EGM Episode : 1419

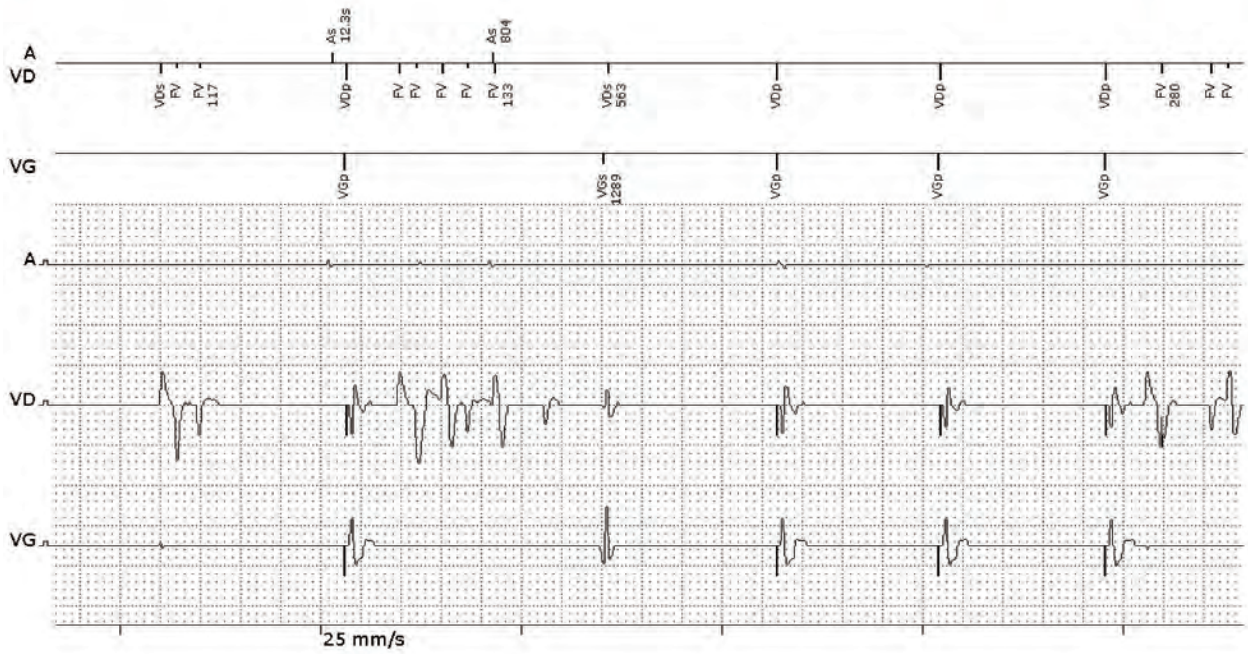


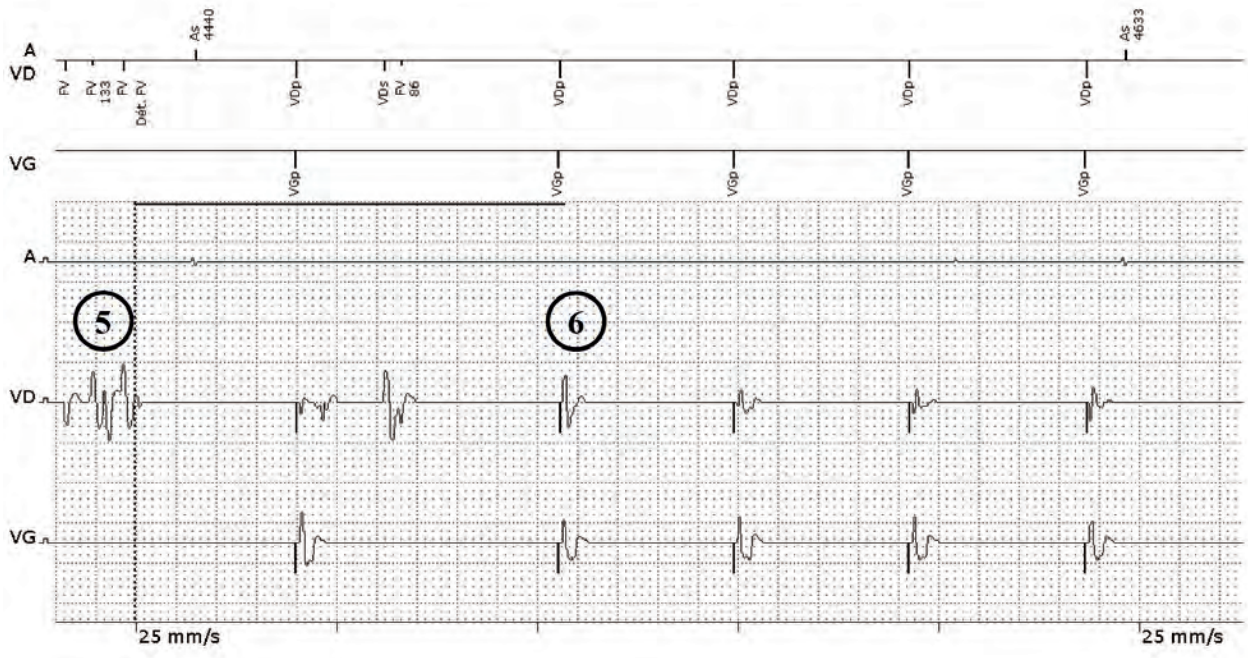


Prothèse Lumax 540 HF-T

N/S :

Enregistrements - EGM Episode : 1419





Tracing 4 ↘ Initial VF counter and number of required intervals

Patient

79-year-old man implanted with an Ilesto 7 HF-T triple-chamber ICD with ablation of the bundle of His for permanent atrial fibrillation, heart failure and multiple episodes of non-sustained VT.

Telemedicine tracing

3 channels are available; the markers with the time intervals, the right ventricular sensing channel (RV) and the LV sensing channel (LV).

① biventricular pacing;
② ventricular doublet;
③ VT detected in VF area;
④ VF counter full (18/24);
⑤ spontaneous termination and interruption of the charge;

Programmer tracing (identical episode)

The 3 channels are the same as for the telecardiology tracing.

⑥ VF counter full and start of the capacitor charge;
⑦ spontaneous termination of the arrhythmia after 29 intervals classified as VF;
⑧ new episode;
⑨ spontaneous termination after 25 intervals classified as VF;
⑩ new episode;
⑪ spontaneous termination after 22 intervals classified as VF;
⑫ new episode;
⑬ VF counter full; one-shot ATP, the intervals preceding diagnosis being stable;
⑭ non-effective burst and spontaneous termination.

Comments

This patient presented multiple episodes of non-sustained ventricular tachycardias detected in the VF zone (VF counter unfilled) but also slightly longer episodes with charging of the capacitors and sometimes non-effective one-shot ATP with subsequent spontaneous termination. These therapies could therefore be considered as appropriate but also as avoidable or unnecessary, the arrhythmia being terminated spontaneously. The programming of the number of intervals required for the initial detection is crucial for the quality of life of the patient, for his/her prognosis as well as for the lifespan of the device. Indeed, programming 30/40 for the initial detection would allow in this patient: 1) avoiding the repeated occurrence of capacitor charges with a significant impact on battery wear; 2) possibly reducing, as seen on the previous tracing, the number of inappropriate therapies due to lead dysfunction; 3) reducing the number of appropriate but avoidable therapies. Associated with the programming of relatively high detection zones, this translates into primary prevention through a significant reduction in mortality. Treating an episode of malignant ventricular arrhythmia with electric shock remains the only option for achieving viable hemodynamics. On the other hand, the latest guidelines, based on all recent studies,

suggest the need to avoid early and overly aggressive treatment of organized and slower ventricular arrhythmias. An electric shock can save a life but is associated with a deleterious effect of its own and should therefore be avoided whenever possible when spontaneous termination is possible or a less aggressive therapy can prove effective. It is therefore advisable 1) not to systematically program too low treatment zones in primary prevention; 2) extend the initial detection counters in the VT zone but also in the VF zone in order to avoid treating spontaneously terminating arrhythmia episodes (appropriate but avoidable therapies). Likewise, it is desirable in this patient to avoid, as much as possible, the occurrence of bursts of antitachycardia pacing in the VF zone, which can prove to be, on the one hand, ineffective with moreover, a significant risk of accelerated progression of the arrhythmia into a very rapid rhythm disorder compromising the survival of the patient in the short term and requiring the delivery of one or more electrical shocks by the device.

Status report

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Ilesto 7 HF-T

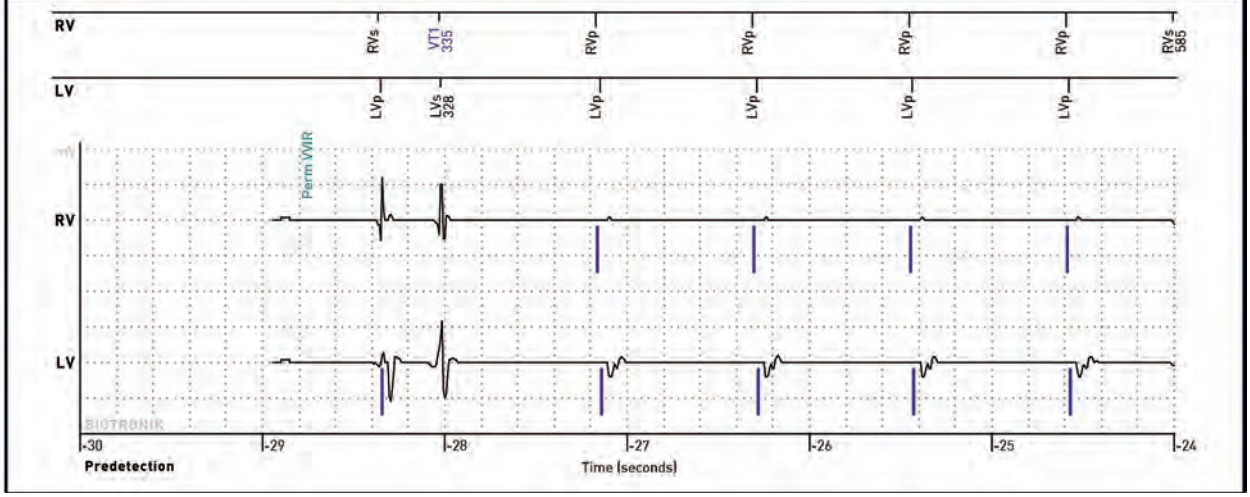
Recordings

Recordings - Episode 10:

General	
Episode number	10
Episode type	VF
Detection	Feb 15, 2016 11:38:46 AM
Termination	Feb 15, 2016 11:39:02 AM
Duration	16s
Device settings no.	17
Detection	
Mean PP at initial detection [ms]	---
Mean RR at initial detection [ms]	229
Onset [%]	57
Stability [ms]	29
Redetection	---

Therapy	
ATP in VT/VF delivered	0
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	1
Maximum energy [J]	40
Termination	
Mean PP at termination [ms]	---
Mean RR at termination [ms]	727
Remark	
none	

IEGM



Status report

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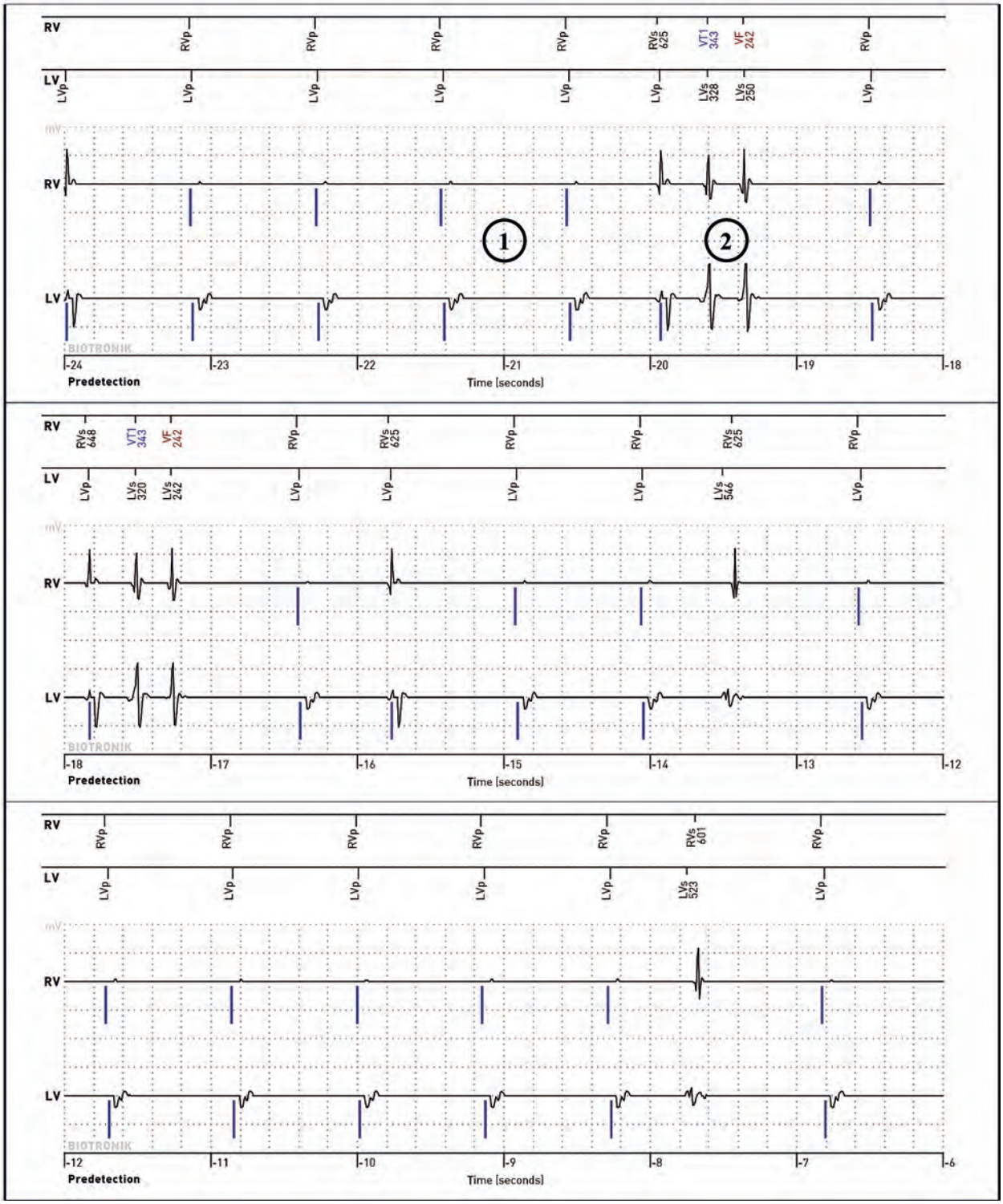
Ilesto 7 HF-T



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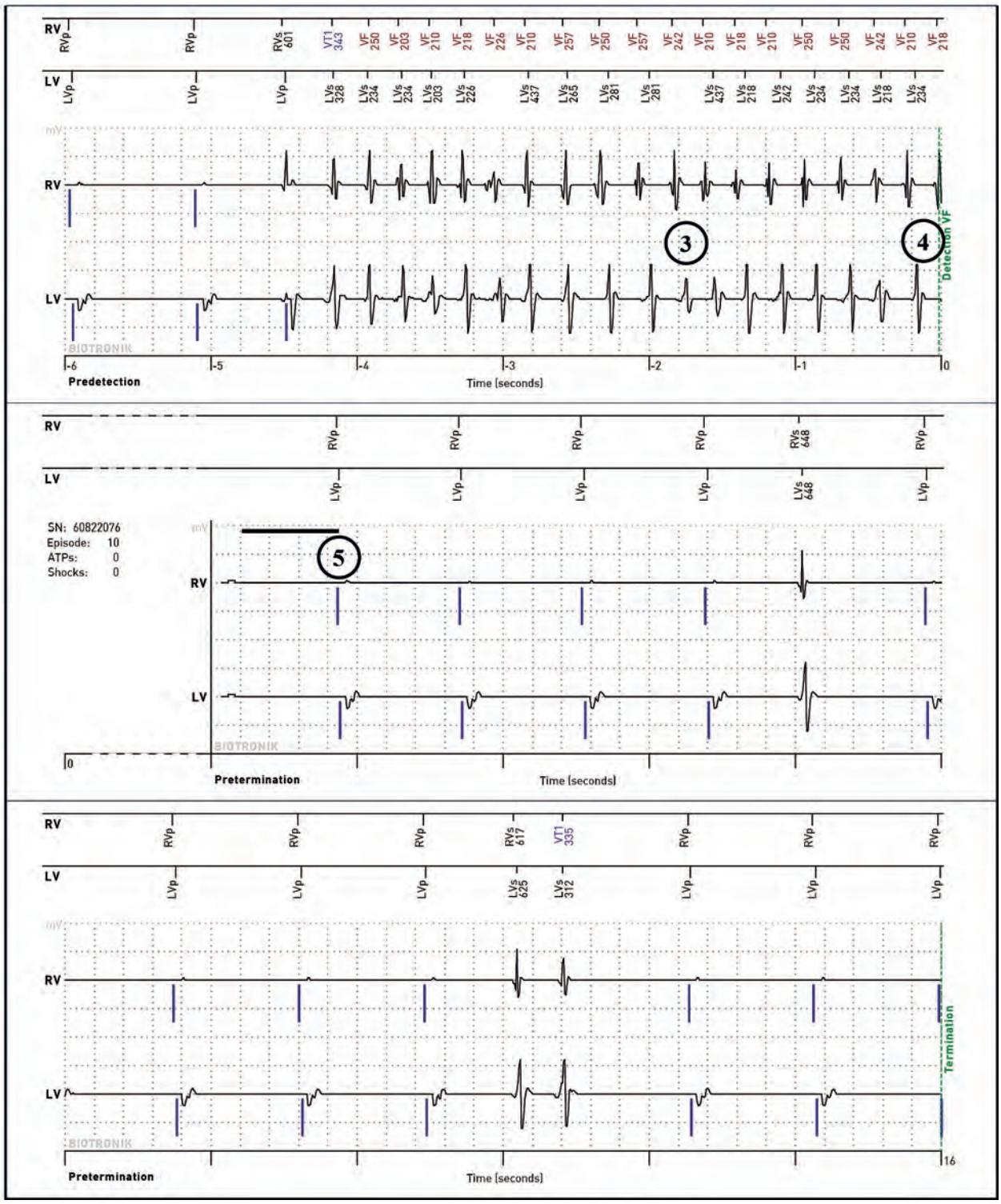
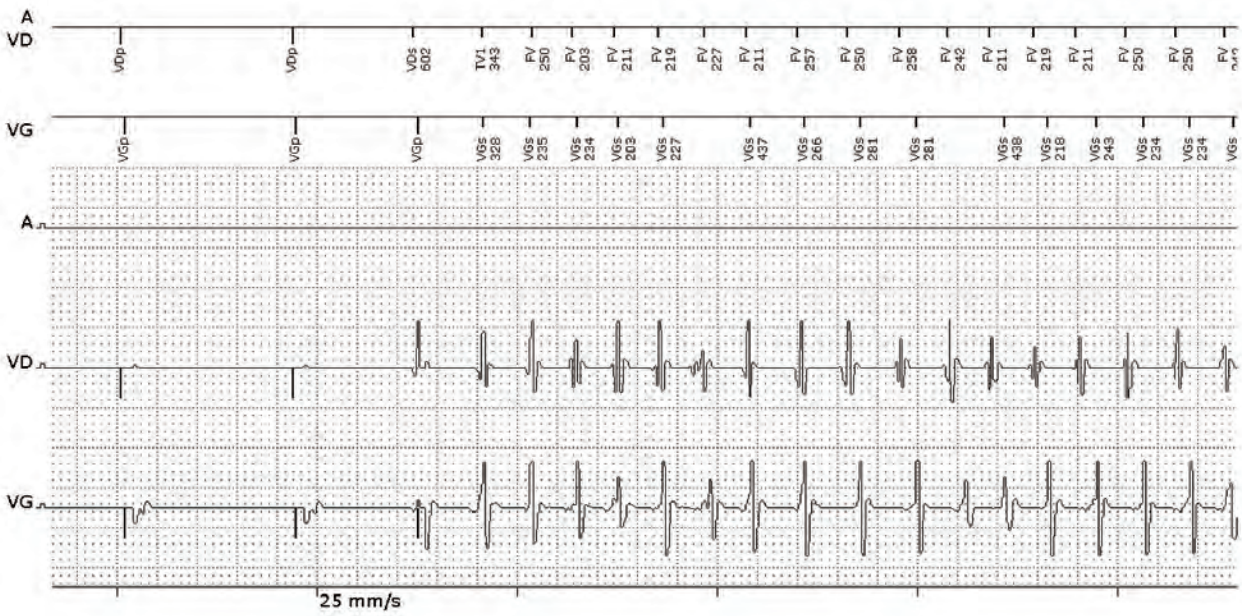
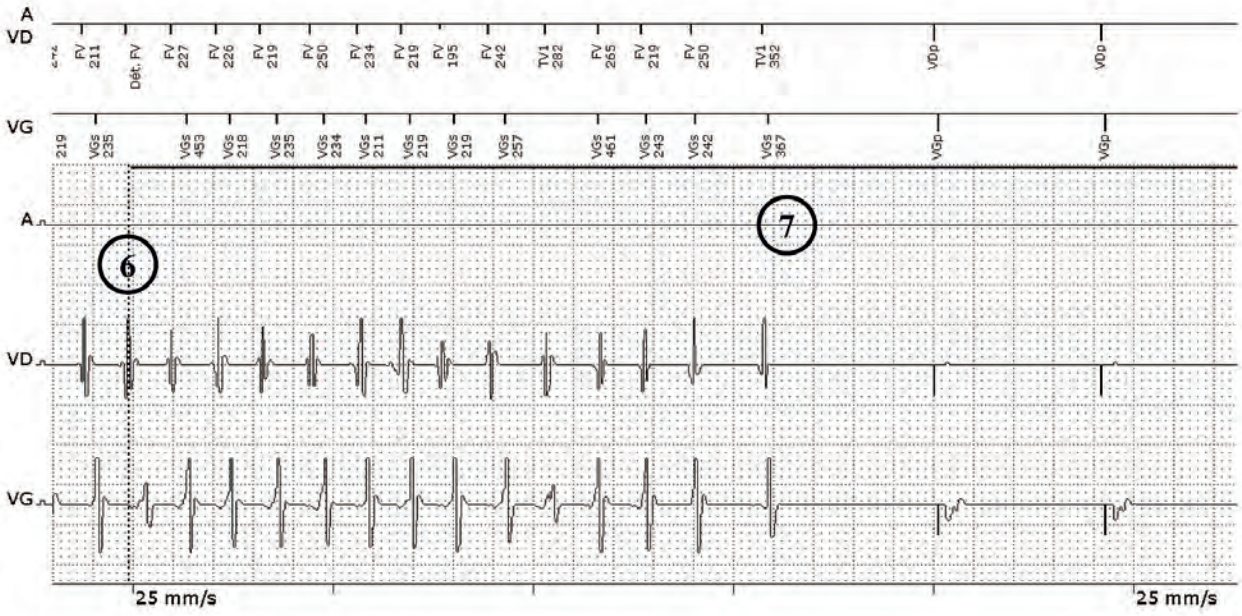


Prothèse Ilesto 7 HF-T

N/S :

Enregistrements - EGM Episode : **10**

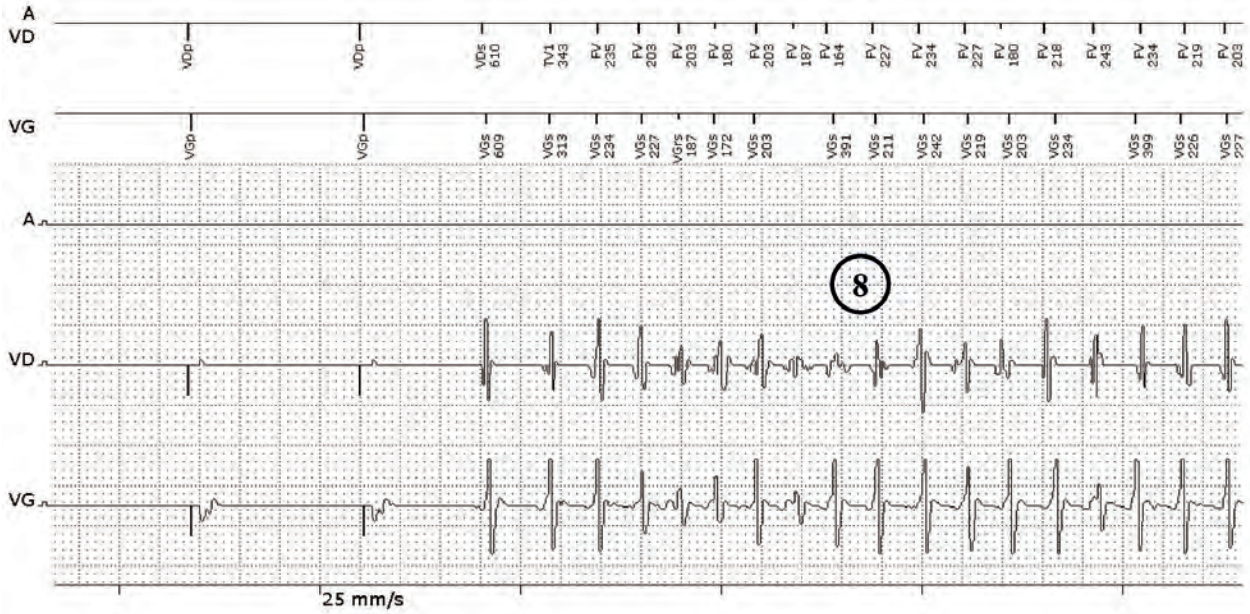


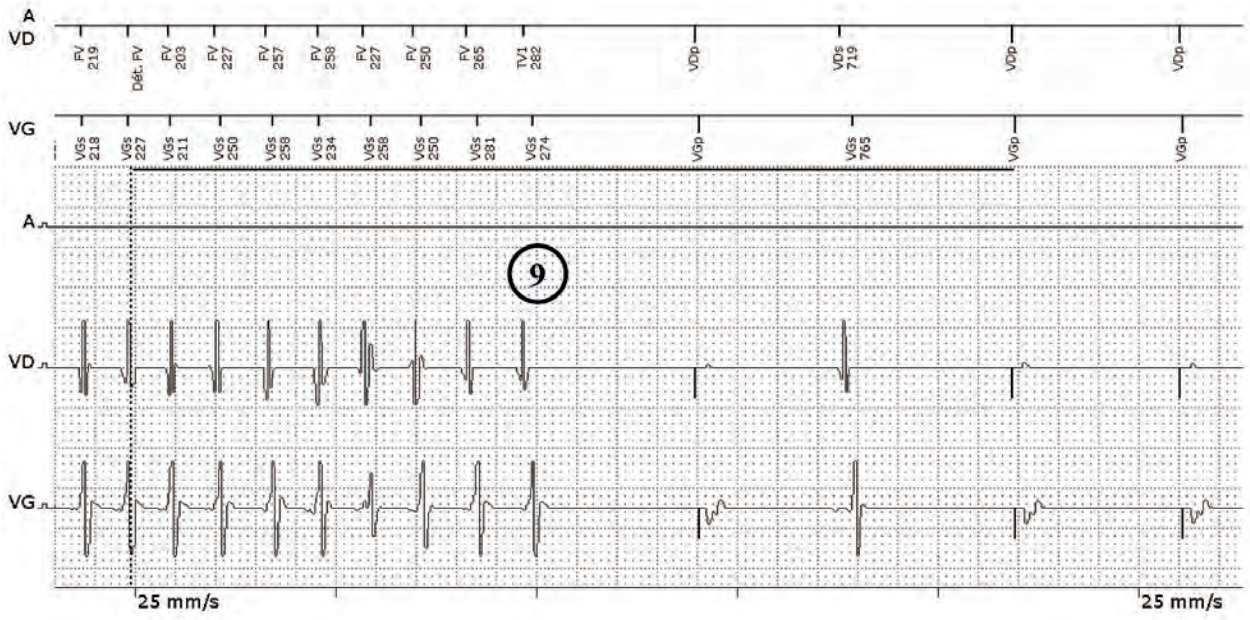


Prothèse Ilesto 7 HF-T

N/S :

Enregistrements - EGM Episode : **9**

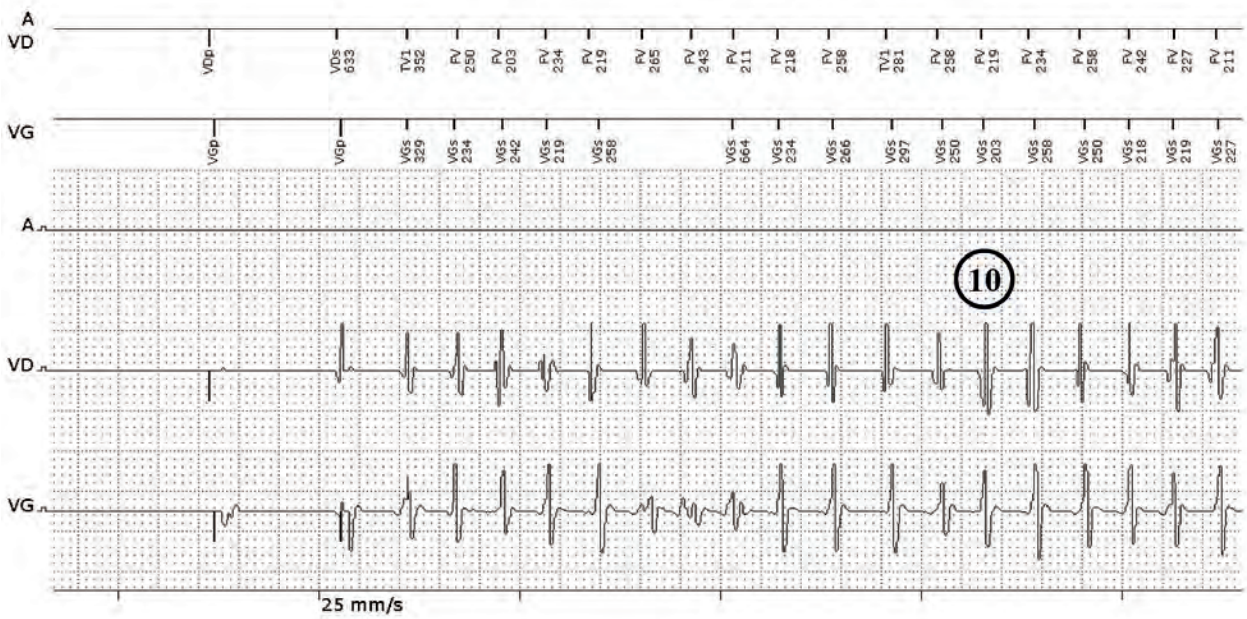


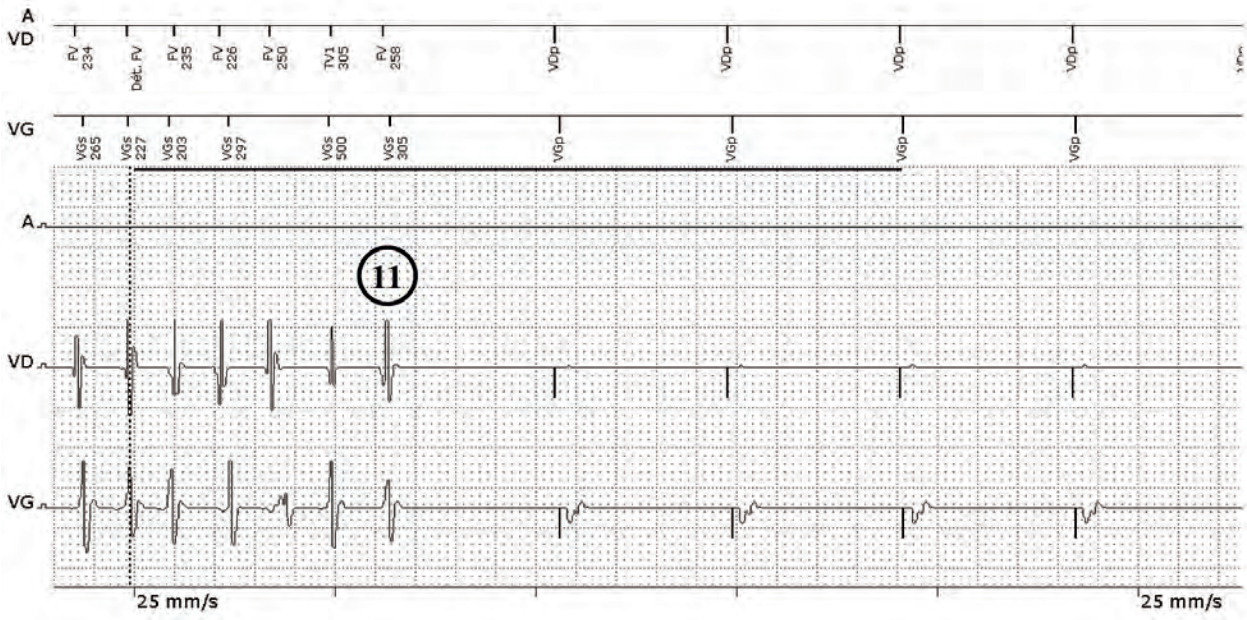


Prothèse Ilesto 7 HF-T

N/S :

Enregistrements - EGM Episode : **7**

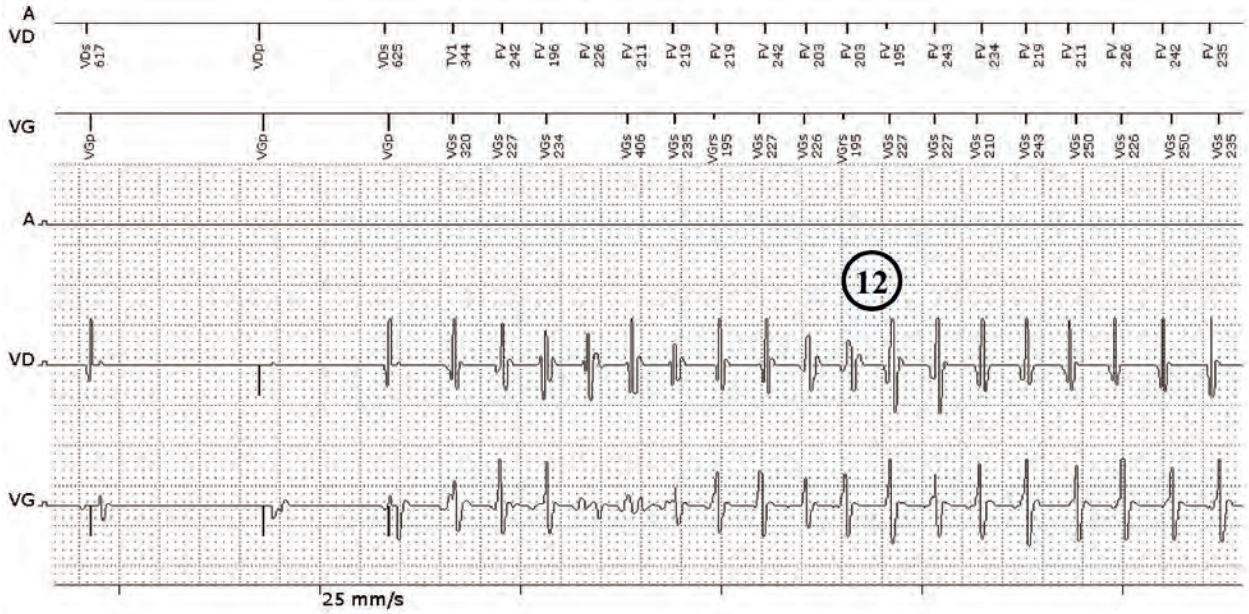


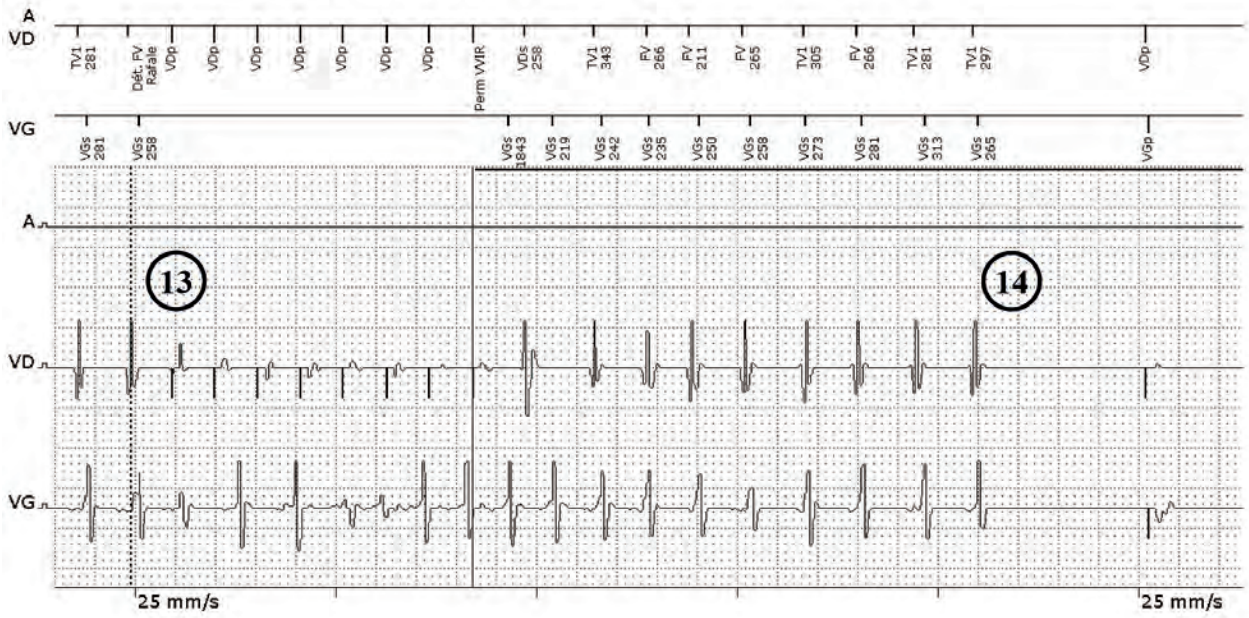


Prothèse Ilesto 7 HF-T

N/S :

Enregistrements - EGM Episode : **6**





Tracing 5 ↘ VT counter and non-sustained VT

Patient

79-year-old man implanted with a Lumax 740 DR-T dual-chamber ICD for ischemic cardiomyopathy with multiple episodes of non-sustained VT.

Telemedicine tracing

4 channels are available; the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the atrial sensing channel (A) and the right ventricular sensing channel (RV).

① ventricular triplet (the VT1 counter increments by +3);
② 3 intervals classified as VP or Vs (the VT1 counter decrements by -3);
③ ventricular quadruplet (the VT1 counter increments by +4);
④ 3 intervals classified a VP or Vs (the VT1 counter decrements by -3);
⑤ ventricular quadruplet (the VT1 counter increments by +4); the VT1 counter is full (the first intervals incrementing the VT1 counter are not visualized on the tracing);
⑥ delivery of 9 antitachycardia pacing bursts;
⑦ end of the episode.

Comments

This tracing allows illustrating one of the limitations of the VT counter and emphasizes the importance of programming the lower limit of the VT zone and the number of intervals necessary for diagnosis. As explained previously, the specificities of the VT counter must be perfectly integrated to allow an optimal programming. The "up and down" counter was specifically developed to effectively detect episodes of monomorphic and regular ventricular tachycardia. An interval classified as VS does not reset the VT1 counter to 0 but decrements the latter by 1 which is very advantageous in the presence of a moderate ventricular undersensing which simply leads to a delay in diagnosis. On the other hand, as in this example, this functioning becomes problematic in patients with repeated episodes of non-sustained VT (when the number of VT1-classified intervals is greater than the VS intervals). The VT1 counter increments progressively, the first interval of the VT1 episode able to occur several tens of seconds before the diagnosis and not be visualized on the tracing (as in this example). This can be accompanied by a significant number of unnecessary therapies with a potentially pro-arrhythmogenic risk. In a patient with many non-sustained VT episodes, it is therefore necessary to increase the number of intervals necessary for diagnosis but, most of all, likely discuss the need to program a VT zone corresponding to the frequency of non-sustained VT episodes.

In the latest recommendations, there are marked differences in terms of advice for the programming of the sensing zone terminals according to the manufacturers. Differences in counter operation explain part of these differences.

Status report

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Lumax 740 DR-T

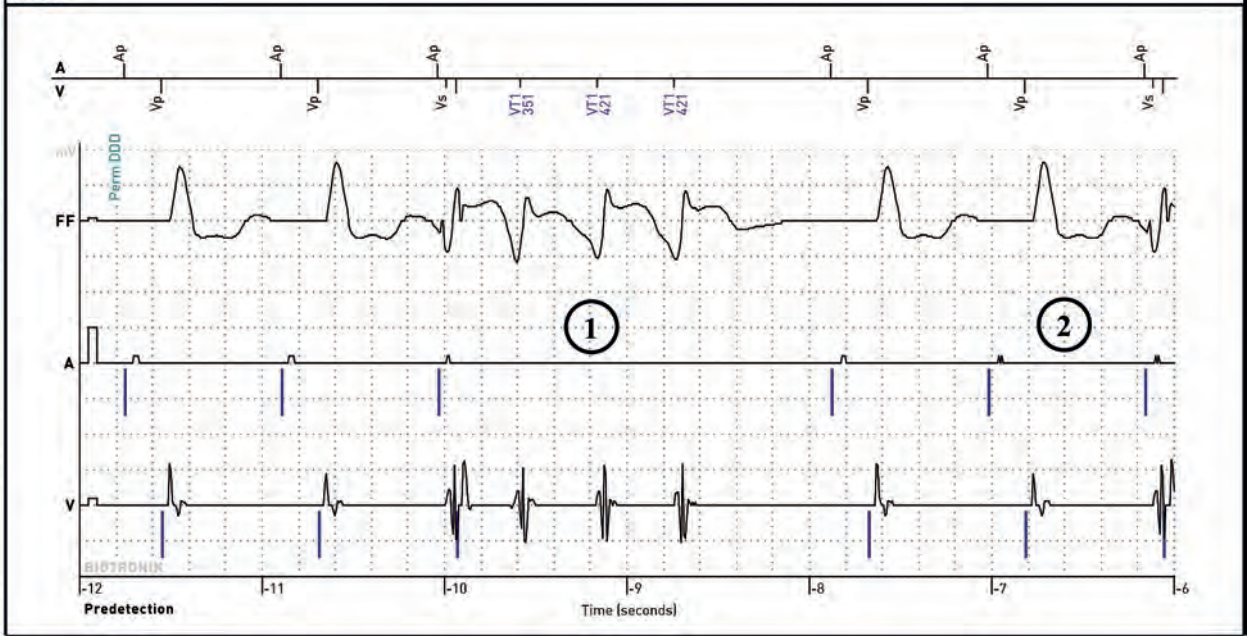
Recordings

Recordings - Episode 94:

General	
Episode number	94
Episode type	VT1
Detection	Sep 20, 2015 12:49:39 AM
Termination	Sep 20, 2015 1:46:56 AM
Duration	57min 17s
Device settings no.	24
Detection	
Mean PP at initial detection [ms]	---
Mean RR at initial detection [ms]	427
Onset [%]	49
Stability [ms]	47
Redetection	VT1: 20

Therapy	
ATP in VT/VF delivered	9
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	0
Maximum energy [J]	---
Termination	
Mean PP at termination [ms]	856
Mean RR at termination [ms]	856
Remark	
Therapy	ATP optimization in VT1 applied

IEGM



Status report

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Lumax 740 DR-T

Implatable Cardioverter Defibrillator - chapter 2

Therapies

Tracing 6 ↘ Electric shock due to ventricular fibrillation

Patient

36-year-old man implanted with a Lumax 740 VR-T single-chamber ICD for a resuscitated sudden death; syncope followed by electric shock.

Telecardiology tracing

3 channels are available; the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the right ventricular sensing channel (RV).

① premature ventricular contractions;

② irregular, polymorphous tachycardia detected in the VF zone with very short ventricular intervals;

③ classification of the episode in the VF zone after 18 intervals classified as VF (18/24 counter full); the average RR during initial sensing (151 ms) corresponds to the average of the 4 intervals preceding the diagnosis and reflects an extremely rapid tachycardia (> 390 beats per minute); in the VF zone, the stability and sudden onset criteria are analyzed but are not integrated into the discrimination (no discrimination other than the rate in the VF zone);

④ electric shock of 40 joules;

⑤ termination of the arrhythmia;

Programmer tracing (same episode)

The 3 channels are the same as for the telecardiology tracing.

⑥ following the classification in VF zone, start of capacitor charge (black line); continuation of this polymorphic and rapid arrhythmia during the charging;

⑦ end of charge;

⑧ interval classified as VF and electric shock of 40 joules (impedance of 53 Ohms);

⑨ effective shock and termination of arrhythmia;

⑩ stoppage (end of episode) after 12 consecutive intervals classified as Vs or VP (12 slow intervals/16); the average RR at the end of the episode (775 ms) corresponds to the average of the 4 intervals preceding the end of the episode.

Comments

Implantable defibrillators have been historically developed to prevent the risk of sudden death and reduce malignant ventricular arrhythmia by electric shock. This tracing corresponds to the normal operation of an ICD. Indeed, an episode diagnosed in the VF zone is accurately detected and effectively treated by an electric shock. At the outset, the arrhythmia is extremely rapid, polymorphous and disorganized. Any attempt to reduce this type of arrhythmia by antitachycardia pacing is seemingly doomed to failure and electric shock remains the therapy of reference in this setting. No discrimination of the origin of the arrhythmia is achieved in this rate range even if the device provides the stability and sudden onset values. It should be noted however that the stability analysis is used in the decision to deliver a one-shot ATP.

In VF zone, the number of shocks is limited to 8 for the same episode, thus avoiding the risk of an endless series of shocks delivered in case of inappropriate therapies. The amplitude of the first 2 shocks is programmable, the next 6 shocks are delivered at maximum energy (40 joules). The amplitude of the first shock can either be programmed to the maximum capacities of the device or to a lower value of 10 joules (25 joules) or to a lower amplitude tested during an induction procedure. Programming a first shock of average amplitude (between 15 and 20 joules) allows reducing the charge time and the delay between the onset of

the arrhythmia and the delivery of the electric shock and can in certain specific cases reduce the risk of loss of consciousness (an important issue for a driver, for example). The choice of the amplitude of the first shock in VF zone thus represents a compromise: an average energy may suffice to stop the VF after a short charge time, but in the event of failure, the second maximum energy shock occurs over a long total VF time; a high starting energy is more efficient on the VF, but at the cost of a longer initial loading time.

When shock confirmation is programmed to ON, if the ICD senses 3 slow intervals out of 4 (intervals classified in the sinus zone) during the charging of the capacitors, the device stops its charge. If the charge is not interrupted, at the end of the charge, the device delivers the shock 30 ms after the sensing of a short interval. If, at the end of charge, the device does not sense a short interval and if 3 long intervals are sensed, the charge is discontinued with a progressive discharge of the capacitors. This dissipation of energy can take approximately ten minutes. During this period, if the device resenses an episode, the charge time is shorter (use of the energy already charged). If a shock is delivered, the next shock is also confirmed. If a charge is interrupted, the following shock is not confirmed. Two consecutive charges cannot be interrupted, which could be problematic in the event of VF undersensing. If the shock confirmation is turned OFF, the charge cannot be interrupted once it has initiated. At the end of the charge, the device attempts to synchronize itself, however if it does not sense an R wave, it delivers a non-synchronized shock 2 seconds after the end of the charge. At the end of the charge, there is a 50 ms ventricular blanking period where no sensing is possible.

A 1-second blanking period without sensing or pacing follows the delivery of an electric shock. Following this blanking period, begins the post-shock pacing whose duration is programmable (from OFF to 10 minutes with a default value of 10 seconds). The post-shock mode is DDI for the DDD(R), DDI(R) or AAI(R) modes, VVI for the VVI(R) mode and VDI for VDD(R) or VDI(R) modes.

Status report

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Lumax 740 VR-T

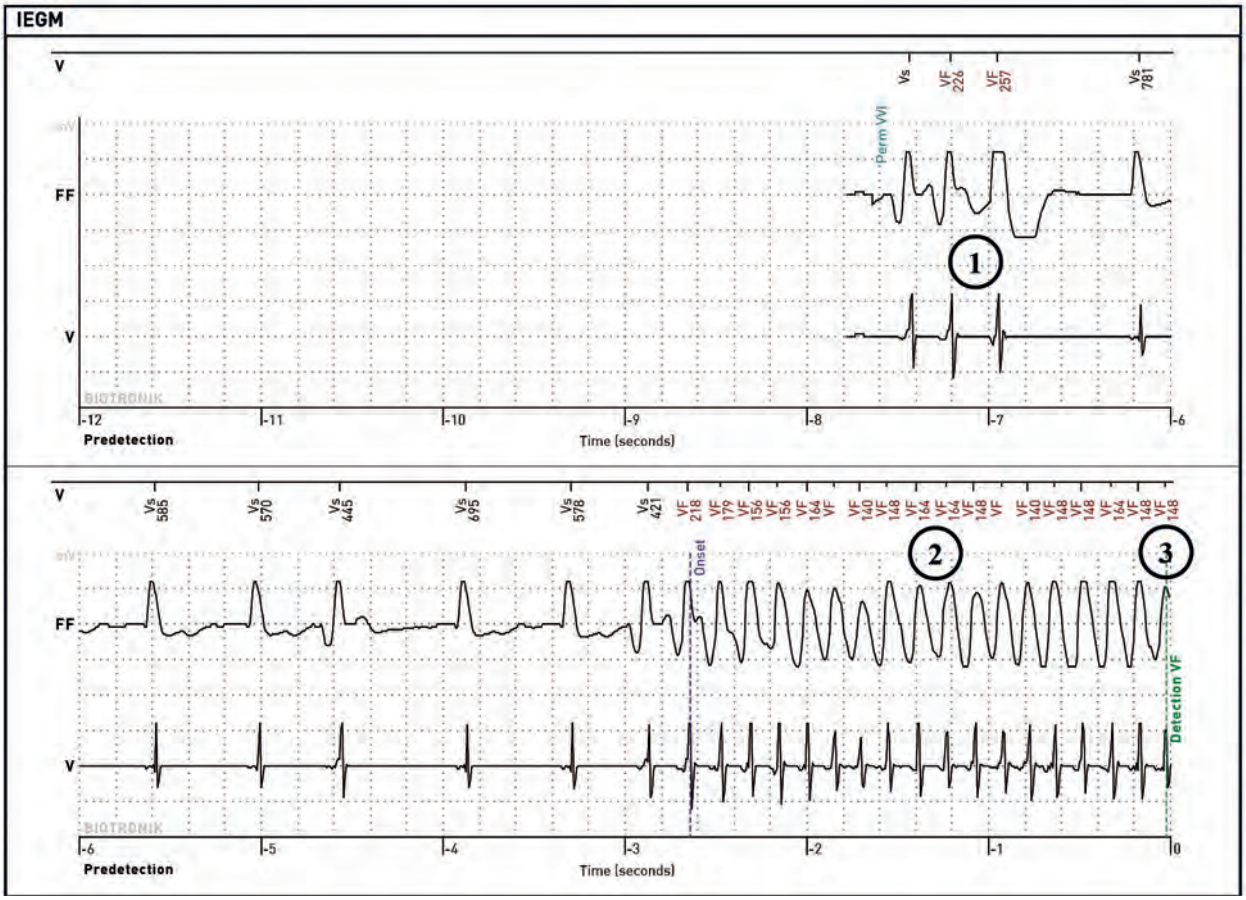
Recordings

Recordings - Episode 7:

General	
Episode number	7
Episode type	VF
Detection	Oct 31, 2014 9:34:39 PM
Termination	Oct 31, 2014 9:34:58 PM
Duration	19s
Device settings no.	7
Detection	
Mean RR at initial detection [ms]	151
Onset [%]	67, fulfilled
Stability [ms]	20
Redetection	---

Therapy	
ATP in VT/VF delivered	0
ATP One Shot delivered	NO
Shocks delivered	1
Shocks aborted	0
Maximum energy [J]	40
Termination	
Mean RR at termination [ms]	775
Remark	
none	

IEGM



Status report

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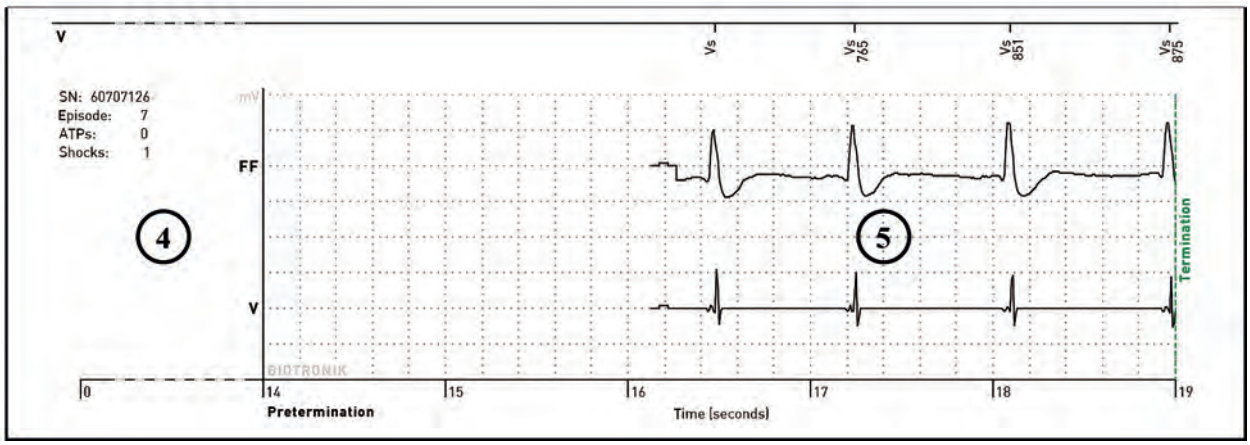
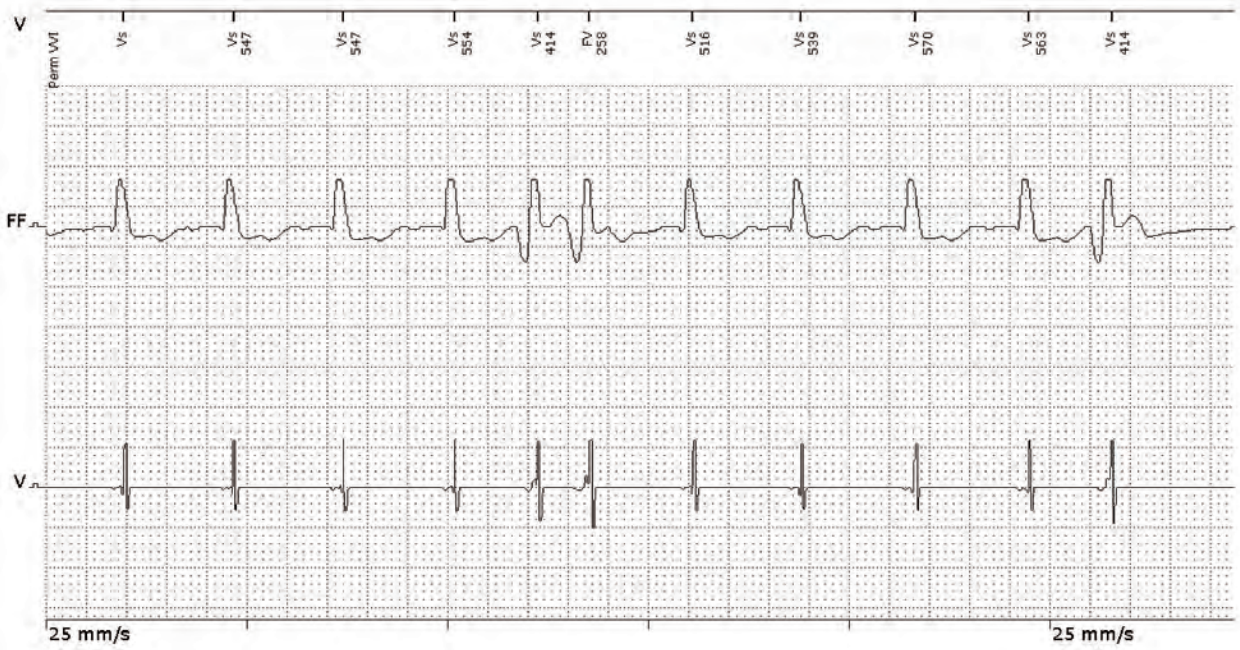
Lumax 740 VR-T

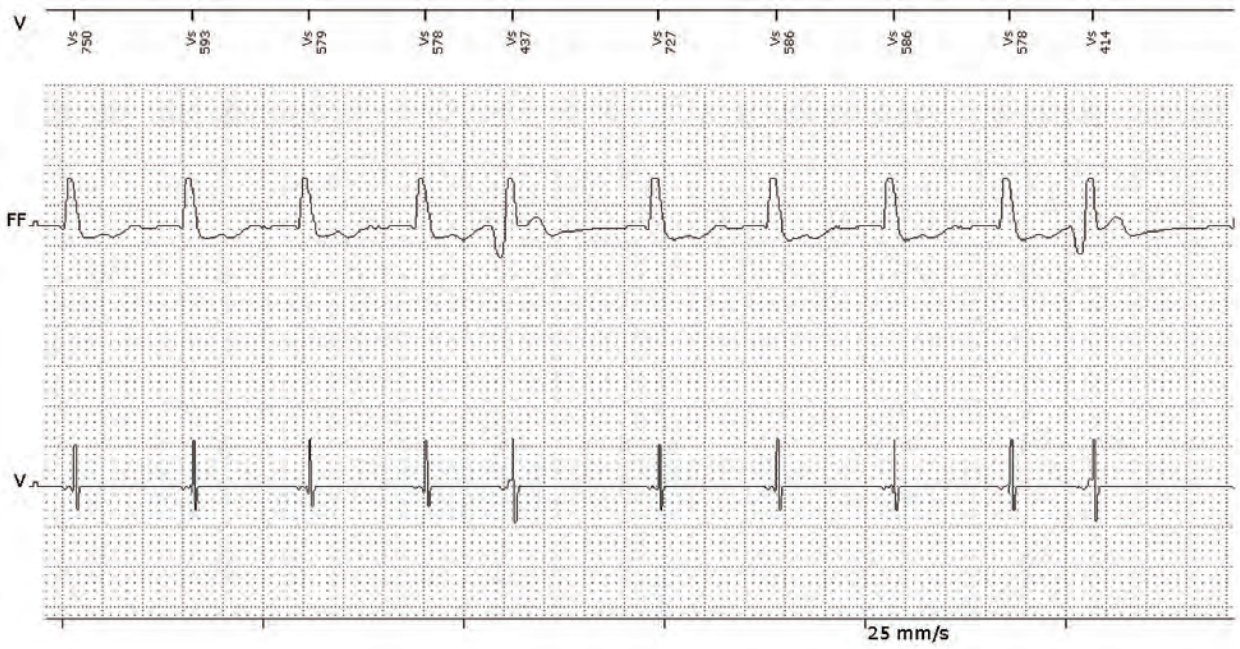


Prothèse Lumax 740 VR-T

N/S :

Enregistrements - EGM Episode : **7**

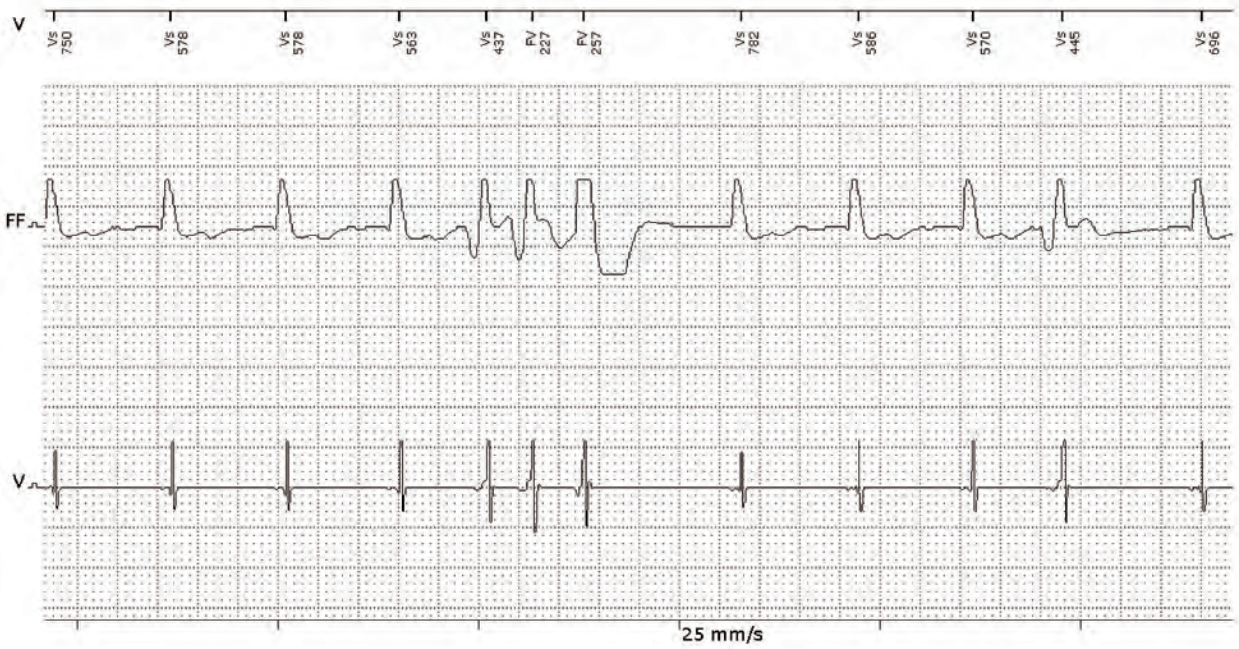


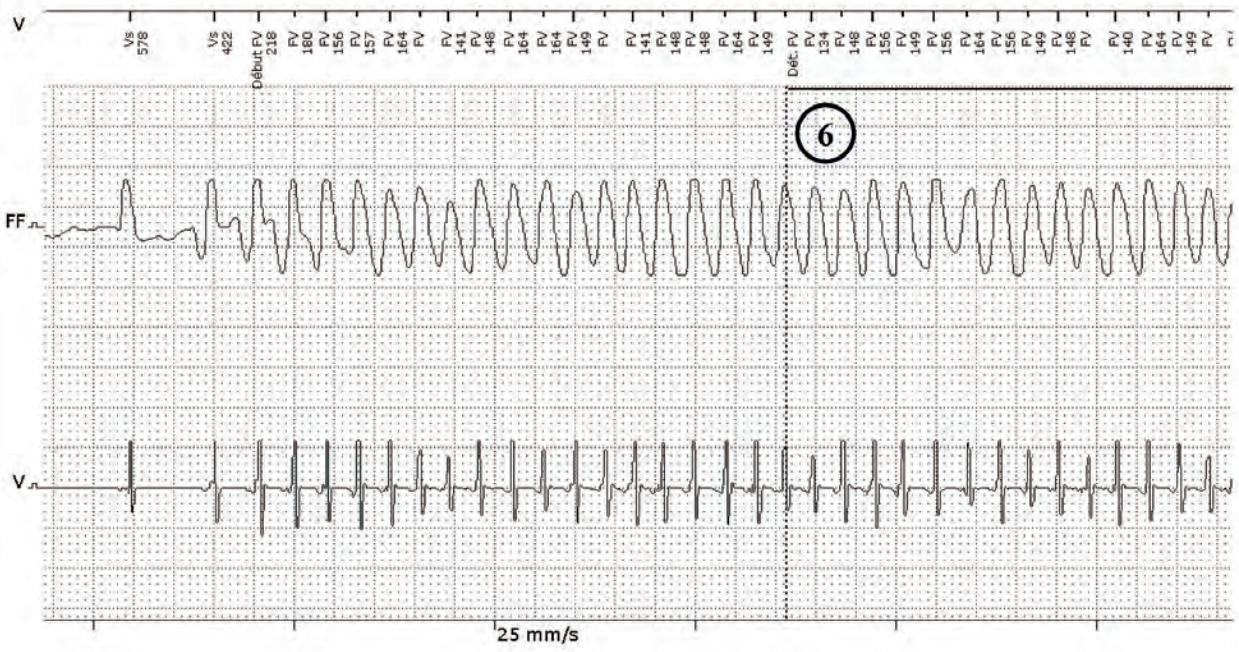


Prothèse Lumax 740 VR-T

N/S :

Enregistrements - EGM Episode : **7**

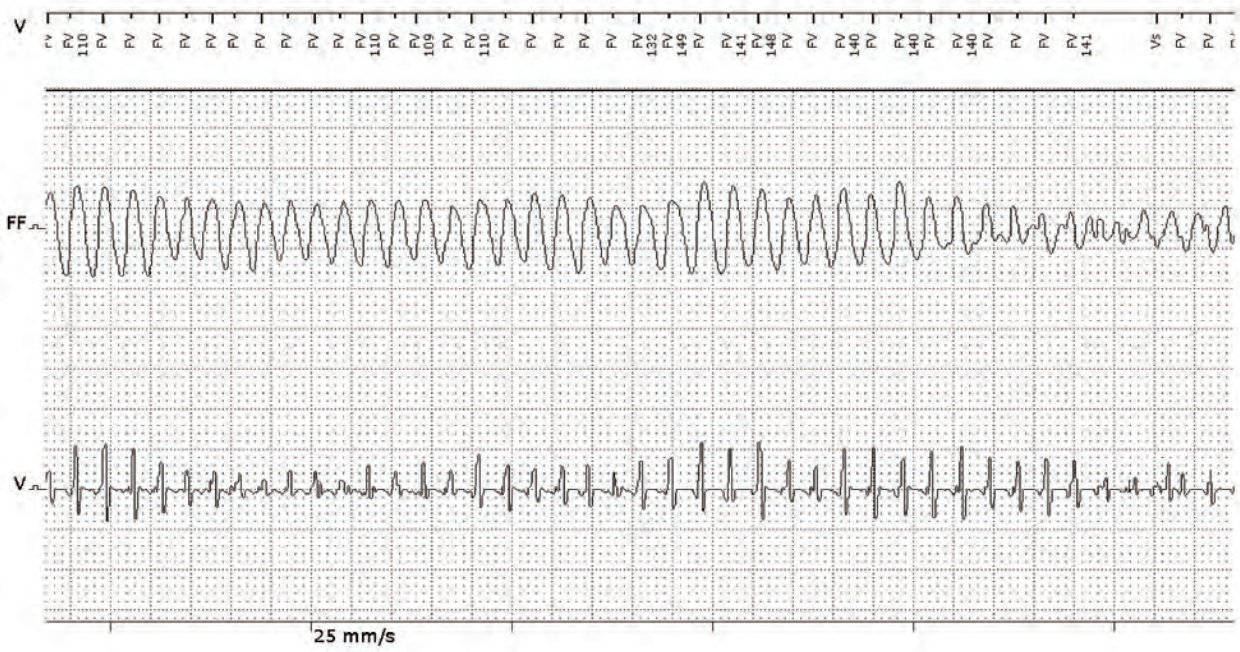


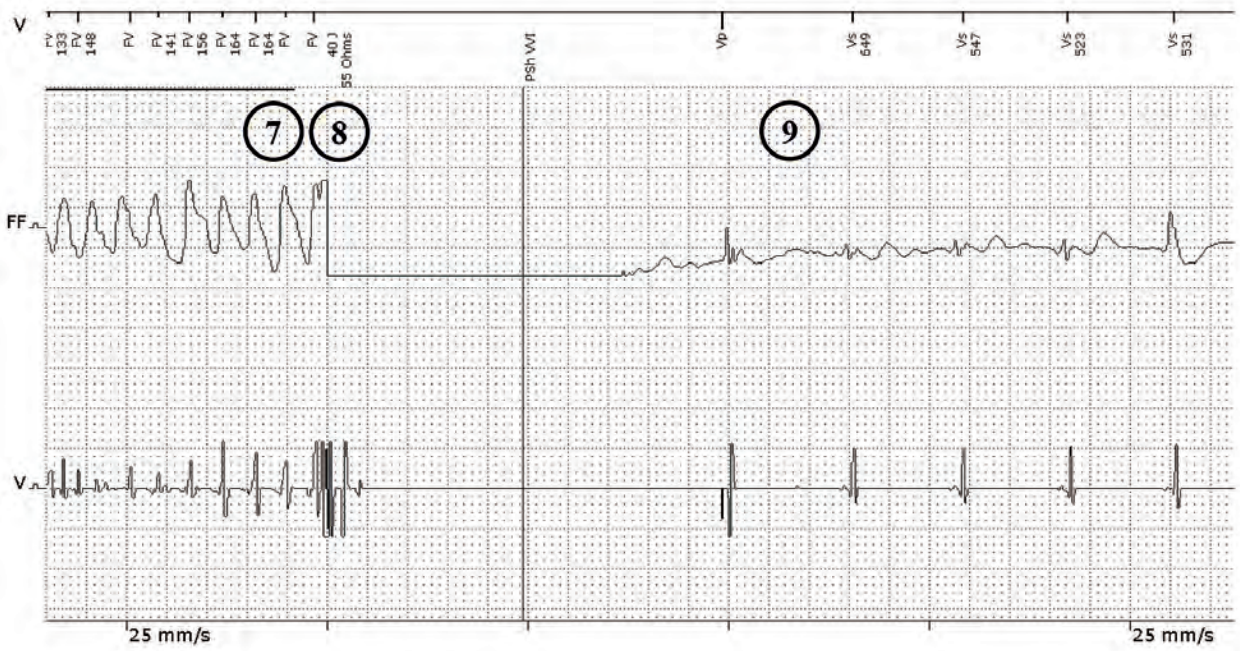


Prothèse Lumax 740 VR-T

N/S :

Enregistrements - EGM Episode : **7**

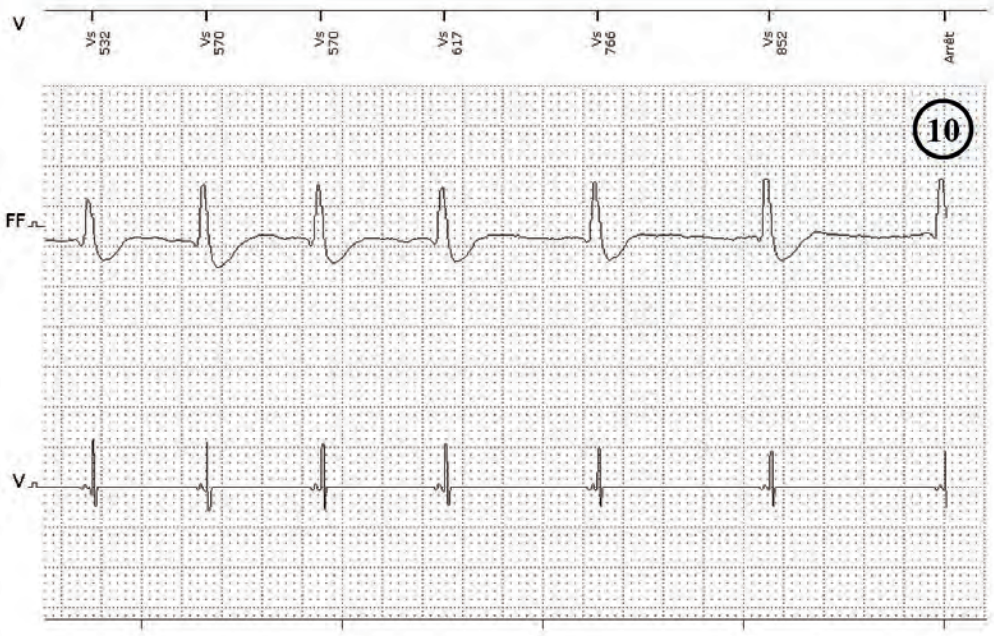




Prothèse Lumax 740 VR-T

N/S :

Enregistrements - EGM Episode : **7**



Tracing 7 ↘ First ineffective electric shock due to ventricular fibrillation

Patient

43-year-old man implanted with a Lumax 340 VR-T single-chamber ICD for severe ischemic cardiomyopathy; syncope followed by electric shock.

Programmer tracing

3 channels are available; the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the right ventricular sensing channel (V).

① sinus rhythm;

② polymorphic ventricular arrhythmia with extremely wide QRS; double counting of the QRS complexes with very short intervals sensed in VF zone at the limit of the programmed blanking value (80 ms);

③ the VF counter is full (programmed at 12/16); start of the capacitor charge (black line);

④ interruption of the charge despite continued arrhythmia following the sensing of 3 intervals out of 4 classified as VS (a single VF zone programmed at 207 beats/minute); there is no undersensing although ventricular intervals are slower than the programmed VF zone;

⑤ continuation of the ventricular arrhythmia; ventricular activity not sensed;

⑥ the VF counter is again full (12/16); new charging of the capacitors;

⑦ undersensed ventricular activity during charging;

⑧ end of charge and delivery of a 40J electric shock;

⑨ ineffective electric shock and continued arrhythmia;

⑩ redetection counter is full; new charging of the capacitors;

⑪ second electric shock of 40J;

⑫ effective electric shock;

⑬ end of the episode after 12 intervals classified as Vs or VP.

Comments

The defibrillation threshold does not correspond to a fixed value. The first maximum energy shock is inefficient, while the second with the same amplitude allows restoring a worrisome situation.

In addition to the amplitude delivered, various parameters can or cannot be modified to optimize the effectiveness of the shocks delivered:

1) the number of phases; historically monophasic, the shock wave has become biphasic in modern ICDs, which allows lowering the defibrillation thresholds. The first phase of a biphasic shock is equivalent to that of a monophasic shock but with a lower critical mass; the second phase reduces the membrane potential as closely to zero as possible, which significantly reduces the defibrillation thresholds and the risk of re-induction.

2) the shape of the shock wave with 2 programming possibilities; for a voltage-controlled shock, the charged voltage is 100%, the voltage tilt of the first phase is 40%, which means that 60% of the initial voltage is delivered during the first phase (fixed tilt at 60); the cut-off voltage of the second phase is 20%, which means that 50% of the remaining voltage (40%/2) is delivered during the second phase (tilt at 50); it is therefore a two-phase voltage-controlled shock with fixed 60/50 tilt; the delivered voltage is constant, the

pulse duration of each phase varies as a function of the impedance of the shock, the pulse duration being longer with higher impedance. There is a second programming possibility for the shock wave (biphasic II, controlled voltage/pulse duration); the charged voltage is 100%, the voltage tilt of the first phase is also 40%; the cut-off of the second phase occurs automatically after a fixed pulse duration of 2 ms regardless of the voltage delivered; this option can be programmed in patients with a high defibrillation threshold especially when the patient is receiving amiodarone therapy known to raise the threshold.

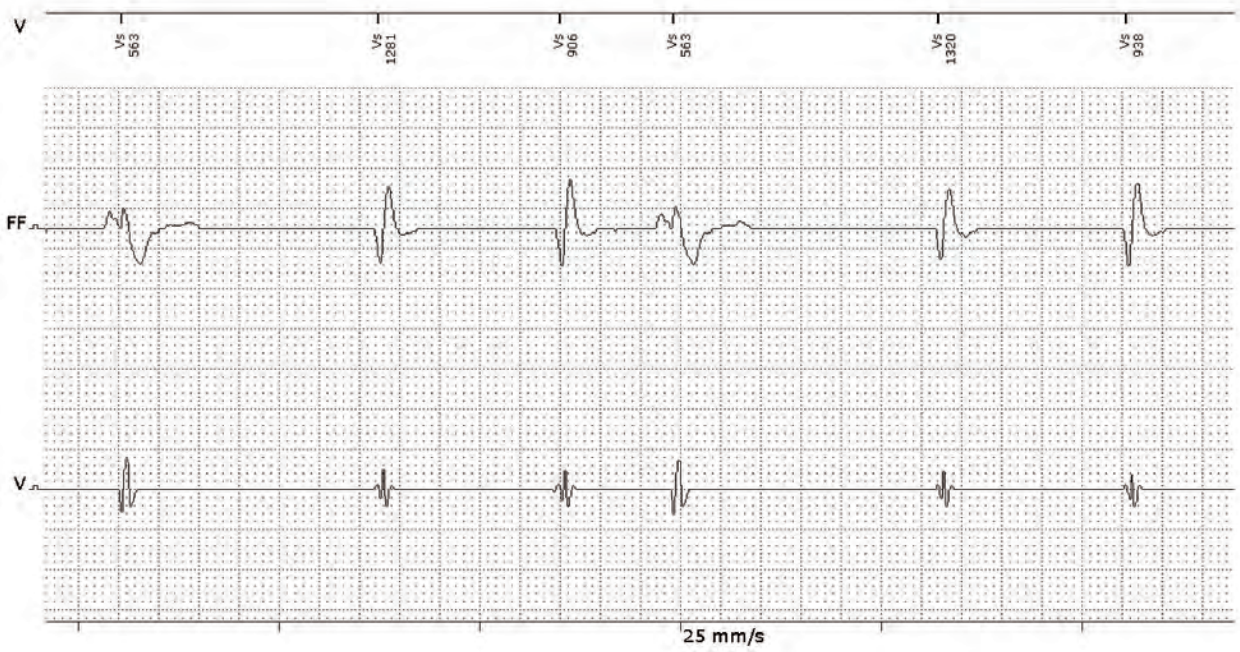
3) the polarity of the shock; modern ICDs allow programming the polarity and shock vector; this functionality can be useful in the event of a high defibrillation threshold by allowing to chose the shock vector offering the best efficiency ratio; the polarity of the shock can be programmed to normal, reverse or alternate; for a single-coil lead, the normal polarity for Biotronik™ ICDs reflects the fact that the shock is delivered between the pulse generator which is the anode for the first phase and the right ventricular coil which is the cathode; it is therefore called a cathodic shock; when the polarity is reversed, the right ventricular coil becomes the anode during the first phase; this reverses the two phases of a biphasic shock (first phase is negative, second phase is positive); it is therefore an anodic shock; in the case of alternating polarity, the first shocks are delivered with normal polarity followed by alternation between normal polarity and inverted polarity when the first maximum energy shock has been delivered; it is therefore possible to alternate the polarities of the shocks (cathodic or anodic) starting from the first full-energy shock.

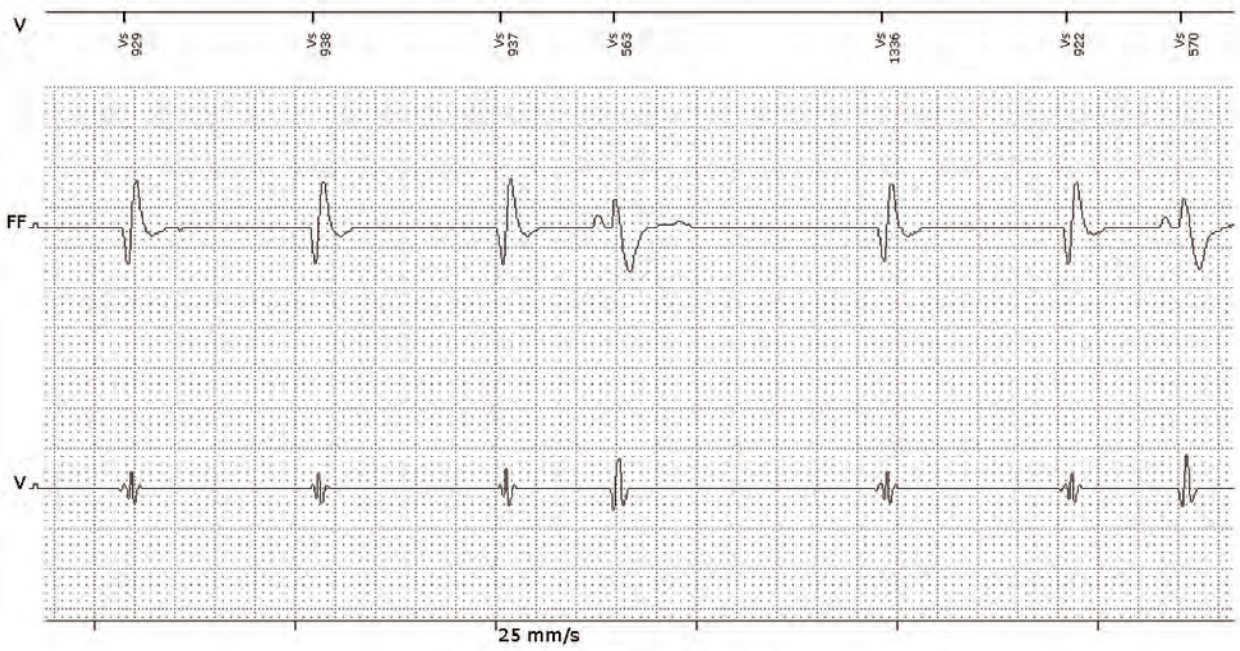
4) the shock vector; the programming of this parameter is contingent on the number of available shock electrodes; the defibrillation shock is transmitted by a dedicated lead which can be single-coil (a single defibrillation electrode or coil placed in the right ventricle) or double-coil (a distal defibrillation electrode placed in the right ventricle, a defibrillation electrode placed more proximally, at the level of the superior vena cava). The single-coil shock is delivered between the distal coil of the right ventricular lead and the pulse generator; the double-coil shock is delivered between three structures: the distal coil, the proximal coil and the pulse generator. The shock vector is programmable with the possibility of programming or deprogramming the proximal electrode in the superior vena cava for a double-coil lead (single-coil shock) and deprogram the pulse generator (cold can); deprogramming a double-coil shock in the presence of a high defibrillation threshold allows excluding the superior vena cava coil when it is positioned too low, floating in the atrium, and part of the energy delivered is dissipated in the atrium.

Prothèse Lumax 340 VR-T XL

N/S :

Enregistrements - EGM Episode : 34

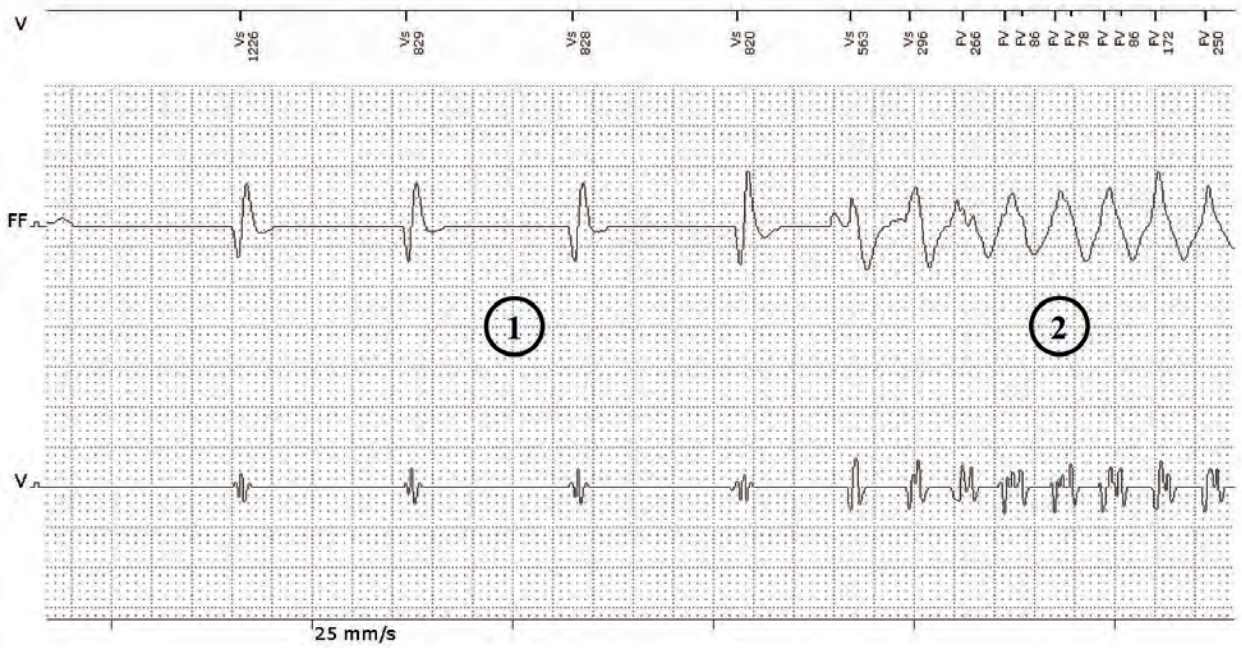


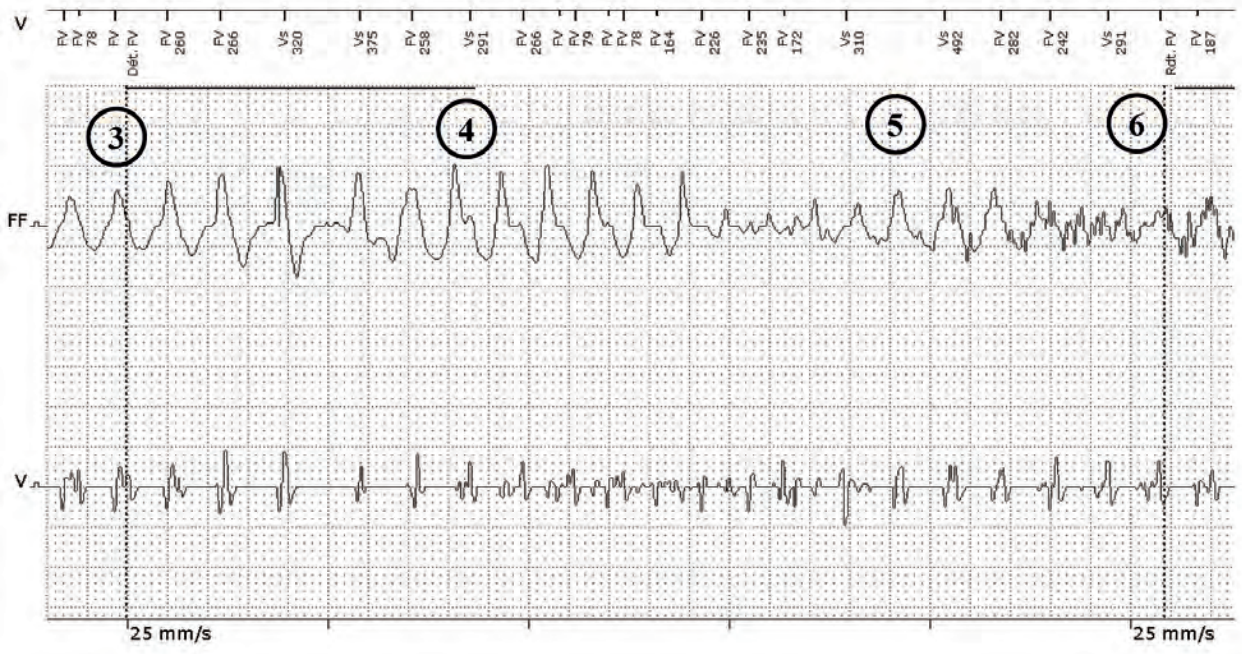


Prothèse Lumax 340 VR-T XL

N/S :

Enregistrements - EGM Episode : 34

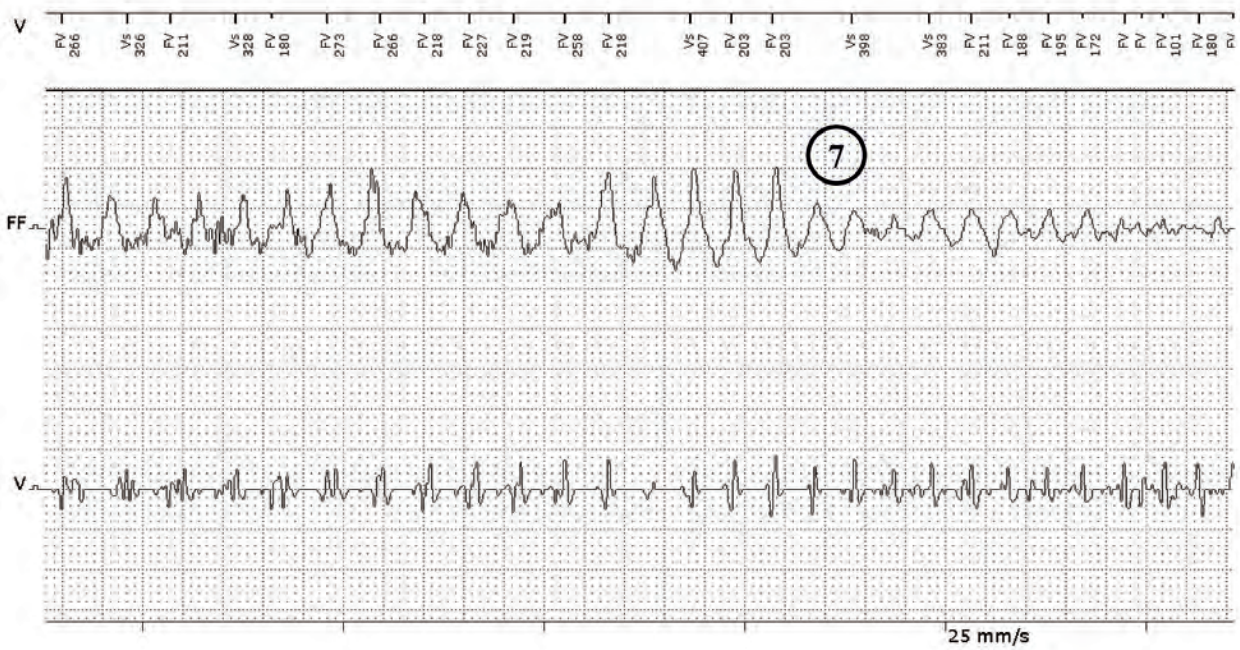


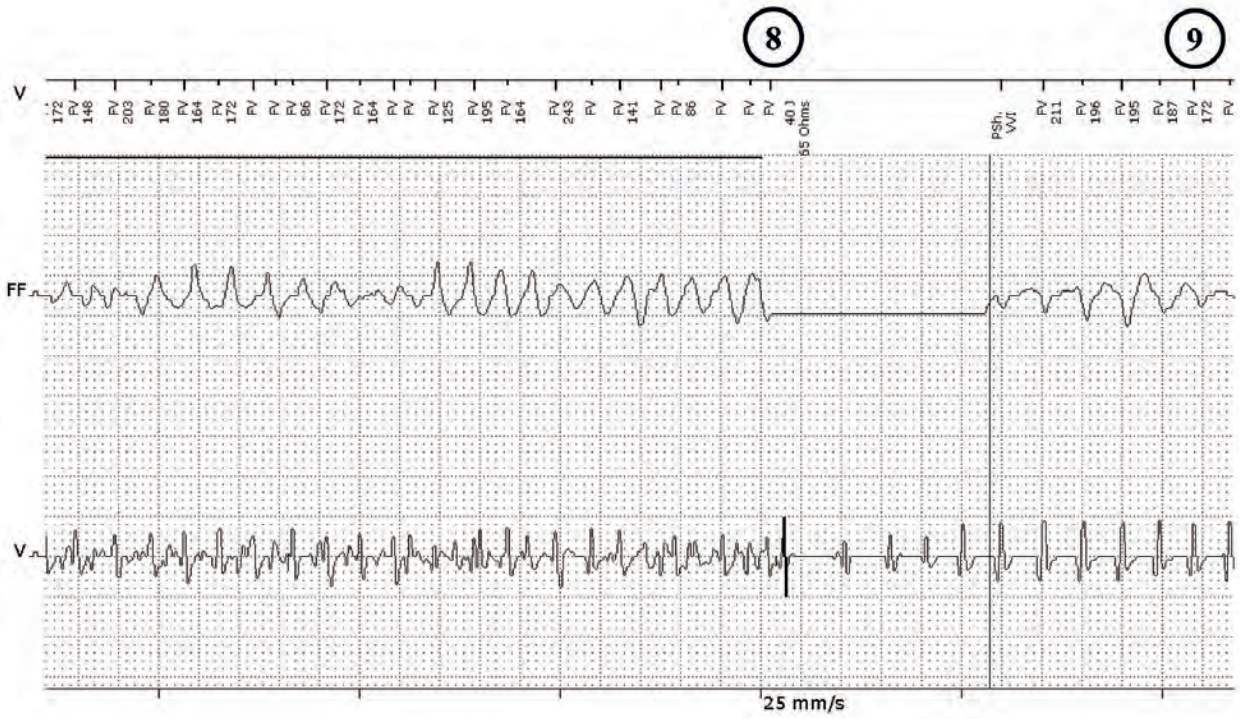


Prothèse Lumax 340 VR-T XL

N/S :

Enregistrements - EGM Episode : 34

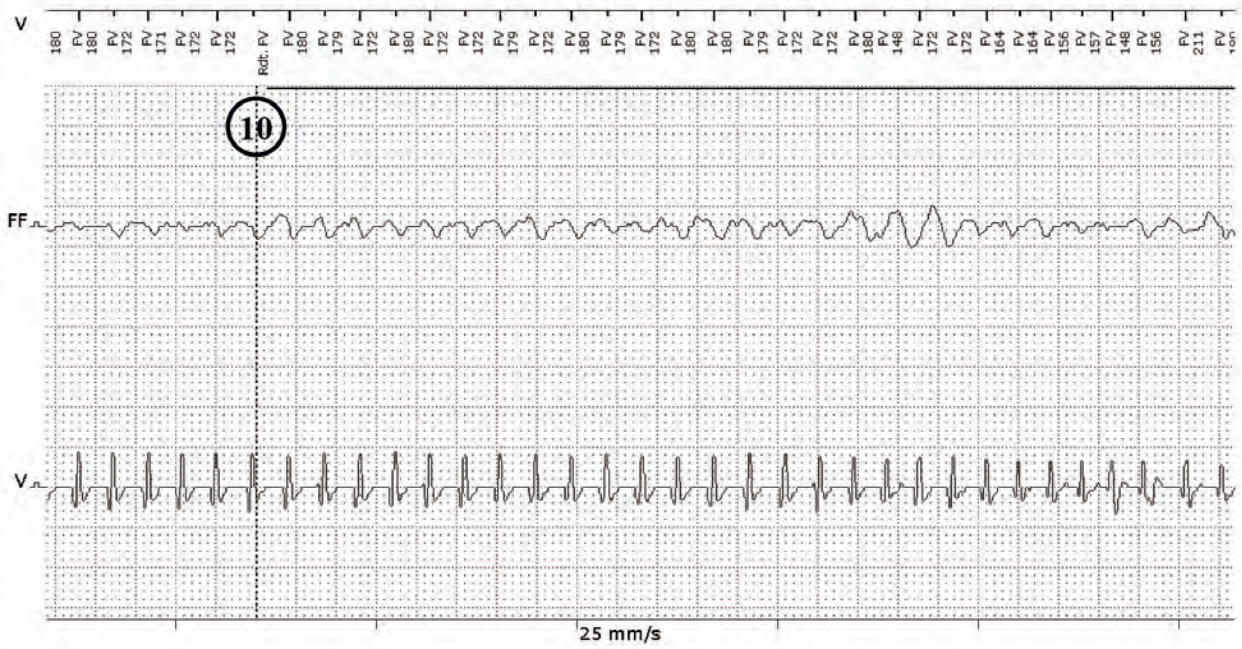


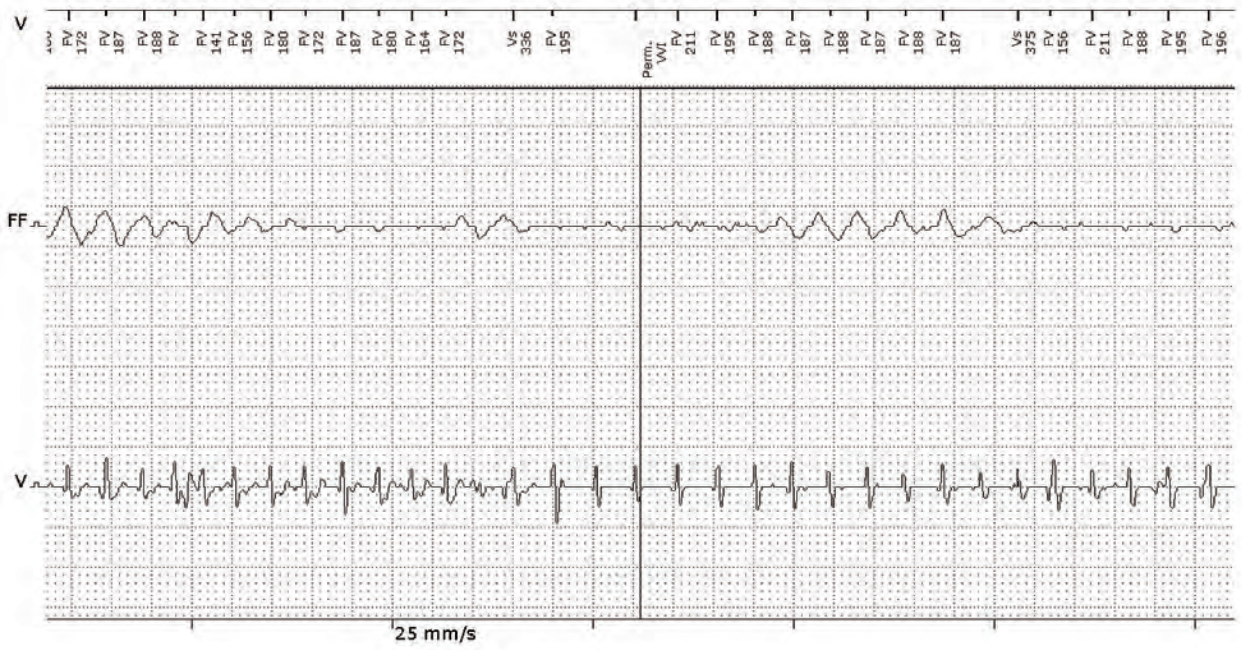


Prothèse Lumax 340 VR-T XL

N/S :

Enregistrements - EGM Episode : 34

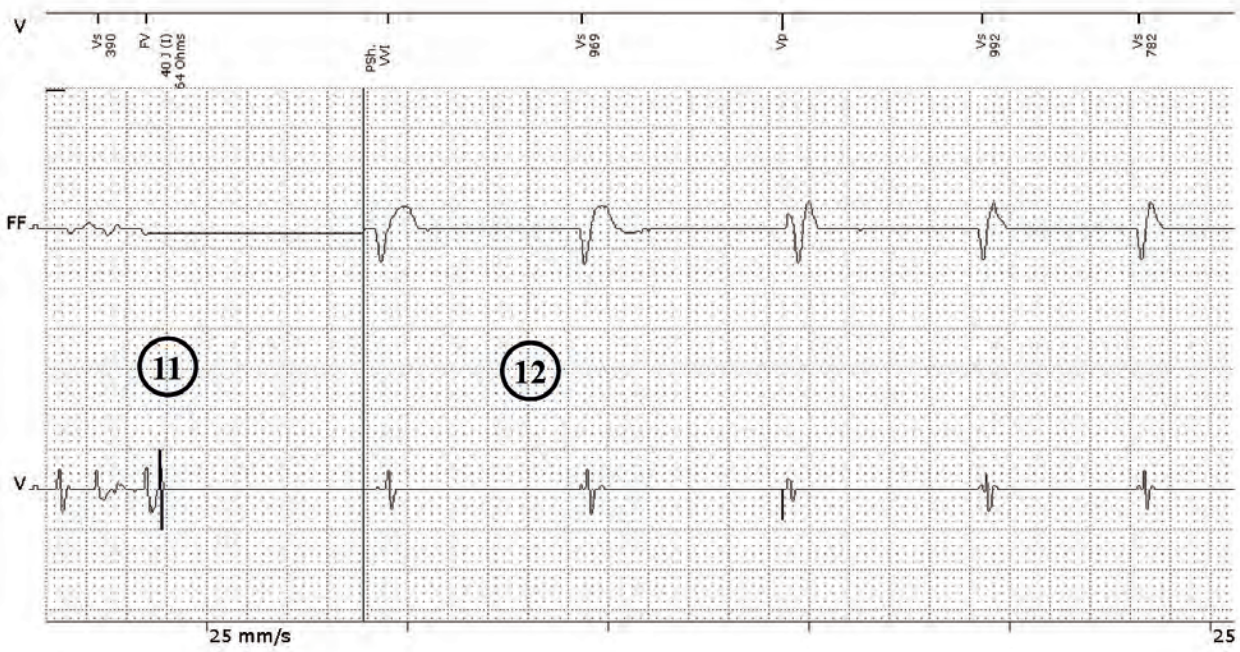


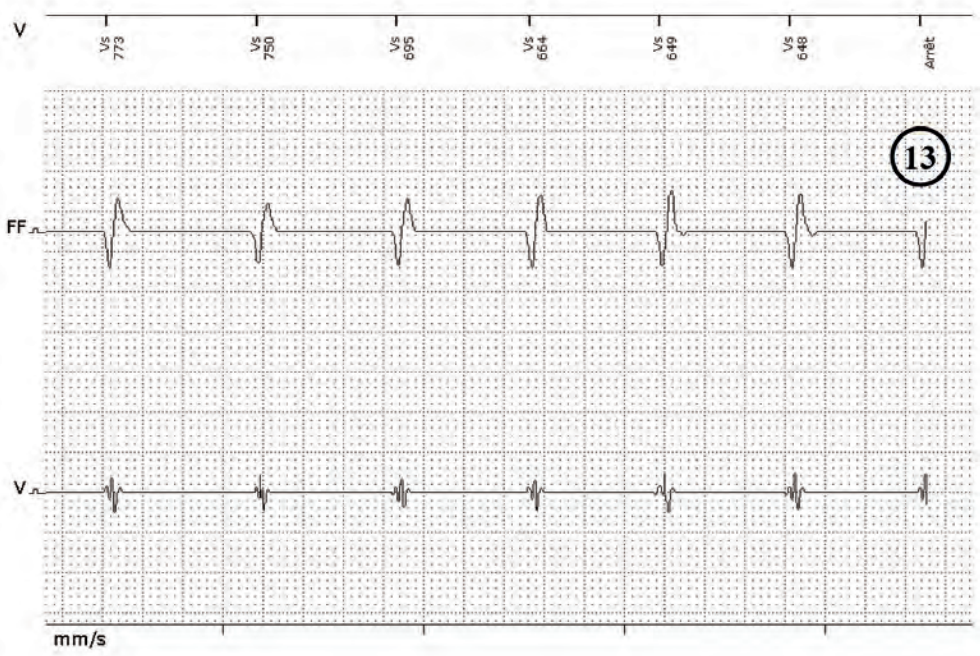


Prothèse Lumax 340 VR-T XL

N/S :

Enregistrements - EGM Episode : 34





Tracing 8 ↘ ATP in the VF zone

Patient

65-year-old man implanted with an Ilesto 7 VR-T single-chamber ICD for ischemic cardiomyopathy; palpitations and syncope with electric shock.

Telemedicine tracing

3 channels are available; the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the right ventricular sensing channel (V).

① sinus rhythm with premature ventricular contractions;
② sudden-onset monomorphic tachycardia detected in VF zone; stable rhythm;
③ classification of the episode in the VF zone after 18 VF intervals without an interleaved interval classified as VT1 or Vs (VF counter full, 18/24);
④ the delivered ATP is not displayed;
⑤ termination of the arrhythmia;
⑥ end of episode after 12 intervals classified as Vs (12 intervals/16 classified as Vs or VP);

Programmer tracing (same episode)

The 3 channels are the same as for the telecardiology tracing.

⑦ VT in VF zone;
⑧ visualization of the burst (8 intervals with fixed rate);
⑨ at the end of the burst, start of the capacitor charge highlighted by the horizontal black line;
⑩ termination of the arrhythmia and discontinuation of the charge after 3 intervals classified as Vs (3 slow intervals/4) since the device considers that the burst was effective;

Programmer tracing (episode corresponding to the syncope)

⑪ new episode of fast, monomorphic, regular VT detected in VF zone;
⑫ one-shot ATP;
⑬ start of the capacitor charge and continuation of the arrhythmia;
⑭ APT has accelerated and disorganized the arrhythmia in VF; undersensing of limited duration;
⑮ at the end of charging, electric shock 40 joules;
⑯ termination of the arrhythmia.

Comments

One of the priority objectives of ICD programming is to minimize the risk of an electric shock while not jeopardizing patient safety. A large number of rapid tachycardias diagnosed in the VF area are organized, monomorphic and are therefore likely to be reduced by an antitachycardia pacing burst. While the effectiveness of an electric shock in terminating rapid ventricular arrhythmia is indisputable, a shock is nonetheless painful and significantly increases energy consumption. The delivery of several successive shocks in a same patient is therefore associated with a risk of premature wear of the batteries, with a significant lowering of the quality of life of the patients (many described cases of depression or anxiety induced by a series of shocks) as well as an altered prognosis (mortality risk increasing in parallel with the number of

delivered shocks). The PainFree Rx trial (prospective, randomized, multicenter study) showed that a single antitachycardia pacing sequence (8 beats at 88%) allowed terminating a large proportion of fast tachycardias in the VF zone and provided a significant benefit in terms of quality of life, by reducing the number of shocks delivered without increasing the risk of sudden death, syncope or accelerated tachycardia. Thus, delivering an antitachycardia pacing sequence in the VF zone often seems to be effective, painless, reduces battery wear and improves the quality of life and should therefore be offered as a first-line option for this range of tachycardias (< 250 beats/minute). It is now recommended to program at least one antitachycardia pacing sequence for tachycardias up to a rate of 230 beats/minute by favoring the burst as opposed to ramp therapy (at least 8 stimuli with 88% coupling).

It is possible to program a burst in the VF zone, the one-shot ATP, which allows a painless treatment of VT while preserving part of the charge. The one-shot ATP is only delivered if the ventricular rhythm sensed in the VF area is considered to be regular (stability threshold at 12%). When the VF counter is full, the device delivers an antitachycardia pacing sequence (by default a burst with 8 stimuli at 85% of the tachycardia cycle length). As soon as the burst is delivered, the capacitors automatically begin charging. If the burst is successful (3 out of 4 intervals classified as VS or VP), the charge is interrupted. Otherwise, the charge continues and the shock is delivered. The duration of the charge is therefore short if the ATP is effective. This allows avoiding a shock (painful for the patient and a likely factor of poor prognosis) at the price of a limited energy consumption (partial and rapidly interrupted charge). It is possible to program the type of ATP (burst or ramp) and the various parameters of a standard sequence (number of intervals, etc). The one-shot ATP is automatically de-programmed after 4 consecutive unsuccessful attempts.

Status report

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Ilesto 7 VR-T

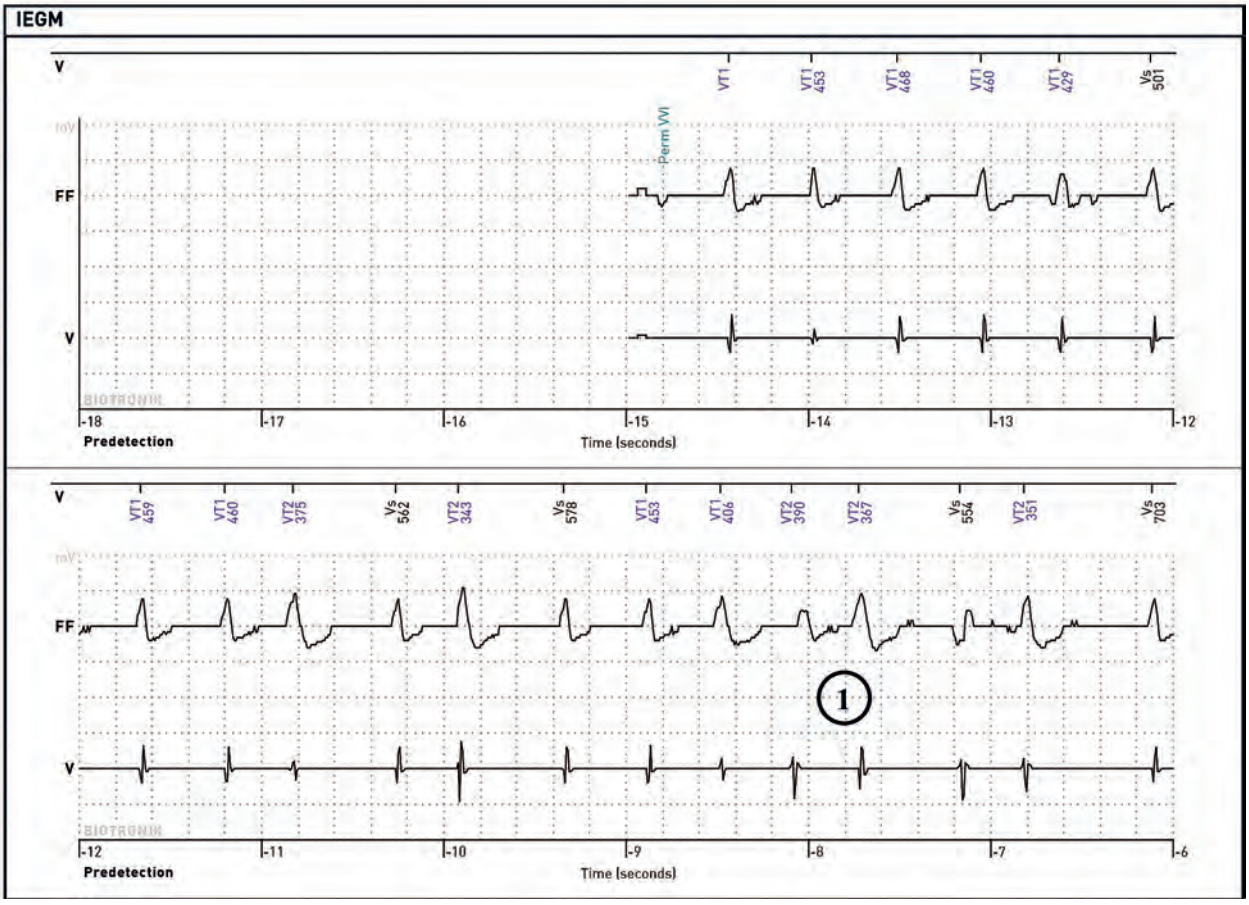
Recordings

Recordings - Episode 8:

General	
Episode number	8
Episode type	VF
Detection	Jan 22, 2016 1:00:56 PM
Termination	Jan 22, 2016 1:01:11 PM
Duration	15s
Device settings no.	7
Detection	
Mean RR at initial detection [ms]	231
Onset [%]	28, fulfilled
Stability [ms]	6
Redetection	---

Therapy	
ATP in VT/VF delivered	1
ATP One Shot delivered	YES
Shocks delivered	0
Shocks aborted	1
Maximum energy [J]	40
Termination	
Mean RR at termination [ms]	467
Remark	
none	

IEGM



Status report

BIOTRONIK
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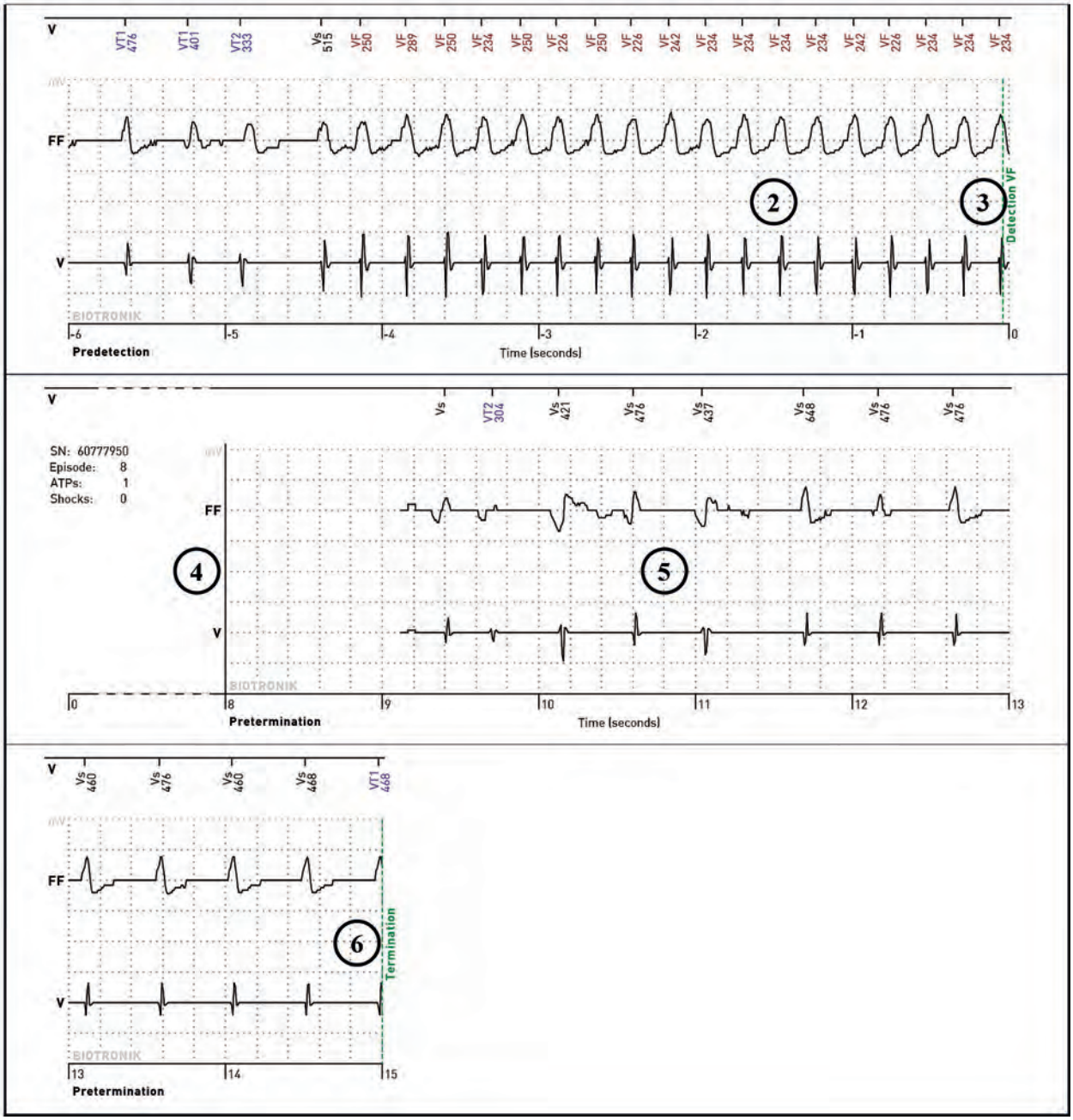
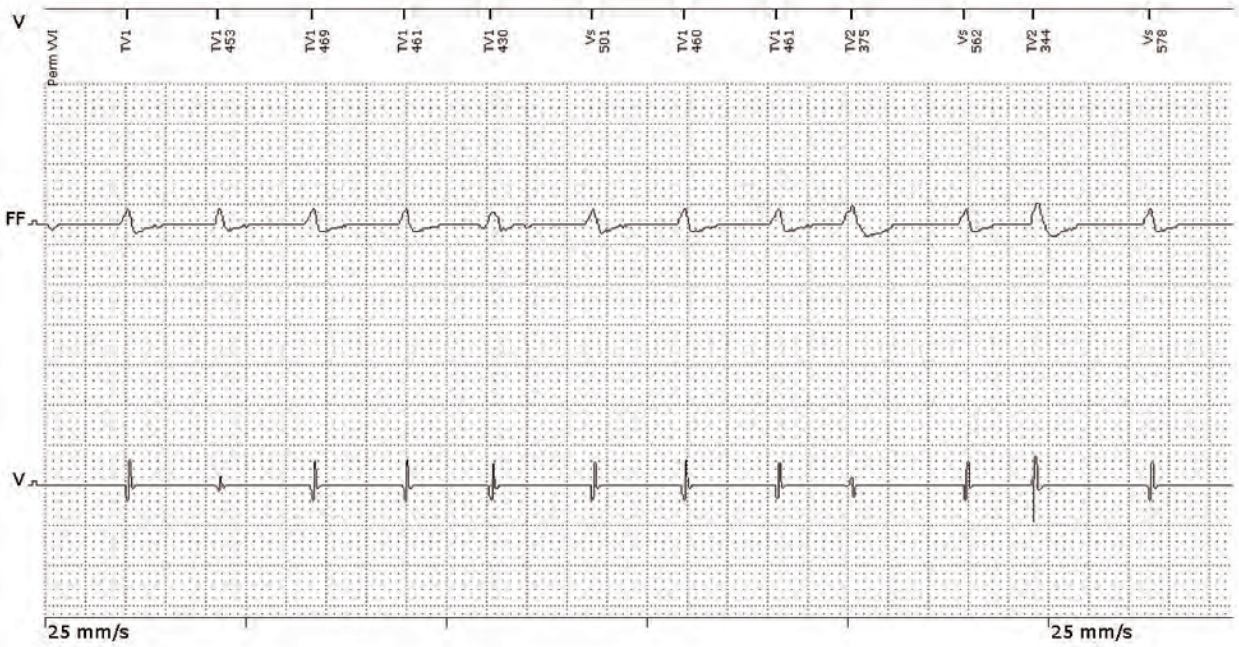
Ilesto 7 VR-T

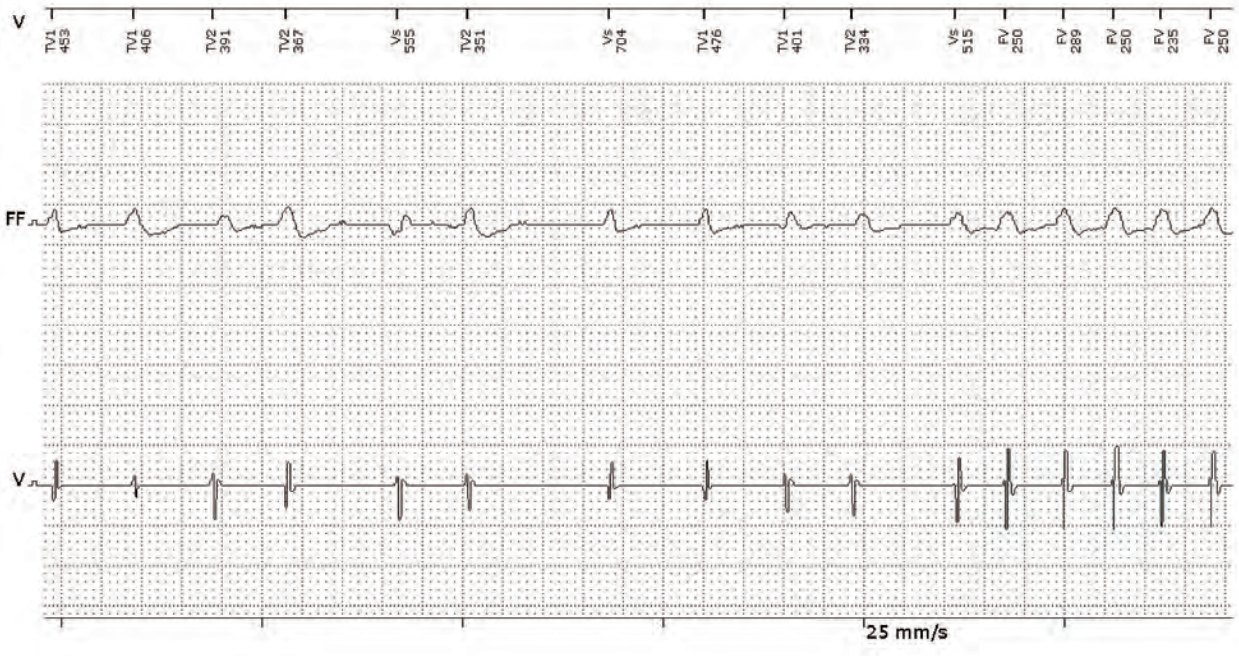


Prothèse Ilesto 7 VR-T

N/S :

Enregistrements - EGM Episode : **8**

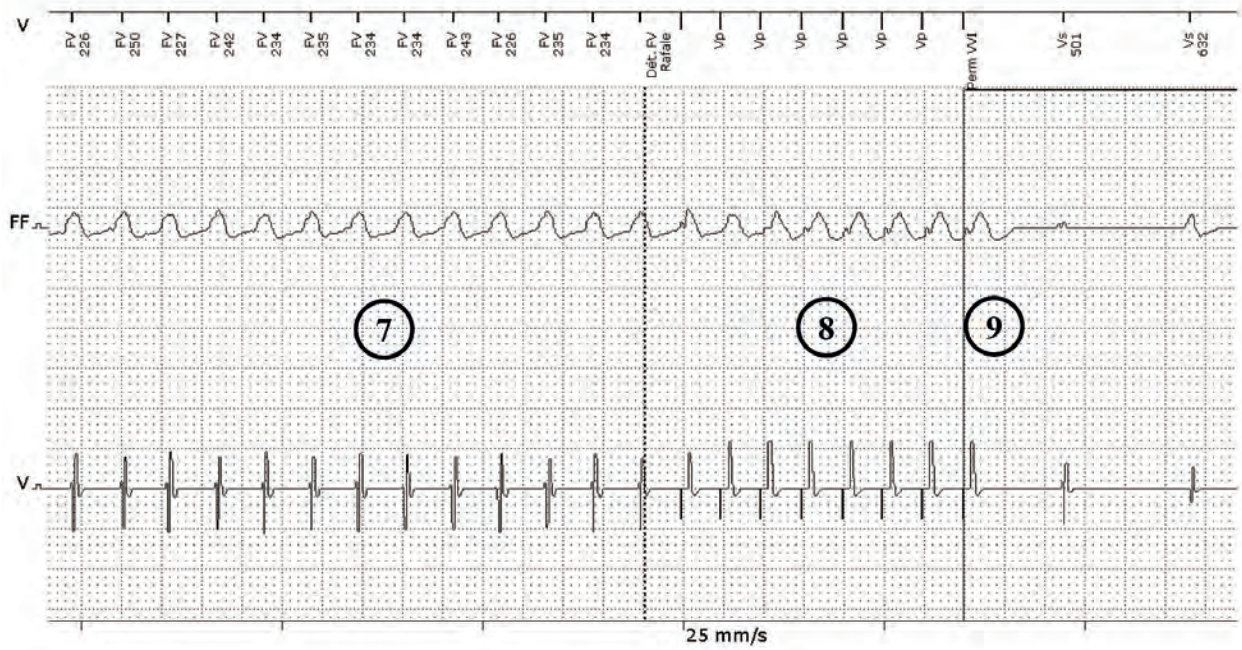


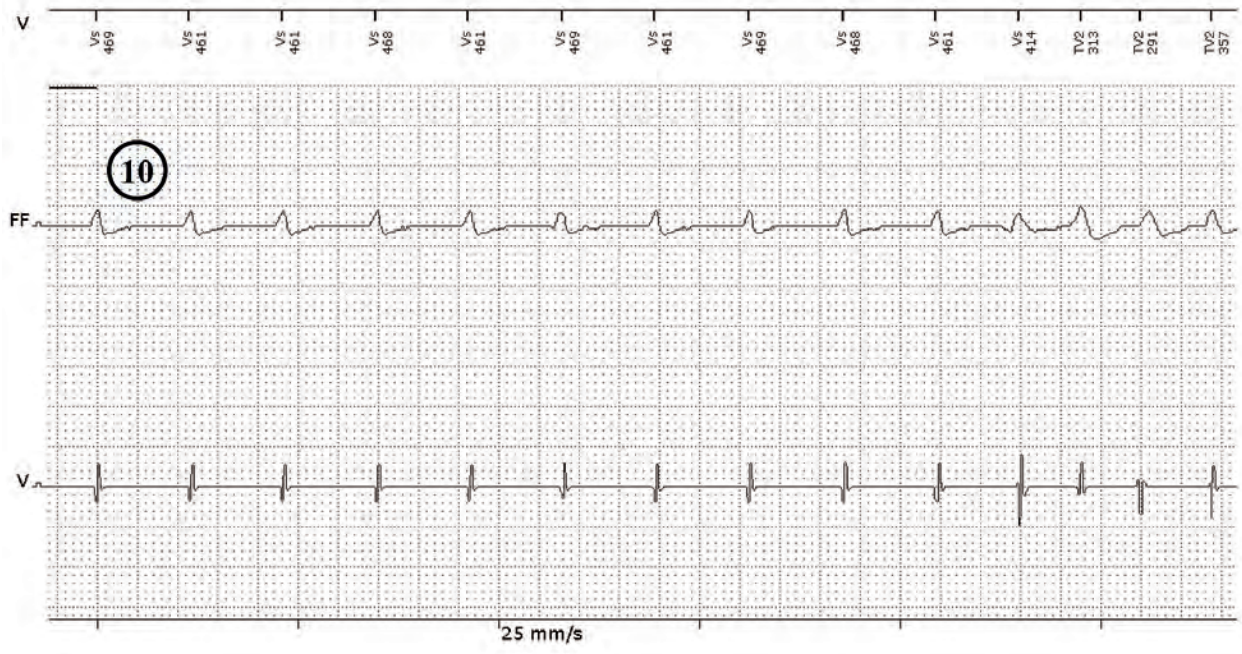


Prothèse Ilesto 7 VR-T

N/S :

Enregistrements - EGM Episode : **8**

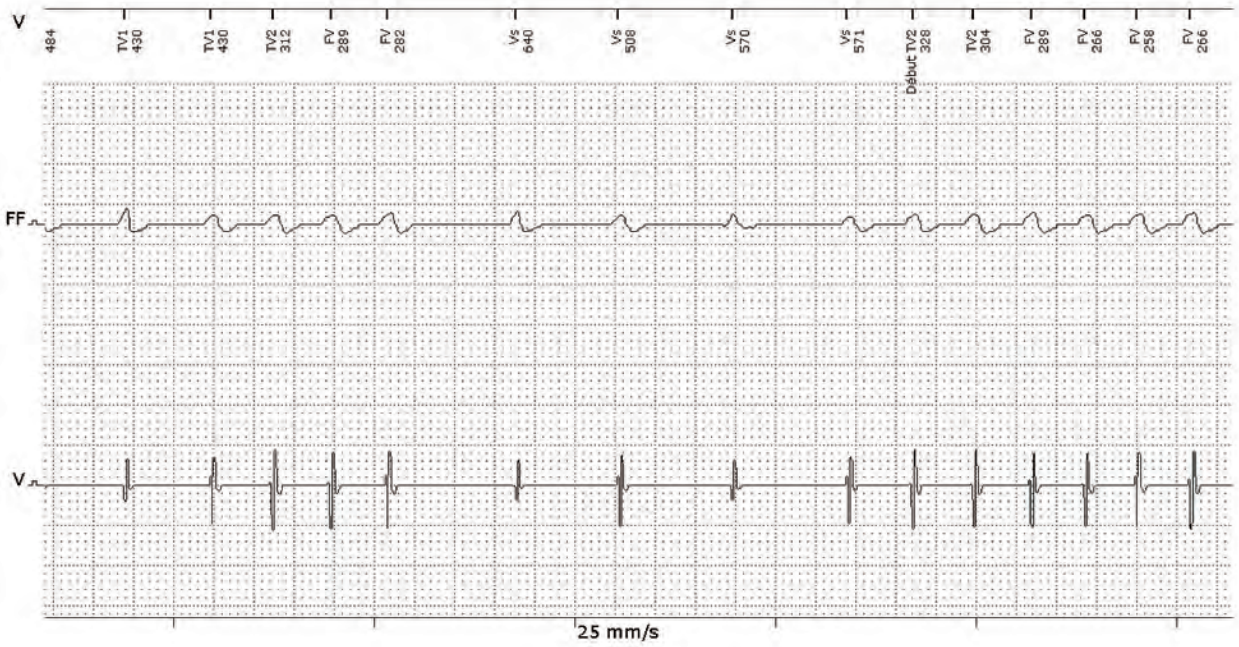


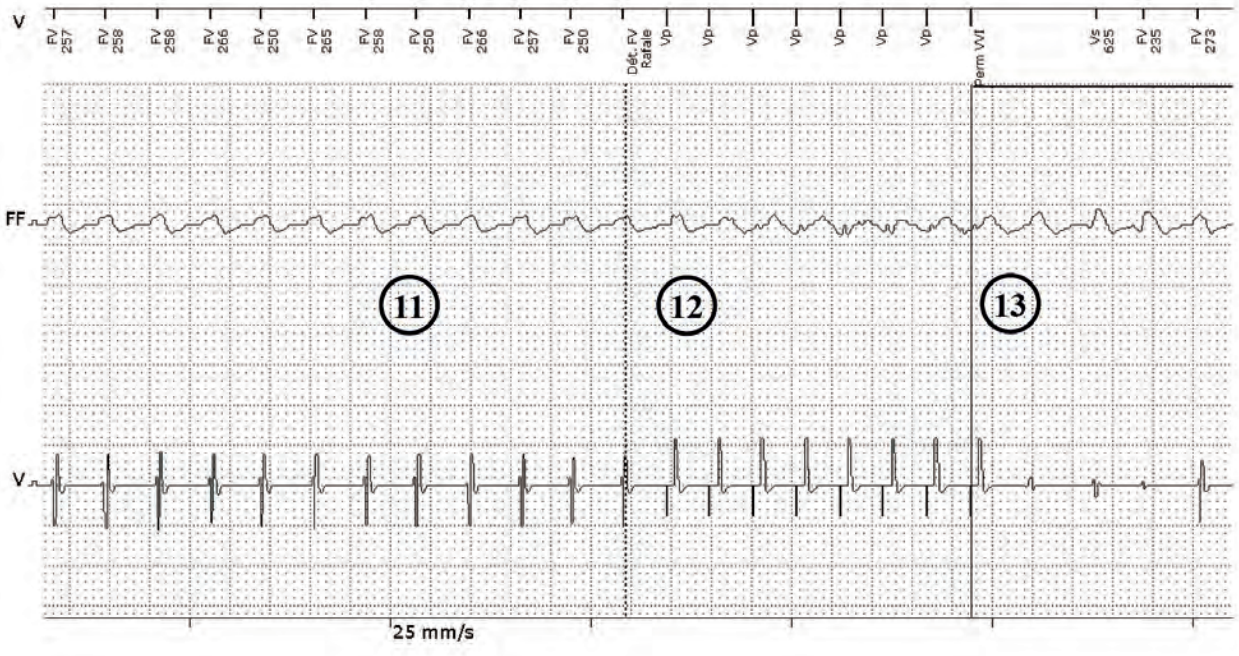


Prothèse Ilesto 7 VR-T

N/S :

Enregistrements - EGM Episode : **6**

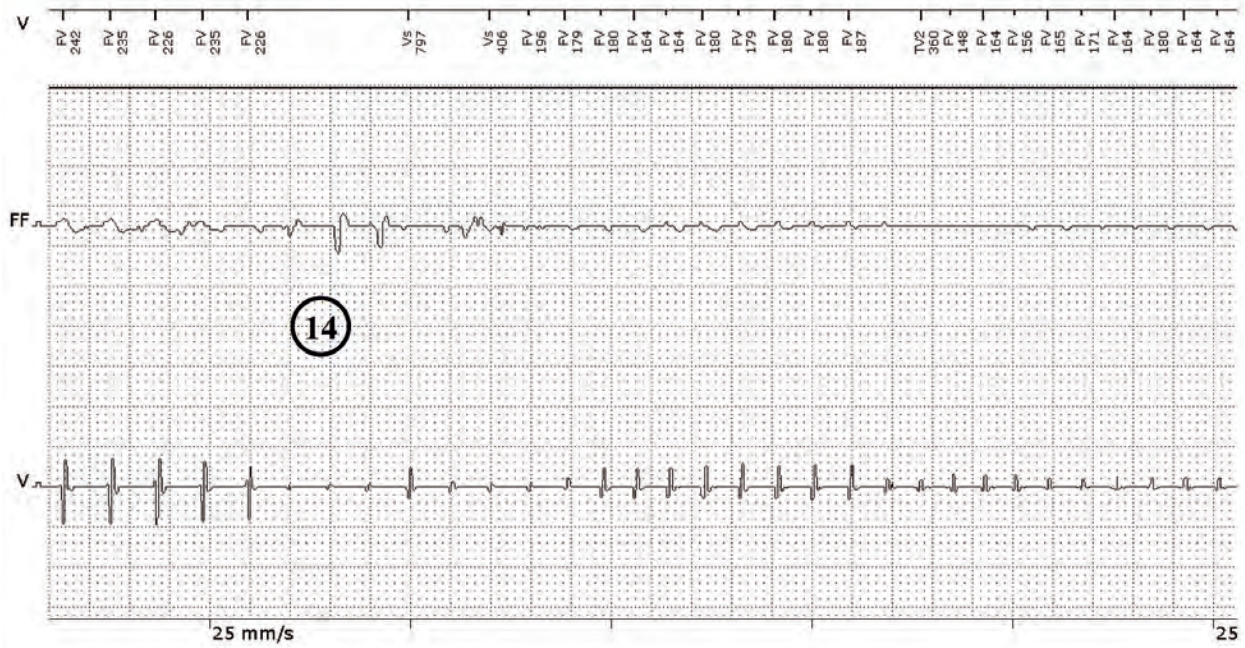


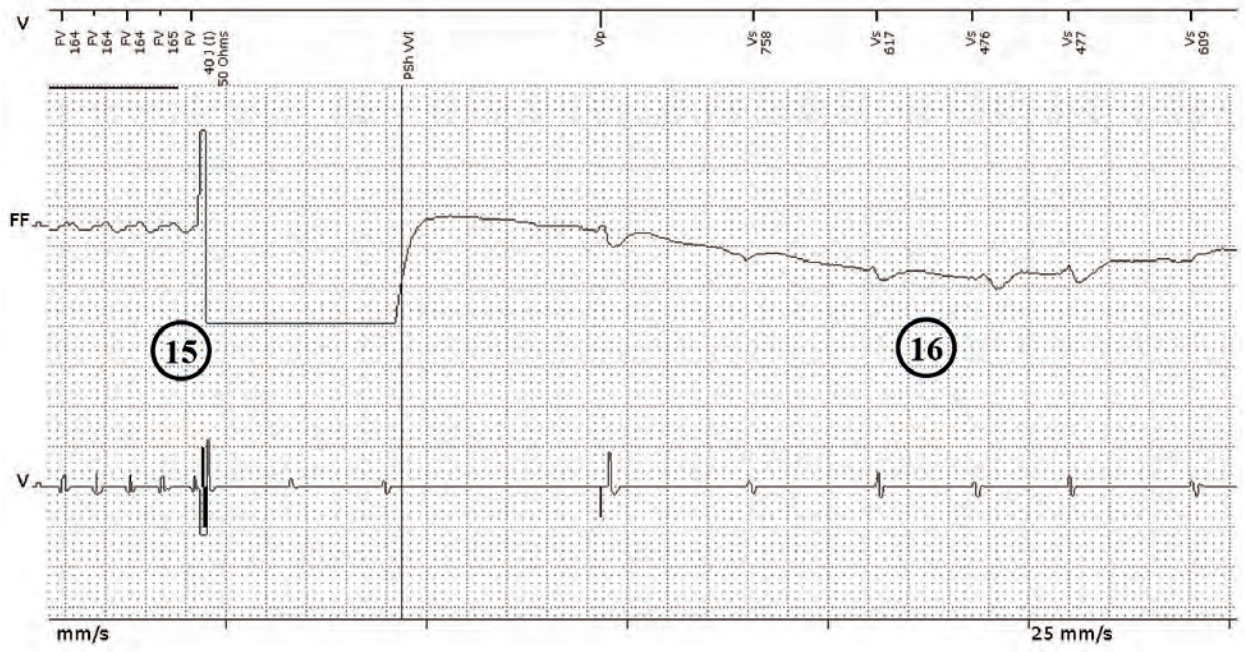


Prothèse Ilesto 7 VR-T

N/S :

Enregistrements - EGM Episode : **6**





Tracing 9 ↘ Sustained VT treated by a burst

Patient

67-year-old man implanted with a Lumax 540 VR-T single-chamber ICD for ischemic cardiomyopathy with ejection fraction of 20%; event report (yellow color) in the setting of a classified VT2.

Telecardiology tracing

3 channels are available: the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the right ventricular sensing channel (RV).

① spontaneous rhythm; the «PermVVI» display at the beginning of the tracing reflects the fact that the ICD is operating in the programmed permanent pacing (VVI) mode;

② premature ventricular contraction;

③ sudden-onset tachycardia detected in the VT2 zone with modification of the morphology relative to sinus rhythm; the «onset» display corresponds to the first interval from which the sudden onset criterion is verified; the average of the previous 4 intervals (680 ms) and the next 4 intervals (367 ms) explains the displayed sudden onset value (46%);

④ classification of the VT2 episode after 24 intervals in VT2 zone without any interleaved interval classified as VT1 or VS; the mean RR during initial sensing (413 ms) corresponds to the average of the 4 intervals preceding the diagnosis; the displayed stability value (3 ms) corresponds to the difference between the longest interval and the shortest interval over the last 4 intervals before classification; it should be noted that the sampling frequencies of the tracing (128 Hz) and the ICD (512 Hz starting from the Lumax 740 ICDs) differ; the resolution of the tracing is therefore 8 ms while that of the device is 2 ms; this explains why the values displayed on the tracing are less accurate than those used by the device for stability measurements, for example; in this instance, the last 4 intervals have a displayed coupling of 414 ms on the tracing which would imply a stability of 0 ms; a more accurate analysis was carried out by the device and showed a variability of 3 ms between these 4 intervals;

⑤ the delivered ATP is not displayed;

⑥ termination of the arrhythmia;

⑦ stoppage (end of episode) after 12 consecutive intervals classified as VS (12 intervals/16 VS); the average RR at the end of the episode (884 ms) corresponds to the average of the 4 intervals preceding the end of the episode;

Programmer tracing (same episode)

The 3 channels are the same as for the telecardiology tracing..

⑧ visualization of the burst (10 pacing stimuli at a fixed rate of 80% of the tachycardia rate); the «PermVVI» display at the end of the burst reflects the fact that the ICD remains in the programmed permanent pacing (VVI) mode during the tachycardia episode and after an antitachycardia pacing sequence.

Comments

The maximal duration of EGMs transmitted by telemedicine is 30 seconds before the initial classification, followed by a maximum of 10 seconds before the end of episode classification; only a maximum amount of information can be transmitted which means that, at times, these values may be lower; the transmitted EGMs correspond to the EGMs retrieved on the programmer albeit with a filtering of the baseline to limit the amount of transmitted information. The duration of the EGMs retrieved on the programmer does not

exceed 3 minutes 30 seconds per episode; the EGM recording begins 5 seconds before the sudden onset diagnosis or 30 seconds before classification if the sudden onset criterion is not met. If the episode lasts more than 3 minutes 30 seconds, the recording is interrupted with systematic visualization of the beginning and the end of the episode.

This tracing demonstrates an example of a VT terminated by an antitachycardia pacing burst which represents first-line therapy for VT <200 beats/minute. Indeed, a priority of the programming of an implantable defibrillator is to minimize as much as possible the number of shocks delivered without compromising patient safety. Ideally, this entails terminating the tachycardia with the least aggressive and least painful therapy possible. Antitachycardia pacing thus represents the first line therapy for organized tachycardias comparatively to electric shocks, the former being less painful and limiting battery consumption and wear. Moreover, the deleterious effect of electric shocks has been clearly demonstrated. The principle behind antitachycardia pacing is to capture the arrhythmia and terminate an organized VT by penetrating its propagation circuit through the ventricles. The ventricle must therefore be paced at a faster rate than that of the tachycardia. The efficacy of this type of therapy has been demonstrated for a wide range of ventricular tachycardia rates up to 250 beats/minute. Antitachycardia pacing reduces nearly 90% of ventricular tachycardias with a rate <200 beats/minute with a moderate risk of acceleration of 1 to 5%. These observations have repositioned the implantable "ICD" as a first-line treatment of arrhythmias by rapid pacing with the possibility of defibrillation only as "backup".

Status report - Jan 9, 2012

To: Service Télécardiologie

BIOTRONIK excellence for life

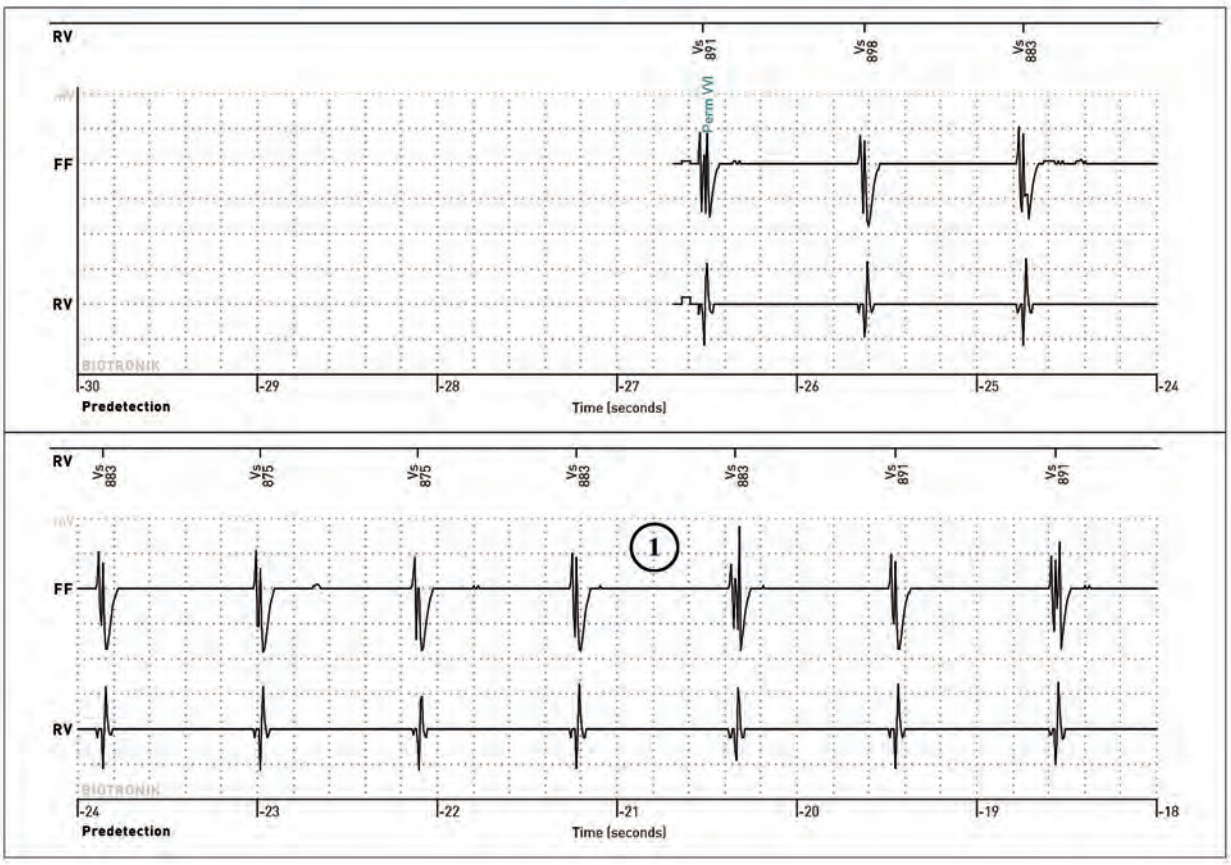
Name:	DOB:	Lumax 540 VR-T (SN 60608840)	Last message: Jan 9, 2012
Patient ID:	Phone:	ICD implanted Aug 17, 2011	Last clinic follow-up: Oct 6, 2011

Recordings

Recordings - Episode 35:

General	
Episode number	35
Episode type	VT2
Detection	Jan 9, 2012 1:48:14 PM
Termination	Jan 9, 2012 1:48:27 PM
Duration	13s
Device settings no.	7
Detection	
Mean RR at initial detection [ms]	413
Onset [%]	46, fulfilled
Stability [ms]	3
Redetection	---

Therapy	
ATP in VT/VF delivered	1
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	0
Maximum energy [J]	---
Termination	
Mean RR at termination [ms]	884
Remark	
none	



Status report - Jan 9, 2012

To: Service Télécardiologie

BIOTRONIK
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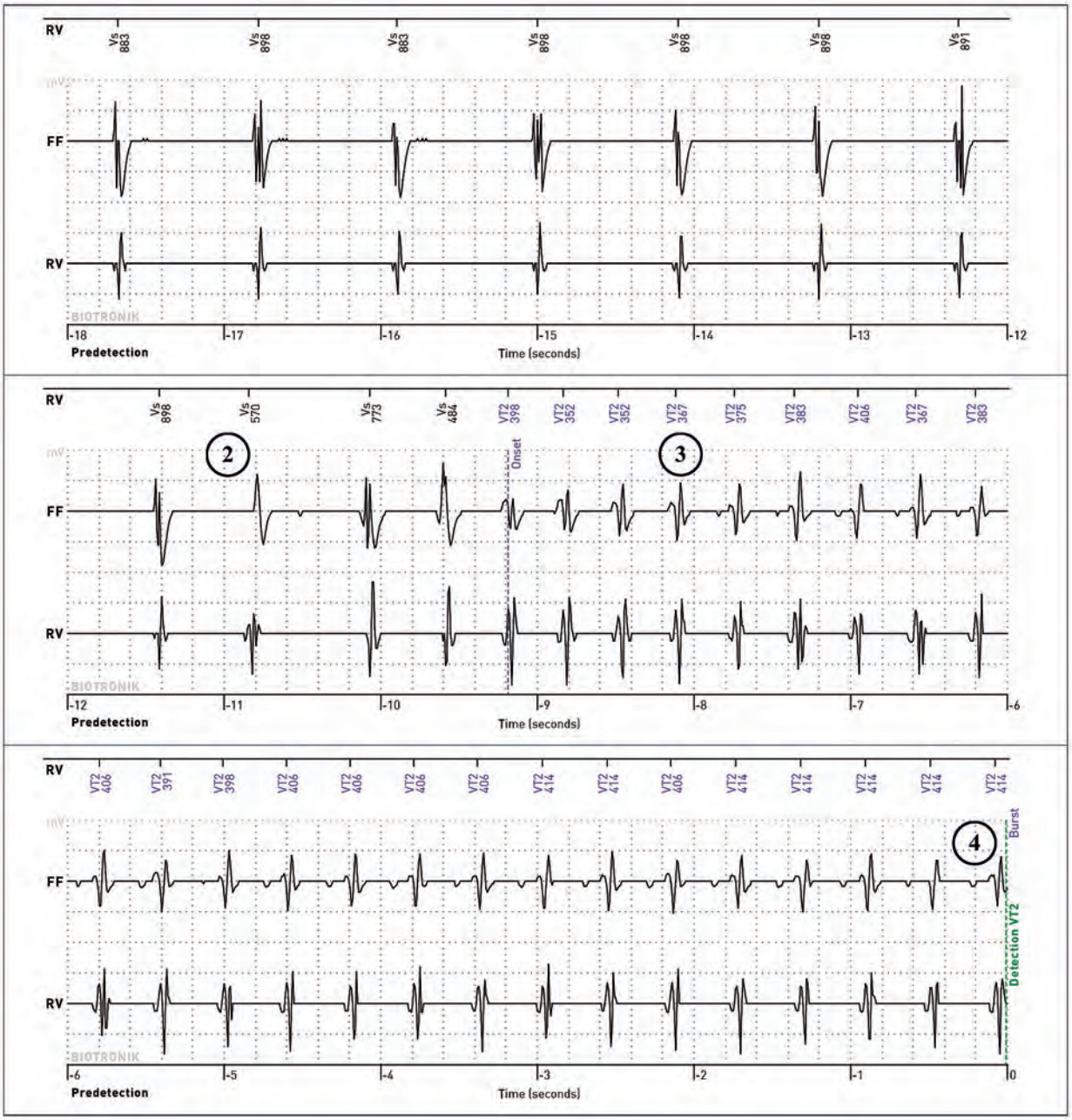
Name:	DOB:	Lumax 540 VR-T (SN 60608840)	Last message: Jan 9, 2012
Patient ID:	Phone:	ICD implanted Aug 17, 2011	Last clinic follow-up: Oct 6, 2011



Status report - Jan 9, 2012

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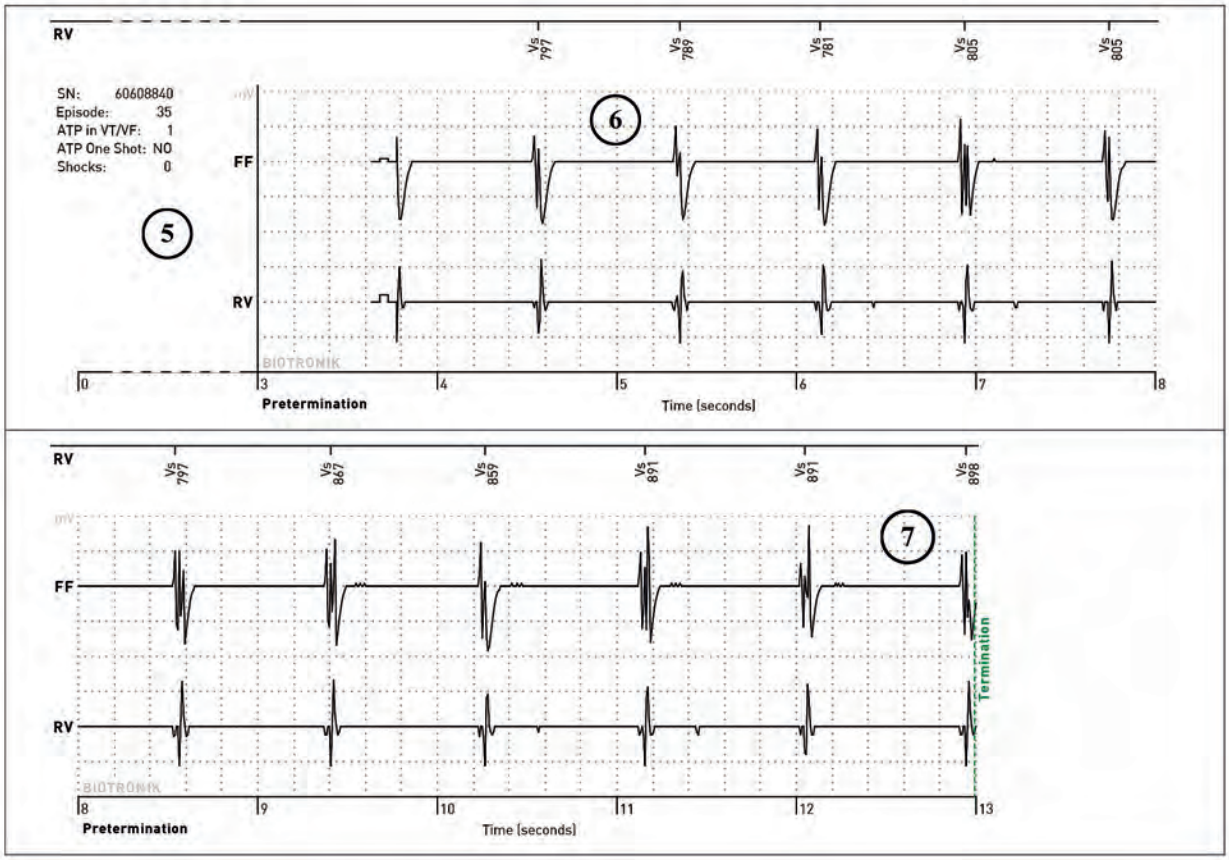
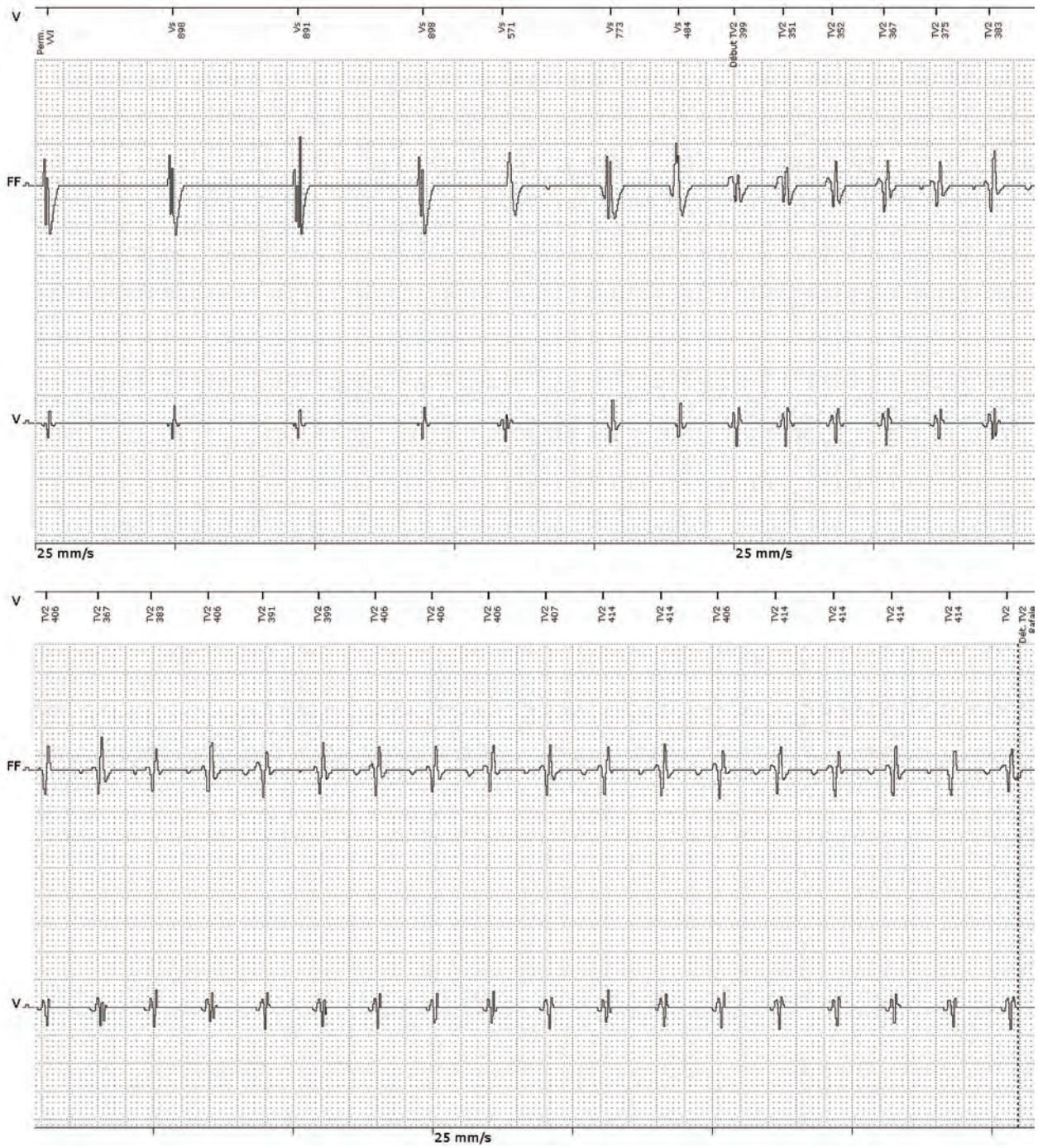
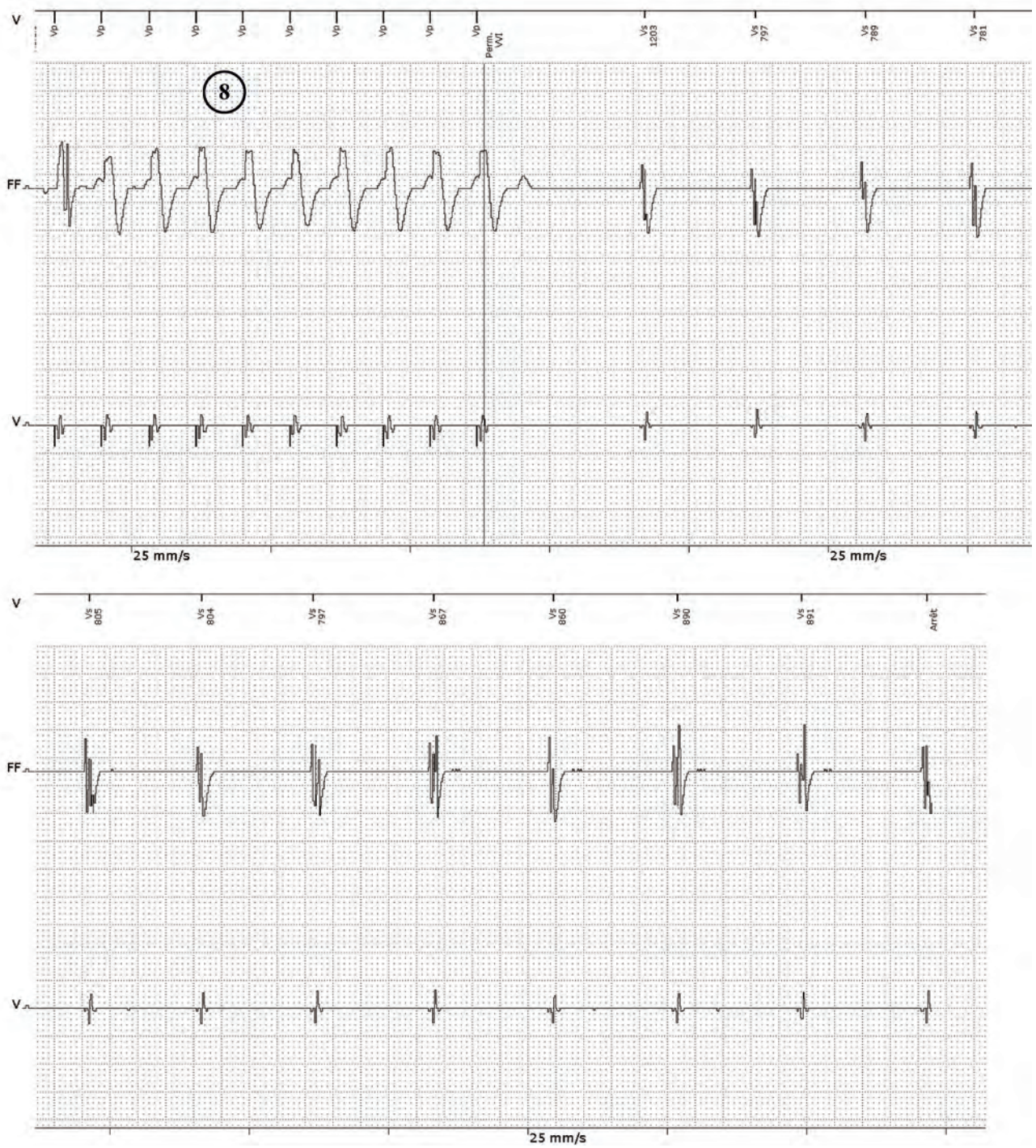


PDF: BIOTRONIK - Lumax 540 VR-T



PDF: BIOTRONIK - Lumax 540 VR-T



Tracing 10 ↘ VT treated by a series of bursts

Patient

76-year-old man implanted with a Lumax 540 VR-T single-chamber ICD for primary cardiomyopathy with an ejection fraction of 25%; event report (yellow color) in the setting of a classified VT1.

Telecardiology tracing

3 channels are available: the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the right ventricular sensing channel (RV).

① first interval classified as VT1 incrementing the VT1 counter by 1;
② interval classified as Vs (430 ms > in the lower VT1 zone) decrementing the VT1 counter (-1) which returns to 0;
③ succession of intervals classified in the VT1 zone;
④ when the VT1 counter reaches 26, classification of the episode in VT1
⑤ delivery of 6 ATP sequences (they are not visualized on the telecardiology report);
⑥ termination of the arrhythmia (end of the episode after 12 intervals classified as VS);

Programmer tracing (same episode)

The 3 channels are the same as for the telecardiology tracing.

⑦ same VT tracing;
⑧ first burst (10 fixed-rate stimuli at 80% of the tachycardia rate);
⑨ after 20 intervals in VT1, the reclassification counter of the VT1 zone is full;
⑩ second burst (11 fixed-rate stimuli 10 ms faster than the previous burst);
⑪ third burst (12 fixed-rate stimuli 10 ms faster than the previous burst);
⑫ fourth burst (13 fixed-rate stimuli 10 ms faster than the previous burst);
⑬ fifth burst (14 fixed-rate stimuli 10 ms faster than the previous burst);
⑭ sixth burst (15 fixed-rate stimuli 10 ms faster than the previous burst);
⑮ termination of the arrhythmia.

Comments

The analyzed episode corresponds to a relatively slow VT (<150 beats/minute); the first 5 bursts are ineffective while the sixth burst allows termination. It should be noted that an additional stimulus is delivered during each burst so as to increase the aggressiveness of each attempt. It is possible to program a large number of pacing sequences to promote a painless termination. It is important, however, to avoid the delivery of overly aggressive therapies (ramps with very short intervals and large number of stimuli) in order to limit the risk of acceleration of the tachycardia. The programming of electric shock is optional for this type of tachycardia and depends on the tolerability of the arrhythmias.

To optimize the effectiveness of anti-tachycardia pacing in the VT zone, various parameters can be programmed:

1) the type of sequence: in a burst, the duration of the intervals is constant during a sequence (no change in interstimuli rate). It is the most commonly used sequence in clinical practice and probably the least aggressive. According to the new guidelines, the burst should be preferred to other sequence types. In ramp therapy, the interval is reduced from one stimulus to the other by the decrement value which is

programmable; it is therefore necessary to program the increment between each interval (programmable between 5 and 40 ms). In a + ES burst (specificity of this manufacturer), at the end of the burst, a short interval pacing stimulus is delivered. This option is no longer available in the Lumax 740 device platform and beyond.

2) the number of programmed sequences varies according to the rate of the tachycardia. In a slow VT zone (<150 beats/minute), a large number of sequences can be programmed in order to delay the delivery of a shock to a tachycardia that does not generally threaten short-term survival. It is also possible to not program an electric shock in this slow VT zone. For tachycardias between 150 and 200 beats/minute, it is common to program 3 to 6 successive antitachycardia pacing sequences.

3) the number of pulses per sequence: on average, 5 to 15 consecutive pulses are programmed in each burst. If the number is insufficient, the pacing sequence may not penetrate the tachycardia circuit and the burst remains ineffective. On the other hand, if the number is too high, the risk is the termination and re-induction of the tachycardia. An additional pacing stimulus can be systematically added from one sequence to another. According to the new guidelines, a minimum of 8 pacing stimuli per sequence should be programmed.

4) the value of the pacing intervals which is programmable between 70 and 95%: the shorter the couplings, the more aggressive the therapy and the greater risk of accelerating the tachycardia. According to the new guidelines, for a burst, an 88% coupling relative to the rate of the tachycardia (calculated over the last 4 intervals preceding the diagnosis) must be programmed.

5) the minimum coupling allows limiting the aggressiveness of a pacing sequence; there is a pacing rate limit that the device cannot exceed (200 ms). When, for example, during a ramp, the minimum coupling is reached, the subsequent intervals are paced with this minimum coupling without additional decrement.

6) the scan decrement; if the rate of the tachycardia remains constant, the second pacing sequence is faster than the first by the decrement value.

7) the pacing site(s) can be programmed; in single- or dual-chamber mode, the pacing is necessarily right ventricular. For a triple-chamber device, the right biventricular or ventricular pacing mode can be programmed. Biventricular pacing appears to be theoretically superior in patients with left ventricular dysfunction, with the majority of tachycardias originating in the left ventricle (less distance between the tachycardia circuit and the pacing site).

The programming is initially empirical but must be subsequently adjusted according to the different arrhythmias recorded by the device and analyzed during patient follow-up, as well as according to the efficacy ratio (episode termination)/deleterious effect (acceleration of the arrhythmia) of a particular type of pacing sequence.

Status report - Mar 14, 2012

To: Service Télécardiologie

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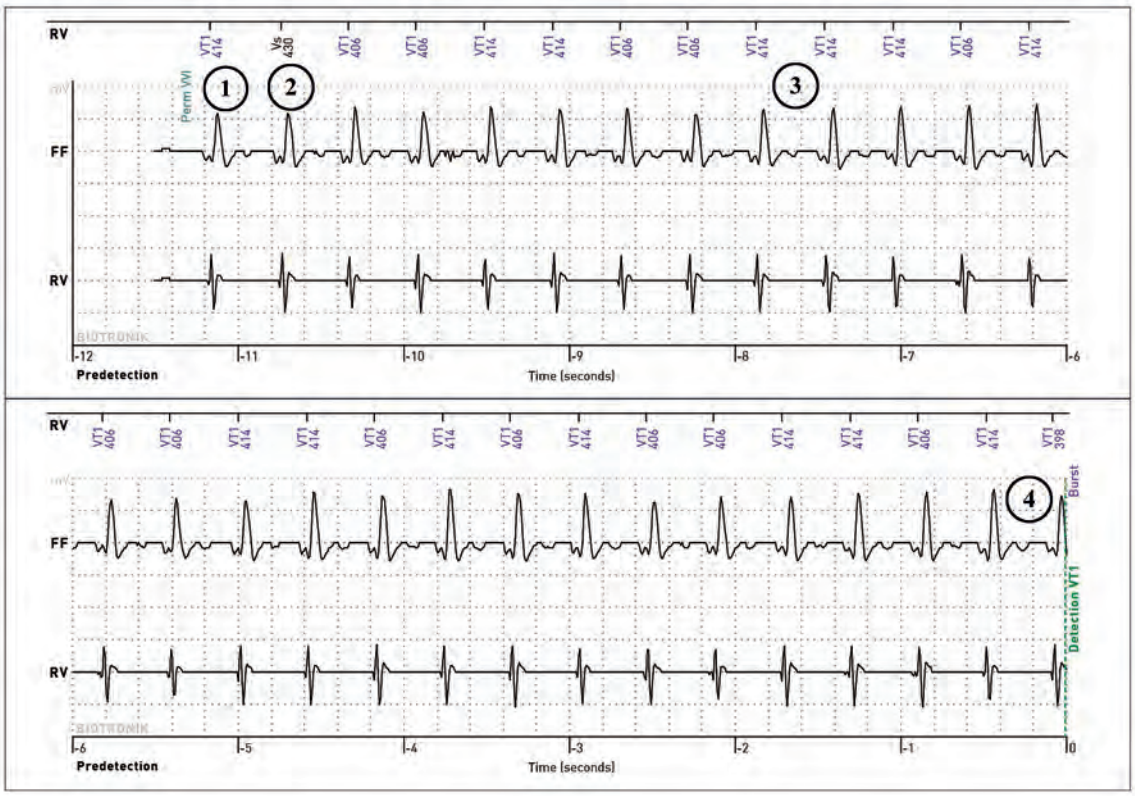
Name	DOB:	Lumax 540 VR-T (SN 60626107)	Last message: Mar 14, 2012
Patient ID:	Phone:	ICD implanted Feb 21, 2012	Last clinic follow-up: Feb 24, 2012

Recordings

Recordings - Episode 8:

General		Therapy	
Episode number	8	ATP in VT/VF delivered	6
Episode type	VT1	ATP One Shot delivered	NO
Detection	Mar 14, 2012 12:02:32 AM	Shocks delivered	0
Termination	Mar 14, 2012 12:03:50 AM	Shocks aborted	0
Duration	1min 18s	Maximum energy [J]	---
Device settings no.	17	**Termination**	
Detection		Mean RR at termination [ms]	815
Mean RR at initial detection [ms]	407	**Remark**	
Onset [%]	10	none	
Stability [ms]	11		
Redetection	VT1: 5		

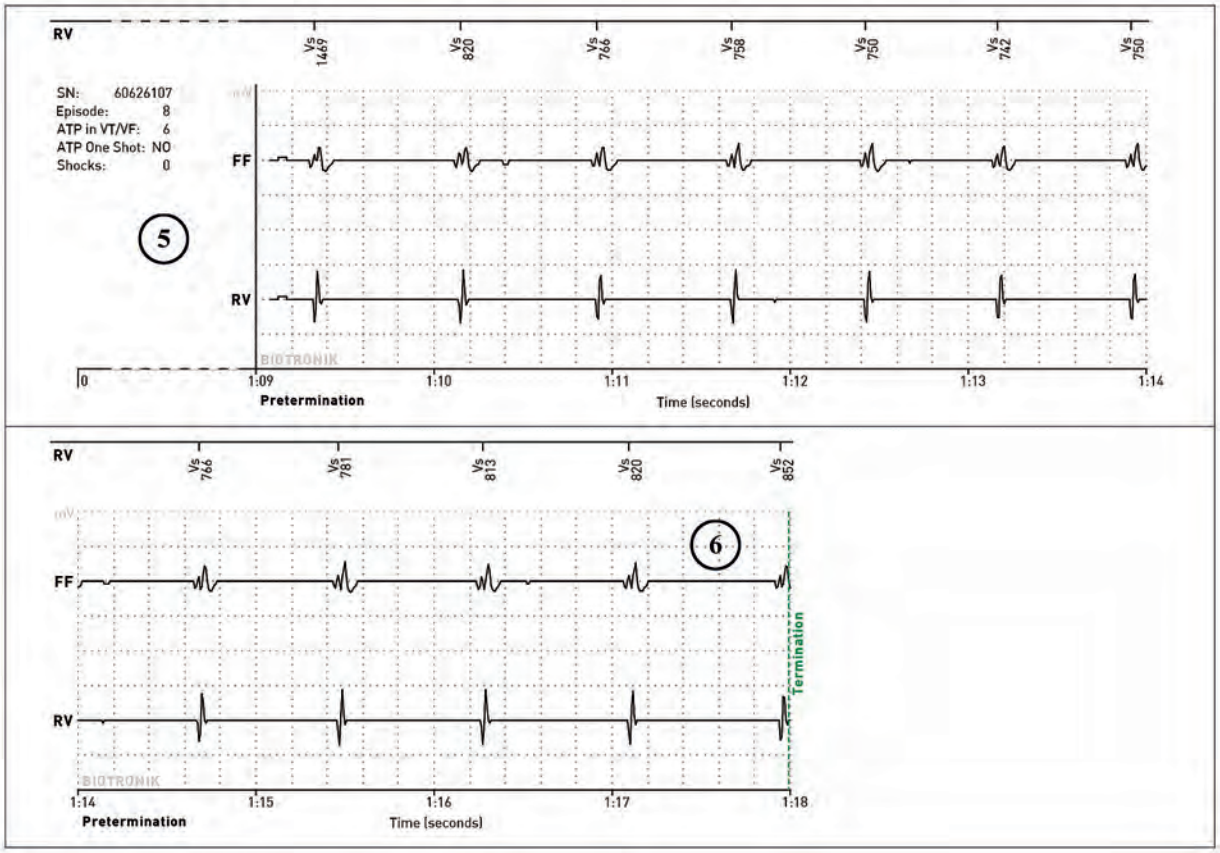


Status report - Mar 14, 2012

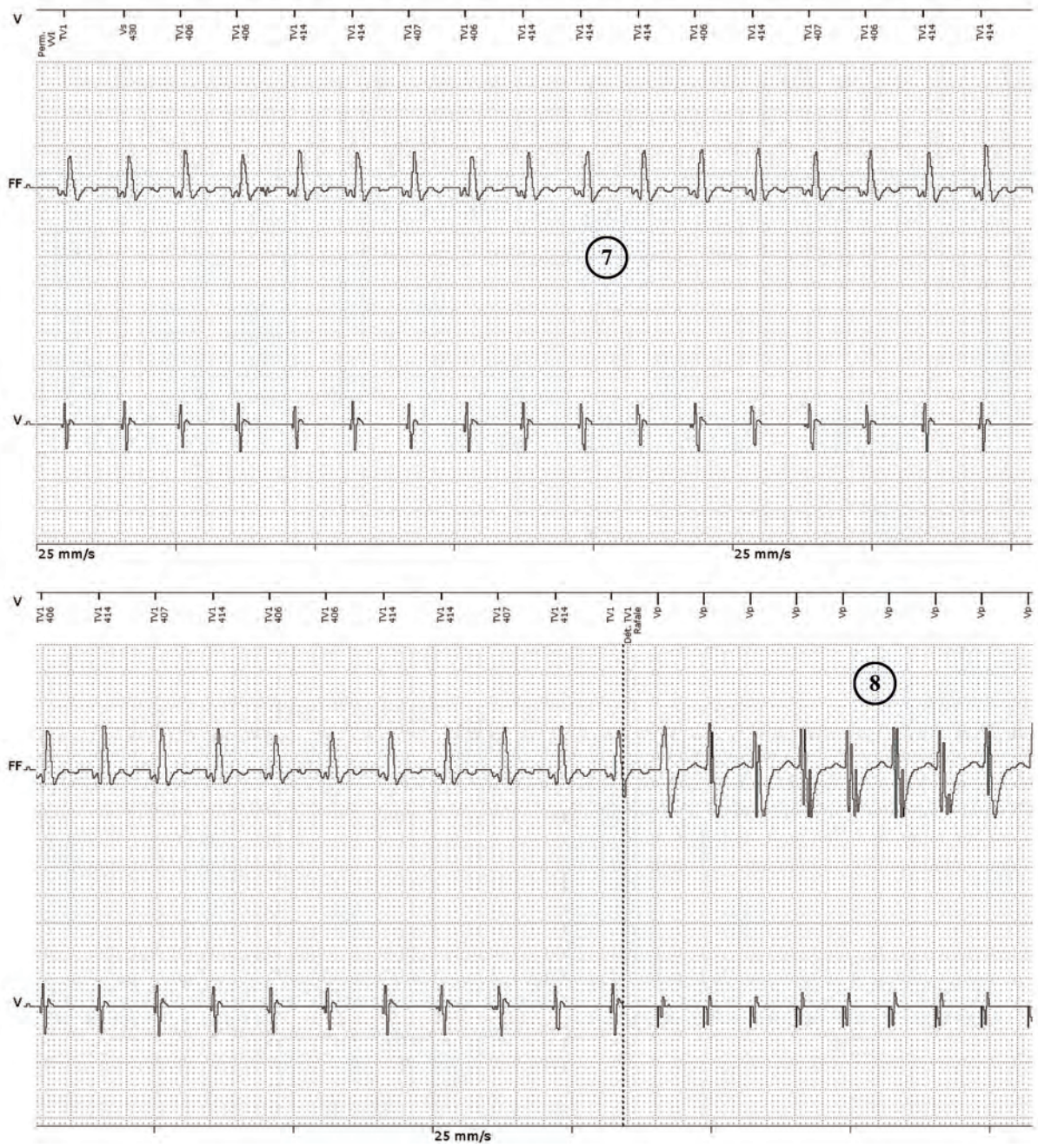
To: Service Télécardiologie

BIOTRONIK
excellence for life

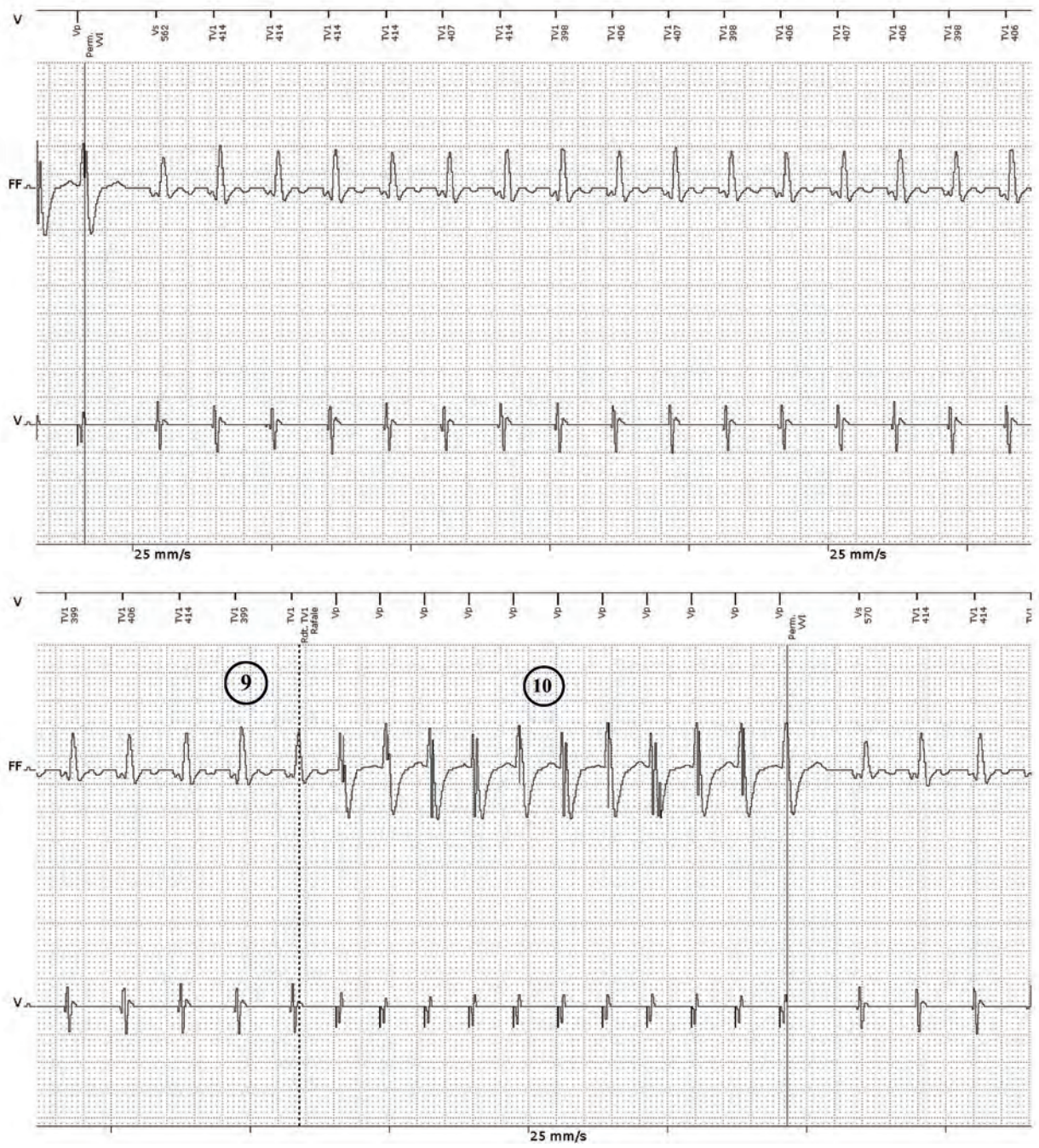
Name:	DOB:	Lumax 540 VR-T (SN 60626107)	Last message: Mar 14, 2012
Patient ID:	Phone:	ICD implanted Feb 21, 2012	Last clinic follow-up: Feb 24, 2012



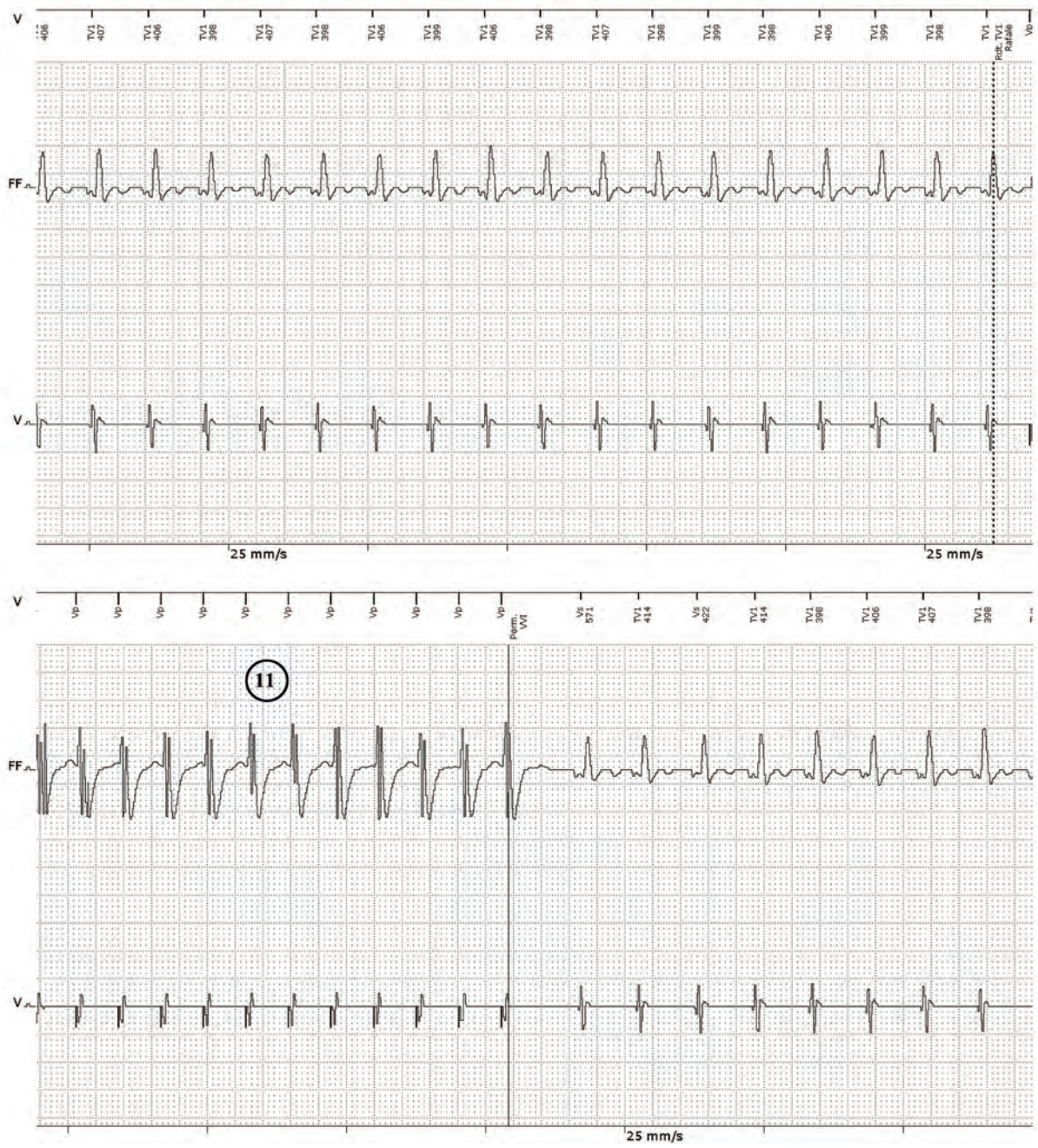
PDF: BIOTRONIK - Lumax 540 VR-T



PDF: BIOTRONIK - Lumax 540 VR-T



PDF: BIOTRONIK - Lumax 540 VR-T



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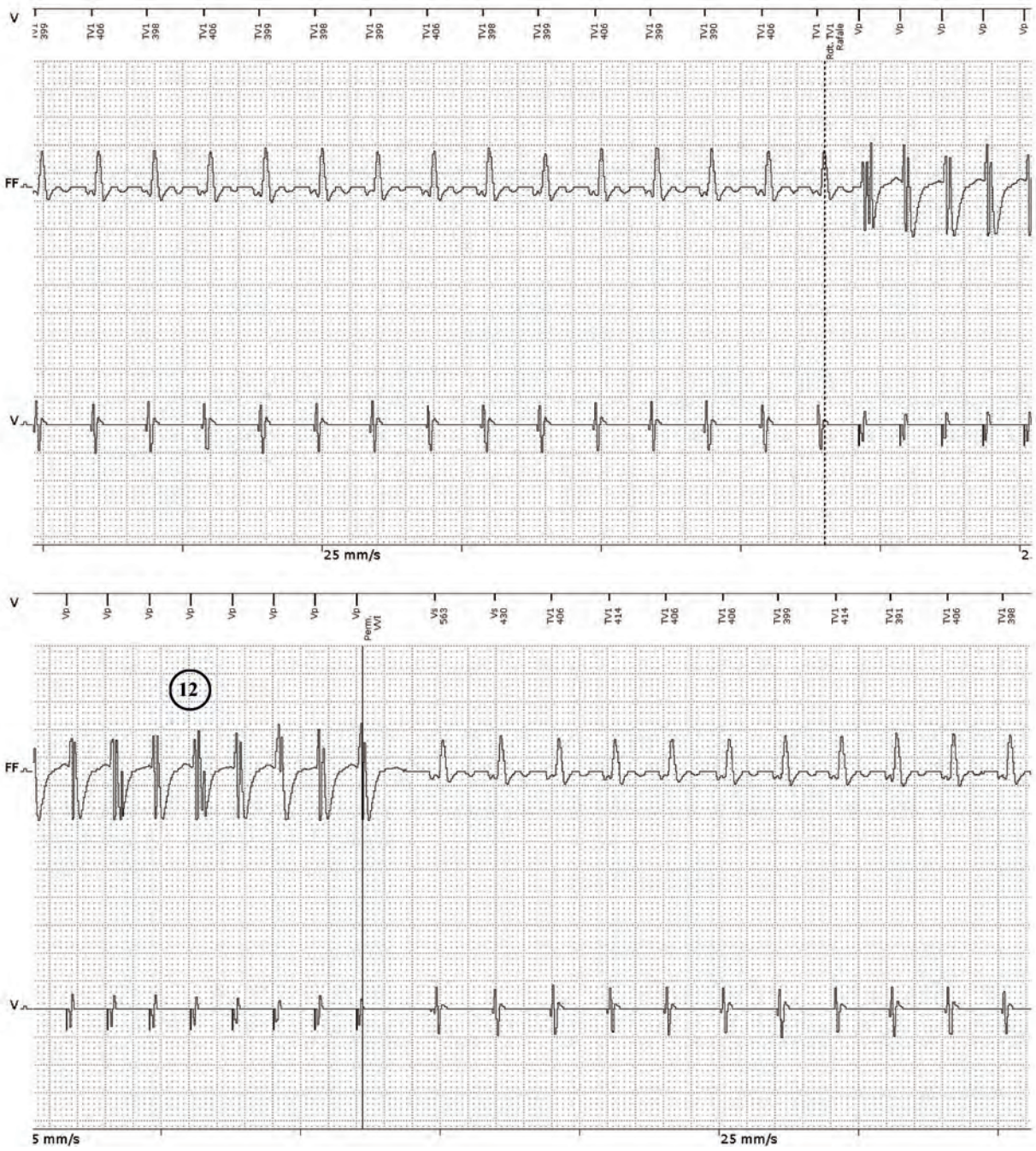
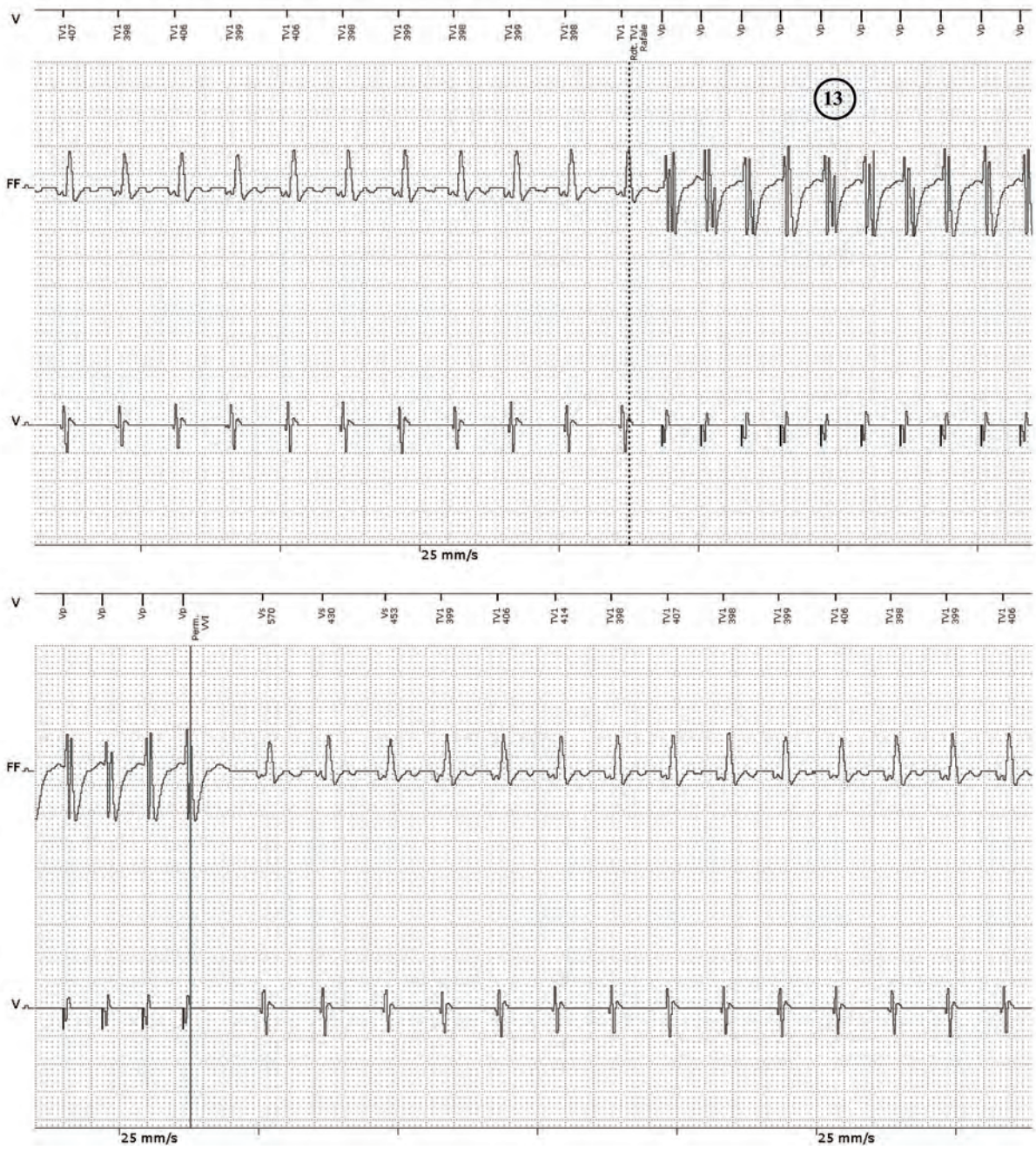
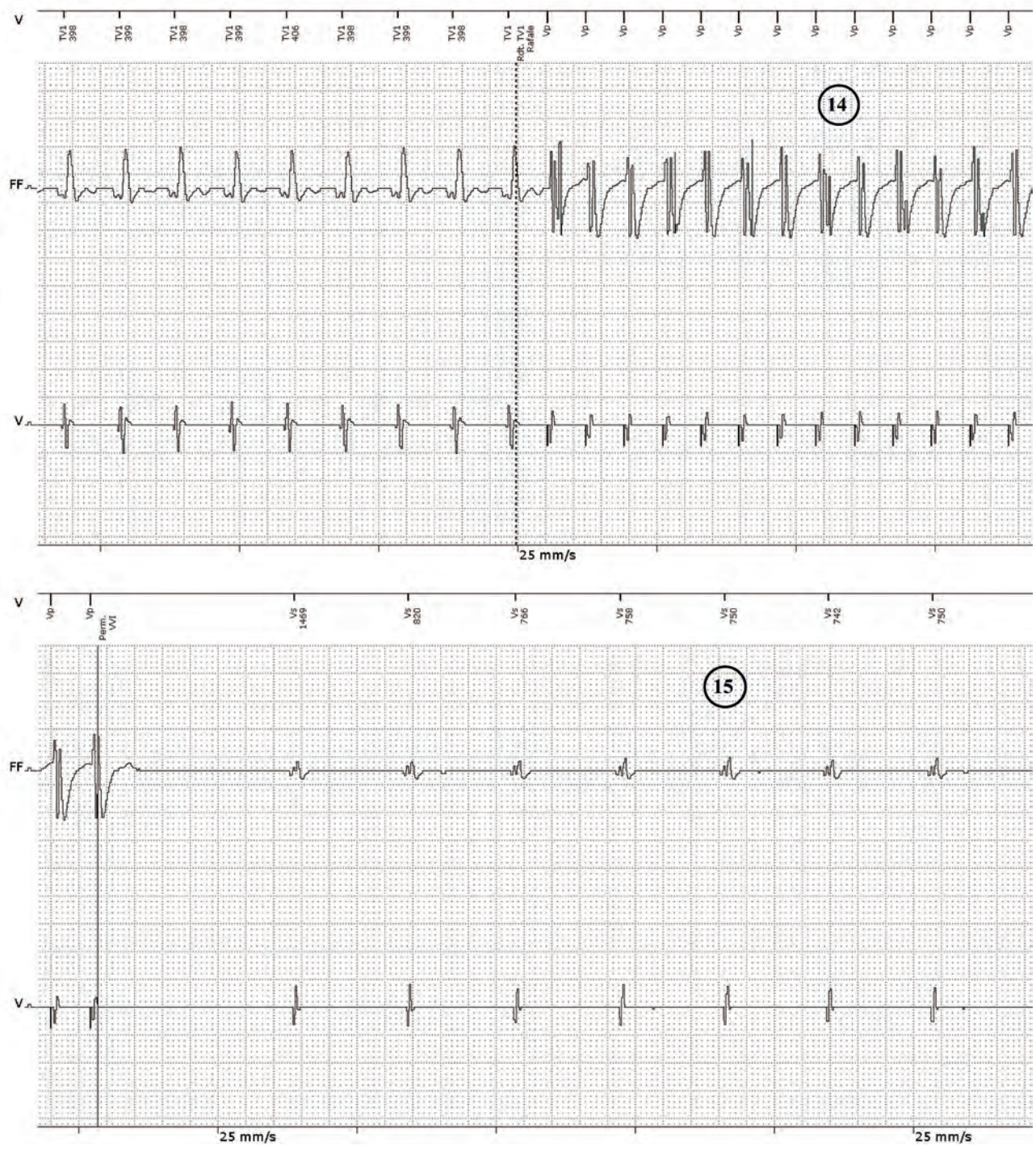


PDF: BIOTRONIK - Lumax 540 VR-T



PDF: BIOTRONIK - Lumax 540 VR-T



Tracing 11 ↘ Electric shock in the VT zone

Patient

Homme de 77 ans implanté d'un défibrillateur triple chambre Lumax 340 HF-T pour une myocardiopathie ischémique avec fraction d'éjection à 25% et bloc de branche droit; palpitations puis choc électrique puis syncope; rapport événement (couleur jaune) dans le cadre d'une TV2 classifiée avec choc inefficace.

Telecardiology tracing

① VT with atrioventricular dissociation;

② alternating intervals between VT1 zone and VT2 zone; it should be noted that the VT1 zone was a monitoring zone; the VT1 counters were full (preceding VT1 episode found at interrogation) although no therapy was delivered;

③ classification of a VT2 episode;

④ delivery of 6 ATP sequences as well as 2 electric shocks; the last electric shock at 40J is visible (shock impedance 54 Ohms); on the presentation, one can see that the initial diagnosis is VT2 with 6 ATP followed by 2 delivered shocks with 1 cancelled shock;

⑤ termination of the arrhythmia; the post-shock « PostSh DDI » display indicates that the ICD is operating in the programmed post-shock pacing (DDI) mode for a programmable duration (nominal: 10 seconds);

⑥ end of episode after 12 consecutive intervals classified as Vs or VP;

Programmer tracing (same episode)

⑦ first burst (10 fixed-rate pacing at 80% of the tachycardia rate, biventricular pacing);

⑧ failure of the burst and persistence of the arrhythmia;

⑨ intervals classified as RVs; in post-therapy confirmation of a VT2, the interval is classified as RVs if in the VT1 zone;

⑩ VT2 reclassification counter full (counter programmed at 14: before resensing: 16 VT2 intervals and 2 RVs intervals) without the end-of-episode counter (12 slow intervals/16) ever being full;

⑪ second burst with 1 additional pacing stimulus;

⑫ unsuccessful burst and VT2 reclassification (counter at 14);

⑬ third burst;

⑭ fourth burst;

⑮ fifth burst;

⑯ sixth burst;

⑰ unsuccessful therapy, the following therapy is a shock of 10J;

⑱ the black line corresponds to the charging of the capacitors which is short for a low-amplitude shock;

⑲ at the end of the charge, search for a short interval and electric shock of 10J (shock impedance 56 Ohms); the shock is synchronized on the R wave and, in this patient, left ventricular depolarization precedes right depolarization and the electrical shock occurs during left ventricular repolarization;

⑳ blanking period of 1 second without detection as a result of the electric shock;

㉑ degradation of the rhythm into VF;

㉒ undersensing of the arrhythmia in the right ventricular channel (better sensing in the left ventricular channel);

㉓ resensing of a VF (8 out of 12 intervals classified as VF);

㉔ new charging of the capacitors;
㉕ at the end of the charge, search for a rapid interval;
㉖ due to a marked right ventricular undersensing, 4 out of 5 intervals are classified as Vs or VP; the shock is not delivered;
㉗ new resensing of VF: (8 out of 12 intervals classified as VF);
㉘ new very short charge, the capacitors not having had the possibility to deplete;
㉙ shock delivered (this shock is not confirmed);
㉚ effective shock, termination of the arrhythmia and end of the episode after 12 RVs or RVp intervals.

Patient

67-year-old man with ischemic cardiomyopathy implanted with a Lumax 540 VR-T ICD; palpitations followed by electric shock.

Telecardiology tracing

① probable VT;
② delivery of 6 antitachycardia pacing sequences followed by an electric shock;
③ termination of the arrhythmia;

Programmer tracing (same episode)

④ ramp corresponding to the sixth antitachycardia pacing sequence;
⑤ start of capacitor charge;
⑥ at the end of the charge, synchronized shock of 40 joules;
⑦ termination of the arrhythmia.

Comments

These tracings show the various possibilities for programming the amplitude of the electric shocks in the VT zone.

For the first episode initially diagnosed in the VT2 zone, the therapies are triggered in consecutive manner which end as soon as the rhythm is once again deemed as slow, or after because all therapies were exhausted. Six bursts did not terminate the arrhythmia. A first shock of 10J was subsequently delivered. This patient presented episodes of VT arising from the left ventricle (LV EGM preceding the RV). The electric shock is synchronized to RV sensing (30 ms later). On this type of arrhythmia, the EGM suggests that the shock was delivered during the onset of the left ventricular repolarization phase. The delivery of a moderate amplitude shock in the left ventricular vulnerable period explains the arrhythmogenic nature of the shock and the degradation of the arrhythmia into ventricular fibrillation. For the second patient, a maximum amplitude shock was directly programmed as a result of antitachycardia pacing.

In the absence of an optimal universal programming, the results of large-scale studies concur on the need to reduce the number of inappropriate or unnecessary therapies without jeopardizing patient safety and prioritize antitachycardia pacing in lieu of electric shocks. It is customary to program increasing aggressive therapies with antitachycardia pacing representing the first-line treatment for monomorphic tachycardia. In the VT zone (<200 beats/minute), a series of bursts rather than ramps (Class I indication) is therefore usually programmed. Indeed, the ratio between termination and acceleration of the arrhythmia appears to favor burst therapy (identical efficacy but less prominent pro-arrhythmogenic feature) compared to the ramp. If the bursts prove unsuccessful, it is then possible to program a series of ramps to promote a non-painful

therapy followed by a series of electric shocks or proceed to the electric shocks directly. Various parameters influence the choice of the amplitude of the first shock in the VT zone, which can be programmed at maximum energy or at a lower amplitude (in the order of 10J). A certain number of advantages can be found in programming a first moderate amplitude shock (10J): 1) this amplitude is very often sufficient to terminate a VT episode; 2) the charge time for this amplitude is very short even though the few seconds difference with a maximum amplitude are not clinically determinant when the shock occurs after 3 burst sequences plus or minus 3 ramp sequences (more than one minute of arrhythmia); 3) battery consumption is less for a shock of 10J versus 35J despite having little impact on the wear of the batteries if the number of shocks delivered is limited; 4) despite the fact that most of the time during a VT episode, the electric shock is delivered while the patient is still conscious, the painful nature of the shock has little bearing on the decision regarding the amplitude of the first shock, given the difficulty in demonstrating a direct link between the amplitude of the shock delivered and the amplitude of the pain incurred; 5) various studies have demonstrated the deleterious nature of an electric shock and its association with an altered prognosis; it thus appears logical to assume that a shock of 10J will have fewer negative consequences than a shock of 35J and would thus favor choosing the least traumatic therapy possible.

The first tracing, however, shows the main limitation of programming a shock of 10J in the VT zone and the resulting pro-arrhythmogenic risk (concept of upper limit of vulnerability). Below a certain variable value depending on the patient and directly related to the defibrillation "threshold", not only can a shock be ineffective in reducing an arrhythmia but can also accelerate and disorganize a monomorphic VT into a polymorphic arrhythmia compromising the patient's prognosis in the short term. This tracing shows a rapid, polymorphic, low voltage and very worrisome arrhythmia induced by the first shock. The induced arrhythmias are often associated with very short ventricular intervals of limited amplitude, increasing the risk of undersensing and inappropriate interruption of capacitor charge. Sensing during this VF episode was very poor: namely, a moderate delay in diagnosis but especially a false diagnosis of return to sinus rhythm and temporary interruption of the charge. Sensing improves in a second step allowing the termination by electric shock. RV sensing was programmed to enhanced T wave suppression without prior oversensing of the T wave. LV sensing was set to Standard. In this patient, it would appear essential to reprogram a standard RV sensing or even an enhanced VF sensing. This new programming can subsequently be validated by induction and verification of accurate sensing of VF.

This type of adverse effect is relatively rare although constitutes a major limitation of the programming of moderate amplitude shocks. Another alternative is therefore to program a first shock of maximum amplitude so as to increase the probability of terminating a VT on the very first attempt, to reduce as much as possible the number of shocks delivered and to be above the upper limit of ventricular vulnerability.

Status report - Oct 2, 2010

To: Service Télécardiologie

BIOTRONIK
excellence for life

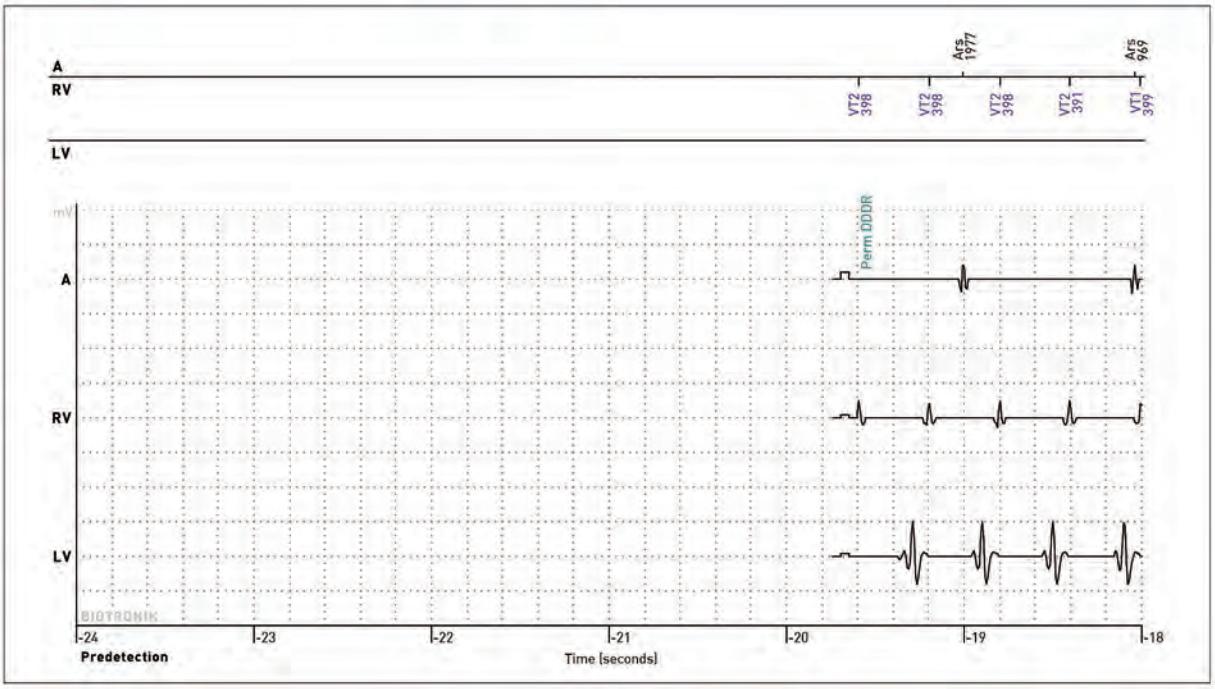
Name:	DOB:	Lumax 340 HF-T (SN 60446370)	Last message: Oct 3, 2010
Patient ID:	Phone: -	CRT-D implanted Jul 23, 2009	Last clinic follow-up: Sep 27, 2010

Recordings

Recordings - Episode 10322:

General	
Episode number	10322
Episode type	VT2
Detection	Oct 2, 2010 10:24:56 AM
Termination	Oct 2, 2010 10:27:02 AM
Duration	2min 6s
Device settings no.	75
Detection	
Mean PP at initial detection [ms]	1686
Mean RR at initial detection [ms]	394
Onset [%]	45
Stability [ms]	5
Redetection	VT2: 6, VF: 2

Therapy	
ATP in VT/VF delivered	6
ATP One Shot delivered	NO
Shocks delivered	2
Shocks aborted	1
Maximum energy [J]	40
Termination	
Mean PP at termination [ms]	992
Mean RR at termination [ms]	985
Remark	
Therapy	first shock ineffective, progressive course of therapy (PCOT) applied, surge guard applied

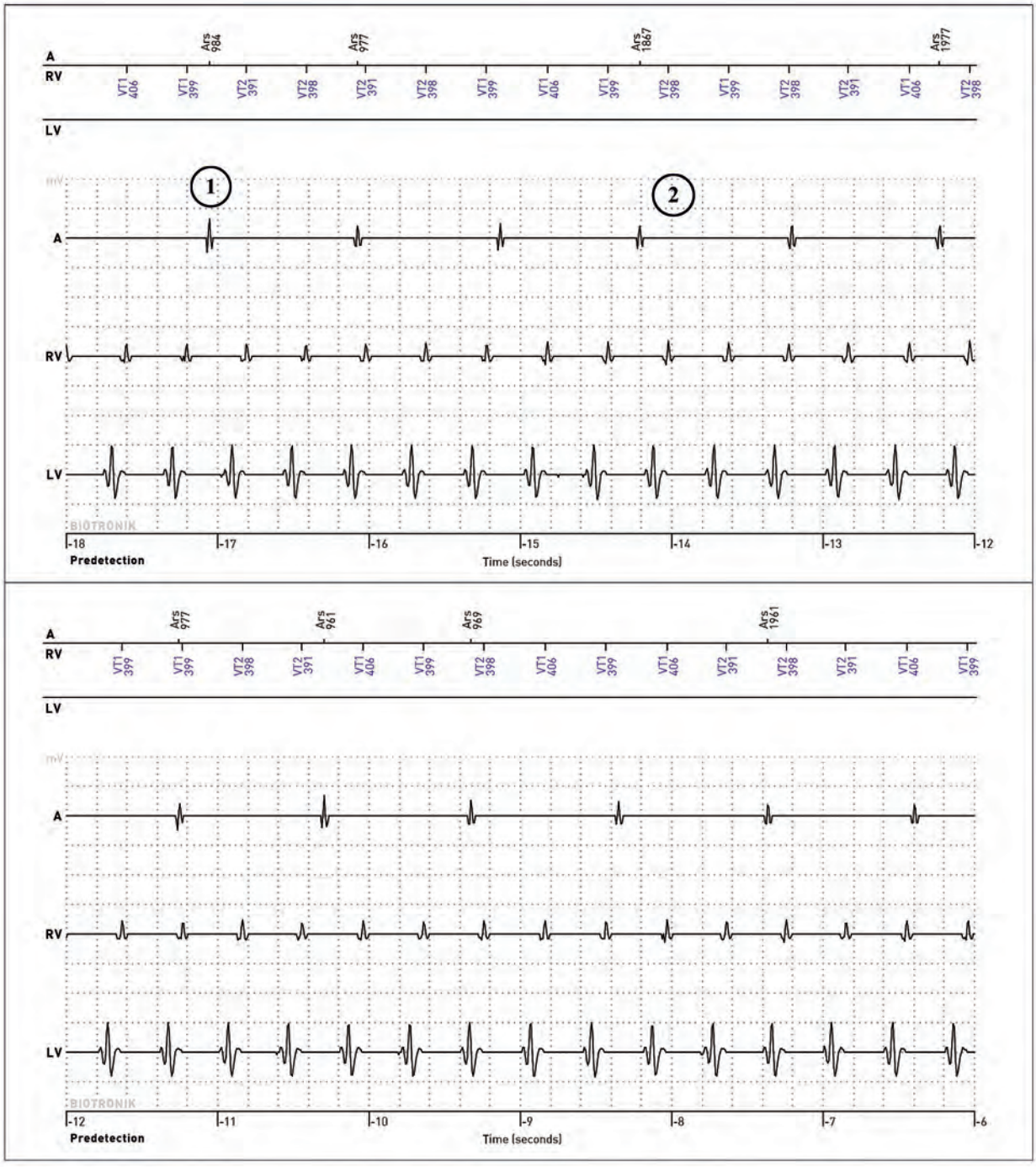


Status report - Oct 2, 2010

To: Service Télécardiologie

BIOTRONIK excellence for life

Name:	DOB:	Lumax 340 HF-T (SN 60446370)	Last message: Oct 3, 2010
Patient ID:	Phone: -	CRT-D implanted Jul 23, 2009	Last clinic follow-up: Sep 27, 2010



Status report - Oct 2, 2010

To: Service Télécardiologie

BIOTRONIK excellence for life

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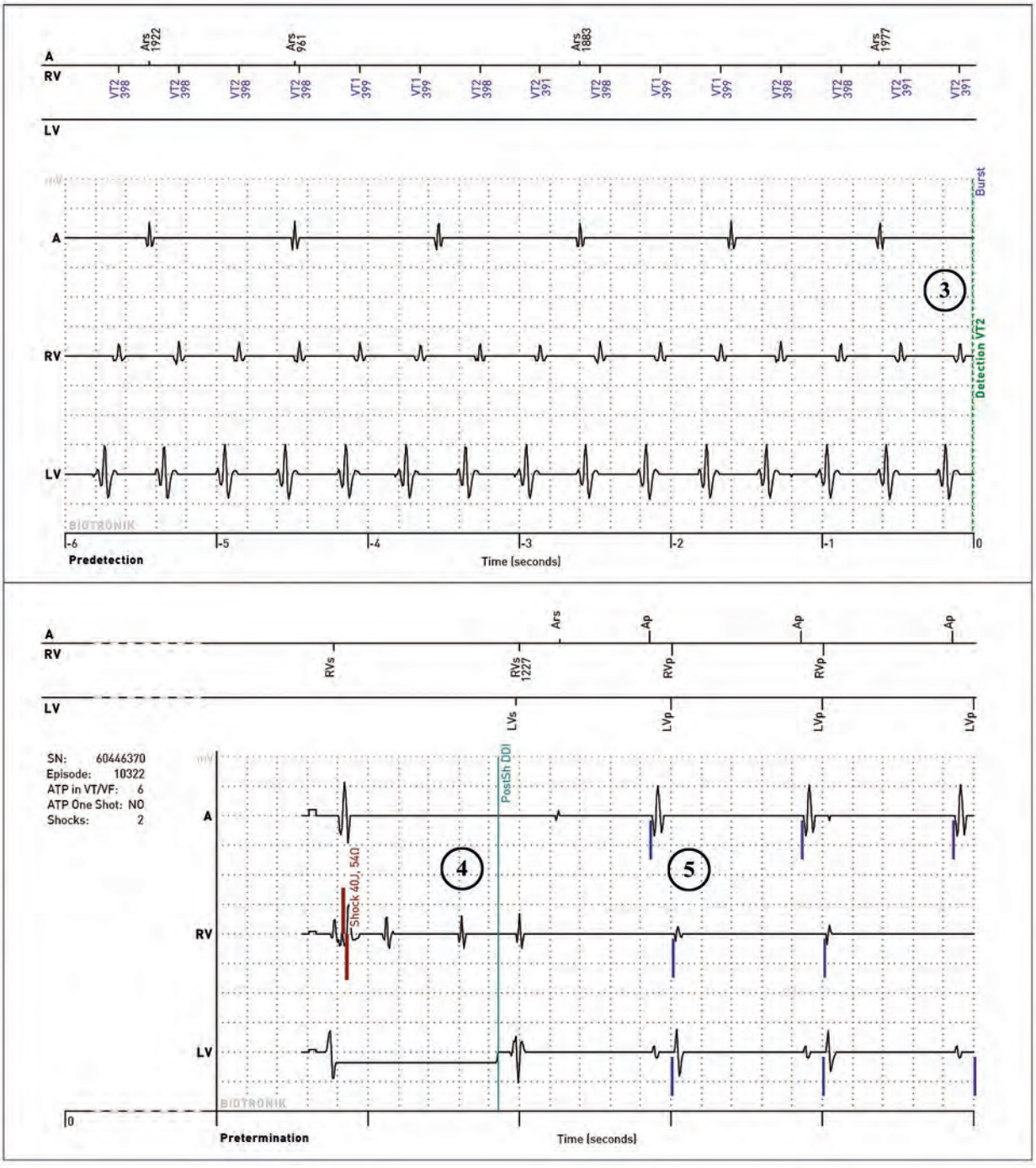
Patient ID:	Phone: -	CRT-D implanted Jul 23, 2009	Last clinic follow-up: Sep 27, 2010



Status report - Oct 2, 2010

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BIOTRONIK excellence for life

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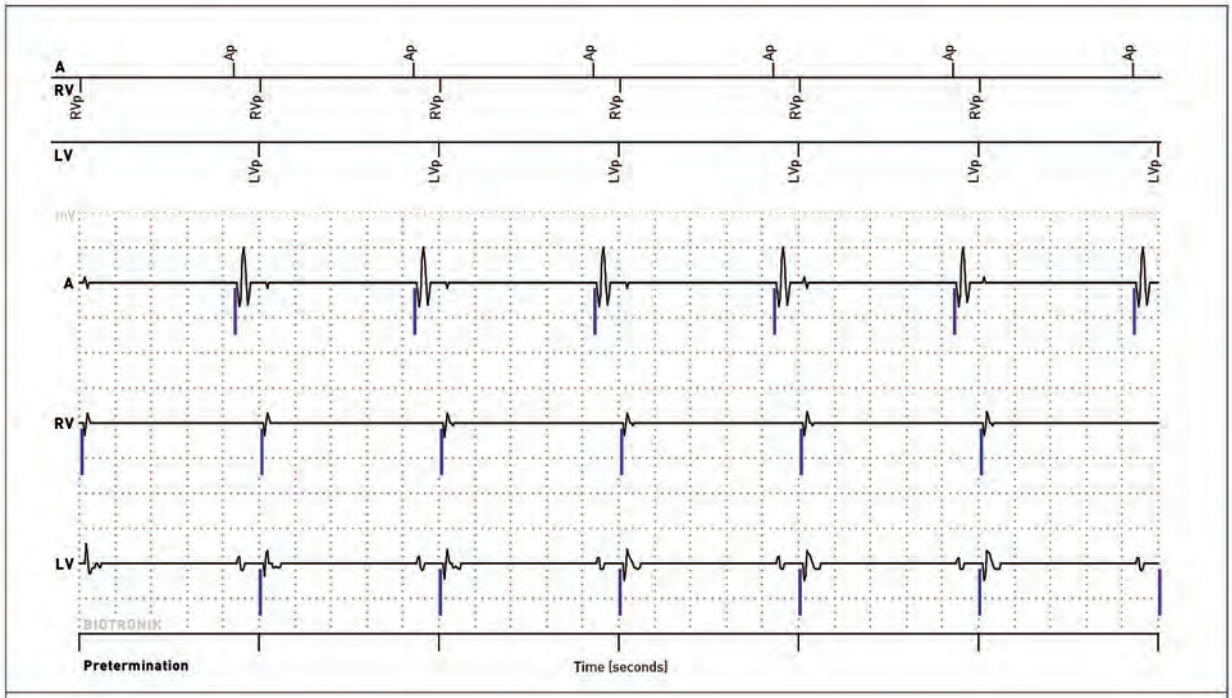
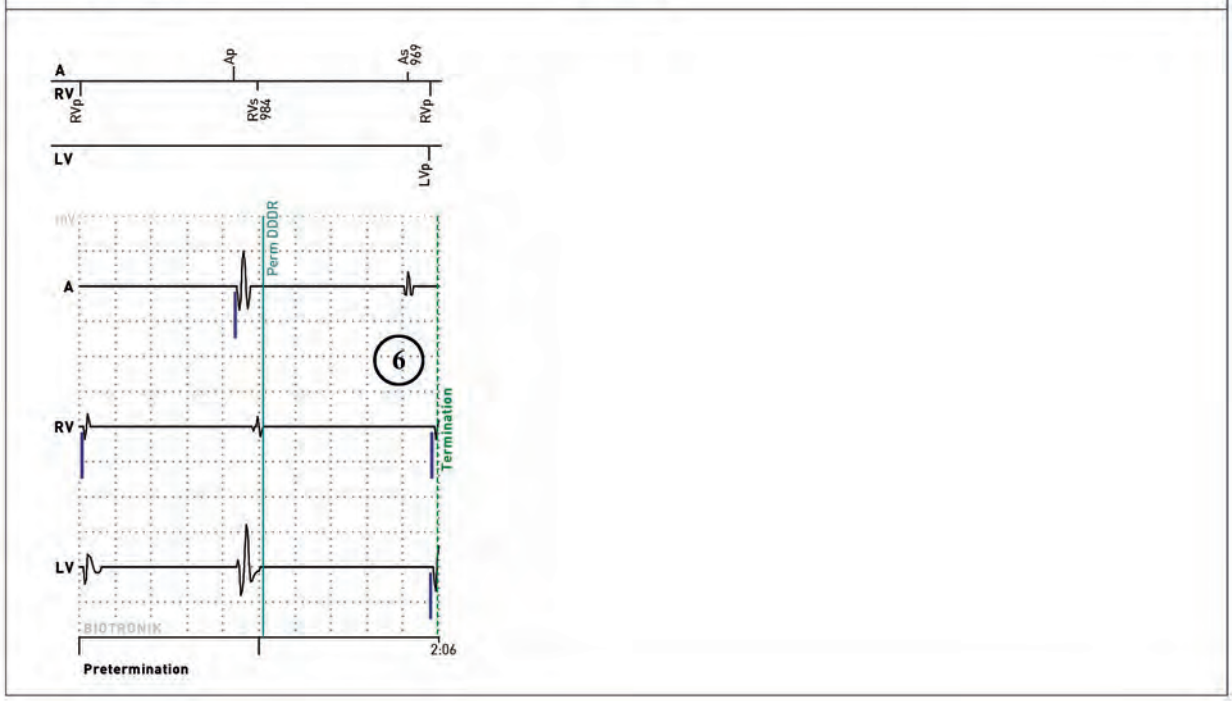
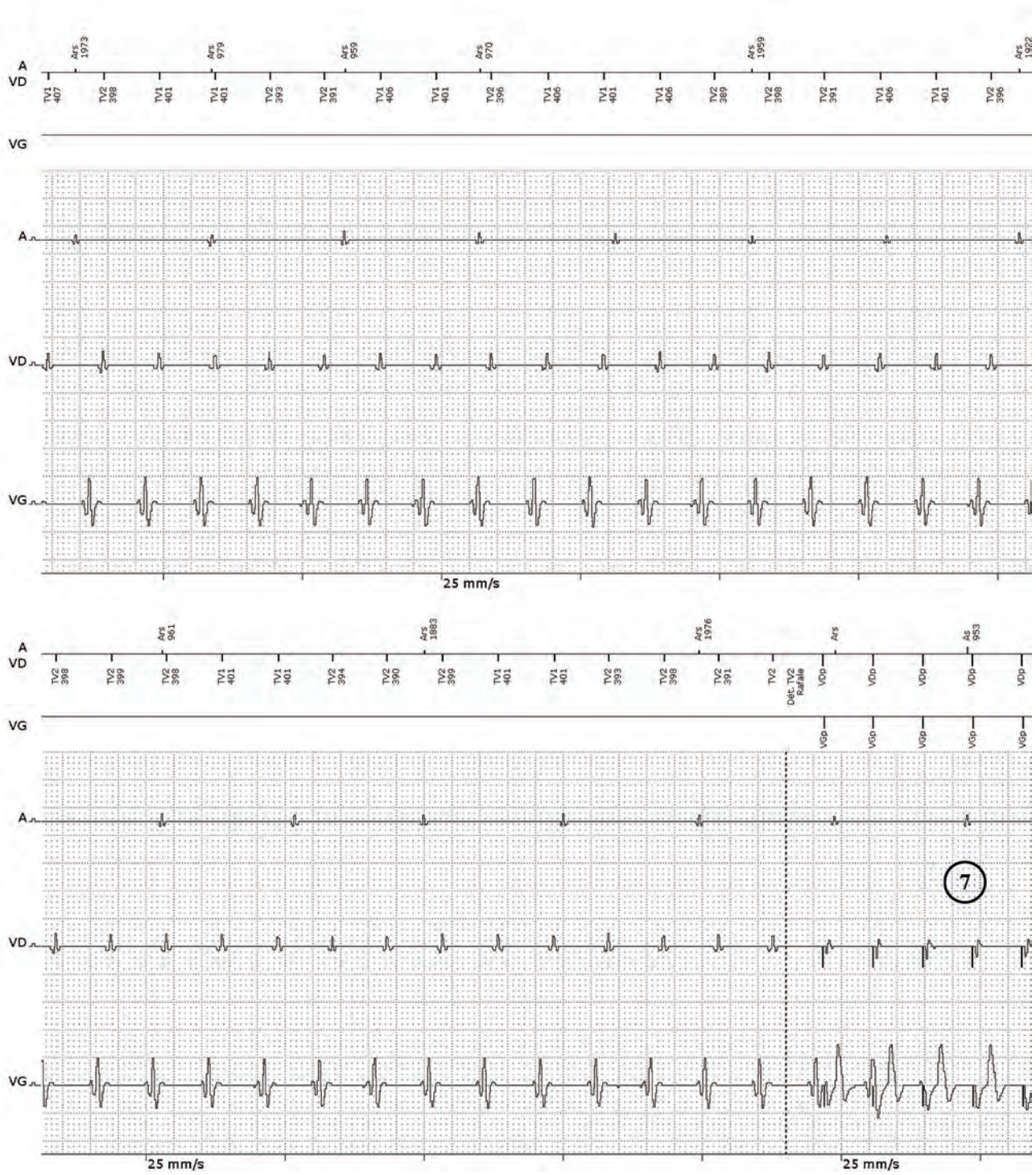
Patient ID:	Phone: -	CRT-D implanted Jul 23, 2009	Last clinic follow-up: Sep 27, 2010





PDF: BIOTRONIK - Lumax 340 HF-T



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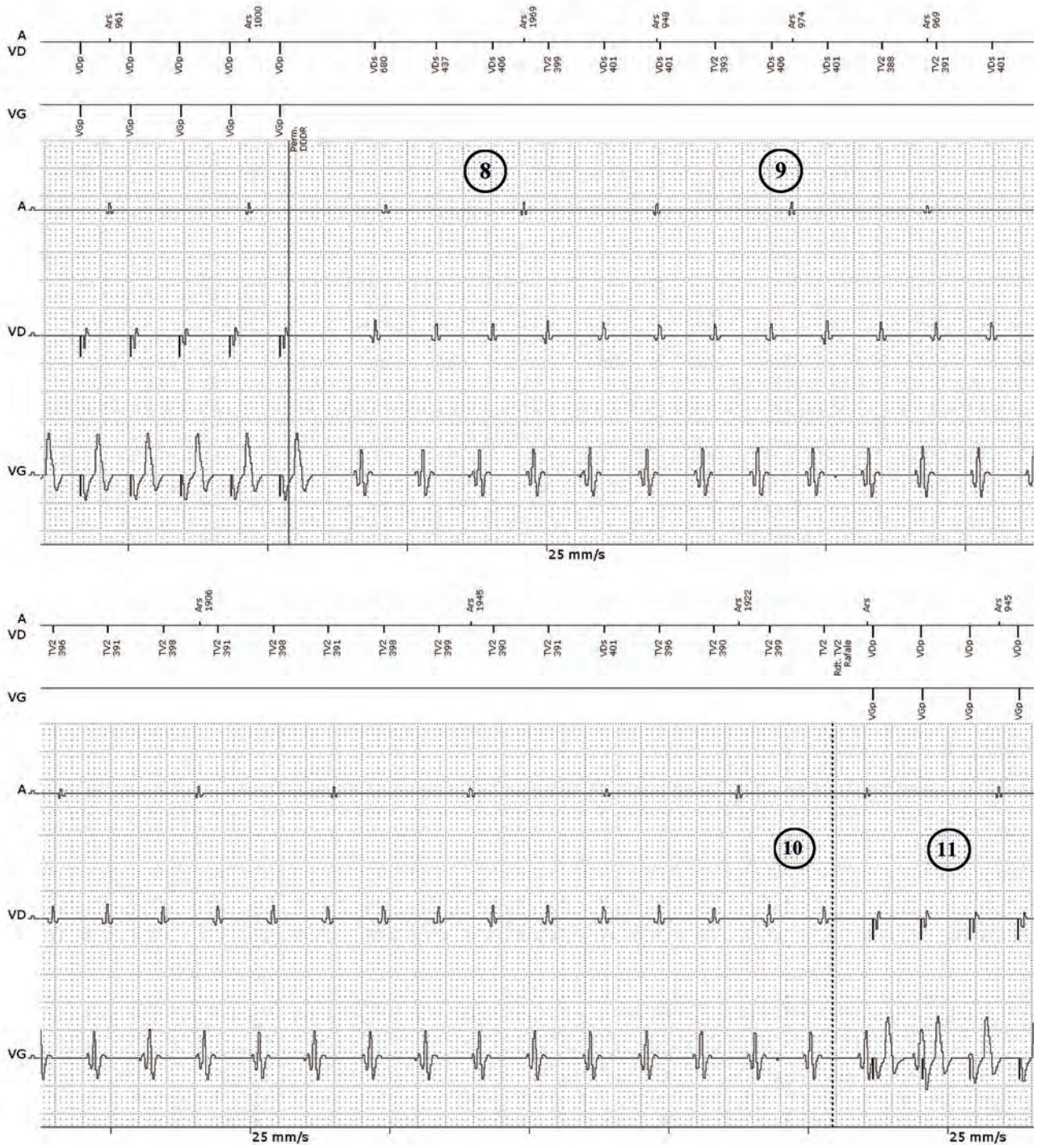

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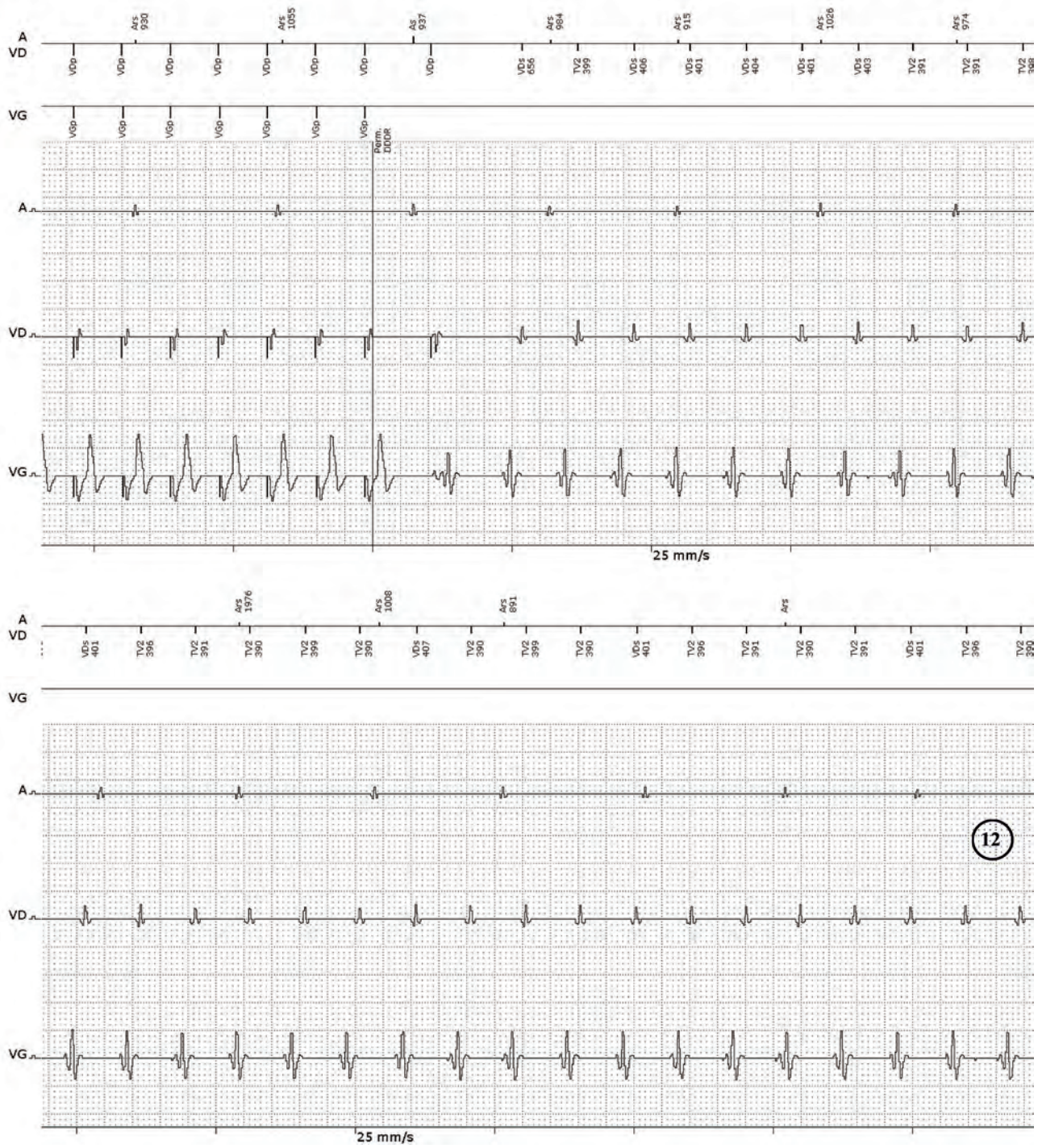

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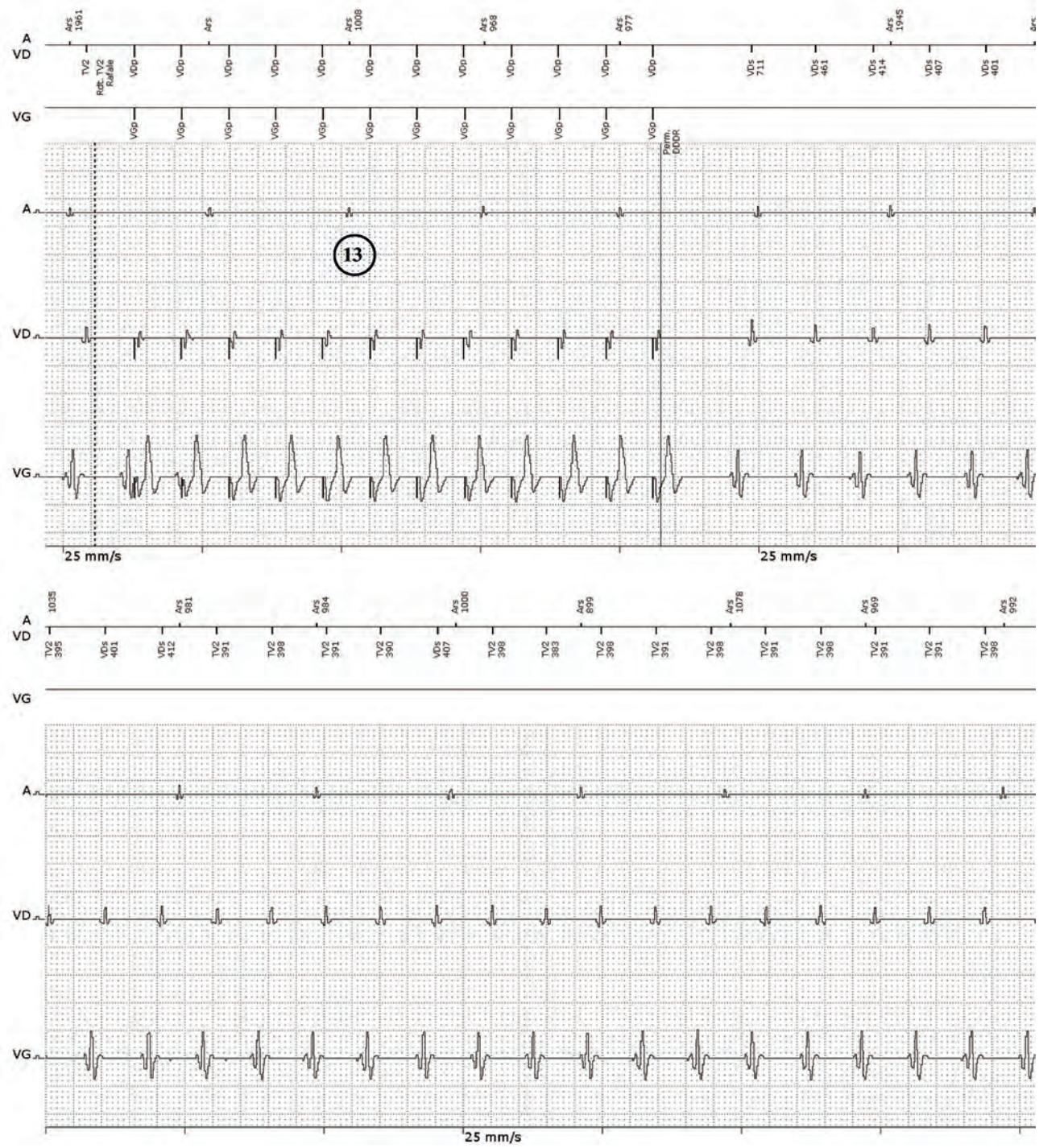

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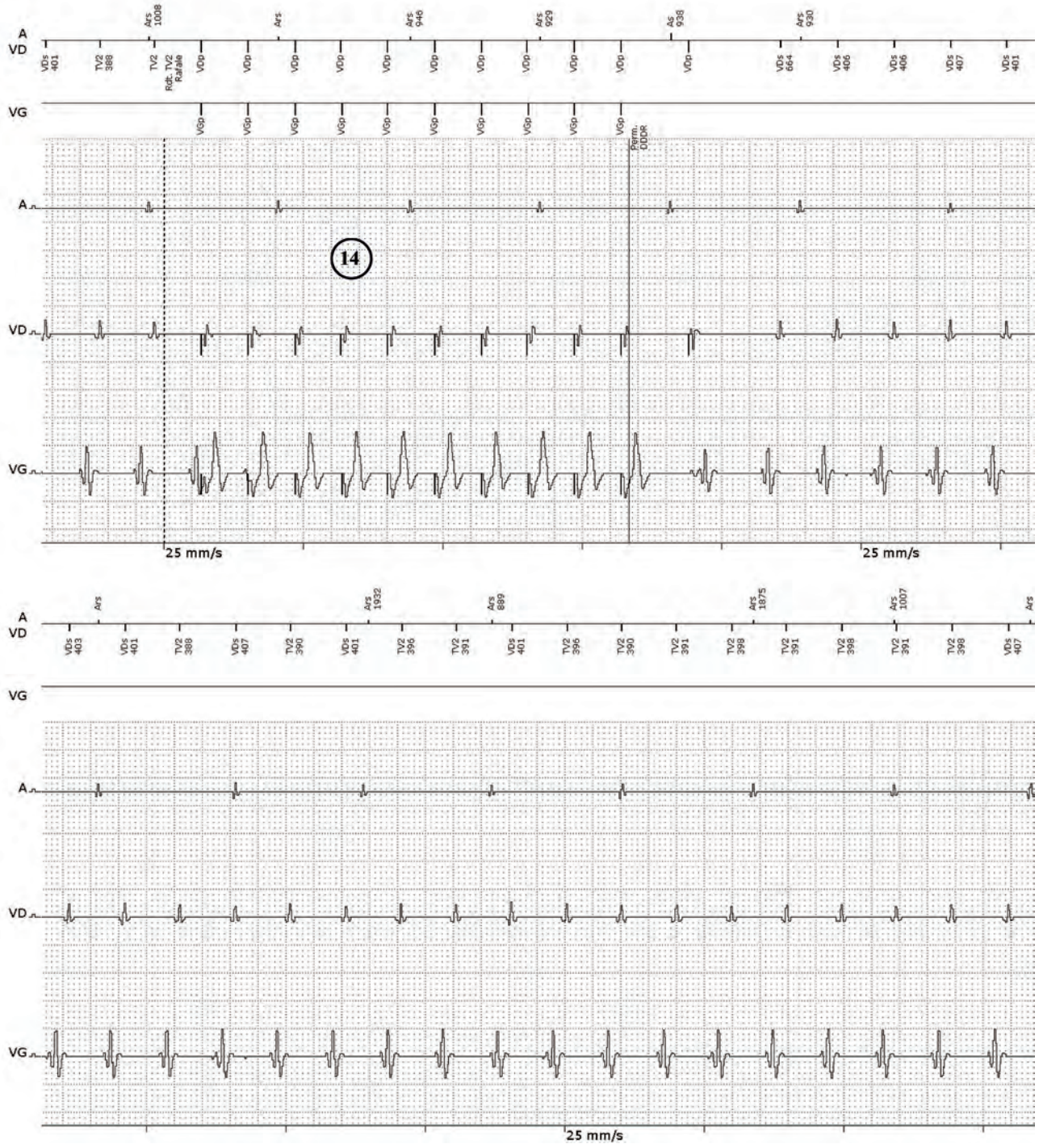

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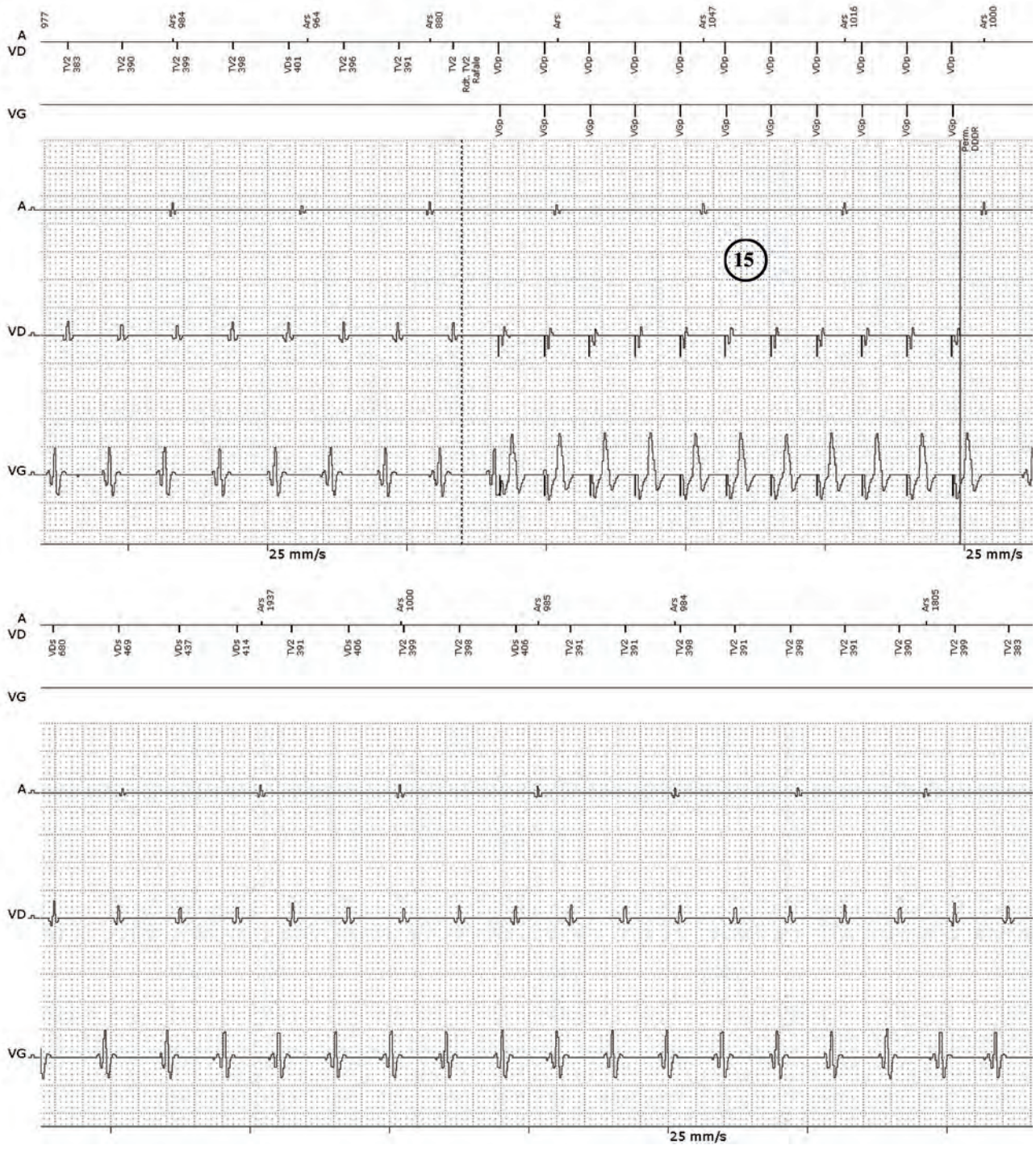

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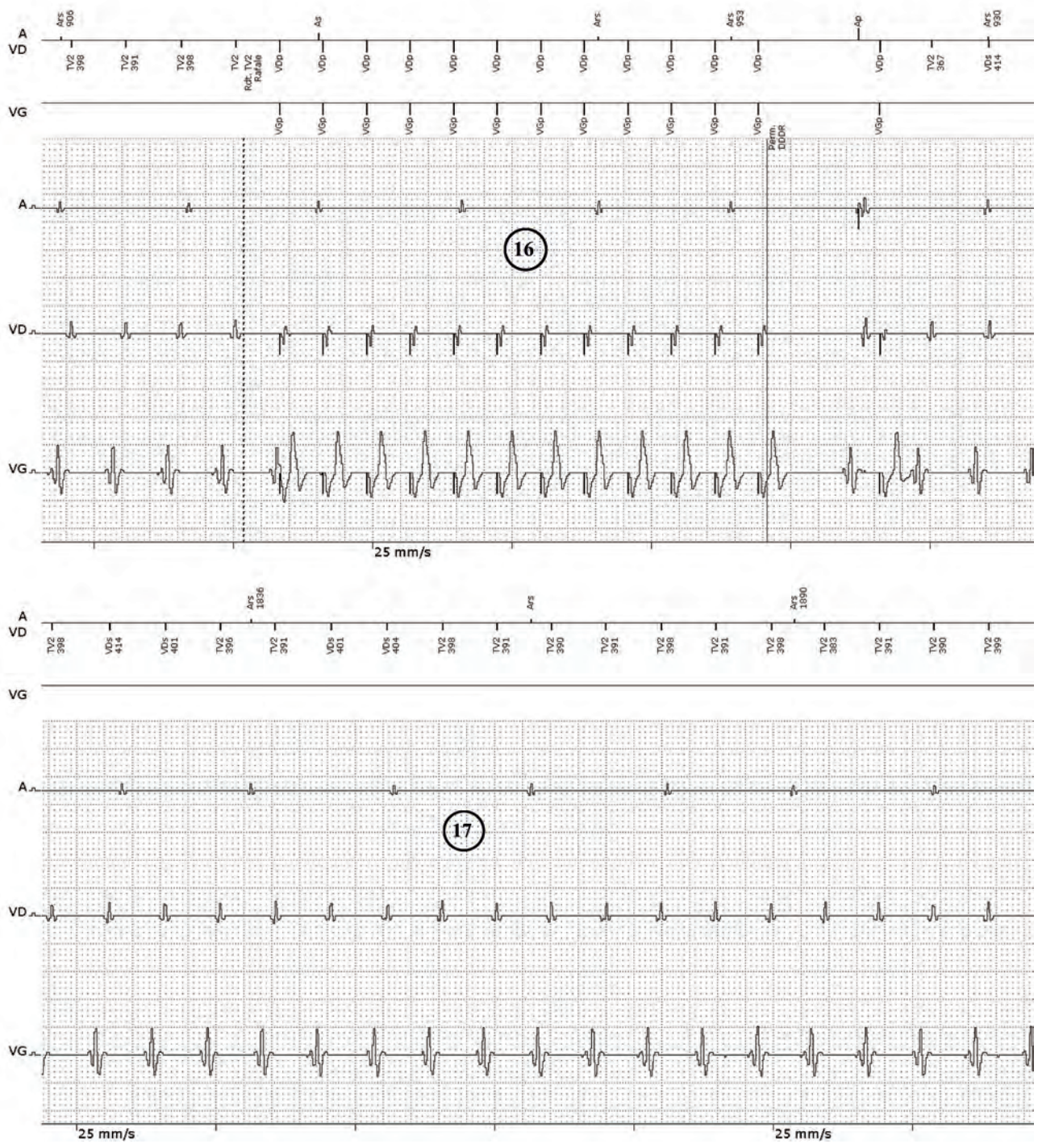

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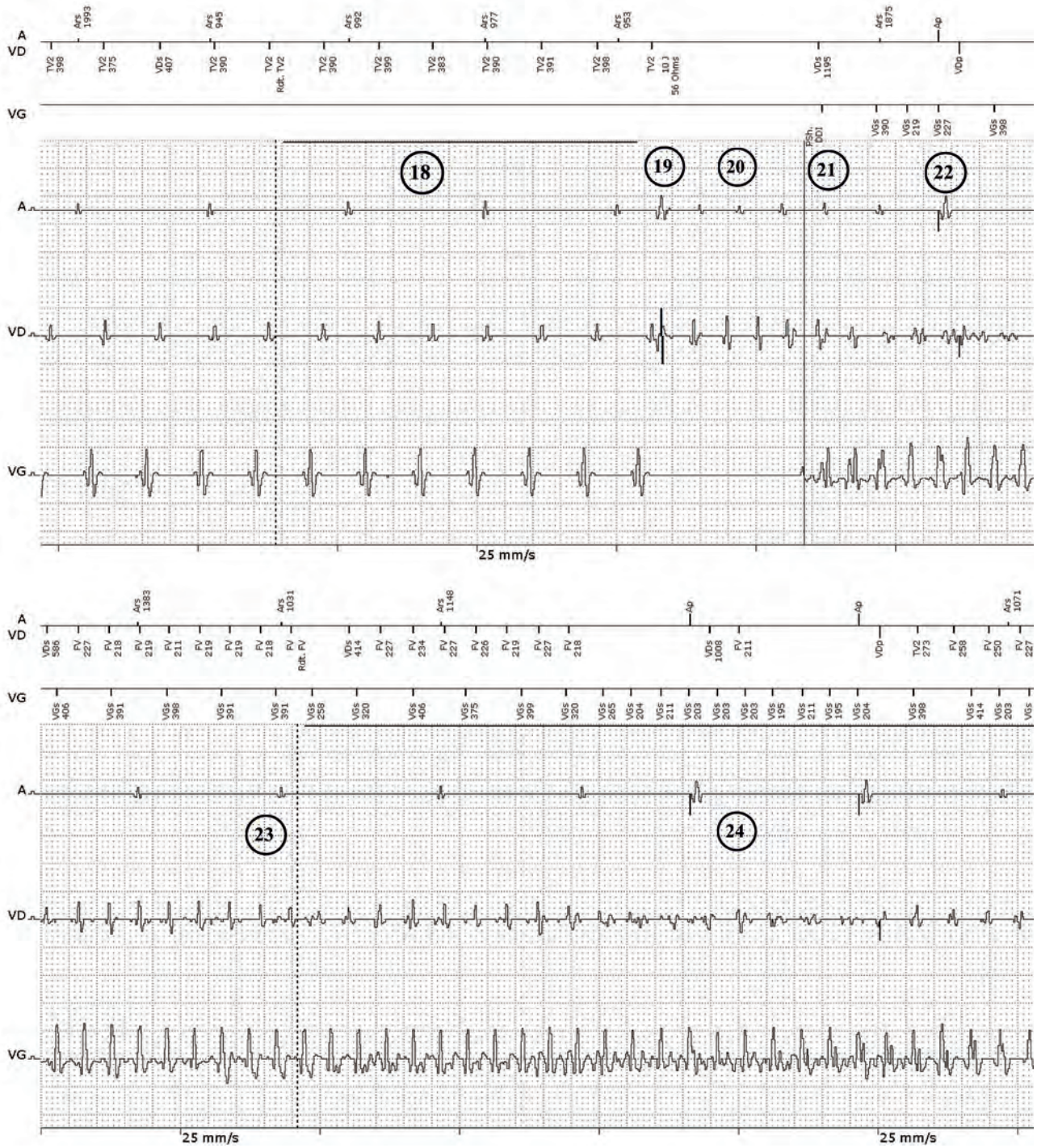

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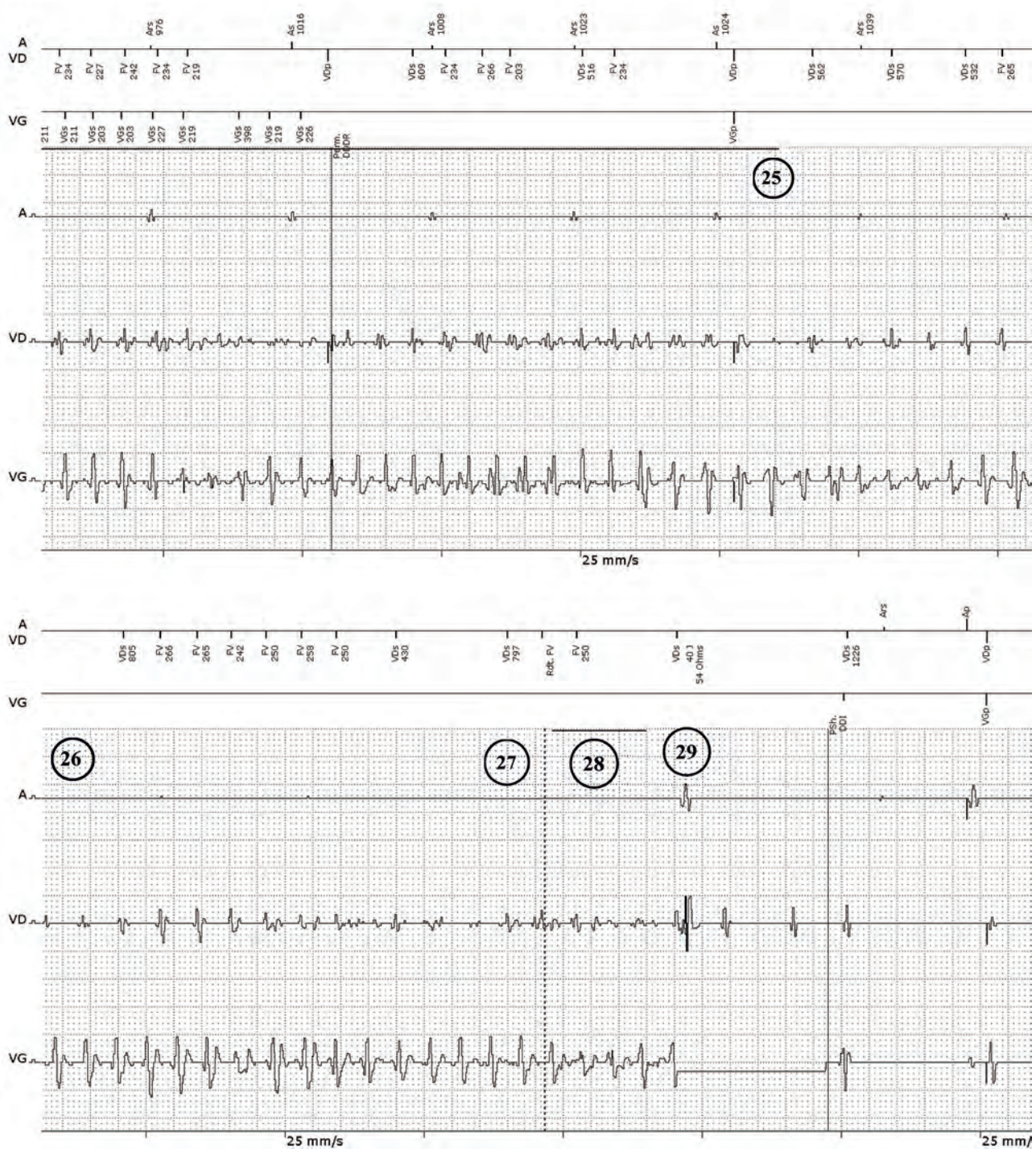
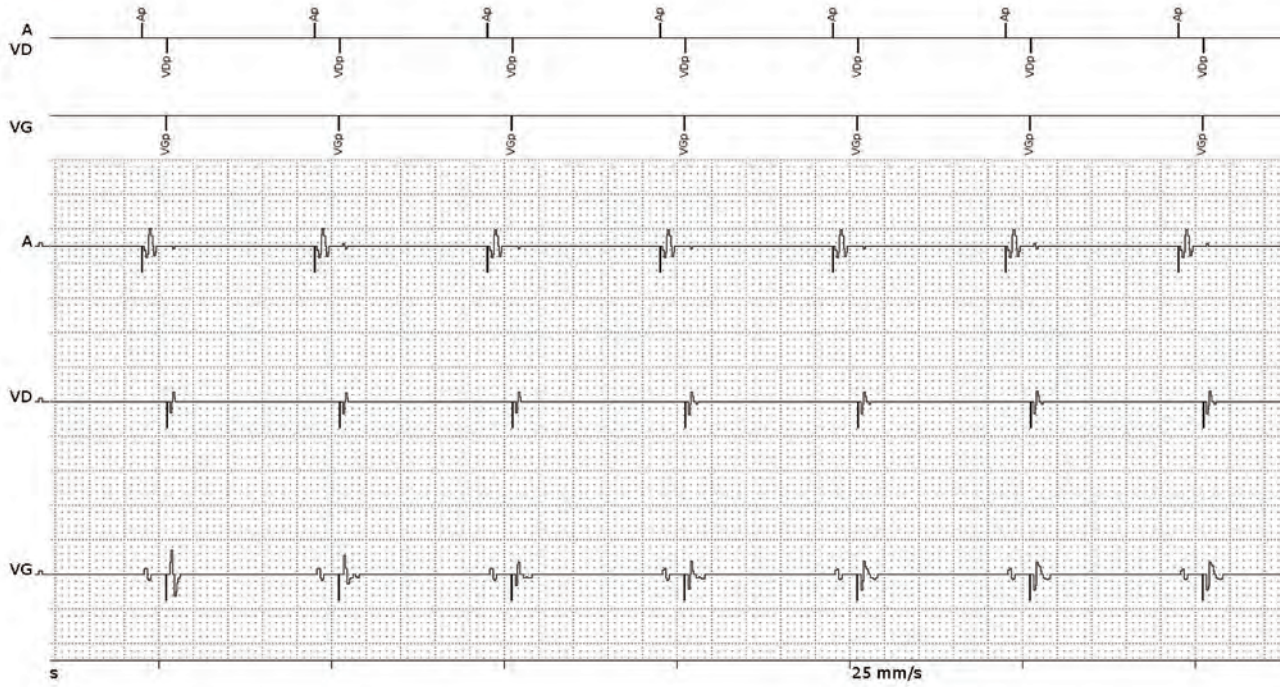
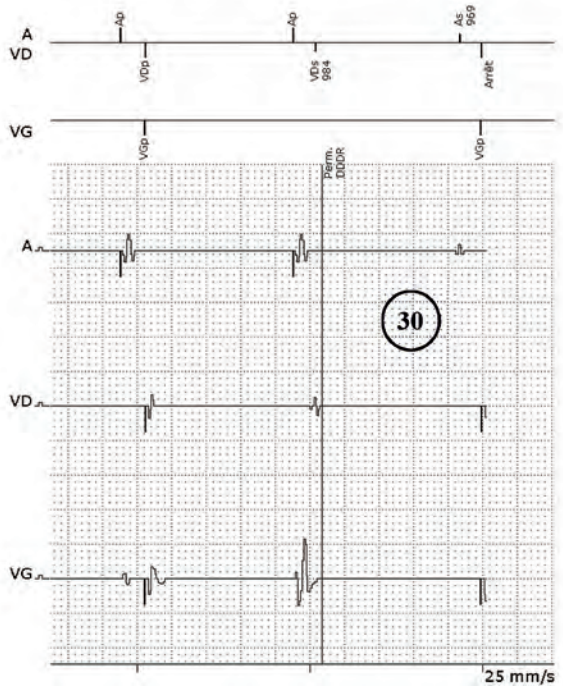


PDF: BIOTRONIK - Lumax 340 HF-T





Status report

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Lumax 540 VR-T

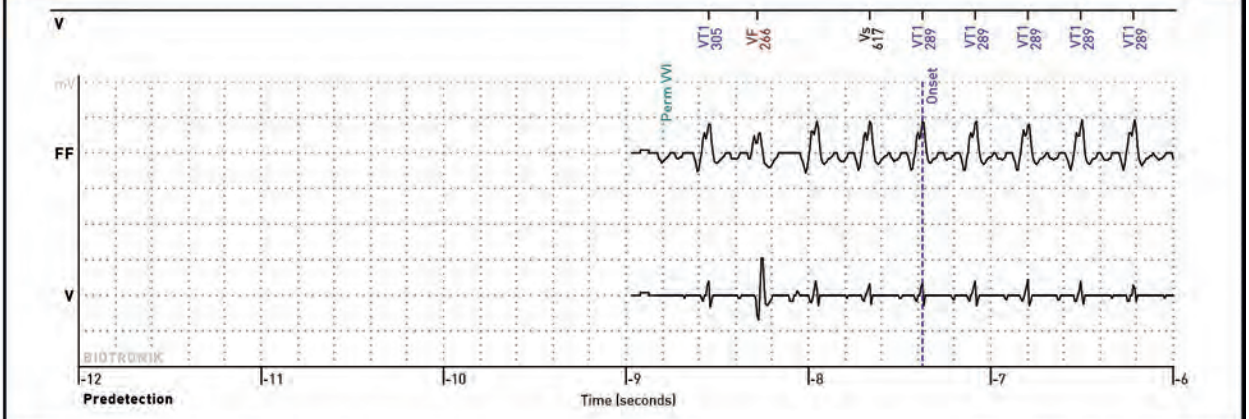
Recordings

Recordings - Episode 16:

General	
Episode number	16
Episode type	VT1
Detection	Jul 15, 2015 12:26:10 PM
Termination	Jul 15, 2015 12:27:25 PM
Duration	1min 15s
Device settings no.	18
Detection	
Mean RR at initial detection [ms]	295
Onset [%]	22, fulfilled
Stability [ms]	11
Redetection	VT1: 6

Therapy	
ATP in VT/VF delivered	6
ATP One Shot delivered	NO
Shocks delivered	1
Shocks aborted	0
Maximum energy [J]	40
Termination	
Mean RR at termination [ms]	761
Remark	
none	

IEGM



Status report

BIOTRONIK
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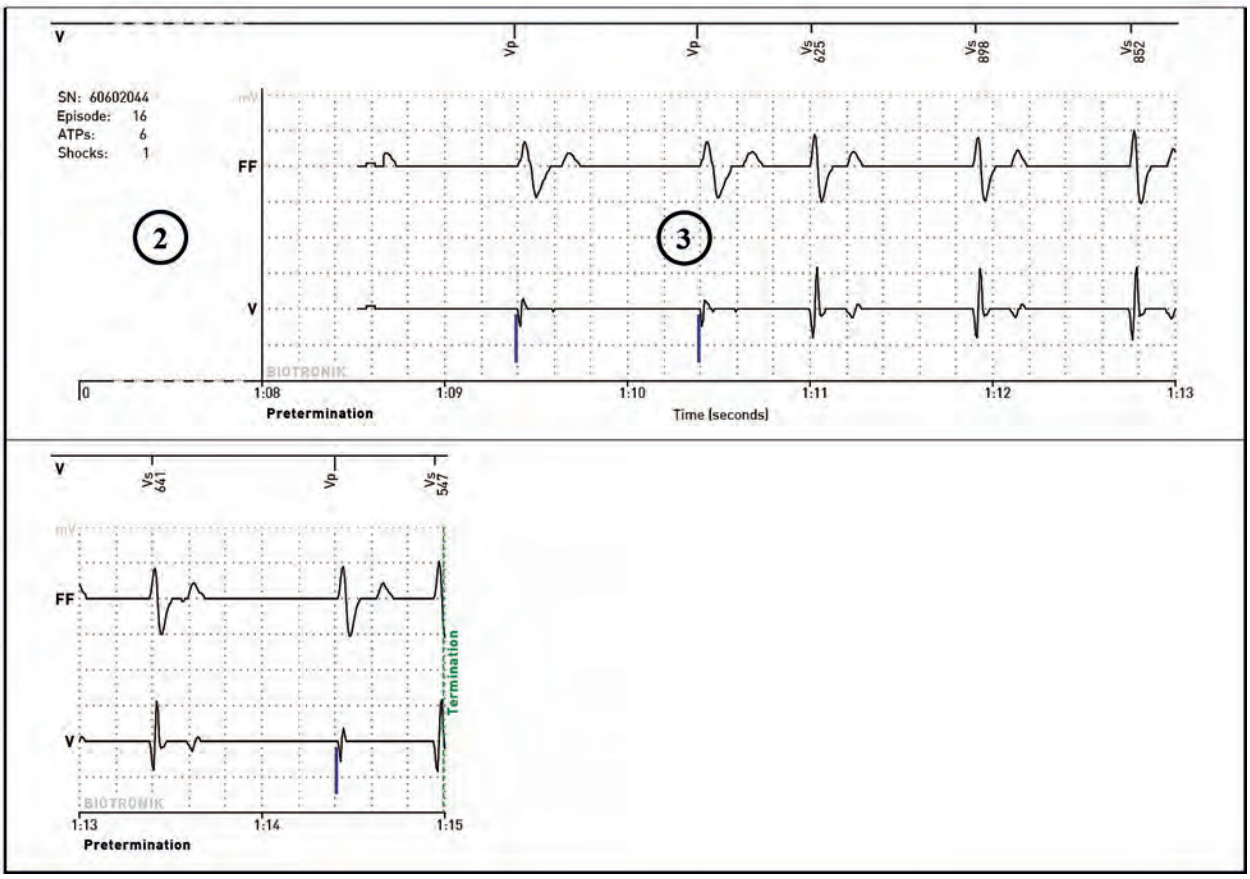
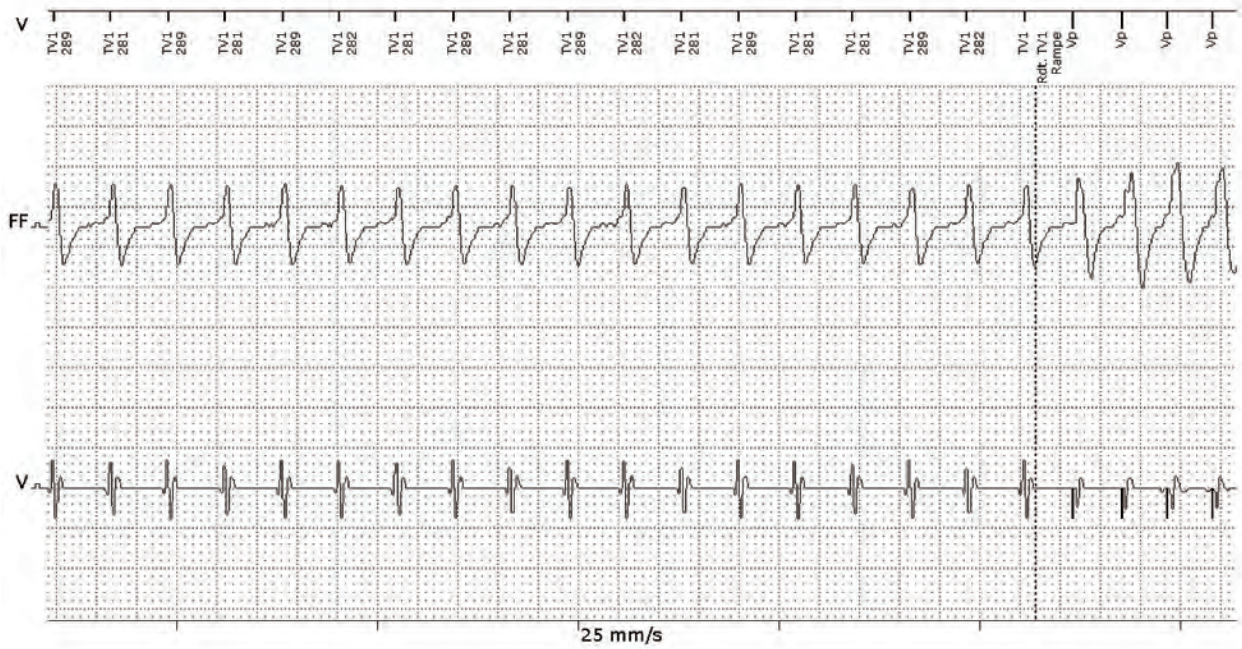
Lumax 540 VR-T

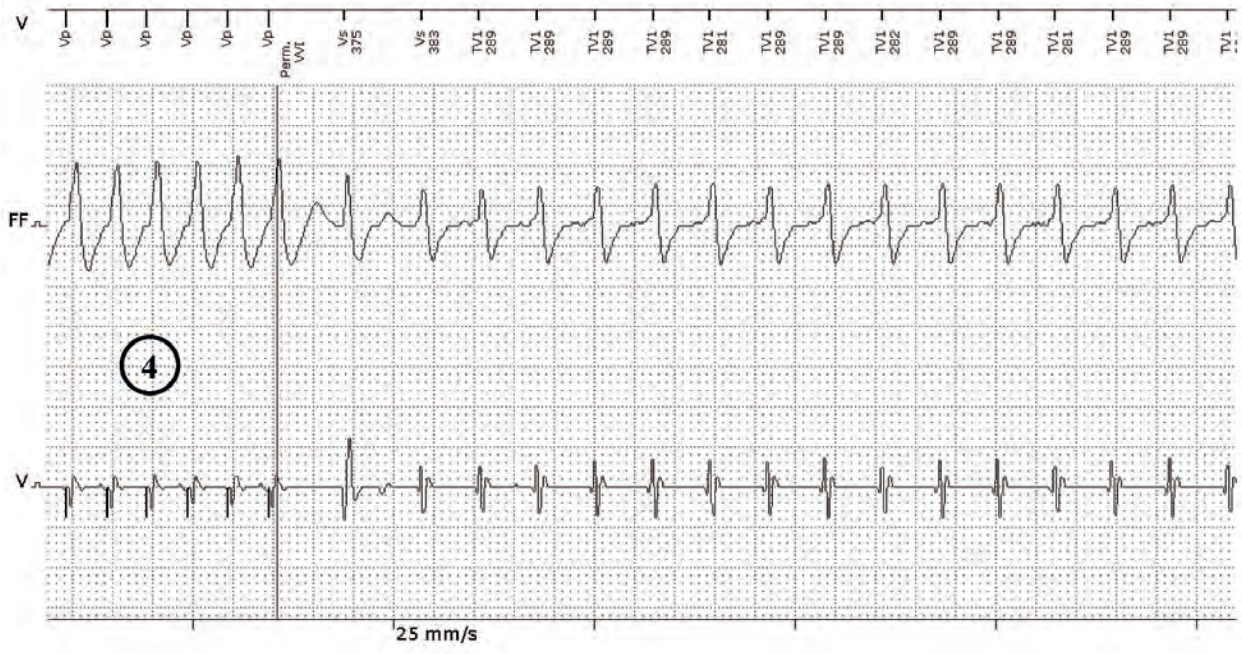


Prothèse Lumax 540 VR-T

N/S :

Enregistrements - EGM Episode : 16

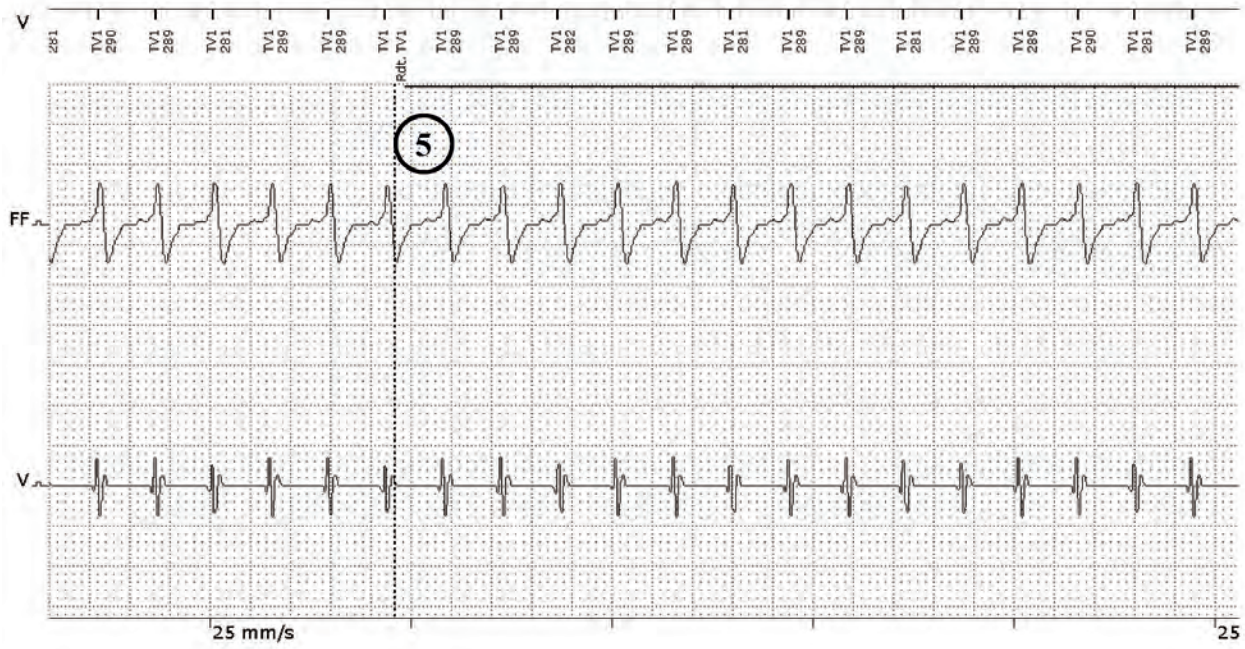


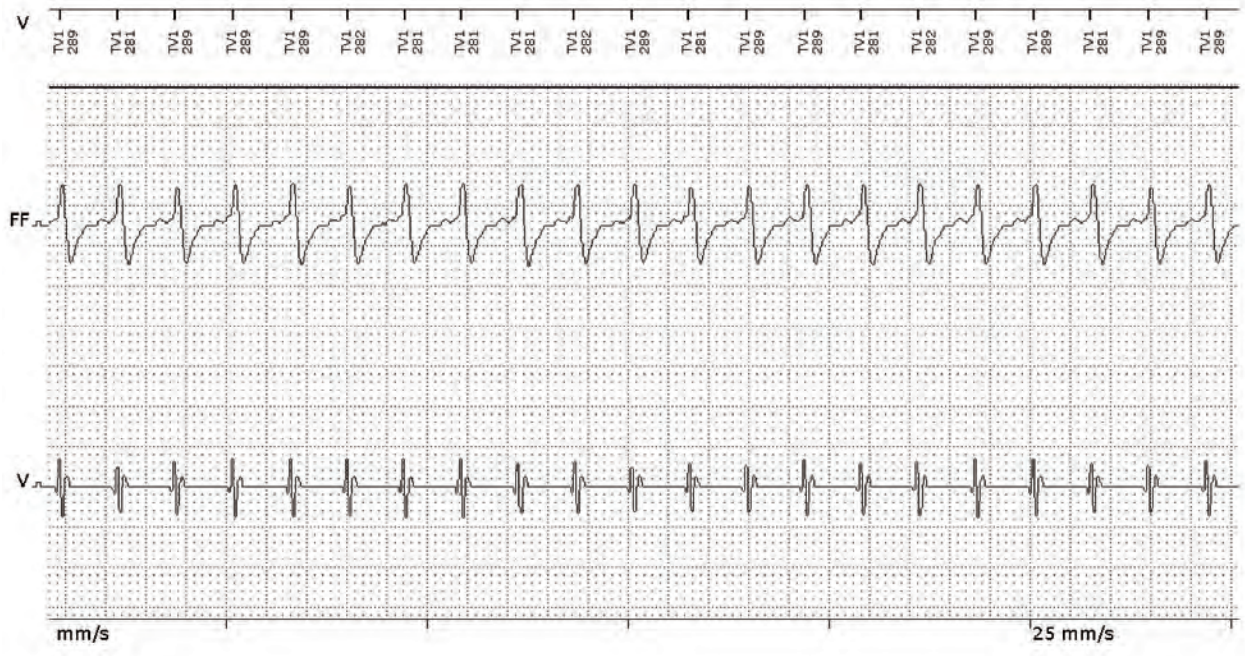


Prothèse Lumax 540 VR-T

N/S :

Enregistrements - EGM Episode : 16

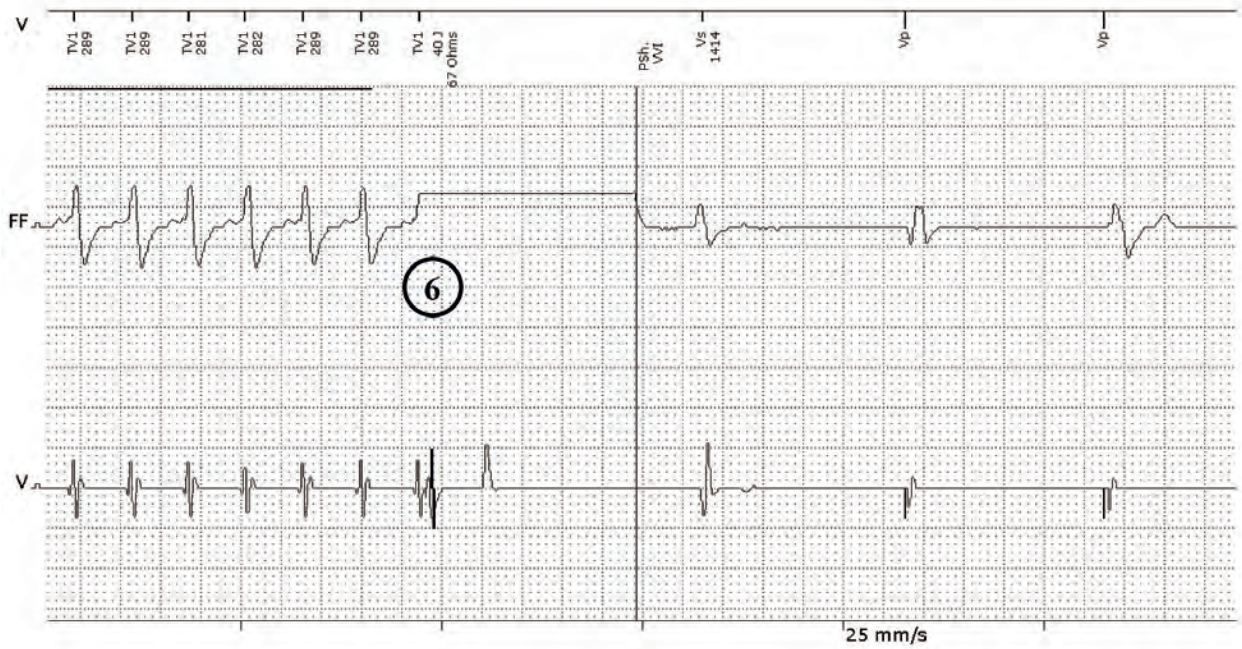


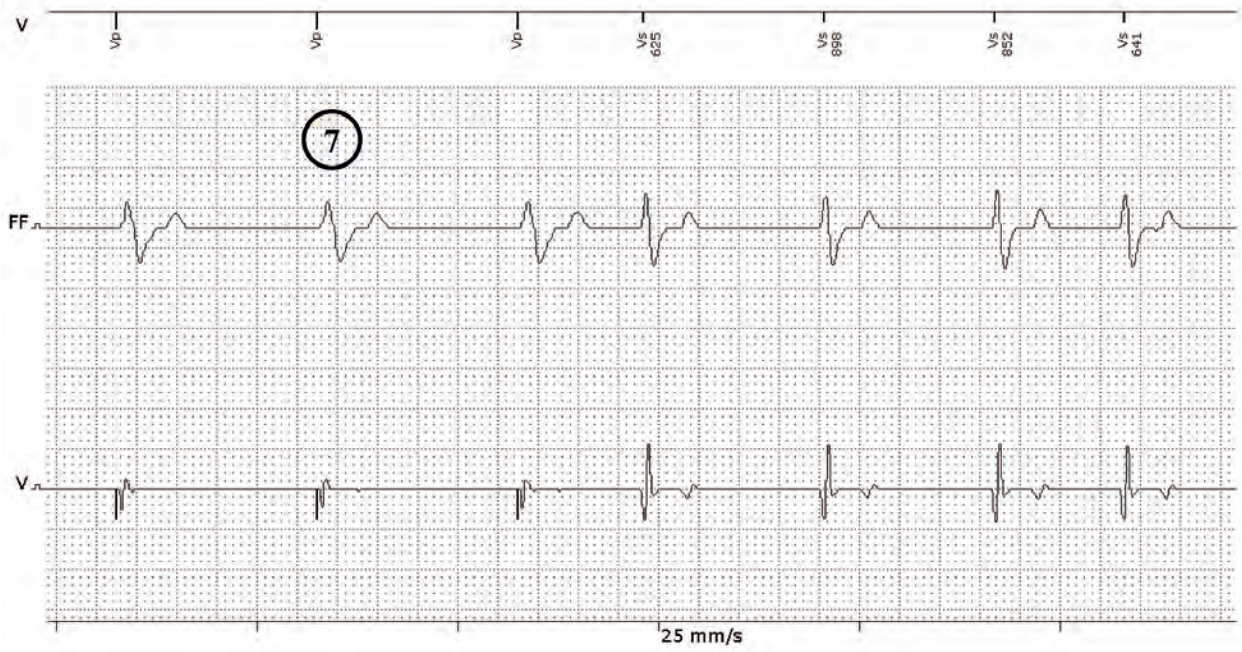


Prothèse Lumax 540 VR-T

N/S :

Enregistrements - EGM Episode : 16





Implatable Cardioverter Defibrillator - chapter 3

Oversensing

Tracing 12 ↘ Electrical shock due to T wave oversensing

Patient

53-year-old man implanted with a Lumax 340 VR-T single-chamber ICD for Brugada syndrome with syncope; electric shock received during an exertion; event report (yellow color) in the setting of a classified VF.

Telecardiology tracing

3 channels are available; the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the right ventricular sensing channel (RV).

① spontaneous rhythm; the « PermVVI » display at the beginning of the tracing reflects the fact that the ICD is operating in the programmed permanent pacing (VVI) mode;

② oversensing of the T wave on spontaneous ventricular activity;

③ oversensing of the T wave on spontaneous ventricular activity;

④ intermittent oversensing of the T wave with alternating intervals classified as VS and VF;

⑤ classification of the VF episode after 8 out of 11 intervals classified in VF zone (VF counter full, programmed to 8/12);

⑥ no therapy delivered;

⑦ persistence of intermittent oversensing;

Programmer tracing (different episode)

The 3 channels are the same as for the telecardiology tracing

⑧ T wave oversensing;

⑨ sensing of a VF (VF counter full, 8 out of 10 intervals classified in the VF zone);

⑩ charging of the capacitors;

⑪ interruption of the charge following the occurrence of 3 successive intervals classified as Vs;

⑫ at the end of the charge, competition between the VF redetection counter (8 out of 12 intervals in VF) and the end-of-episode counter (12 out of 16 intervals classified as Vs or VP);

⑬ VF redetection counter full; new capacitor charge;

⑭ short charge time since the capacitors are already partially charged;

⑮ end of charge;

⑯ electric shock (40 joules, 68 Ohms) synchronized on the first interval classified as VF at the end of the charge.

Comments

This patient presented several episodes of T wave oversensing upon exertion with delivery of shock or interruption of the charge. T wave oversensing currently remains a significant problem in the management of ICD-implanted patients since it can be accompanied by the occurrence of inappropriate therapies particularly during exertion (when RT and TR intervals correspond to the VF zone due to sinus tachycardia). T wave oversensing is associated with a typical alternating pattern between 2 morphologically different signals, namely a high frequency signal (R wave) and a low frequency signal (T wave). For each cardiac cycle, the device counts the R wave and the T wave as a second additional signal resulting in a doubling of the heart rate. The alternating interval duration (RT intervals and TR intervals) is usually pronounced

for slow rates (short RT intervals and long RT intervals) although often less during exertion (RT and RT intervals roughly equivalent) or for patients with long QT syndrome.

Any oversensing of the T wave should be considered as an emergency, with mandatory modification of the programming to avoid the occurrence of inappropriate therapies. An electrical shock or an antitachycardia pacing sequence delivered as a result of T wave oversensing may be accompanied by a proarrhythmogenic effect with the risk of inducing polymorphic ventricular arrhythmia. Indeed, the electric shock synchronizes either on the R wave or on the T wave, with a 50% probability that the shock is delivered on the T wave, hence during the vulnerable ventricular period. Patients with T wave oversensing and high defibrillation threshold are particularly at risk. If the defibrillation threshold is high and approaches the maximum capabilities of the device, the upper vulnerability value is also high. A shock delivered on the T wave therefore has a very high probability of inducing ventricular fibrillation (concept of upper limit of vulnerability) which will subsequently be very difficult to terminate even with a maximum defibrillation shock (high defibrillation threshold).

Status report - Oct 11, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

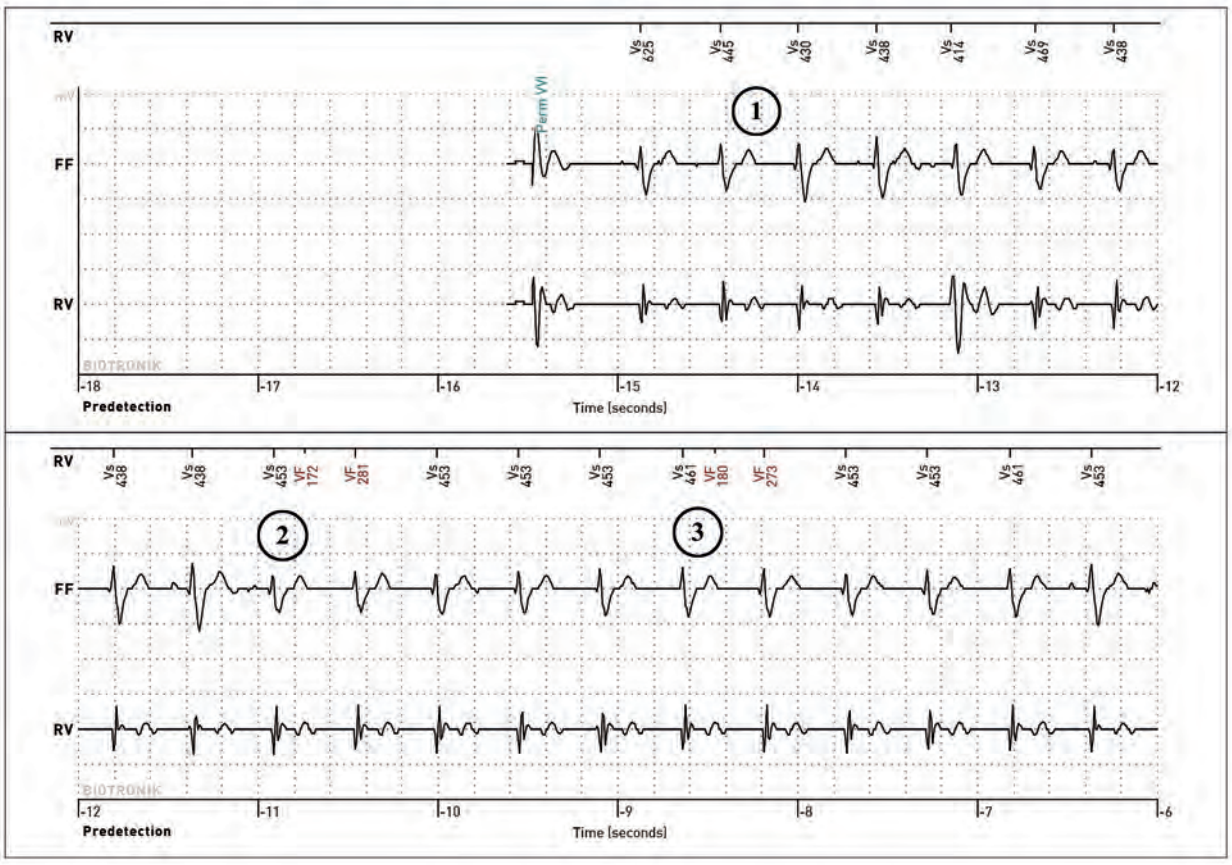
Name:	DOB:	Lumax 340 VR-T (XL) (SN 60466421)	Last message: Oct 11, 2013
Patient ID:	Phone: -	ICD implanted May 17, 2010	Last clinic follow-up: Oct 29, 2012

Recordings

Recordings - Episode 15:

General	
Episode number	15
Episode type	VF
Detection	Jul 26, 2012 3:36:15 PM
Termination	Jul 26, 2012 3:36:33 PM
Duration	18s
Device settings no.	7
Detection	
Mean RR at initial detection [ms]	225
Onset [%]	59
Stability [ms]	105
Redetection	---

Therapy	
ATP in VT/VF delivered	0
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	1
Maximum energy [J]	40
Termination	
Mean RR at termination [ms]	366
Remark	
none	



Status report - Oct 11, 2013

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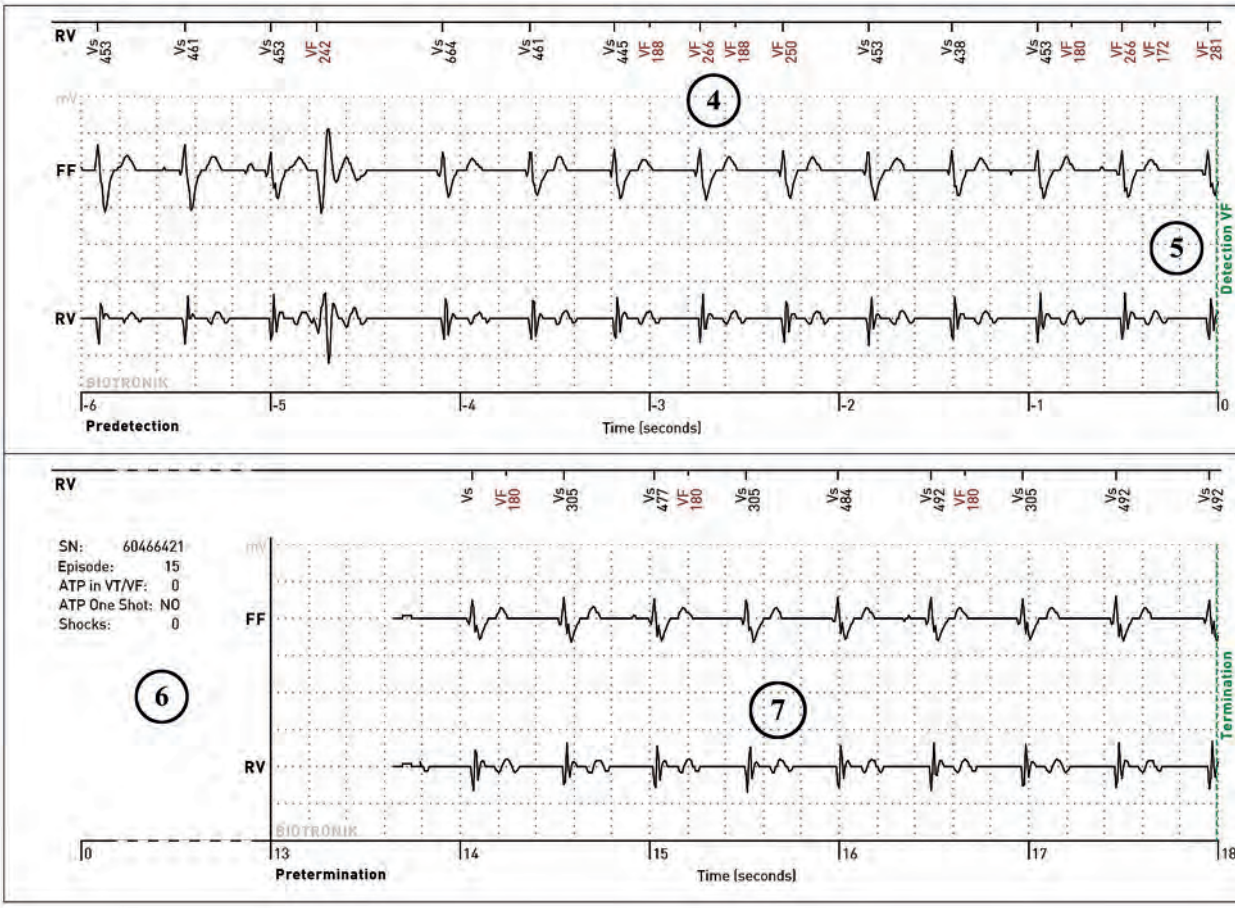
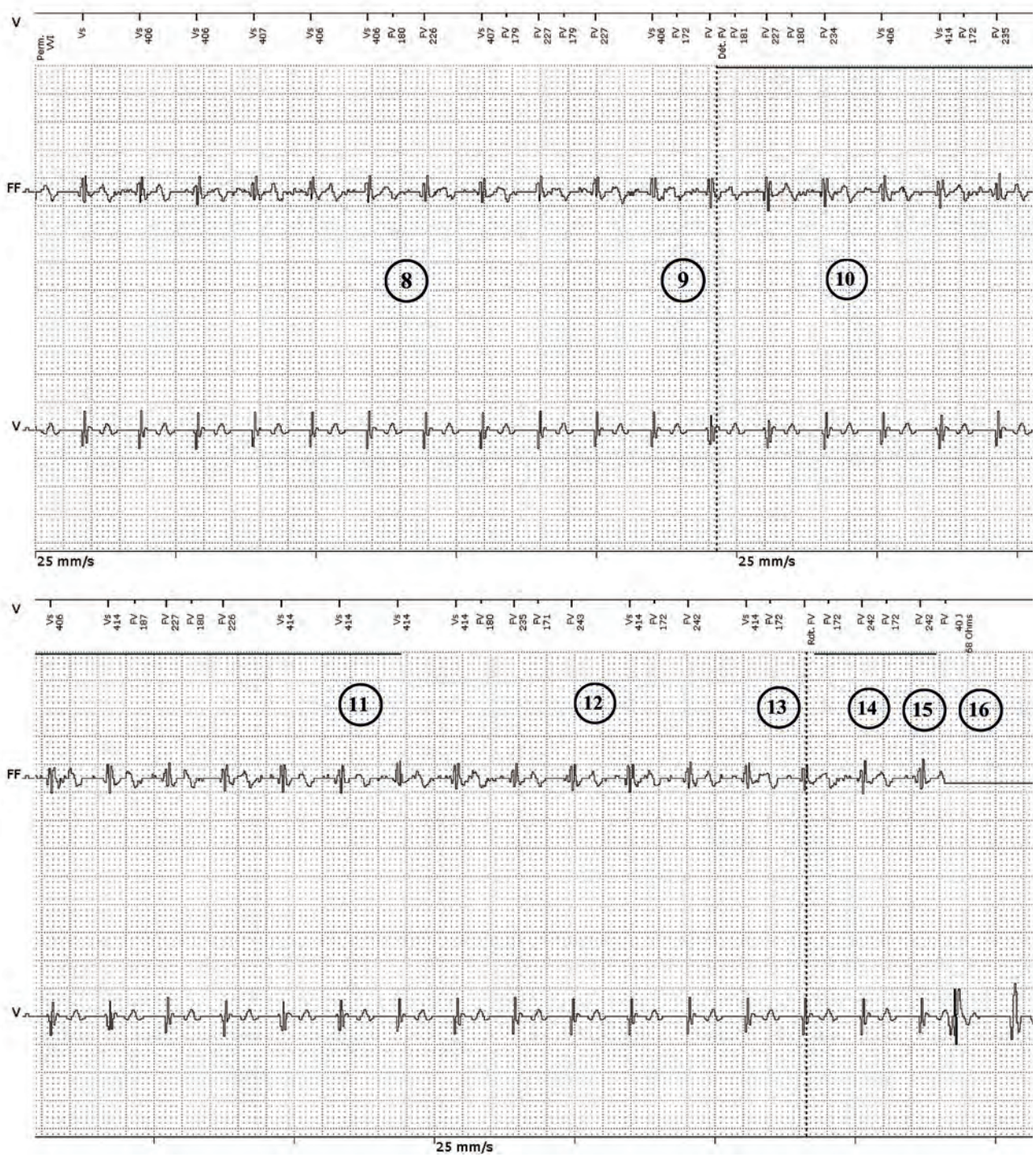
BIOTRONIK excellence for life

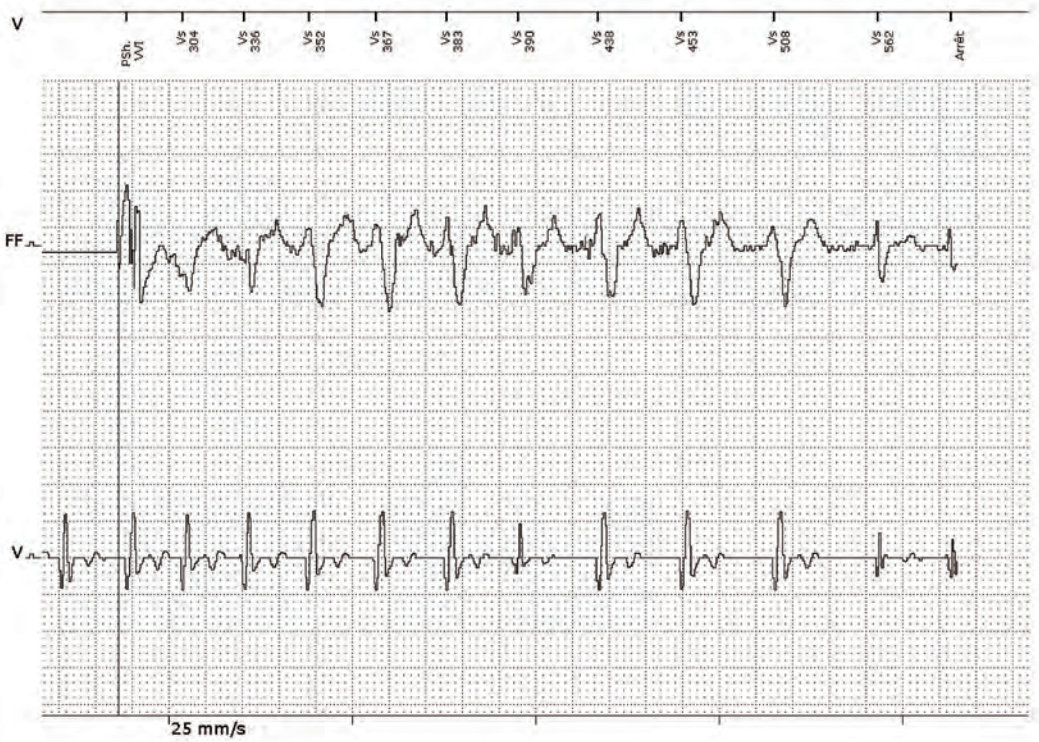
Name:	DOB:	Lumax 340 VR-T (XL) (SN 60466421)	Last message: Oct 11, 2013
Patient ID:	Phone: -	ICD implanted May 17, 2010	Last clinic follow-up: Oct 29, 2



Oversensing

PDF: BIOTRONIK - Lumax 340 VR-T XL




V
PSh.
VVI
Vs
304
Vs
336
Vs
352
Vs
367
Vs
383
Vs
390
Vs
438
Vs
453
Vs
508
Vs
562
Arrêt
FF
V
25 mm/s

Tracing 13 ↘ T wave oversensing and inappropriate therapy

Patient

A 37-year-old man implanted with a Lumax 740 VR-T single-chamber ICD for Brugada syndrome with a history of resuscitated sudden death; event report in the setting of a classified VF.

Telecardiology tracing

4 channels are available; the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the atrial sensing channel (AA), the right ventricular sensing channel (RV).

① sinus tachycardia;

② T wave oversensing corresponding to a substantial decrease in the amplitude of the previous R wave; the amplitude of the T wave does not appear to be modified;

③ the VF counter is full (programmed to 18/24); delivery of a one-shot ATP burst;

④ end of the episode;

Programmer tracing (same episode)

The 4 channels are the same as for the telecardiology tracing.

⑤ wave oversensing following a small-amplitude R wave;

⑥ the VF counter is full; one-shot ATP followed by start of the capacitor charge;

⑦ charge interruption after 3 consecutive Vs intervals (ventricular undersensing).

Comments

Three different electrophysiological conditions can lead to T wave oversensing due to spontaneous ventricular activity: 1) delayed T wave: this is a typical pattern in patients with long QT syndrome in whom repolarization is delayed; the T wave occurs when the ventricular sensitivity is at its maximum level. In this type of channelopathy, there is also a risk of dynamic changes in the duration of the QT interval induced by catecholamines, as well as of the morphology and amplitude of the T wave thereby increasing the risk of inappropriate therapies during exertion; 2) large amplitude T wave and normal R wave: this pattern is preferentially observed in patients with hypertrophic cardiomyopathy, short QT syndrome, certain forms of long QT syndrome, certain metabolic abnormalities (hyperkalemia, hyperglycemia) as well as certain reversible causes of repolarization abnormalities (acute alcoholism; 3) small R wave amplitude which was the case in this patient: when the R wave is of low amplitude, the probability of T wave oversensing increases (adjustment of the sensitivity level as a function of the amplitude of the preceding signal). As a result, the device rapidly reaches high sensitivity levels which favor T wave oversensing particularly during exertion (possible decrease in the R wave amplitude and slight increase in T wave amplitude). A sudden and rapid decrease in R wave amplitude after implantation may be a manifestation of lead micro-dislodgement. A small amplitude R wave can also be observed in patients with right ventricular arrhythmogenic dysplasia, Brugada syndrome, cardiac sarcoidosis or dilated cardiomyopathy altering the right ventricle. This limits the possibility of correcting this oversensing by reducing ventricular sensitivity which could lead to an undersensing of a VF. These situations are therefore difficult and often only lead to programming compromises. It is possible to modify various settings separately (these settings can be accessed by a code known to Biotronik™ employees) or to program an enhanced suppression of the T wave. Two parameters are thus modified relative to standard programming: the upper threshold is increased to 75% of the R wave amplitude (versus 50% with standard programming) and the high-pass filter is increased to 32 Hz to filter the T wave (« softer » or lower-frequency signal than an R wave). This option is hardly feasible in this patient given the risk of undersensing.

This type of tracing has nowadays become exceptionally scarce. Indeed, starting with the Lumax 740 platform, various modifications have been made to the Biotronik™ devices, considerably reducing the incidence of T wave oversensing. Compared to the Lumax 540 platform and prior models, different elements of the ventricular sensing process have been modified: 1) the analog-to-digital converter has been modified with integration of a 10-bit parallel converter allowing better adjustment to rapid signals and better signal amplitude resolution; this new converter also reduces energy consumption and potentially prolongs the life of the device; 2) the filters have also been modified, the low-pass filter is no longer programmable and the high-pass 2 filter no longer exists; 3) for the old platforms, the incoming signal was systematically rectified (a negative signal resulted in a signal of the same amplitude but with a positive deflection), which is no longer the case starting with the Lumax 740 platform. When a signal reaches the sensing threshold, the device opens a 110 ms sensing window; during this interval, the device searches for the largest absolute value (positive or negative) of the signal amplitude which then corresponds to the value of the measured R wave; this value has consequently been prolonged from 80 to 110 ms to allow a better assessment of long-duration signals. After this 110 ms window, the sensing threshold is set at 50% (modifiable) of this measurement as in previous generations; the starting value can be much higher than in the previous platforms, the R wave can be measured up to a value of 25 mV (which considerably reduces the risk of T wave oversensing). The threshold remains fixed at 50% for 240 ms; the threshold subsequently decreases after 350 ms (110 + 240 ms) to 25% (modifiable) of the amplitude; on previous platforms, this duration was 360 ms; the ensuing decrement is 12.5% every 156 ms; this decrement is relatively large so as to reach maximum sensing values to accurately sense a VF episode despite a potentially high initial value; the values of 12.5% and 156 ms are not modifiable; 4) the sensing circuit after ventricular pacing has also been modified; after ventricular pacing, the device analyzes the amplitude of the evoked response for 110 ms without possibility of double sensing during a period of 120 ms (modification relative to the previous platforms or this blanking was programmed to Auto); there is an absolute blanking of 19.5 ms following the stimulus to avoid sensing of the spike; the behavior is thereafter identical to that occurring after ventricular sensing.

Status report

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Lumax 740 VR-T DX

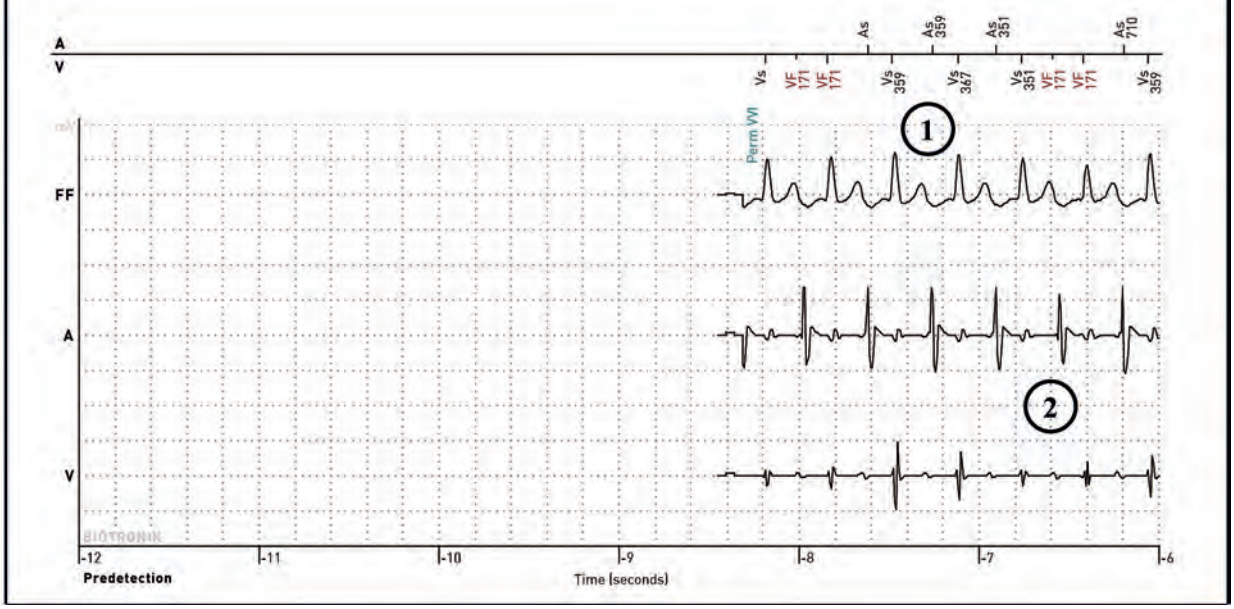
Recordings

Recordings - Episode 702:

General	
Episode number	702
Episode type	VF
Detection	May 8, 2017 11:29:08 AM
Termination	May 8, 2017 11:29:17 AM
Duration	9s
Device settings no.	10
Detection	
Mean PP at initial detection [ms]	---
Mean RR at initial detection [ms]	180
Onset [%]	50, fulfilled
Stability [ms]	16
Redetection	---

Therapy	
ATP in VT/VF delivered	1
ATP One Shot delivered	YES
Shocks delivered	0
Shocks aborted	1
Maximum energy [J]	40
Termination	
Mean PP at termination [ms]	371
Mean RR at termination [ms]	557
Remark	
none	

IEGM



Status report

BIOTRONIK
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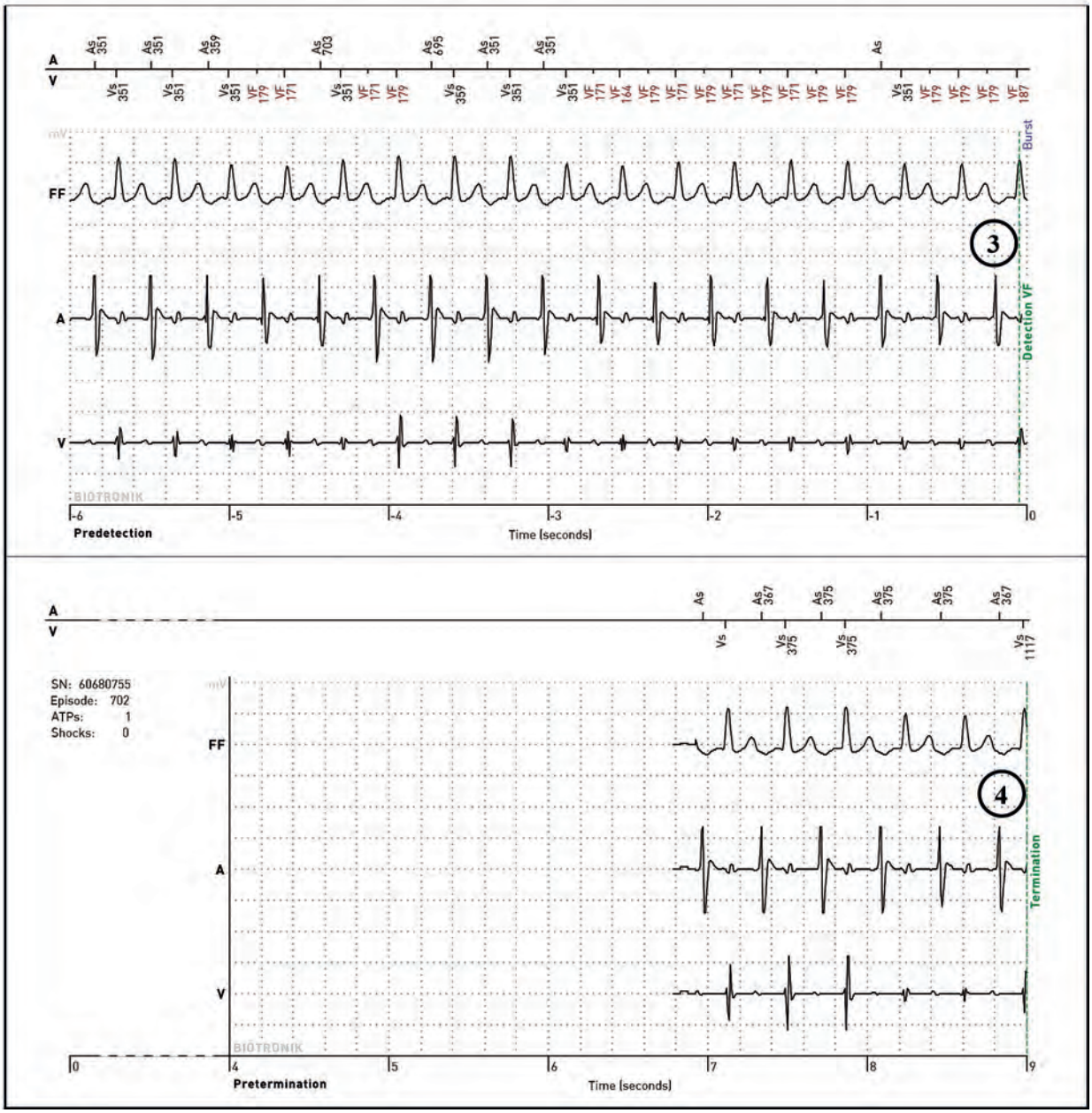
Lumax 740 VR-T DX

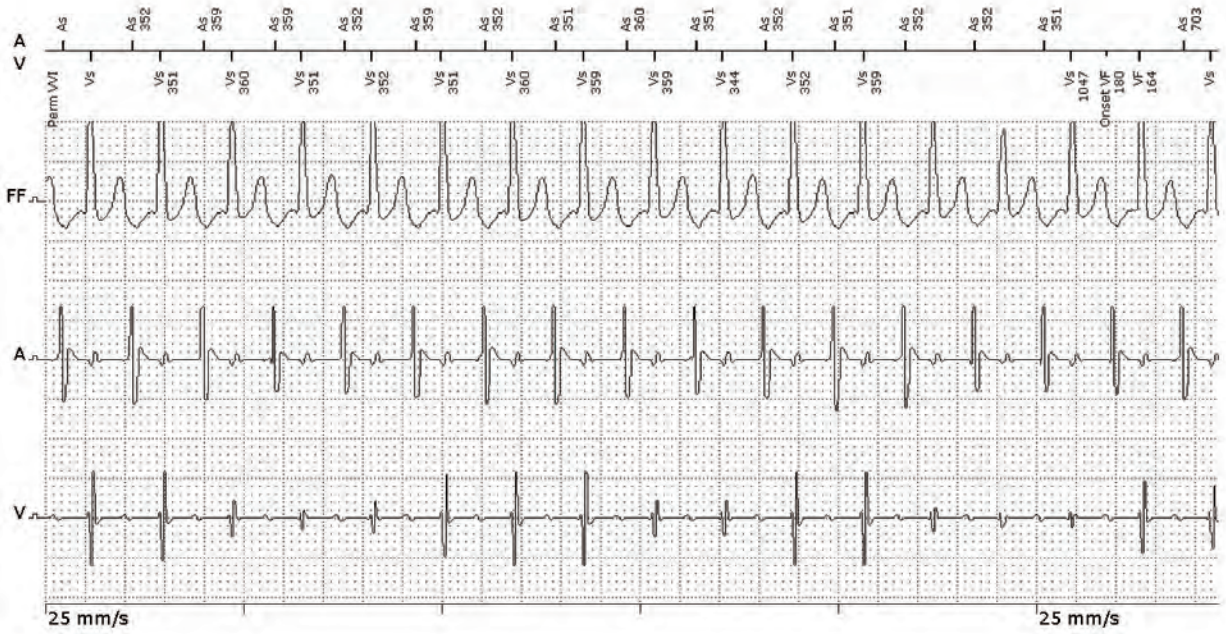


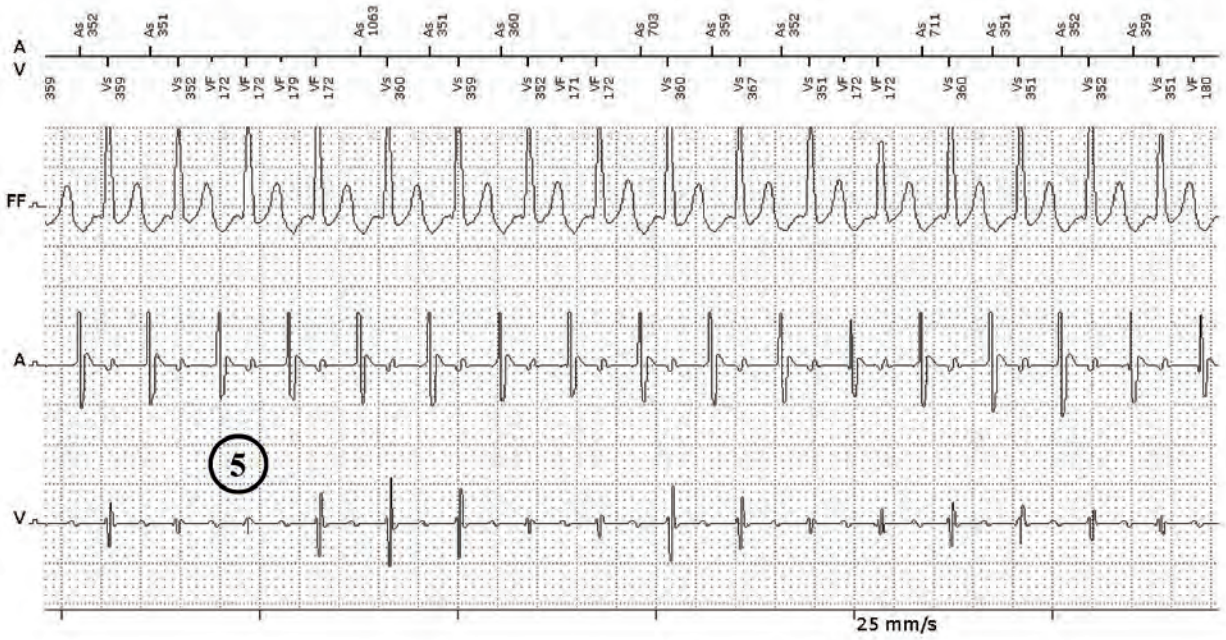
Oversensing

Device Lumax 740 VR-T

S/N:

Recordings - IEGM Episode: **702**

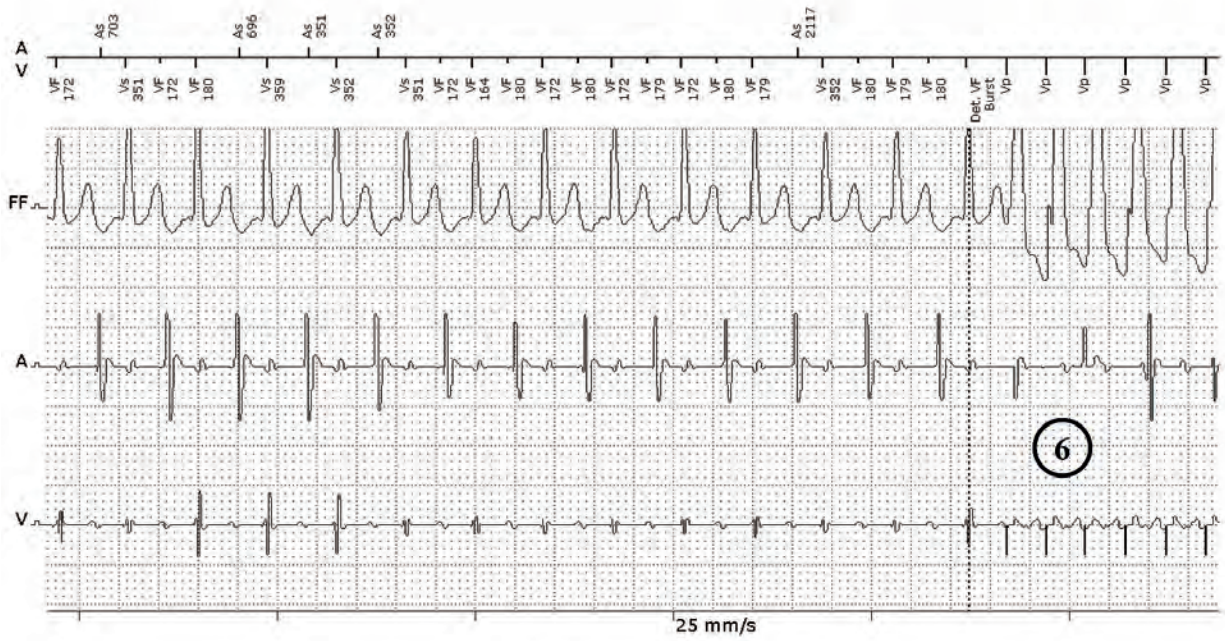


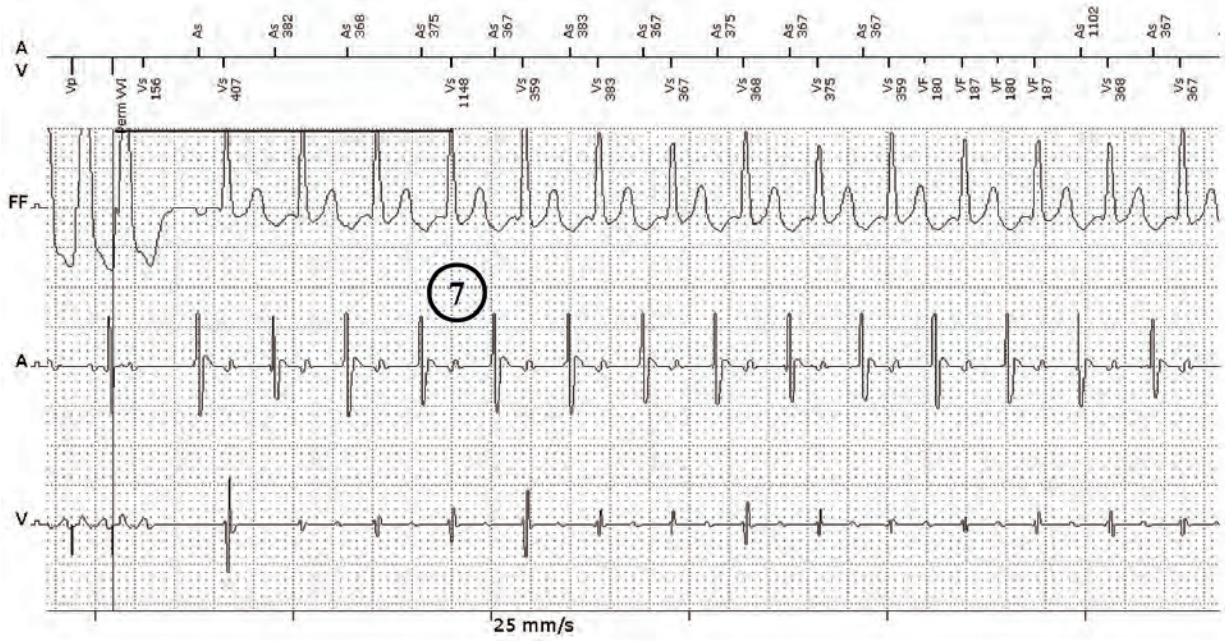


Device Lumax 740 VR-T

S/N:

Recordings - IEGM Episode: **702**



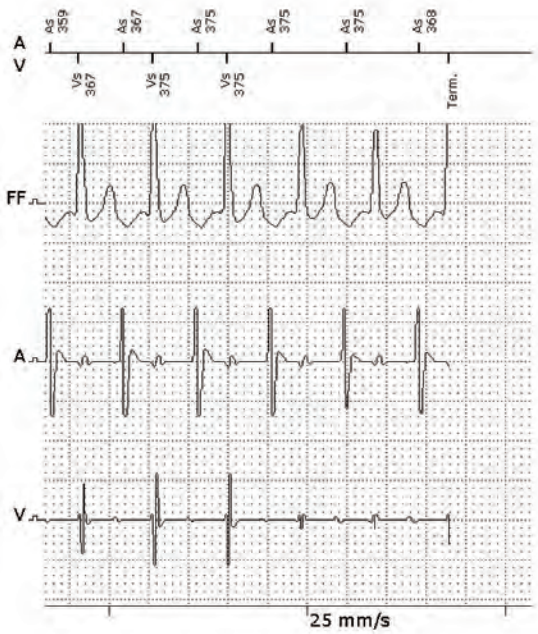


Oversensing

Device Lumax 740 VR-T

S/N:

Recordings - IEGM Episode: **702**



Tracing 14 ↘ Ventricular undersensing

Patient

28-year-old woman implanted with a Lumax 540 VR-T single-chamber ICD for resuscitated sudden death; systematic programming of an enhanced T wave suppression to limit the risk of inappropriate therapy due to T wave oversensing in the presence of an R wave of modest amplitude (3 mV); event report (yellow color) in the setting of the recording of a SVT.

Telecardiology tracing

3 channels are available; the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the right ventricular sensing channel (RV).

① fast spontaneous rhythm with intervals classified in the VT1 zone;

② premature ventricular contraction classified in the VF zone;

③ ventricular undersensing with the next interval classified as Vs;

④ premature ventricular contraction classified in the VF zone and next interval classified as Vs;

⑤ episode classified as SVT when the VT1 counter is filled; the Vs intervals decrement the counter by 1 and the VF intervals increment the VT1 counter by 1; this episode is classified as SVT given its irregular nature (99 ms);

⑥ no therapy delivered;

⑦ persistence of ventricular undersensing.

Comments

In this young patient, an enhanced T wave suppression had been systematically programmed to limit the risk of inappropriate therapy due to T wave oversensing. She presented poor ventricular sensing with R waves measured between 3 and 4 mV at rest explaining a change in the programmed sensitivity (from 0.8 to 0.5 mV). On this tracing, there is a great variability in the amplitude of the ventriculograms. The absence of sensing of spontaneous low-amplitude ventricular signals occurs after a higher-amplitude signal. It should be reminded that the sensing level adapts to the amplitude of the previous QRS. This explains the high probability of undersensing low-amplitude signals occurring after a high-amplitude signal. This undersensing in sinus rhythm is highly worrisome, since a correct sensing of the arrhythmia is an essential prerequisite for the delivery of any therapy. The programmed sensitivity value leaves very little margin. It is possible to return to a standard programming or to reprogram with enhanced VF sensing. In this patient, an induction procedure seems indispensable to validate proper sensing in VF. In case of doubt, repositioning of the right ventricular lead may be necessary.

Status report - Oct 11, 2013

To: Service Télécardiologie

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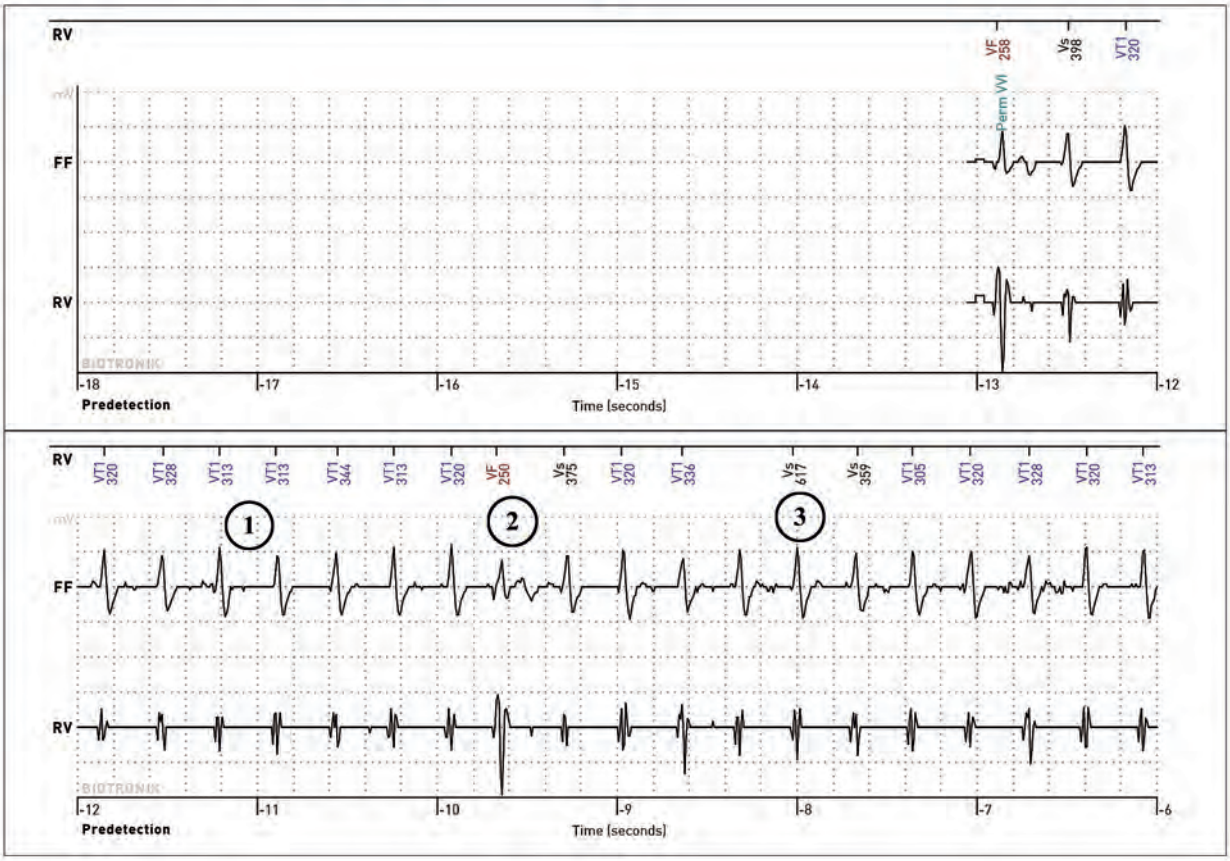
Name: DOB: - Lumax 540 VR-T (SN 60450588) Last message: Oct 9, 2013
Patient ID: Phone: ICD implanted Aug 16, 2010 Last clinic follow-up: Sep 23, 2013

Recordings

Recordings - Episode 22:

General	
Episode number	22
Episode type	SVT
Detection	Jun 18, 2012 12:28:00 AM
Termination	Jun 18, 2012 12:28:03 AM
Duration	3s
Device settings no.	14
Detection	
Mean RR at initial detection [ms]	319
Onset [%]	51, fulfilled
Stability [ms]	99
Redetection	---

Therapy	
ATP in VT/VF delivered	0
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	0
Maximum energy [J]	---
Termination	
Mean RR at termination [ms]	494
Remark	
Detection	SVT (RR unstable)

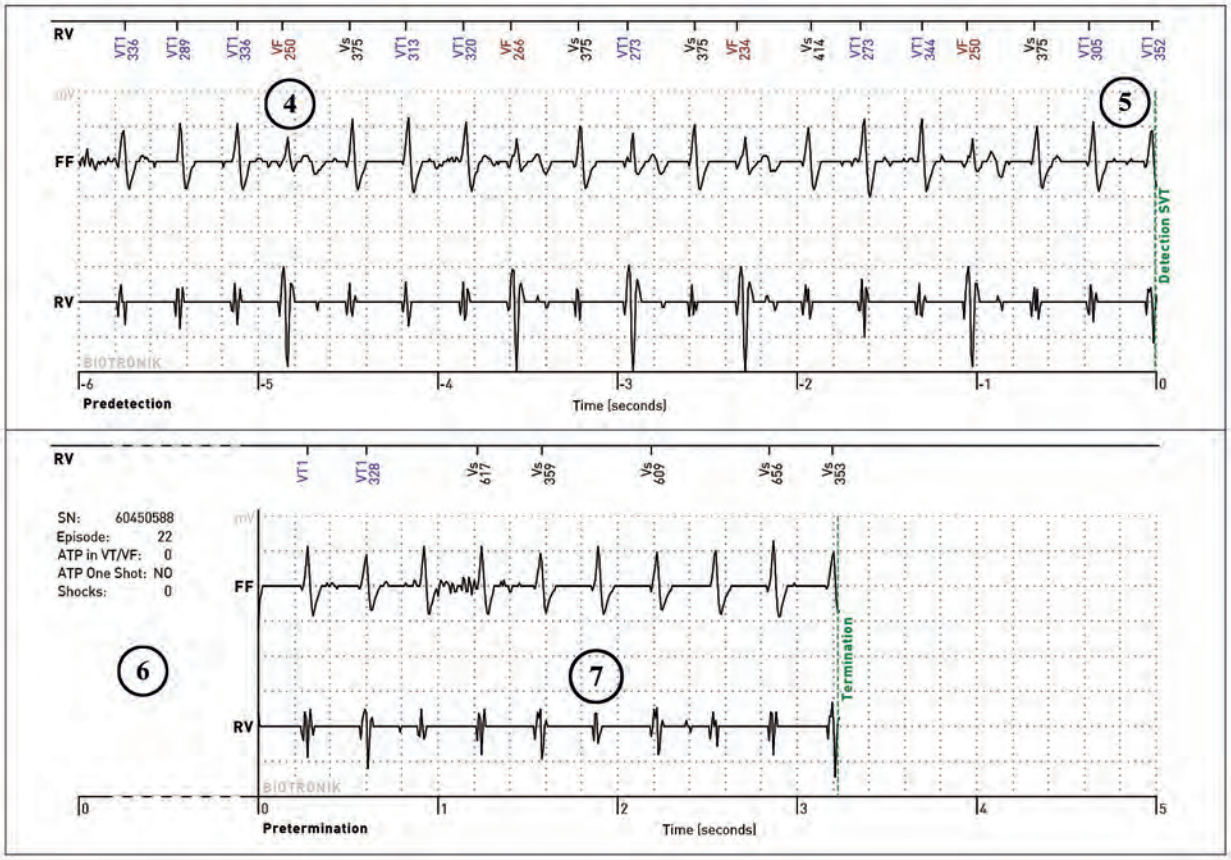


Status report - Oct 11, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

Name:	DOB: -	Lumax 540 VR-T (SN 60450588)	Last message: Oct 9, 2013
Patient ID:	Phone:	ICD implanted Aug 16, 2010	Last clinic follow-up: Sep 23, 2013



Tracing 15 ↘ Double counting of the R wave due to bundle branch block

Patient

64-year-old man implanted with a Lumax 340 DR-T dual-chamber ICD for ischemic cardiomyopathy with right bundle branch block and left anterior fascicular block; recording and transmission of a periodic EGM.

Telecardiology tracing

4 channels are available: the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the atrial sensing channel, the right ventricular sensing channel (RV); 30 seconds of EGM are available.

① spontaneous sinus rhythm; oversensing of a supernumerary ventricular signal corresponding to a double counting of the R wave at the end of ventricular blanking;

② permanent oversensing; alternating intervals classified as VS and intervals classified as VF, the VF counter is never filled and no episode is recorded.

Comments

In the absence of technical or rhythmic problems, the device transmits a periodic 30-second EGM to verify the morphological quality of the endocardial signals. The transmission of a periodic EGM sometimes allows diagnosing asymptomatic oversensing episodes (P wave, T wave, double counting of the R wave), lead fracture (atrial or ventricular) or loss of left ventricular capture in CRT patients which would not otherwise be recorded, given that the VT or VF counters are not full. In this patient, one out of 2 intervals is classified as VS (decrements the VT counter by -1), the other is classified as VF (increments the VT counter by +1). The VT counter remains blocked at 0. Similarly, the probability VF counter is never filled. There is, however, a risk of inappropriate therapies in the presence of sinus tachycardia (the VS interval becomes VT1) or premature ventricular contractions.

In rare patients with severe intra-ventricular conduction disorder and wide QRS, the ventricular EGM can exceed the duration of the post-ventricular refractory period resulting in the same signal being sensed twice. Certain drugs (particularly sodium channel blockers for elevated heart rates) or certain metabolic disorders (hyperkalemia) can favor this oversensing by prolonging the duration of the QRS. The double counting of the R wave can also occur in a patient with a dual-chamber ICD, a prolonged PR interval and loss of right ventricular capture. The defibrillator counts both the paced ventricular event and the spontaneous ventricular activity conducted from the atrium. Similarly, in a patient with a triple-chamber ICD and loss of right ventricular capture, the device can count both the ventricular paced event and the right ventricular depolarization arising from left ventricular capture.

The EGM pattern during a double counting of the R wave is relatively characteristic with alternation between 2 ventricular interval durations. The second signal is usually sensed at the end of the ventricular refractory period (the R1R2 interval is exactly equal to the programmed ventricular refractory period or within a limit of + 20 ms) and always corresponds to the VF zone. The classification of the second interval (R2R1) is contingent on the programming of the tachycardia zones and the heart rate (higher probability of being in the tachycardia zone if the rate is high and the tachycardia zones are programmed low).

The post-ventricular ventricular refractory period is the parameter incorporated in the various ICDs to solve this oversensing problem without jeopardizing the sensing quality of a VF episode. In older platforms, double counting was relatively common especially when this type of device was connected to an integrated bipolar lead. Two reasons were invoked: a very short post-ventricular ventricular refractory period (in the order of 80 ms) and the large spacing of the 2 sensing electrodes on an integrated bipolar lead favoring the prolongation of the duration of the ventricular EGM.

Status report - Jan 23, 2013

To: Service Télécardiologie

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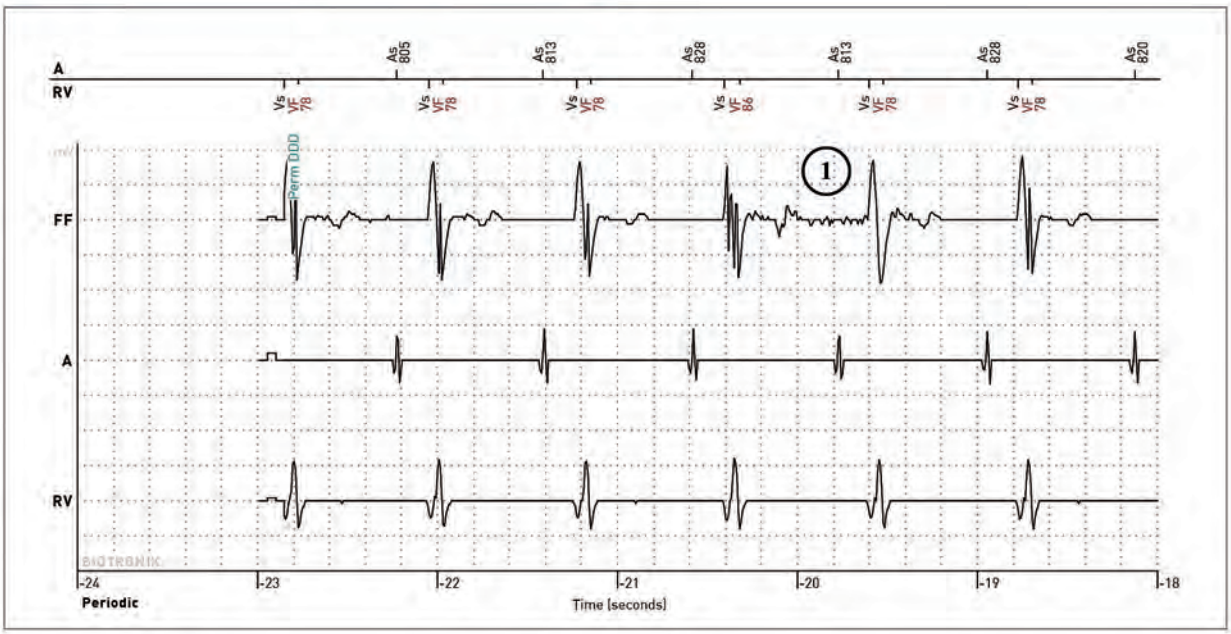
Name:	DOB:	Lumax 340 DR-T (SN 60437433)	Last message: Jan 20, 2013
Patient ID:	Phone: -	ICD implanted May 6, 2009	Last clinic follow-up: Oct 9, 2012

Recordings

Recordings - Episode 5:

General	
Episode number	5
Episode type	Periodic IEGM
Detection	Dec 13, 2009 12:40:42 AM
Termination	---
Duration	---
Device settings no.	11
Detection	
Mean PP at initial detection [ms]	---
Mean RR at initial detection [ms]	---
Onset [%]	---
Stability [ms]	---
Redetection	---

Therapy	
ATP in VT/VF delivered	---
ATP One Shot delivered	---
Shocks delivered	---
Shocks aborted	---
Maximum energy [J]	---
Termination	
Mean PP at termination [ms]	---
Mean RR at termination [ms]	---
Remark	
none	

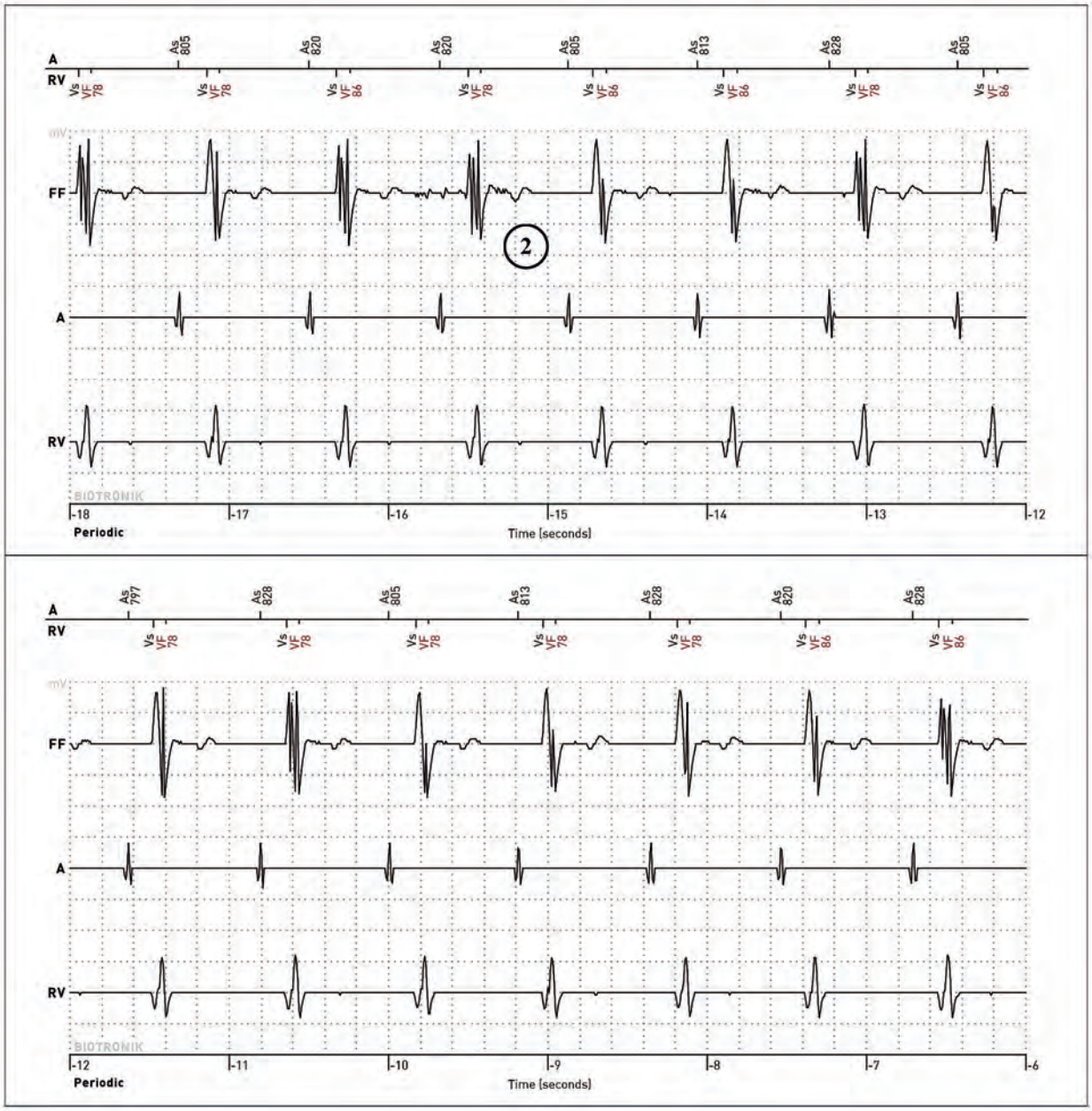


Status report - Jan 23, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

Name:	DOB:	Lumax 340 DR-T (SN 60437433)	Last message: Jan 20, 2013
Patient ID:	Phone: -	ICD implanted May 6, 2009	Last clinic follow-up: Oct 9, 2012



Status report - Jan 23, 2013

To: Service Télécardiologie

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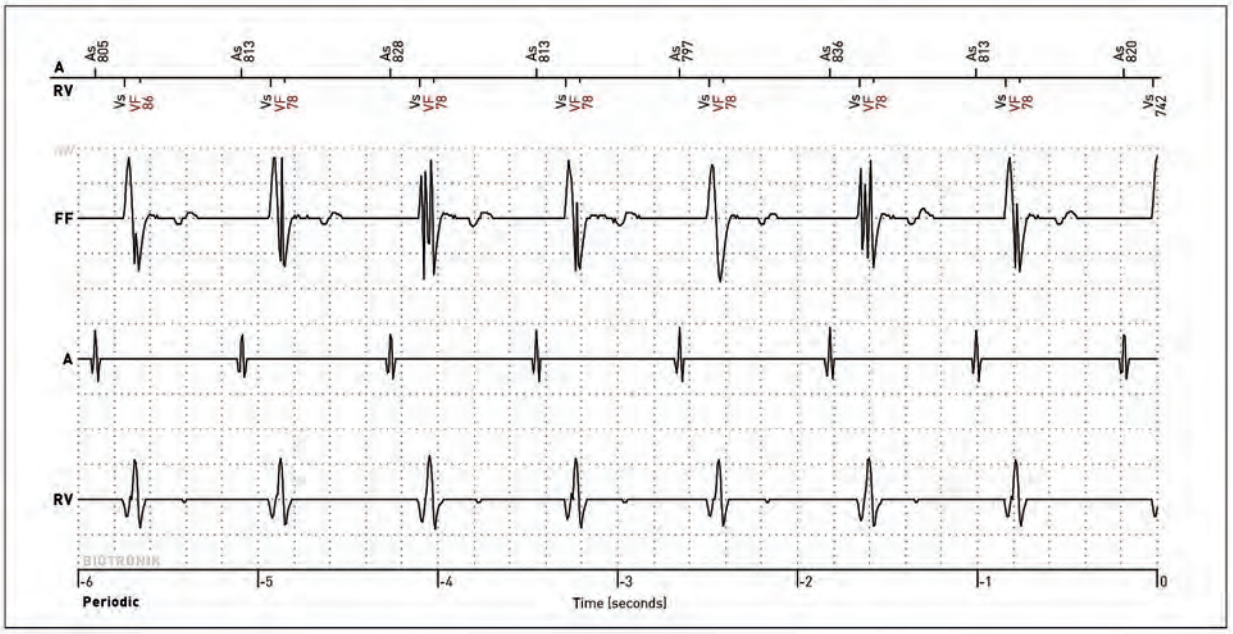
Name:	DOB:	Lumax 340 DR-T (SN 60437433)	Last message: Jan 20, 2013
Patient ID:	Phone: -	ICD implanted May 6, 2009	Last clinic follow-up: Oct 9, 2012



Tracing 16 ↘ Double-counting of the R wave due to slow VT

Patient

85-year-old man implanted with a Lumax 740 HF-T triple-chamber ICD for severe ischemic cardiomyopathy with left bundle branch block; recording and transmission of an EGM corresponding to a VT1 episode.

Telecardiology tracing

4 channels are available: the markers with the time intervals, the atrial sensing channel (A), the right ventricular sensing channel (RV) and the left ventricular sensing channel (LV).

① slow VT episode with atrioventricular dissociation; rate slightly above 100 beats/minute; the ventricular intervals are not sensed in one of the tachycardia zones;

② double counting of the QRS; the same ventriculogram is sensed twice at the end of the post-ventricular refractory period;

③ double quasi-permanent counting; the intervals classified as VT1 and VF increment the VT1 counter (+1); the intervals classified as PVC or paced (RVp) decrement the VT1 counter (-1);

④ the VT1 counter is full; delivery of an ATP burst;

⑤ termination of the ventricular arrhythmia and biventricular pacing.

Comments

The double counting of the R wave can occur during a sinus rhythm, during a premature ventricular contraction or solely during a slow VT as in this patient. QRS complexes can be considerably expanded in this setting, since double counting leads to the risk of incorrect classification in VT or VF zones and to the occurrence of unnecessarily aggressive therapies.

The double counting of the R wave is an exceptional occurrence on the latest generation of ICDs. The risk of oversensing has been considerably reduced by a prolongation of the post-ventricular ventricular refractory period from 80 ms to 110 ms on the new platforms. This value can also be changed using a code known to the employees of Biotronik™. The prolongation of the ventricular refractory period generally allows eliminating the problem of double counting and must therefore be proposed in first intention, while bearing in mind that excessive prolongation can lead to an increased risk of undersensing of a true VF. Lowering ventricular sensitivity may sometimes resolve the problem, although this option may also generate a risk of VF undersensing. Moreover, this option is often ineffective since the second ventricular signal can be of at least equal amplitude to the first. Setting a very high VF zone to avoid inappropriate therapies in this setting also does not appear suitable. In the rare instances where the refractory period cannot be sufficiently prolonged, the implantation of a new pacing/defibrillation lead can be proposed.

In patients with very broad QRS, it is essential during implantation to carefully analyze the pattern and width of the ventricular intra-cardiac electrogram and to verify the absence of any double ventricular counting. It is also probably more appropriate to implant, in this setting, a dedicated bipolar lead rather than an integrated bipolar lead which favors double counting.

In this patient, the ventricular refractory period was probably programmed too short, whereas the prolongation of this refractory period to 130 ms without any change in sensitivity allowed eliminating this double counting.

Status report

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Lumax 740 HF-T

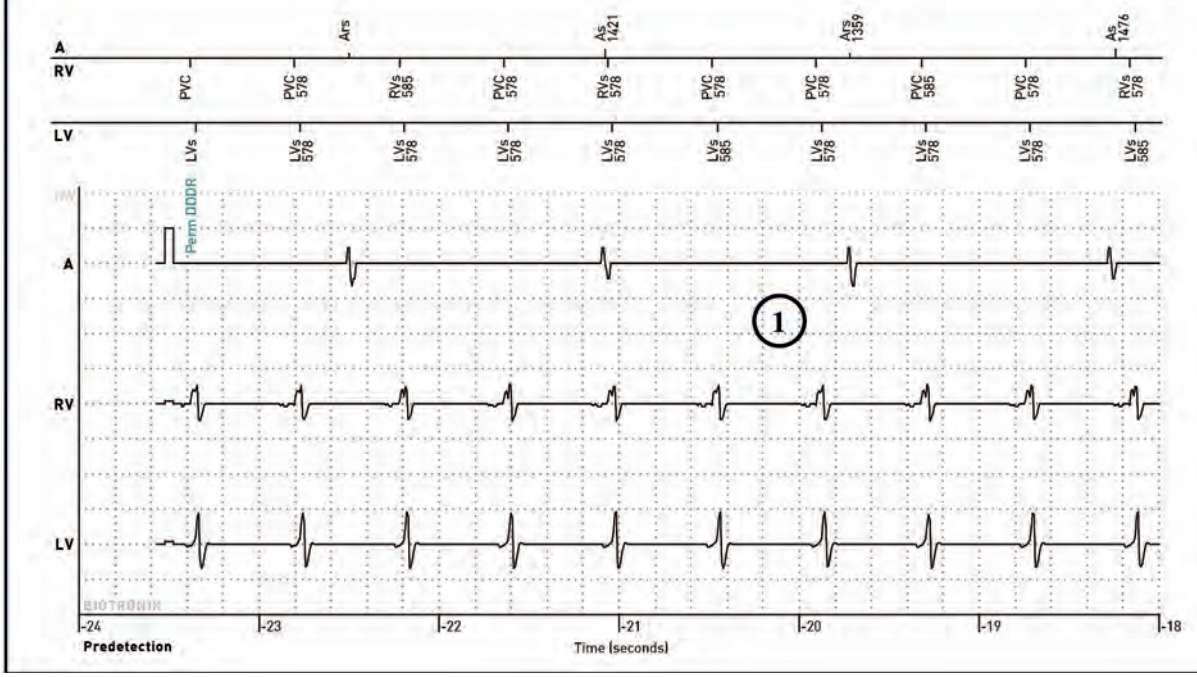
Recordings

Recordings - Episode 64:

General	
Episode number	64
Episode type	VT1
Detection	Nov 6, 2014 10:04:50 PM
Termination	Nov 6, 2014 10:05:06 PM
Duration	16s
Device settings no.	29
Detection	
Mean PP at initial detection [ms]	---
Mean RR at initial detection [ms]	355
Onset [%]	82
Stability [ms]	> 247
Redetection	---

Therapy	
ATP in VT/VF delivered	1
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	0
Maximum energy [J]	---
Termination	
Mean PP at termination [ms]	973
Mean RR at termination [ms]	982
Remark	
Therapy	ATP optimization in VT1 applied

IEGM



Status report

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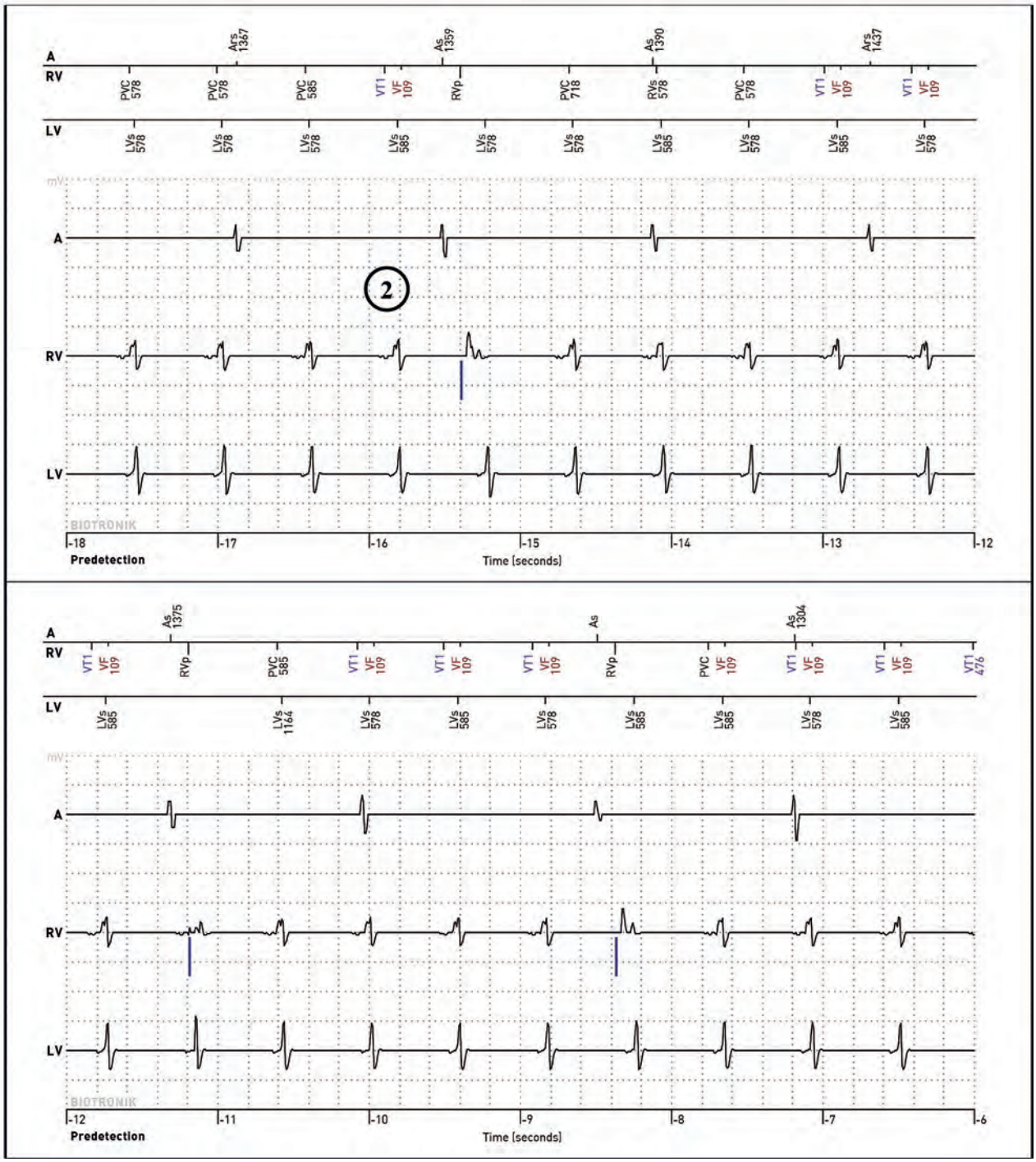
Lumax 740 HF-T



Status report

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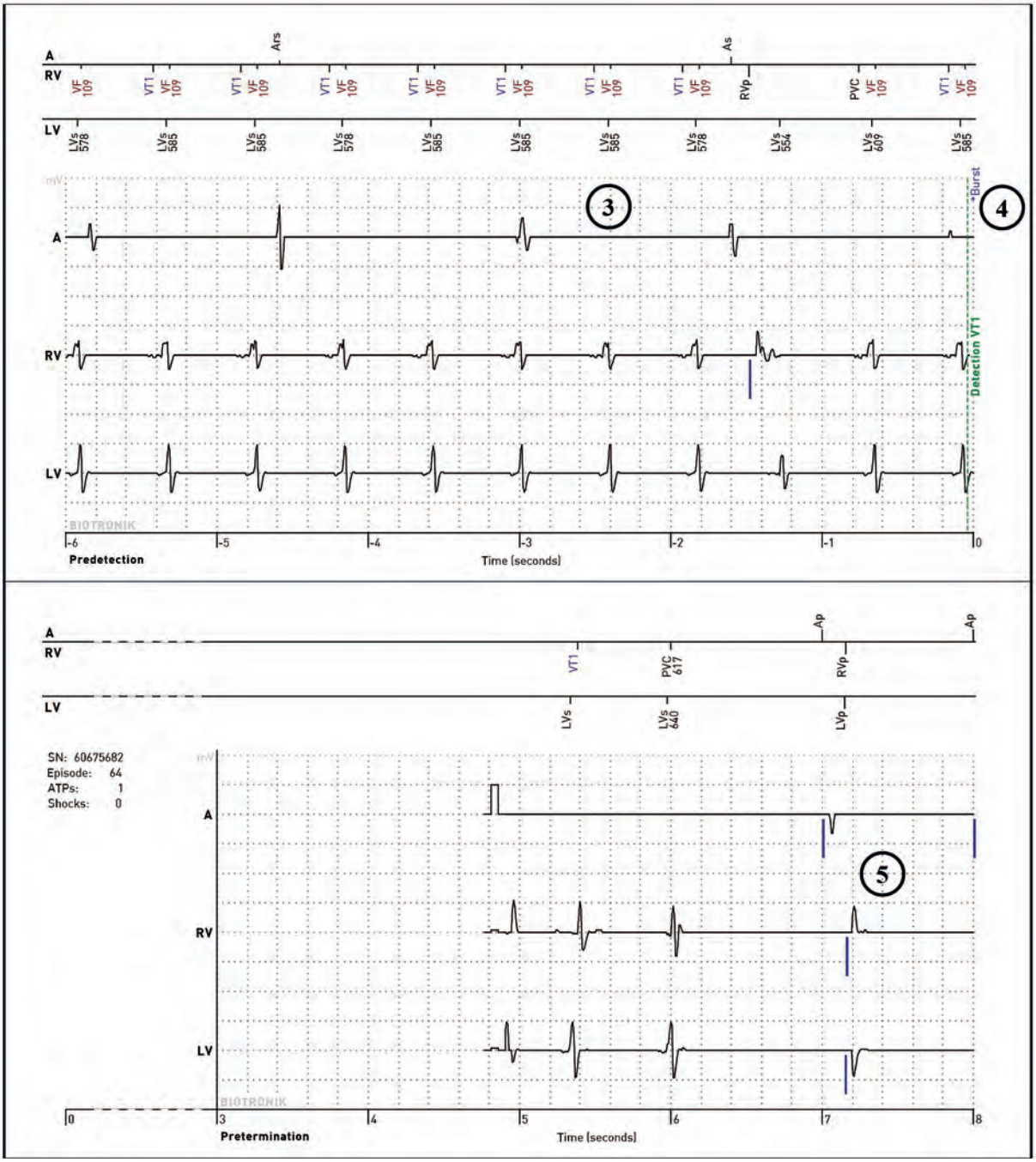
Lumax 740 HF-T



Status report

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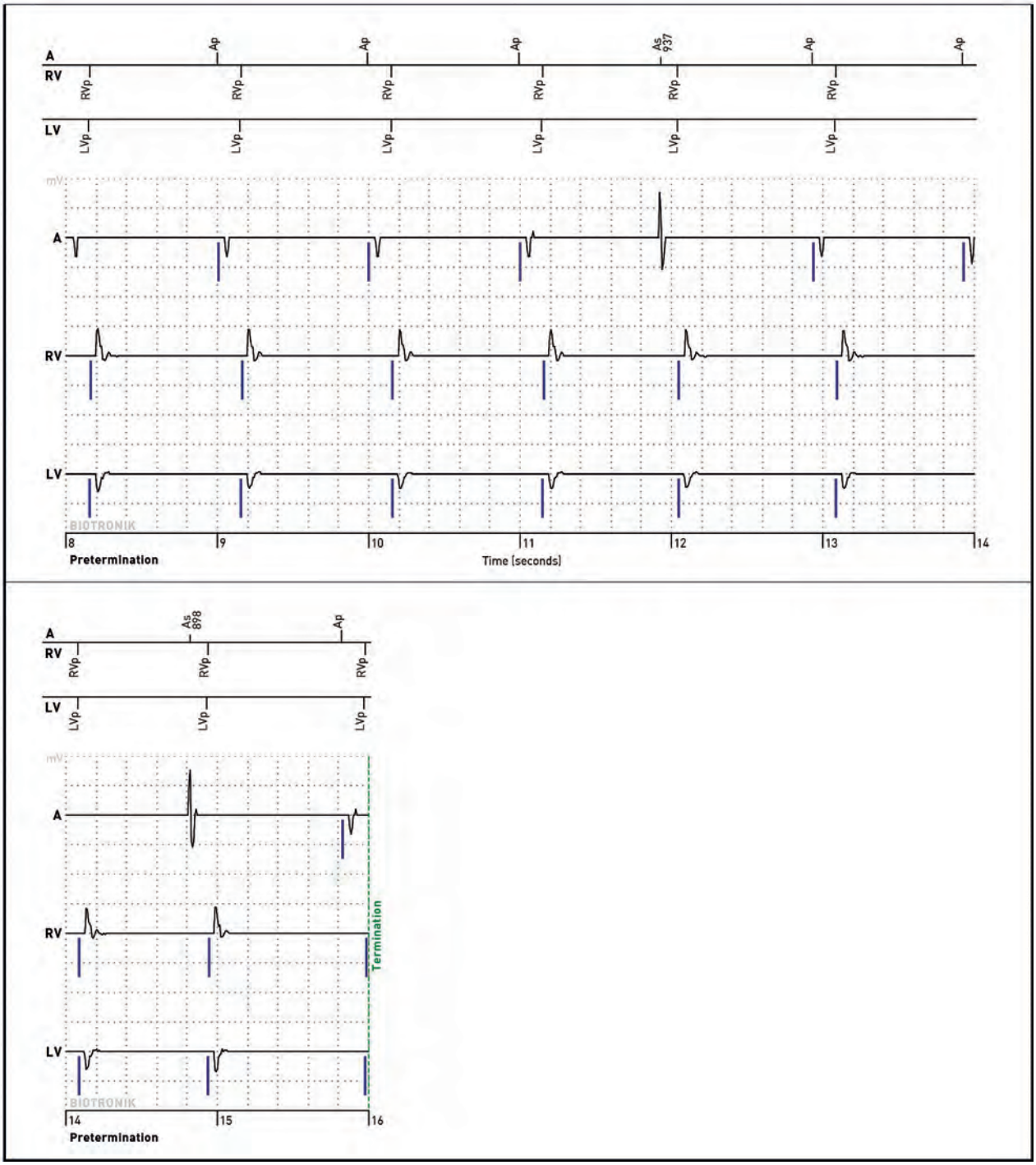
Lumax 740 HF-T



Tracing 17 ↘ Oversensing of diaphragmatic myopotentials

Patient

69-year-old man implanted with a Lumax 340 HF-T triple-chamber ICD for ischemic cardiomyopathy with left bundle branch block; event report (yellow color) in the setting of a classified VF.

Telecardiology tracing

① paced rhythm in the atrium and biventricular pacing;
② oversensing of a rapid small amplitude signal in the VF zone in the right ventricular channel;
③ classification of the VF episode after 12 out of 16 intervals classified in the VF zone (3 Vs and 1 VT2, 12 VF: VF counter filled);
④ no therapy delivered;
⑤ end of the episode;

Programmer tracing (same episode)

⑥ start of the charge (black line);
⑦ discontinuation of the oversensing and interruption of the charge after 3 paced ventricular intervals.

Comments

This patient presented oversensing of myopotentials originating from the diaphragm. A deep inspiration enabled replicating the phenomenon.

Two types of myopotentials can be oversensed by an ICD:

1) diaphragmatic myopotentials: the use of a high self-adjusting sensitivity allows optimizing the quality of the sensing of the low-voltage VF signals, but also increases the risk of oversensing of diaphragmatic myopotentials at the end of diastole when the sensitivity reaches its maximum. Diaphragmatic myopotential oversensing is rare but has been increasingly observed in patients implanted with an integrated bipolar lead positioned at the apex of the right ventricle. Permanent ventricular pacing is associated with an increased risk of oversensing of these myopotentials since, after pacing, the time spent at maximum sensitivity is prolonged especially at slow heart rates. An integrated bipolar lead favors the phenomenon due to a wider sensing antenna. Diaphragmatic myopotentials correspond to low-amplitude, high-frequency signals, most often detected exclusively on the sensing channel (absent on the far-field channel). The two main characteristics of this type of signal are that their amplitude varies with the respiratory cycle and that can be replicated by specific maneuvers (deep inspiration, Vasalva, forced cough). Oversensing occurs initially at the end of diastole when sensitivity is maximal. Sensing of the true R wave (of high amplitude) modifies the sensitivity level and interrupts, at least temporarily, the oversensing of these small signals, which explains why prolonged oversensing only occurs in pacemaker-dependent patients (absence of spontaneous R wave, sensitivity level permanently at maximum). Oversensing may be avoided by reducing the sensitivity level with the need to verify the accurate sensing of VF signals. In paced patients, an increase in the minimal pacing rate may also have a favorable effect. In some instances, it may be necessary to implant a new defibrillation (DF4 system) or pacing (DF1 system) lead at a remote distance from the diaphragm (septum or infundibulum).

2) pectoral myopotentials: in an ICD, the pulse generator being positioned in the pocket near the pectoral muscles (and thus not part of the sensing circuit), the pectoral myopotentials should therefore not generate oversensing. The amplitude of these myopotentials is greater when recorded at the level of the far-field channel which includes the pulse generator (sensing between the right ventricular coil and the generator). On the other hand, if there is an insulation break (typically an erosion leading to a current leak) at the

level of the pocket portion of the lead (friction between the pulse generator and the lead), then the sensing (near-field) channel may oversense the pectoral myopotentials, which can lead to pacing inhibition and/or the occurrence of inappropriate therapies. Analysis of the EGMs in this setting reveals the presence of very rapid non-physiological (high-frequency) signals. Oversensing can be replicated by isometric movements of the arm ipsilateral to the generator or by manipulation of the lead in the pocket. When there is suspicion of pectoral myopotential oversensing, a chest X-ray must be performed along with complete control verification of the device (impedance values, pacing and sensing thresholds). The presence of an abnormally low impedance value (pacing and/or defibrillation) or a sudden decrease in this value is suggestive of an insulation break. In very rare cases, myopotential oversensing can be observed when a DF1 system has been implanted with inversion of the pins in the connector.

Status report - Mar 1, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

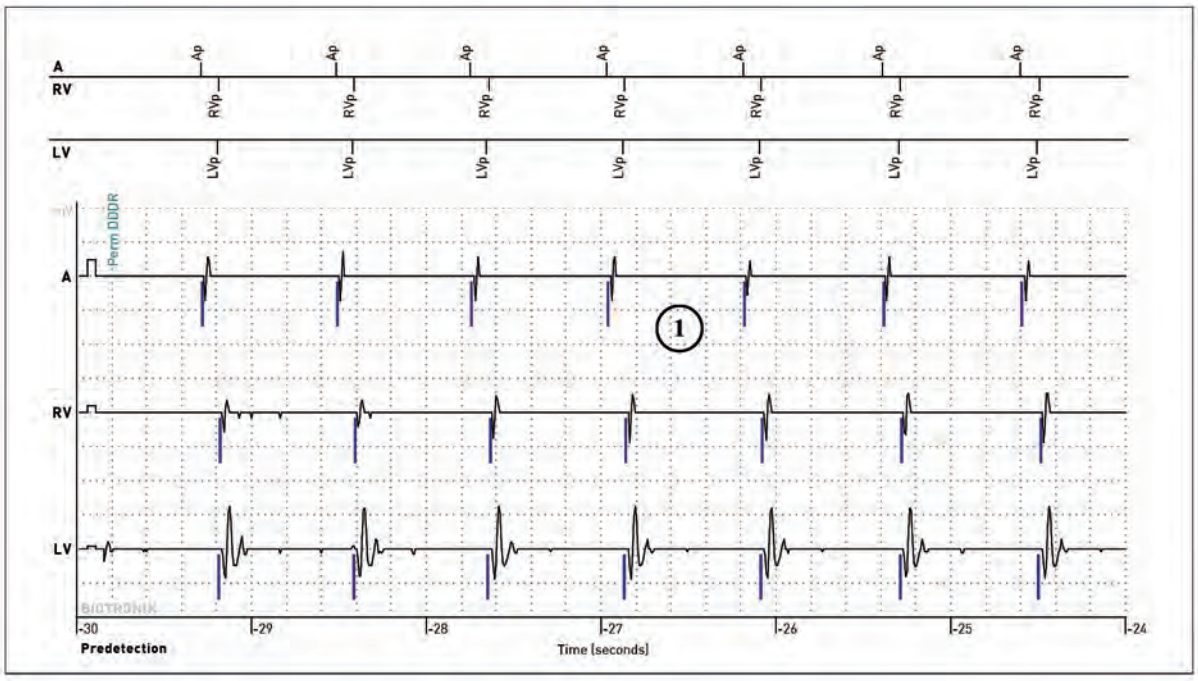
Name:	DOB: -	Lumax 340 HF-T (SN 60461375)	Last message: Mar 1, 2013
Patient ID:	Phone: -	CRT-D implanted Feb 8, 2010	Last clinic follow-up: Feb 20, 2013

Recordings

Recordings - Episode 18:

General	
Episode number	18
Episode type	VF
Detection	Jan 7, 2013 12:54:50 AM
Termination	Jan 7, 2013 12:55:02 AM
Duration	12s
Device settings no.	125
Detection	
Mean PP at initial detection [ms]	1089
Mean RR at initial detection [ms]	284
Onset [%]	82, fulfilled
Stability [ms]	> 247
Redetection	---

Therapy	
ATP in VT/VF delivered	0
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	1
Maximum energy [J]	40
Termination	
Mean PP at termination [ms]	841
Mean RR at termination [ms]	841
Remark	
none	

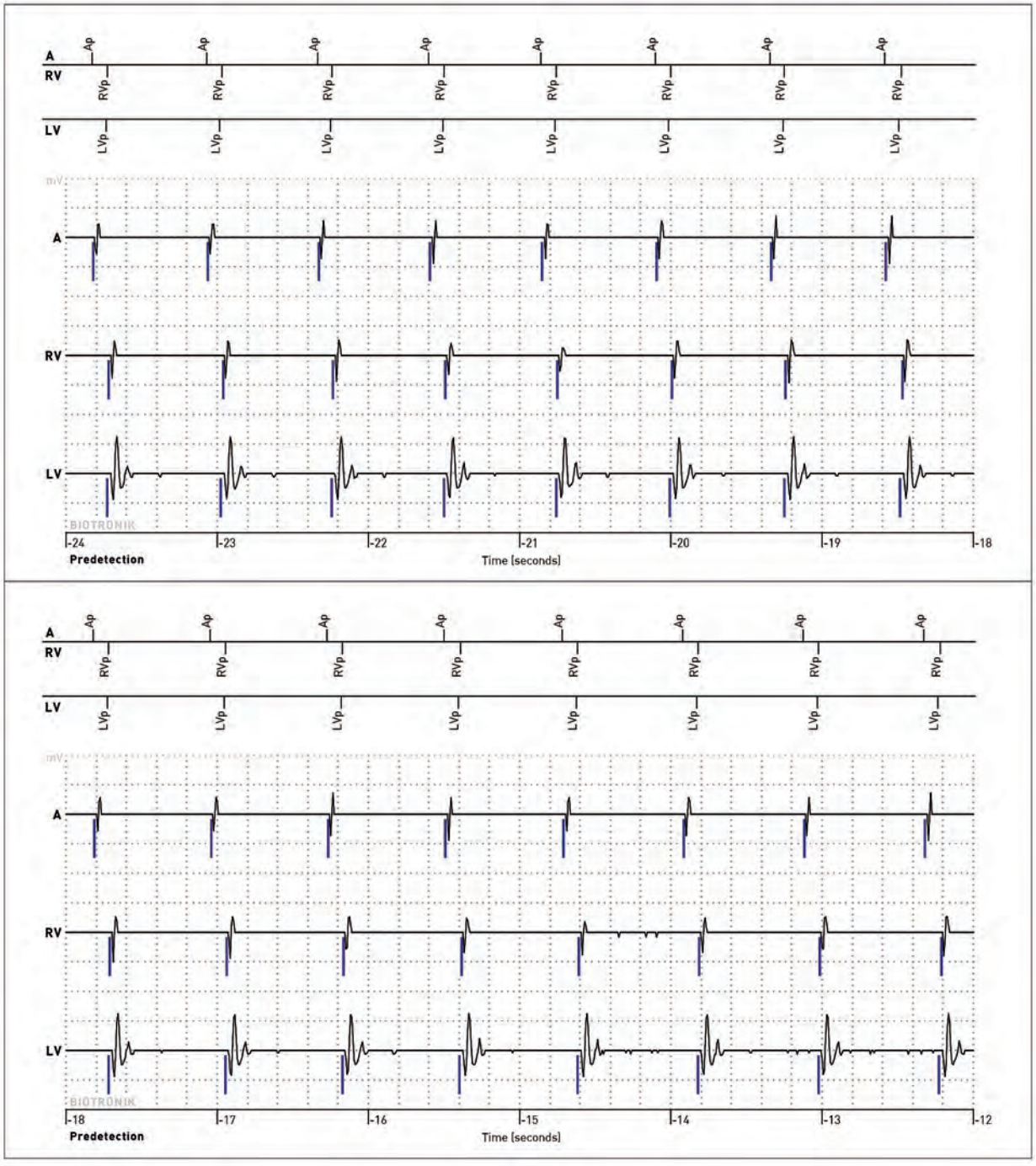


Status report - Mar 1, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

Name:	DOB: -	Lumax 340 HF-T (SN 60461375)	Last message: Mar 1, 2013
Patient ID:	Phone: -	CRT-D implanted Feb 8, 2010	Last clinic follow-up: Feb 20, 2013

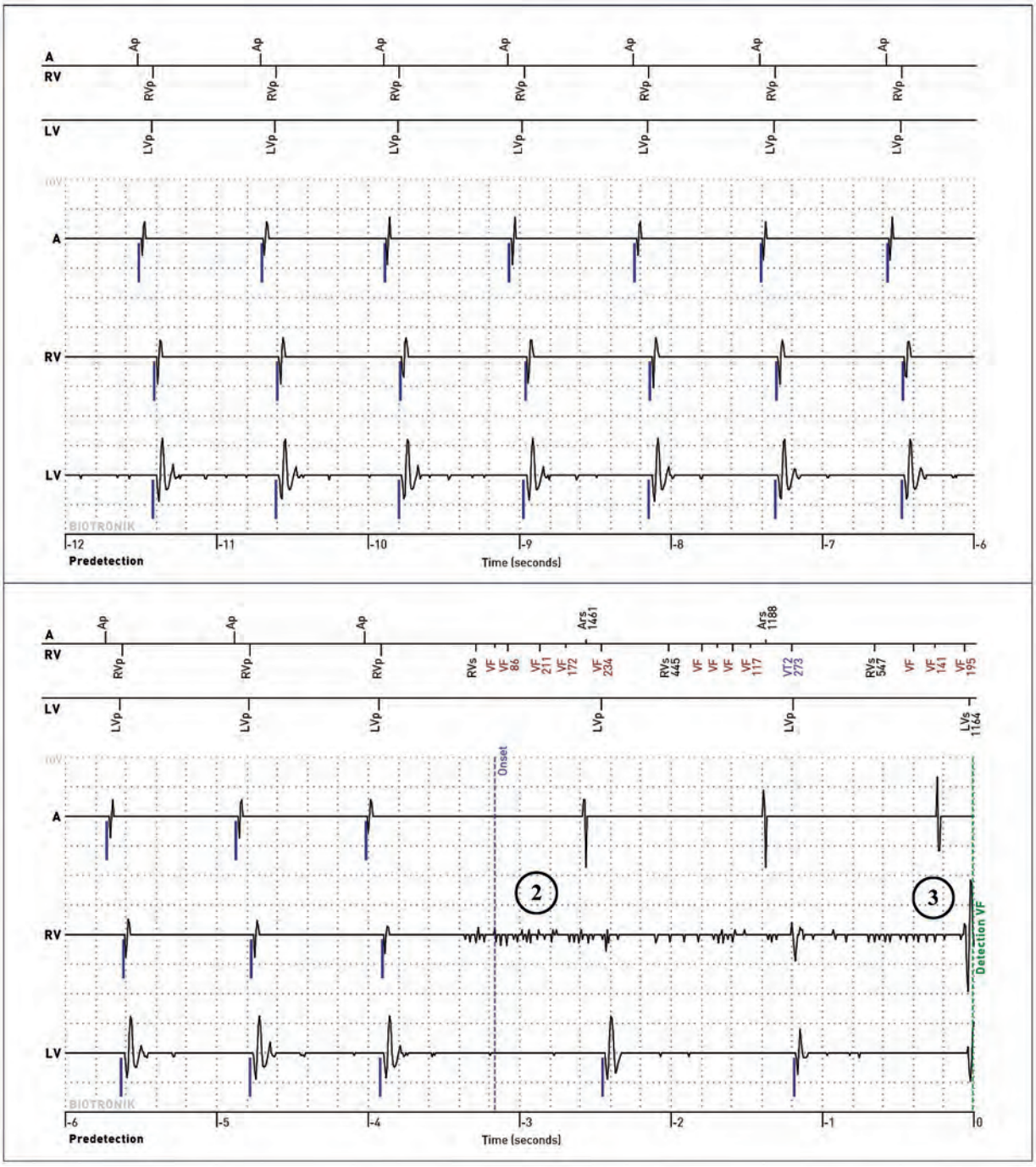


Status report - Mar 1, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

Name:	DOB: -	Lumax 340 HF-T (SN 60461375)	Last message: Mar 1, 2013
Patient ID:	Phone: -	CRT-D implanted Feb 8, 2010	Last clinic follow-up: Feb 20, 2013

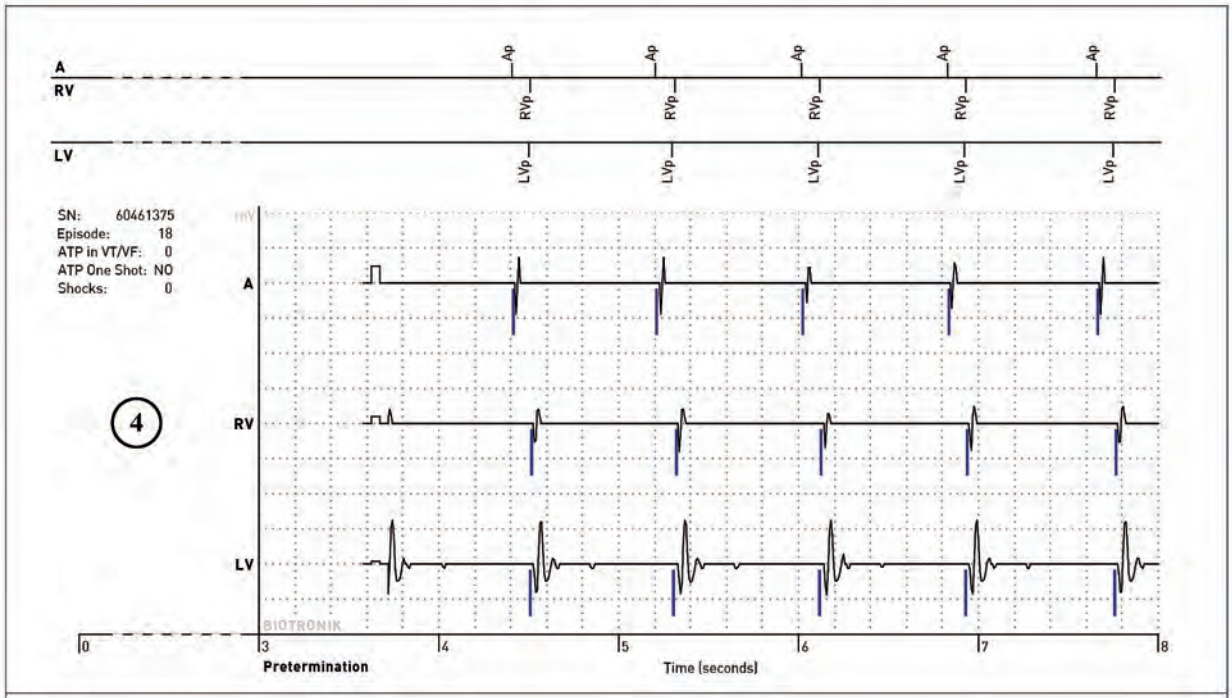


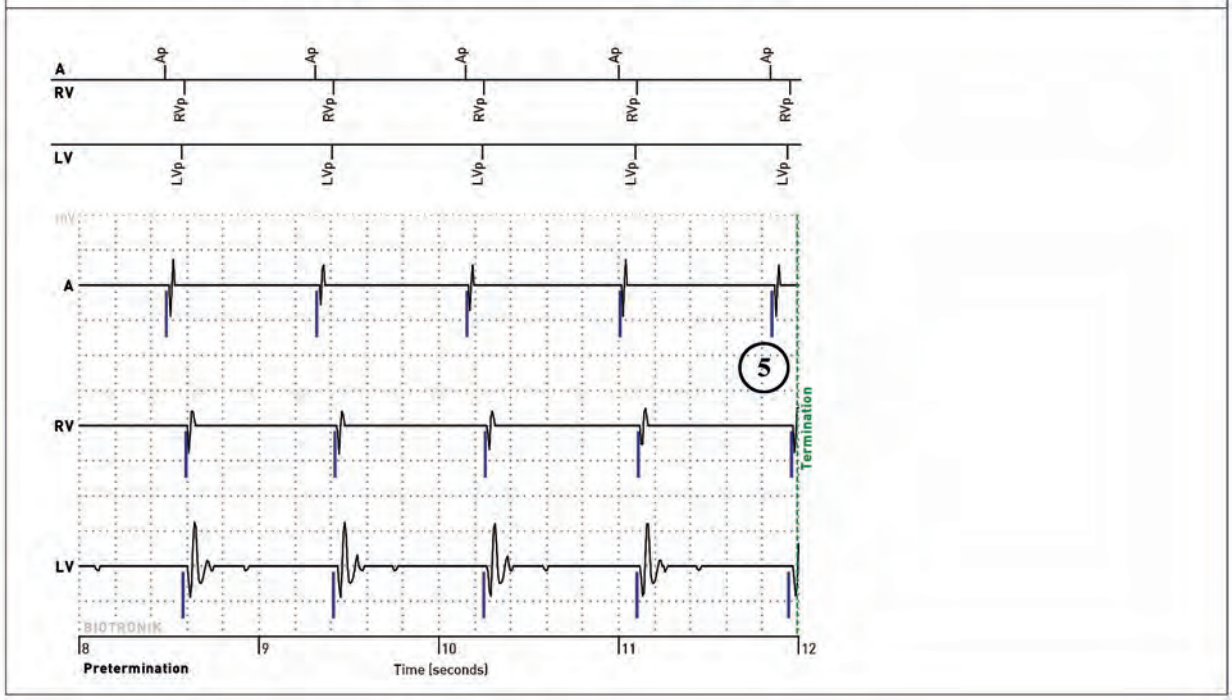
Status report - Mar 1, 2013

To: Service TélécØrdiologie

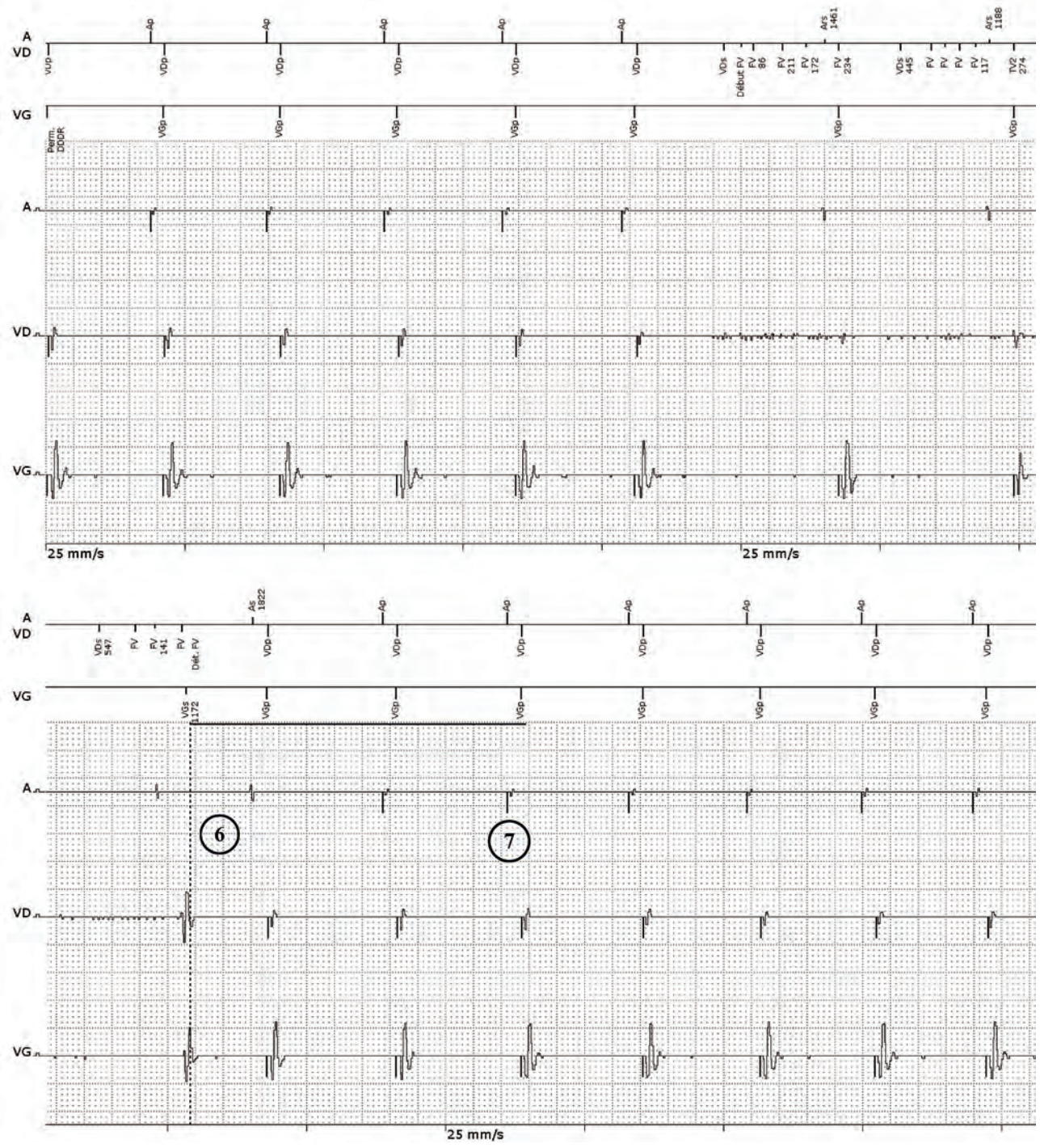
BIOTRONIK excellence for life

Name:	DOB: -	Lumax 340 HF-T (SN 60461375)	Last message: Mar 1, 2013
Patient ID:	Phone: -	CRT-D implanted Feb 8, 2010	Last clinic follow-up: Feb 20, 2013





PDF: BIOTRONIK - Lumax 340 HF-T



Tracing 18 ↘ Oversensing of a 50 Hz signal

Patient

Patient with ischemic cardiomyopathy implanted with an Ilesto DR-T dual-chamber ICD; recording of an episode classified as VF in the device memory in conjunction with interference generated by a poorly insulated household appliance.

Telecardiology tracing

① the EGM shows a characteristic pattern of oversensing of an electromagnetic interference with non-physiological signals detected in the 3 channels (far-field, atrial and right ventricular) saturating the baseline; the amplitude is maximal in the far-field channel; the intervals are classified in the VF zone;

② the VF counter is full; delivery of an electric shock;

③ discontinuation of the oversensing, once the shock has been delivered.

Comments

The potential risk of electromagnetic interference with an implantable defibrillator has been frequently described including in the hospital environment, in the patient's home or during his/her professional activities. Interference may occur by conduction if the patient is in direct contact with the emitting source or by radiation if the patient is within an electromagnetic field. The most recent ICDs are protected against the vast majority of sources of interference that the patient may encounter in his or her daily life. The parasitic signals are typically filtered, the analysis being restricted to a narrow bandpass corresponding to the physiological signals (high-pass and low-pass filters). However, the high adaptive sensitivity required in an ICD for accurate signal detection during ventricular fibrillation may favor the sensing of non-physiological signals corresponding to the same bandpass. Electromagnetic interference signals may not be appropriately filtered and lead to more or less severe consequences ranging from the occurrence of inappropriate therapies to pacing inhibition in a pacemaker-dependent patient, inappropriate mode switching due to false diagnosis of supraventricular arrhythmia, rapid ventricular pacing synchronized to atrial oversensing, suspension of therapy detection, or fallback to asynchronous mode. Exceptionally, interference with a high intensity electromagnetic field can cause permanent damage to the circuits.

The diagnosis of electromagnetic interference is based on the concordance between exposure to a source at the time of the episode and oversensing of characteristic signals (rapid, regular and saturating the baseline). Electromagnetic interference at the mains frequencies (60 Hz in the USA and 50 Hz in Europe) occurs when the patient is in physical contact with poorly insulated electrical equipment. If the oversensing is prolonged, a single electric shock is most often curative since the patient usually interrupts his activity immediately. Electromagnetic interference is more frequent for an integrated bipolar lead than for "true" bipolar sensing, the sensing antenna being wider. The characteristic high-frequency, non-physiological signals are sensed on the various available channels (possible diagnosis of dual tachycardia, AF + VF) and are generally of greater amplitude on the far-field channel than on the sensing (near-field) channel.

The main preventive measure consists of identifying the emitting source and avoiding the use of certain poorly insulated instruments. Since this patient was monitored remotely, we received an alert the next day and were able to link the sensed episode to the use of a poorly insulated domestic appliance.

Status report

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Ilesto 7 DR-T

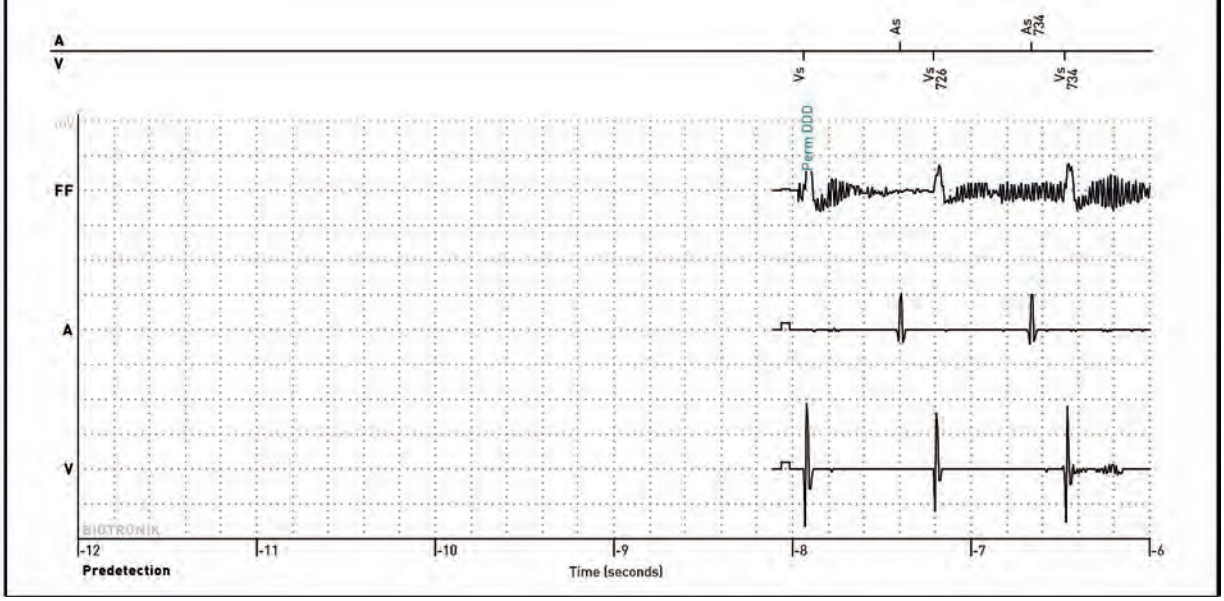
Recordings

Recordings - Episode 743:

General	
Episode number	743
Episode type	VF
Detection	Aug 27, 2016 12:38:20 PM
Termination	Aug 27, 2016 12:38:53 PM
Duration	33s
Device settings no.	22
Detection	
Mean PP at initial detection [ms]	---
Mean RR at initial detection [ms]	380
Onset [%]	84, fulfilled
Stability [ms]	> 247
Redetection	VF: 1

Therapy	
ATP in VT/VF delivered	0
ATP One Shot delivered	NO
Shocks delivered	1
Shocks aborted	1
Maximum energy [J]	40
Termination	
Mean PP at termination [ms]	720
Mean RR at termination [ms]	720
Remark	
none	

IEGM



Status report

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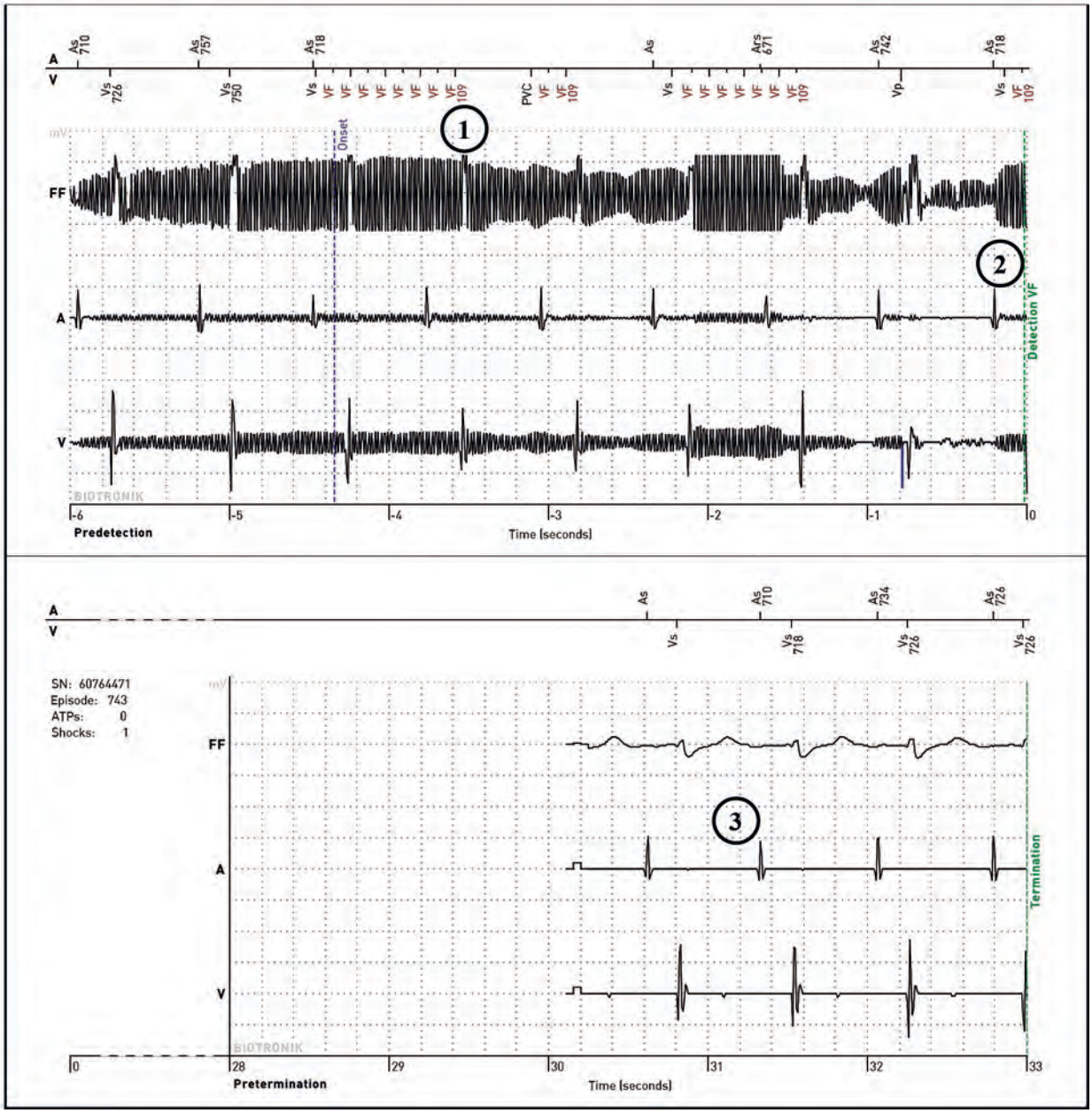
Ilesto 7 DR-T



Tracing 19 ↘ Interference with an electric scalpel

Patient

67-year-old man with ischemic cardiomyopathy implanted with a Lumax 540 DR-T dual-chamber ICD; recording of an episode classified as VF in the device memory.

Telecardiology tracing

① oversensing lasting a few seconds on the 3 channels (far-field, atrial channel, right ventricular channel) of a non-physiological, very rapid, disorganized signal with variable amplitude;

② after repeated oversensing over short periods, the VF counter is filled; no therapy is delivered (charging of the capacitors without delivery of shock);

③ discontinuation of the oversensing.

Comments

This tracing corresponds to an oversensing caused by an electric scalpel during a hip surgery, the ICD not having been deactivated. When an ICD recipient undergoes a surgical intervention, the surgeon must be advised to use the electric scalpel in bipolar mode, for brief durations and to place the grounding plates away from the pulse generator so as to maintain the ICD system outside of the field generated by the electric scalpel. The ICD should be temporarily deactivated in order to completely eliminate the risk of interference, with the patient being monitored with an external defibrillator available nearby if necessary. Two options can be chosen to disable the device: application of a magnet to the pulse generator or deprogramming of the device. The application of a magnet is generally preferred because 1) in case of a occurrence of a true arrhythmia compromising the survival of the patient, the medical team can immediately reactivate the system by removing the magnet (resumption of sensing of tachycardias immediately upon removal of the magnet); 2) absence or delay in the reactivation of therapies are not uncommon when the ICD has been deprogrammed.

Status report

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Lumax 540 DR-T

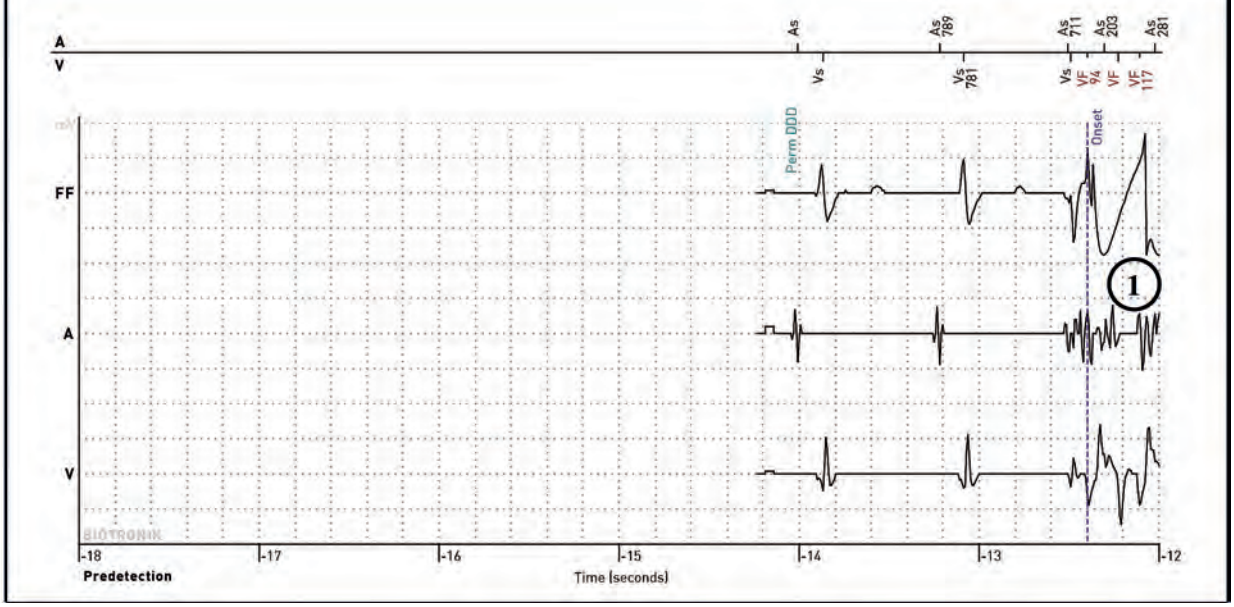
Recordings

Recordings - Episode 147:

General	
Episode number	147
Episode type	VF
Detection	Mar 4, 2014 1:30:49 PM
Termination	Mar 4, 2014 1:31:07 PM
Duration	18s
Device settings no.	3
Detection	
Mean PP at initial detection [ms]	494
Mean RR at initial detection [ms]	480
Onset [%]	84, fulfilled
Stability [ms]	> 247
Redetection	---

Therapy	
ATP in VT/VF delivered	0
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	1
Maximum energy [J]	40
Termination	
Mean PP at termination [ms]	805
Mean RR at termination [ms]	804
Remark	
none	

IEGM



Status report

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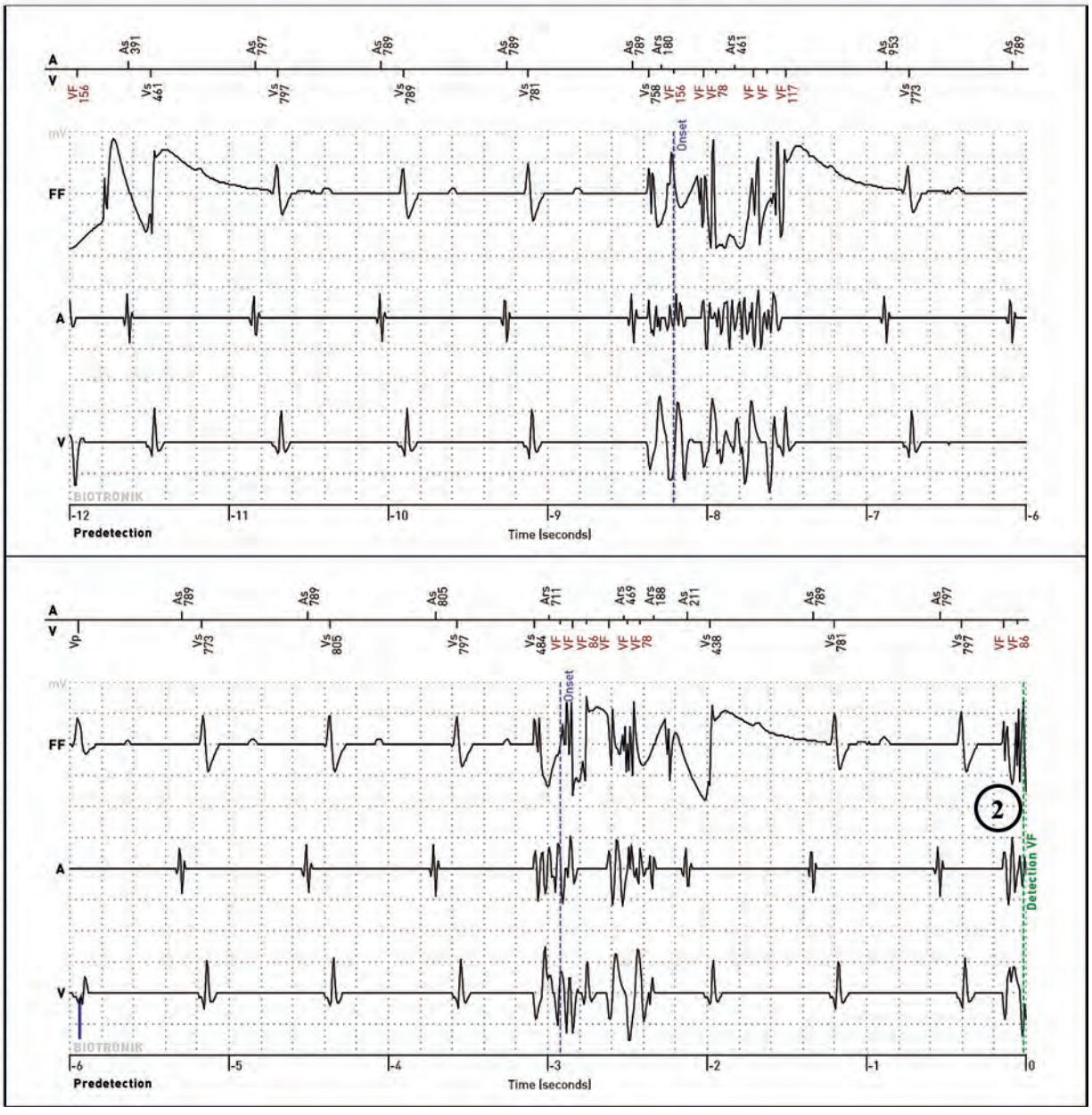
Lumax 540 DR-T



Status report

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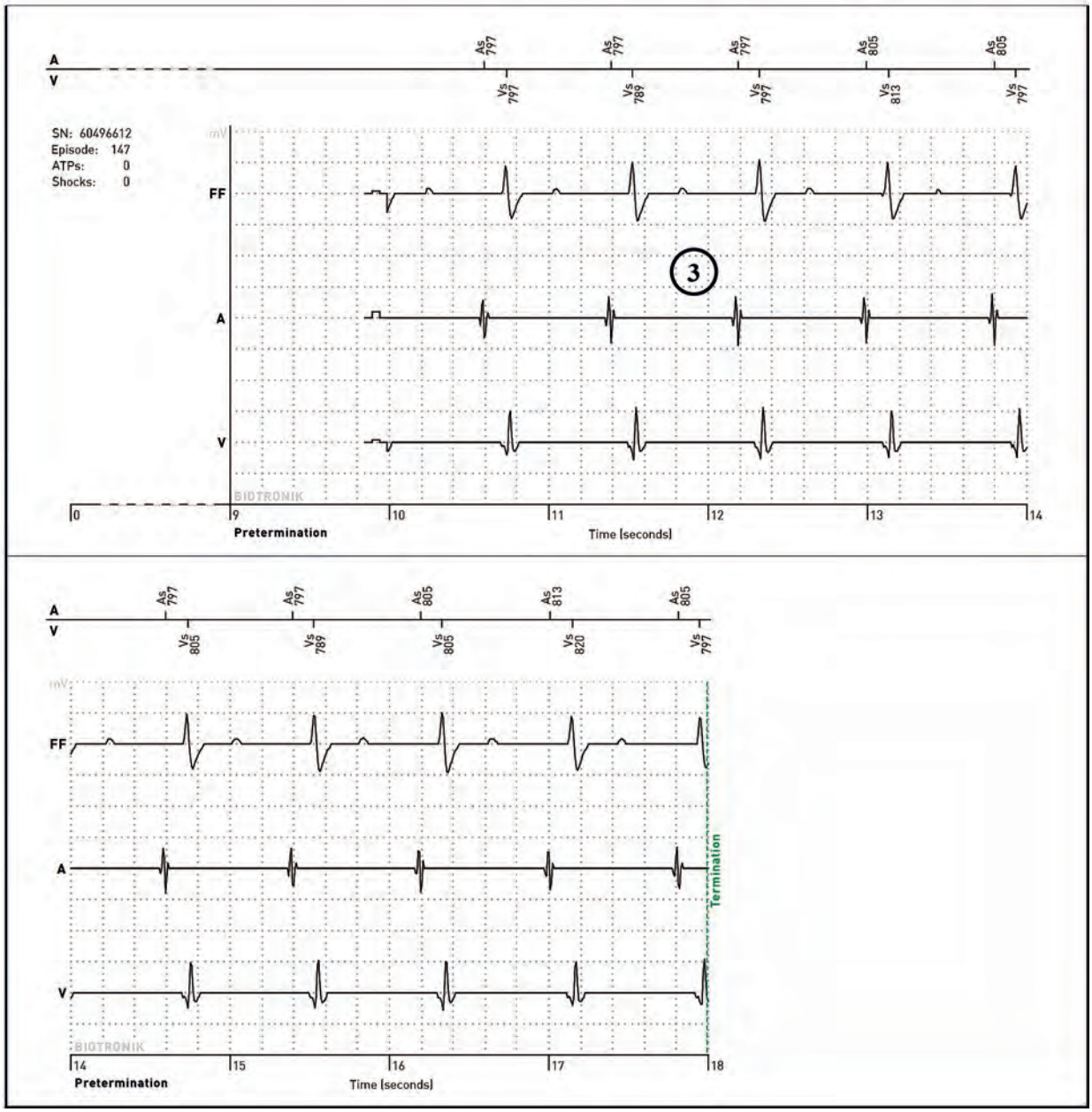
Lumax 540 DR-T



Tracing 20 ↘ Lead dysfunction

Patient

67-year-old man with ischemic cardiomyopathy implanted with a Lumax 540 HF-T triple-chamber ICD; recording of an episode classified as VF in the device memory.

Telecardiology tracing

① the EGM is very evocative of a lead dysfunction with evidence of intervals of disorganized amplitude and frequency in the right ventricular channel at the limit of the programmed blanking period (80 ms);

② prolonged oversensing with signals not related to the QRS complexes;

③ the VF counter is full;

④ charging of the capacitors which is interrupted upon discontinuation of the oversensing.

Comments

This tracing allows demonstrating a characteristic pattern of lead dysfunction with oversensing of rapid, anarchic signals, at the limit of the programmed refractory period. In the early stages of dysfunction, the device memory usually features multiple episodes of non-sustained VT without abnormality of lead measurements. In a second step, a clear break in the different impedance, threshold and right ventricular sensing curves can be observed. In the presence of a suspected lead dysfunction, various exams and measurements must be performed: 1) chest X-ray: radiographic abnormalities are not systematic and a typical pattern of lead fracture is not observed in over 50% of cases; 2) repetitive pacing and defibrillation impedance measurements: the latest generations of ICDs perform periodic (daily) impedance measurements with good correlation between sub-threshold measurements and actual measurements on an effectively-delivered high amplitude shock. The presence of an abnormal value or significant variations in the daily measurements (break in the impedance curve) may reveal a lead dysfunction albeit with moderate sensitivity. Indeed, a significant number of patients present a lead dysfunction revealed by the presence of oversensing episodes without abnormal impedance measurements or abrupt variations in values. A low impedance value is suggestive of an insulation break (current leakage) while a high value is suggestive of a conduction wire break (loss of continuity of the defibrillation circuit); 3) evaluation of the sensing and pacing thresholds: the alteration in standard pacing parameters is often delayed; the sensitivity relative to a decrease in ventricular sensing or an increase in pacing thresholds in predicting lead fractures is therefore very low; 4) analysis of the different endocardial electrograms: the pattern of endocardial EGMs associated with a lead fracture is suggestive but non-specific: intermittent sensing of disorganized, rapid, non-physiological cardiac cycles with possible saturation of the amplifiers (conductor wire break) or low amplitude (sensing of myopotentials due to insulation break). These signals exhibit significant variability in both amplitude and frequency, are intermittent in the cardiac cycle and are most often recorded in the VF zone with values at the limit of the post-ventricular refractory period. They can affect the sensing channel and/or the far-field channel depending on the fracture site and only may become apparent after an electrical shock has been delivered on an actual VF episode.

In this asymptomatic patient, remote monitoring allowed an early diagnosis and thus avoided the occurrence of inappropriate therapies. Early diagnosis also avoids the succession of inappropriate charging of the battery which, even if deviated, are energy-consuming and can greatly reduce the life of the device. Explantation of the lead showed an insulation break with friction between the pulse generator and the damaged portion of the lead.

Status report

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Lumax 540 HF-T

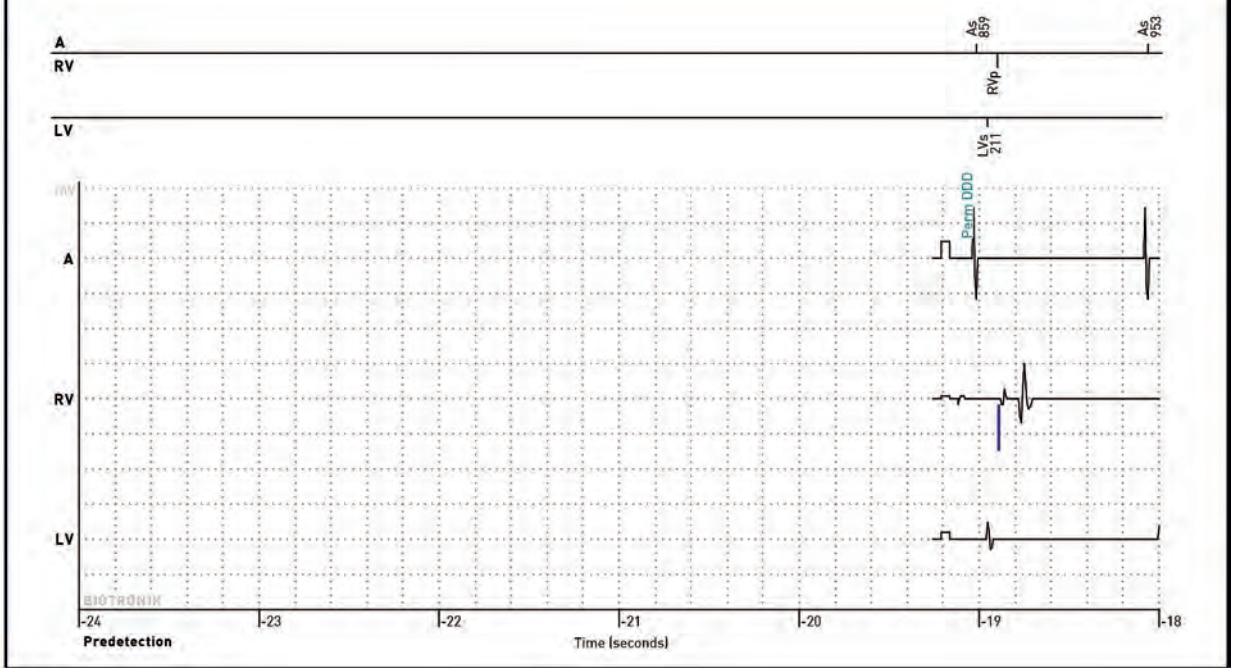
Recordings

Recordings - Episode 12:

General	
Episode number	12
Episode type	VF
Detection	Sep 13, 2013 6:07:01 AM
Termination	Sep 13, 2013 6:07:16 AM
Duration	15s
Device settings no.	24
Detection	
Mean PP at initial detection [ms]	1229
Mean RR at initial detection [ms]	346
Onset [%]	86, fulfilled
Stability [ms]	> 247
Redetection	---

Therapy	
ATP in VT/VF delivered	0
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	1
Maximum energy [J]	40
Termination	
Mean PP at termination [ms]	812
Mean RR at termination [ms]	749
Remark	
none	

IEGM



Status report

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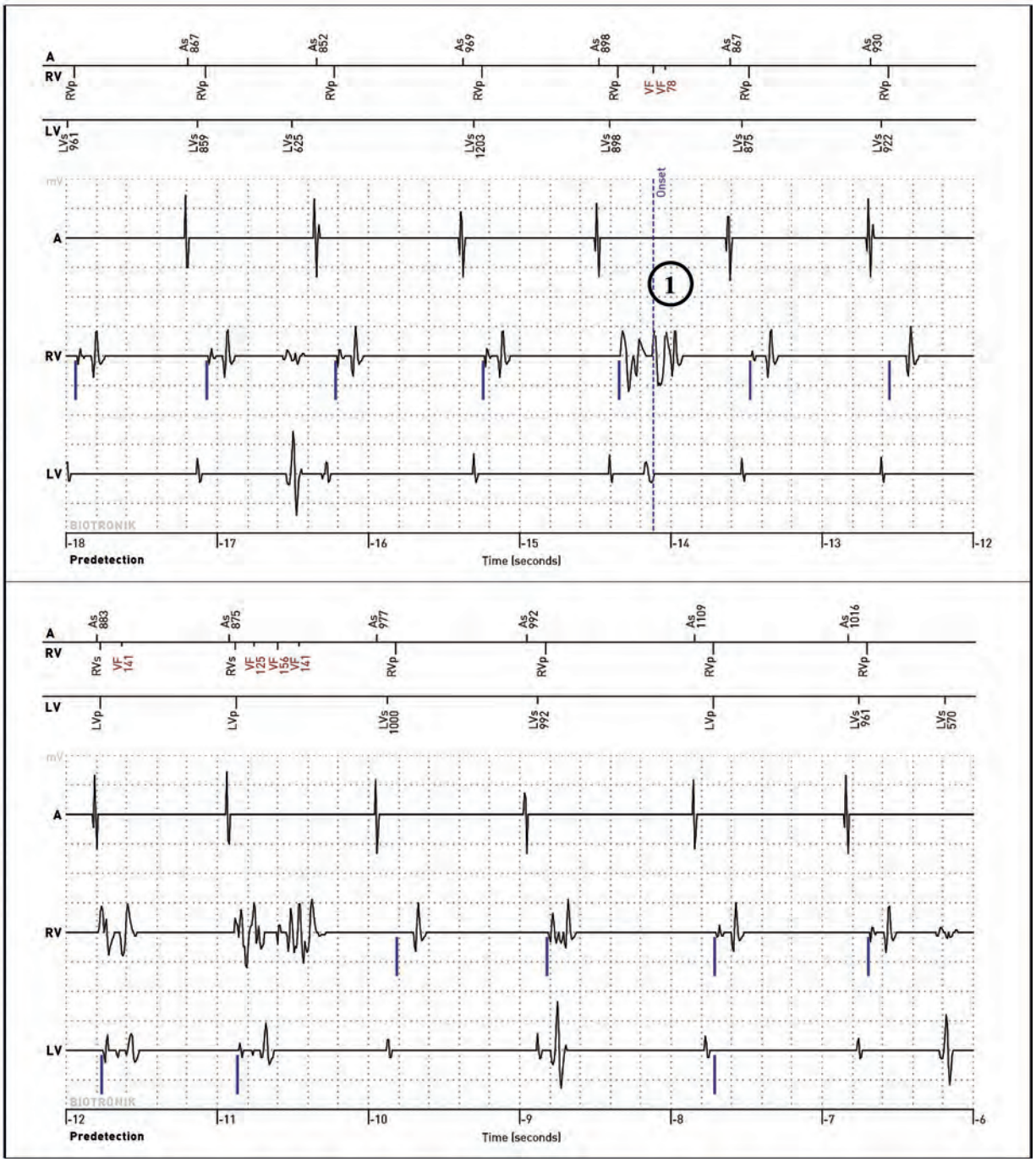
Lumax 540 HF-T



Status report

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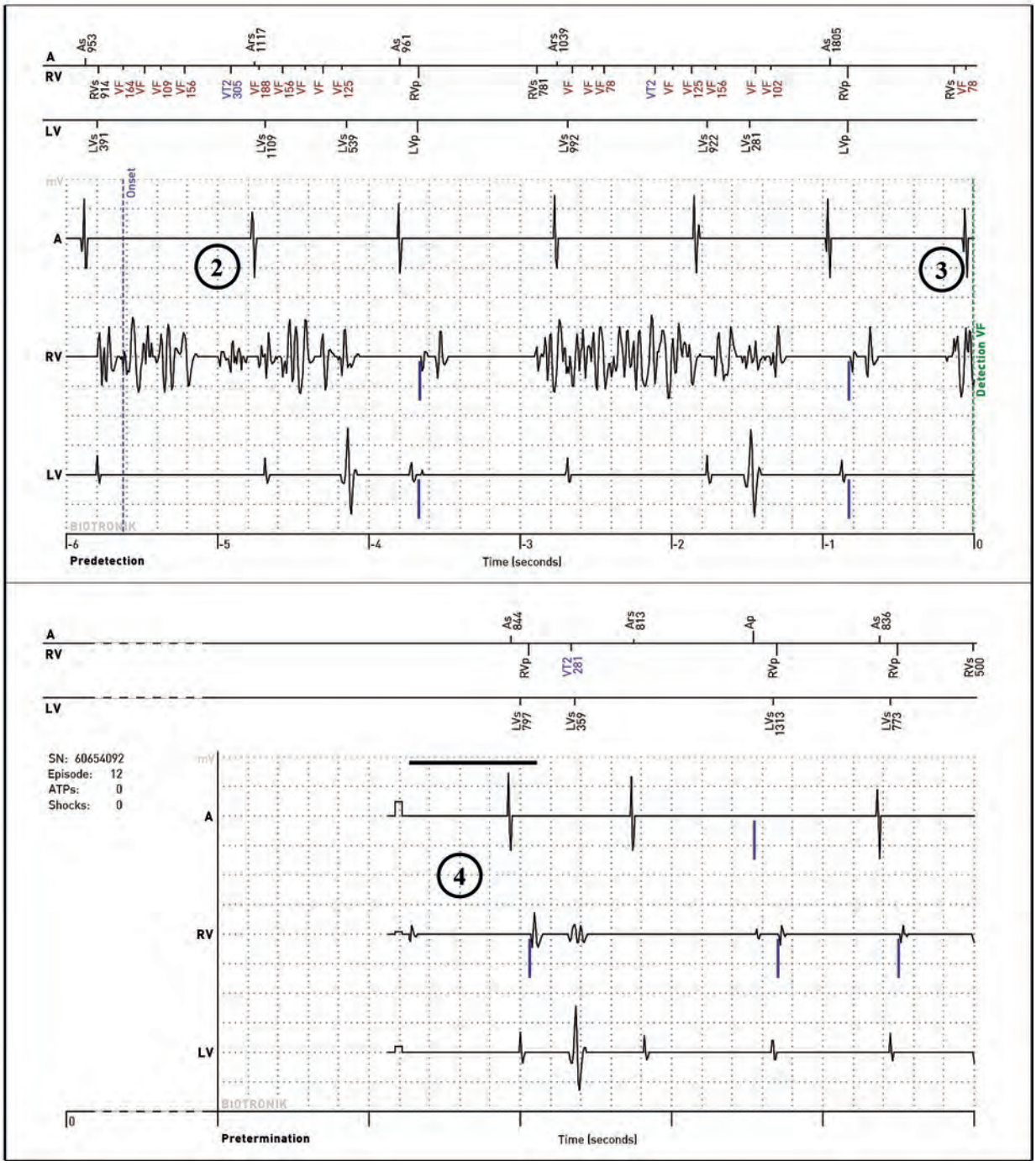
Lumax 540 HF-T



Status report

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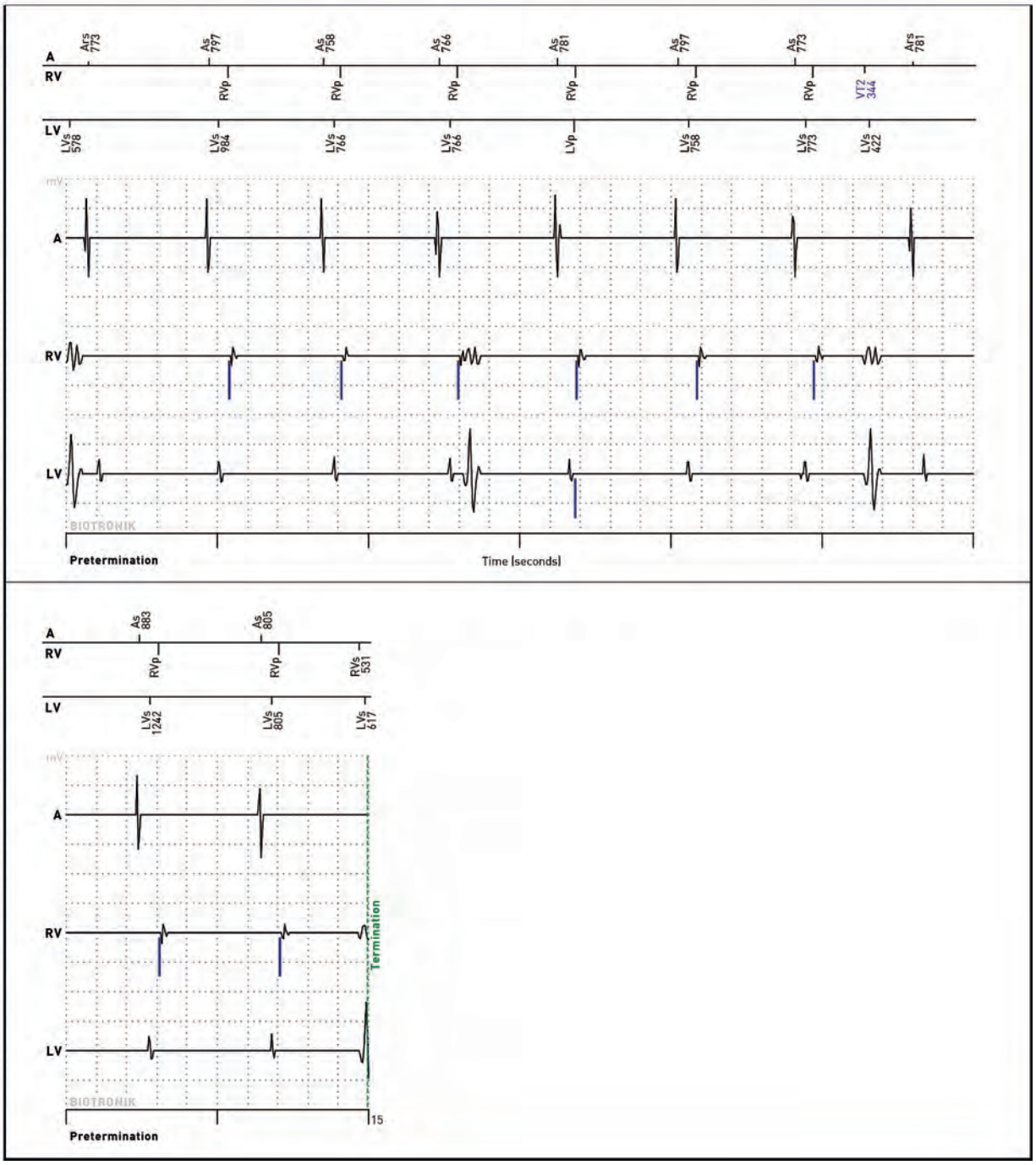
Lumax 540 HF-T



Tracing 21 ↘ Lead fracture

Patient

23-year-old woman implanted with a Lumax DR-T dual-chamber ICD for resuscitated sudden death; event report (yellow color) in the setting of a VF episode.

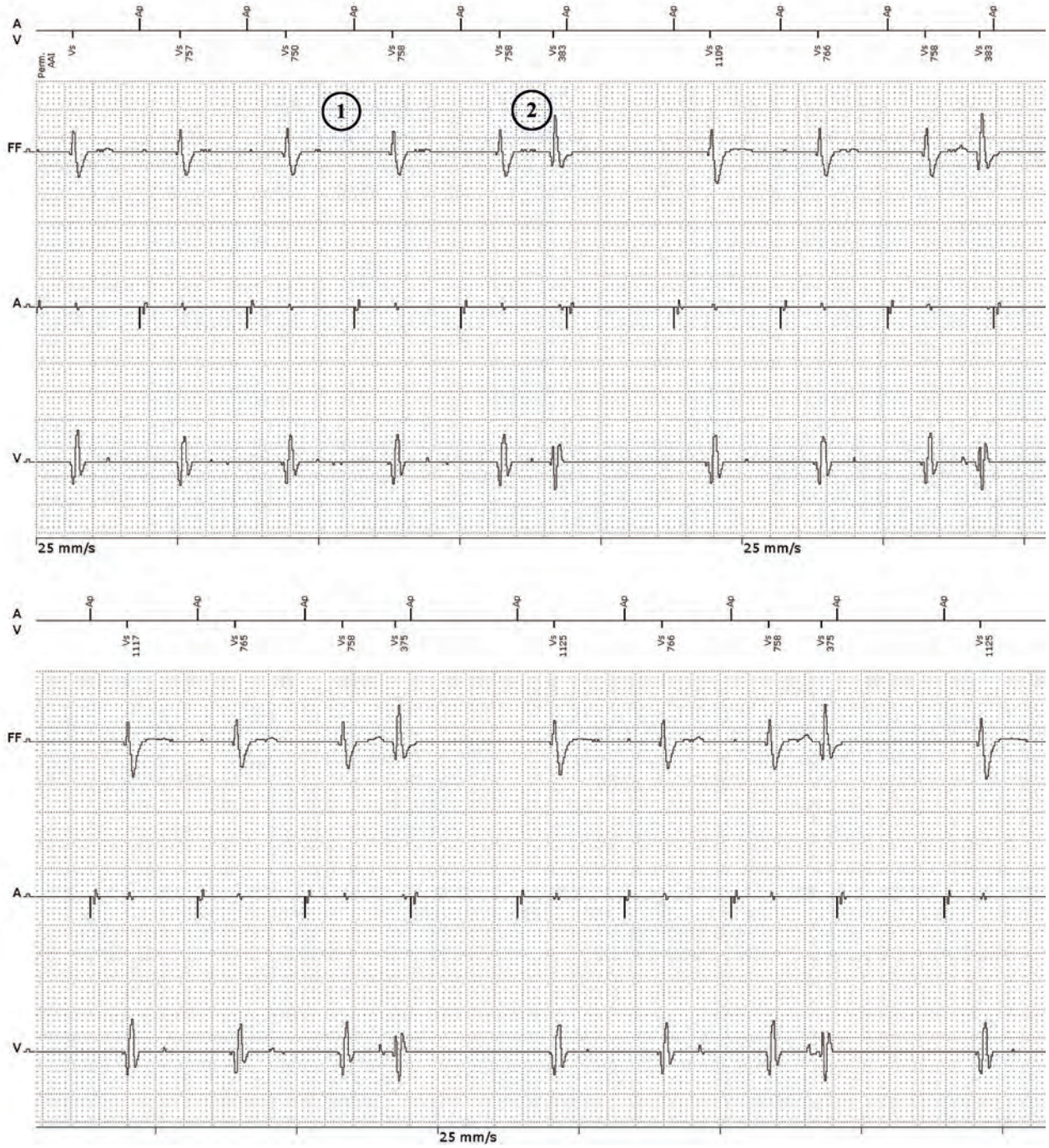
Programming tracing

① paced rhythm in the atrium and sensed in the ventricle;
② PVC;
③ polymorphic ventricular arrhythmia sensed in the VF zone;
④ sensing of a VF episode and charging of the capacitors;
⑤ end of the charge;
⑥ shock delivered (40 joules, 65 Ohms) on the first interval classified as VF following the charge;
⑦ effective shock;
⑧ oversensing of a disorganized high-amplitude ventricular signal initially following the R wave at the level of the sensing channel and the far-field channel;
⑨ increase of the oversensing, the signals no longer in rhythm with the QRS complexes;
⑩ the oversensing is prolonged although the VF redetection counter (24 out of 30 intervals) is never filled.

Comments

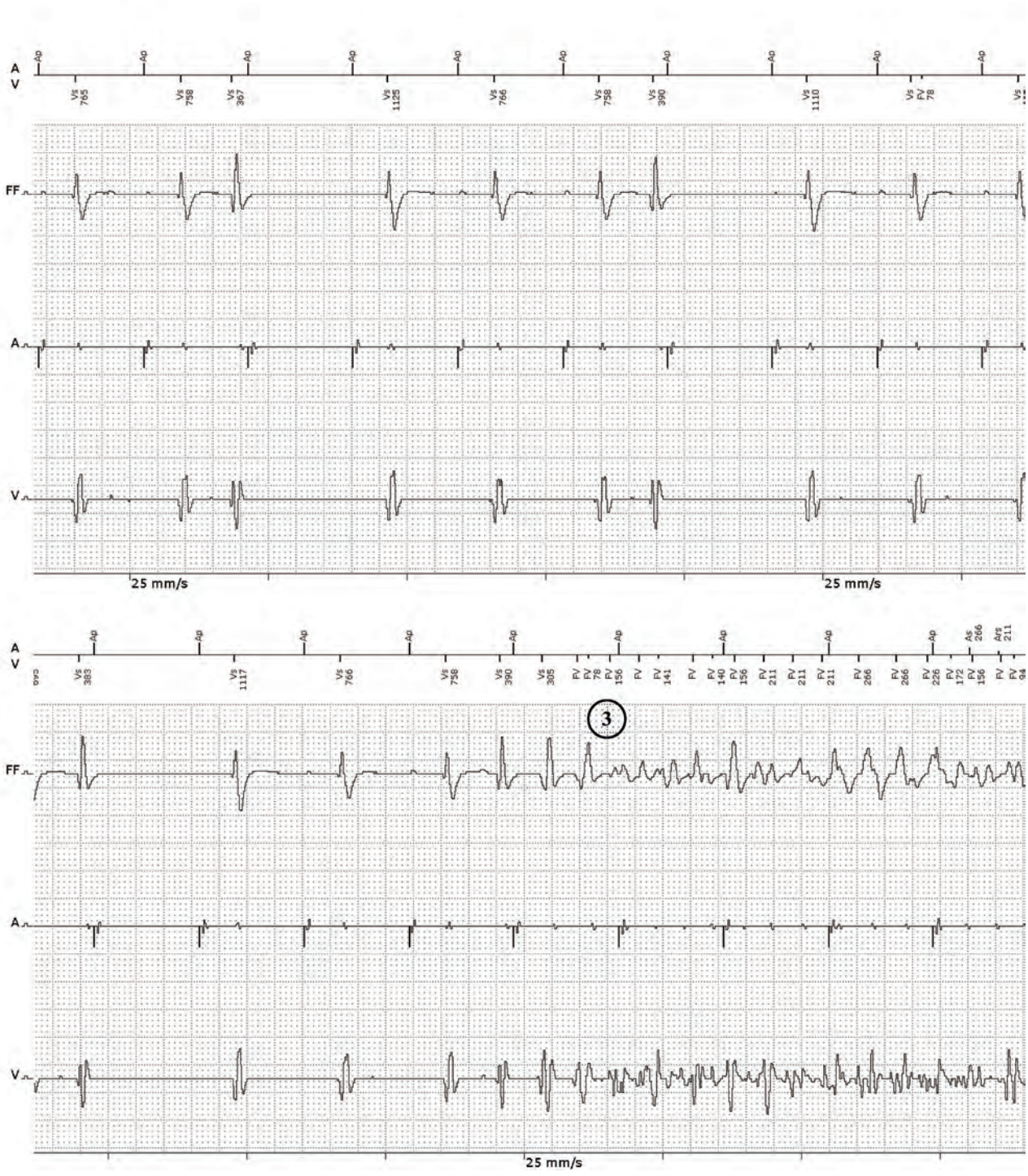
A lead fracture is revealed in this patient as a result of the sensing of a VF episode and the delivery of an electric shock. The delivered electric shock sometimes stretches an already strained and previously weakened lead, thereby favoring its fracture. The first shock delivered on the ventricular arrhythmia episode is effective with a shock impedance within the normal range with no oversensing episode recorded beforehand in the device memory. The pacing impedances were also strictly normal prior to the episode with a clear increase in values as a result of this episode. The association of very short, disorganized intervals and high impedance values is suggestive of a lead fracture. This patient underwent a lead extraction and implantation of a new ipsilateral lead.

PDF: BIOTRONIK - Lumax 340 DR-T



Oversensing

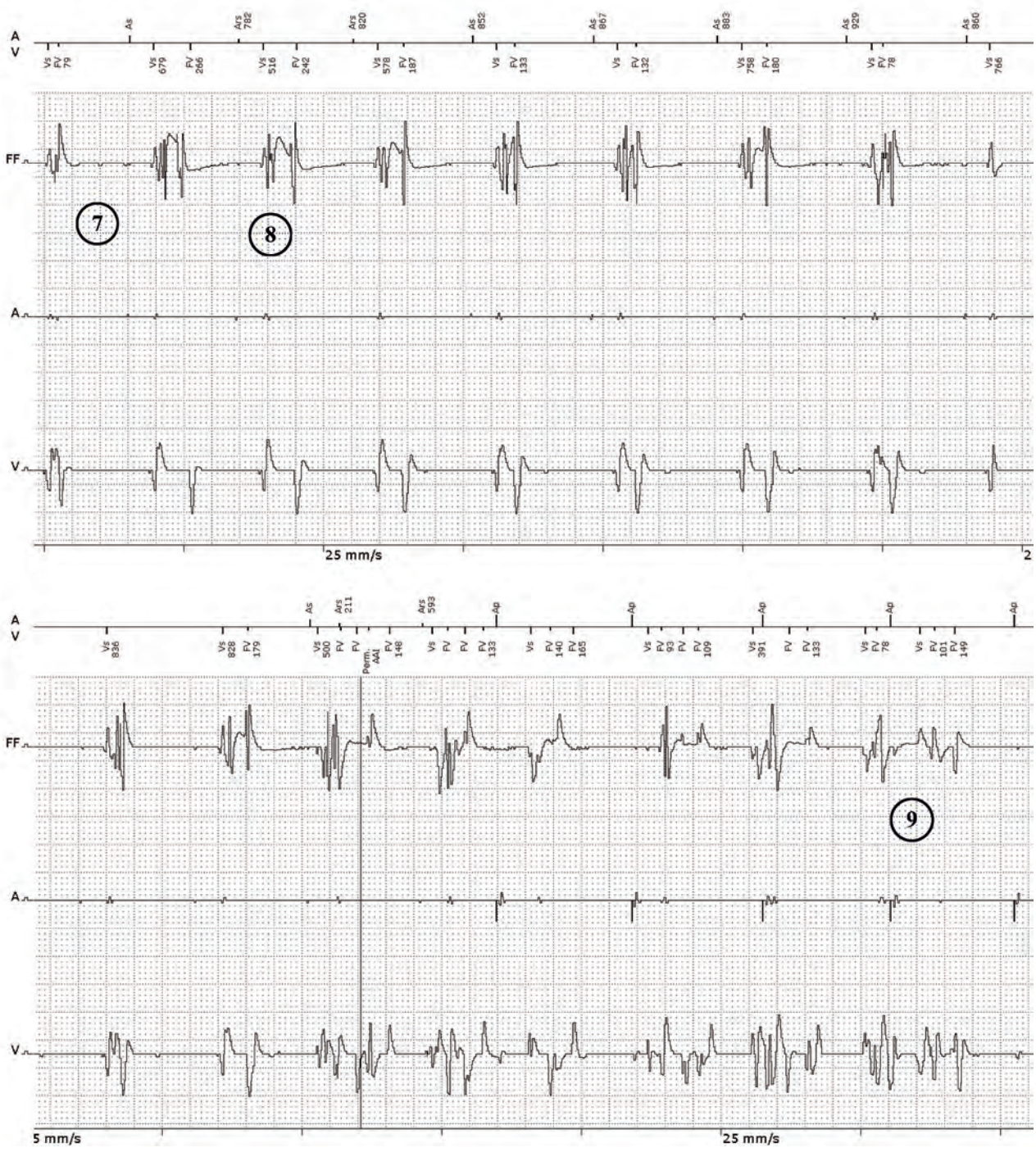
PDF: BIOTRONIK - Lumax 340 DR-T



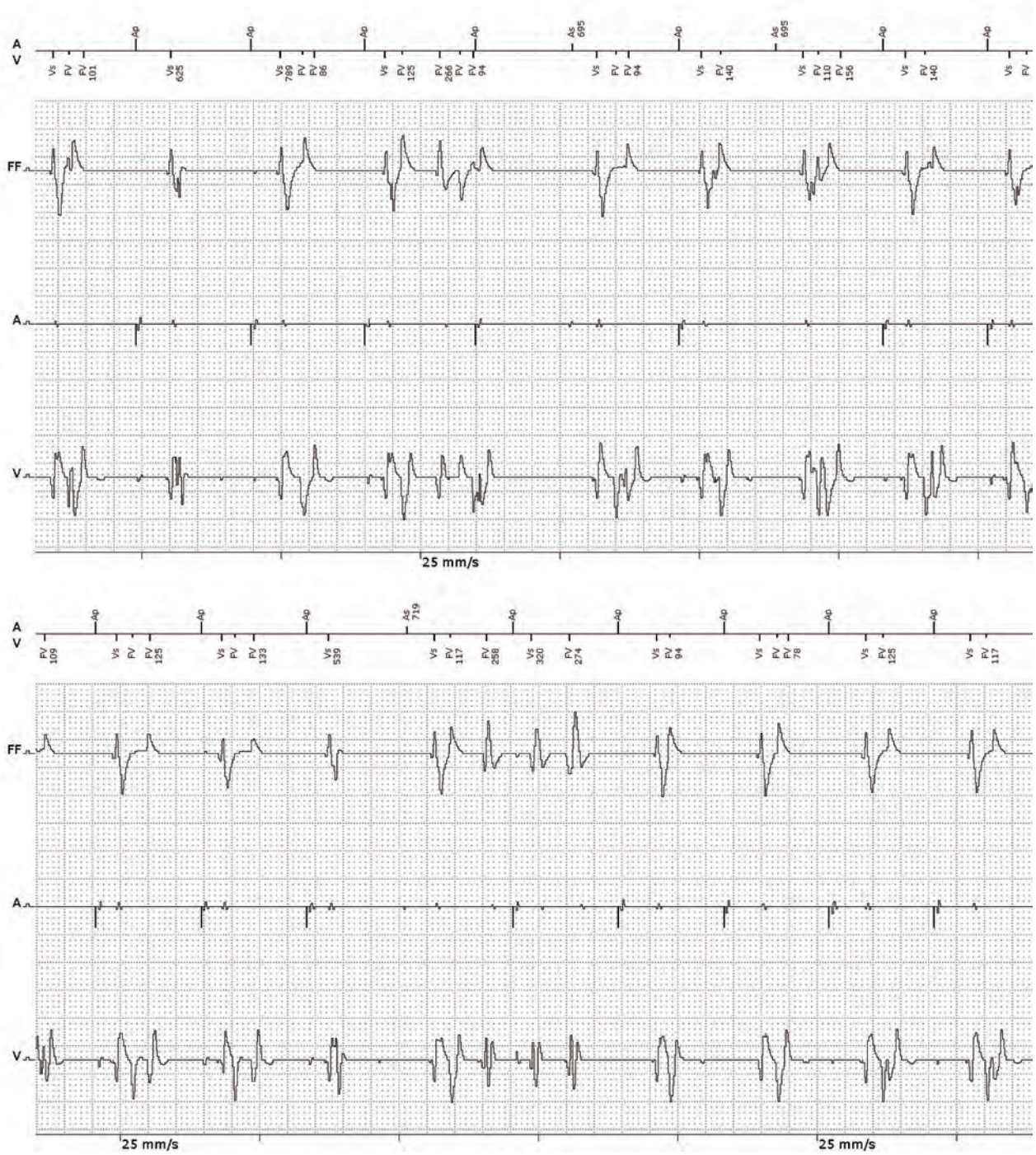
PDF: BIOTRONIK - Lumax 340 DR-T

Oversensing

PDF: BIOTRONIK - Lumax 340 DR-T

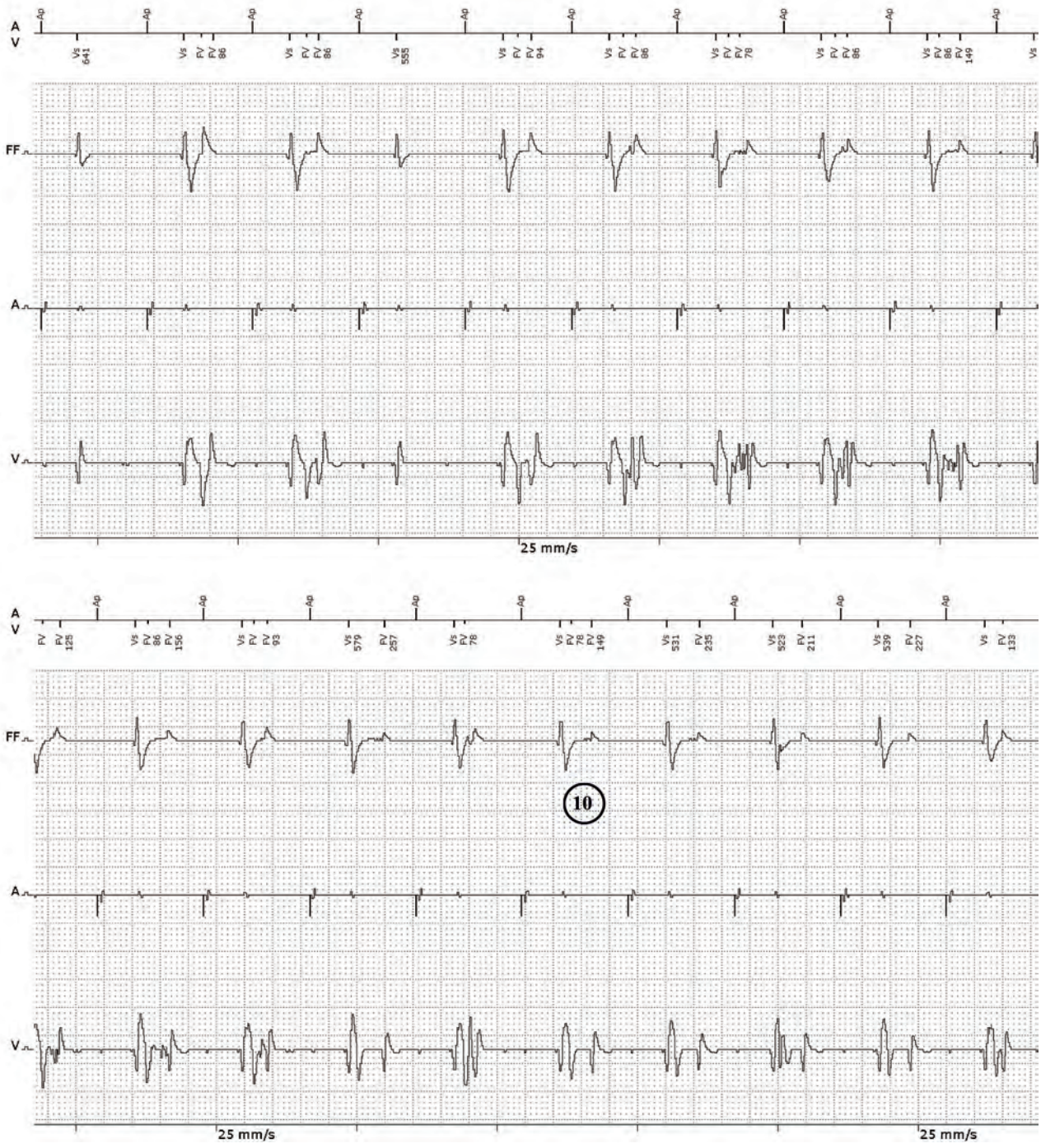


PDF: BIOTRONIK - Lumax 340 DR-T



Oversensing

PDF: BIOTRONIK - Lumax 340 DR-T



Tracing 22 ↘ Lead alert message, out of range shock impedance

Patient

73-year-old woman implanted with a Lumax VR-T DX single-chamber ICD for primary prevention of ischemic cardiomyopathy with ejection fraction of 28%, followed by telecardiology; alert message.

Telemedicine report

Alert message (red color status) for an abnormal out-of-range shock impedance measurement (< 30 Ohms or > 100 Ohms); the shock impedance is measured at 105 ohms; as seen on the curve, this impedance was stable at first (around 80 ohms, which is slightly high but acceptable for a single-coil lead) and then increased relatively rapidly to exceed the threshold of 100 ohms, which justifies an alert message; the right ventricular pacing impedance is within normal limits with a slight increase in its value over the last few days; the quality of the sensing and right ventricular pacing remains perfectly normal without any recent variation in measured values.

Comments

This example illustrates one of the challenges encountered with remote monitoring. Telemedicine allows highlighting this shock impedance value deemed abnormal. It also enables the monitoring of the dynamics of these parameters. In this patient, the value exceeds the programmed limit, prompting the issuing of an alert message. Several options are possible: 1) consider that this high impedance reflects a lead malfunction; the lead being recent, an extraction can easily be envisioned with implantation of a new lead; this option seems nonetheless overly aggressive and probably premature; 2) induce ventricular fibrillation in order to verify the effectiveness of the defibrillation function and to measure the impedance on an effectively delivered shock; 3) continue the monitoring with daily analysis of the shock and pacing impedances, verify both sensing and pacing efficiency, and importantly, perform an analysis of the dynamics of the evolution of the measured values; this latter option was favored in this patient; the shock impedance gradually stabilized at around 120 ohms

Telemedicine allows a close monitoring with daily controls when an abnormal value is detected although not justifying a re-intervention as such.

Quick View - Dec 30, 2012

To: Service TélécØrdiologie

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Name:
Patient ID:
DOB:
Phone: -
Lumax 740 VR-T DX (SN 60639943)
ICD implanted Jul 27, 2012
Last message: Dec 30, 2012
Last clinic follow-up: Nov 6, 2012

Device status	
Status	OK
Battery status	BOL (EOS ERI MOL2 MOL1 BOL)
Battery voltage	3.12 V (Dec 30, 2012)
Charge time	9.6 s for 40 J (Oct 17, 2012 12:59:16 AM)

Findings
Daily shock impedance out of range

Tachy settings	Zone limit	1st ATP	2nd ATP	1st shock	2nd shock	3rd - nth sho.
VT1	370 ms	OFF	OFF	OFF	---	---
VT2	OFF	---	---	---	---	---
VF	280 ms	Burst		40 J	40 J	6 * 40 J

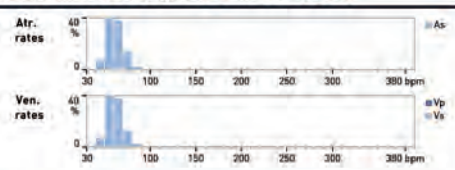
Brady / AF settings	
Mode	VVI
Basic rate / UTR [bpm]	40 / ---
AV delay	---
Mode switching	---

Brady leads	RA lead	RV lead
Pacing impedance [ohm]		680
Pacing threshold [V]		0.5
Sensing ampl. mean / min [mV]	4.8 / 4.3	5.4 / 4.9
Programmed [V@ms]		1.5 AUTO @ 0.40

Shock lead	
Daily shock lead imp. [ohm]	105
Last delivered shock imp. [ohm]	---

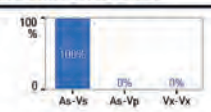
Ven. arrhythmias since Nov 7, 2012	VT1	VT2	VF
Episodes	0	0	0
ATP started / succ.	0 / 0		0 / 0
Shocks started / aborted / succ.	0 / 0 / 0		
Last episode: Periodic IEGM (Dec 13, 2012 1:42:20 AM)			

Rate histogram from Nov 7, 2012 until Dec 13, 2012



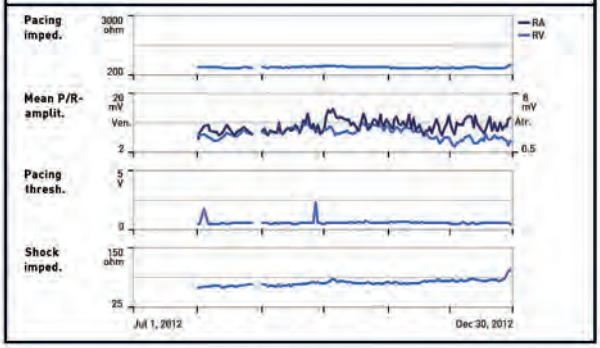
Atrial arrhythmias since Nov 7, 2012	
Atrial burden	0.0% of day
Mean ven. heart rate during atr. burden	---
Atrial arrhythmia ongoing at end of mon. interv.	NO
Atrial monitoring episodes	0
Number of mode switching per day	---
SVT episodes	0

Event episodes since Nov 7, 2012

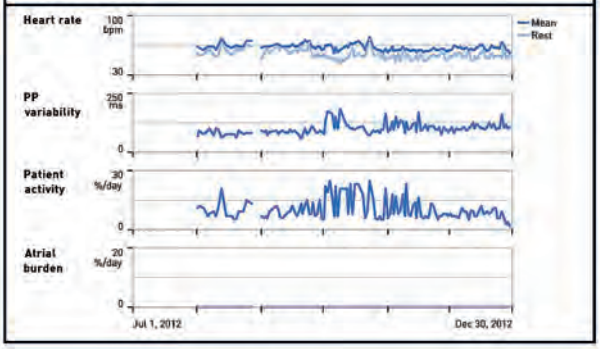


Pacing	
RVp	0%

Lead trends



Long term trends



Status report - Dec 30, 2012

To: Service Télécardiologie

BIOTRONIK excellence for life

Name: DOB: Lumax 740 VR-T DX (SN 60639943) Last message: Dec 30, 2012
Patient ID: Phone: - ICD implanted Jul 27, 2012 Last clinic follow-up: Nov 6, 2012

Status: RED

Status - Summary:

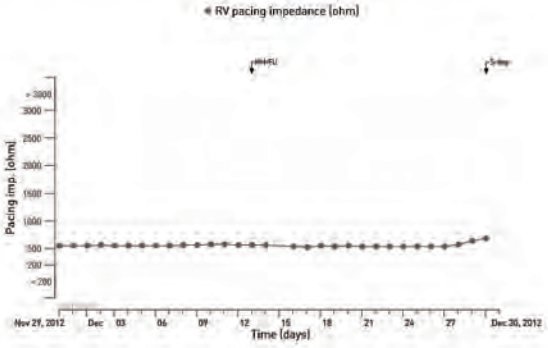
Status summary for patient ID

Category	Status	Finding	Info
Lead	**RED**	**Daily shock impedance out of range (< 30 ohm or > 100 ohm)** Last value 105 ohm measured on Dec 30, 2012 1:43:30 AM	**New.**
Automatic remark:	Follow-up recommended		

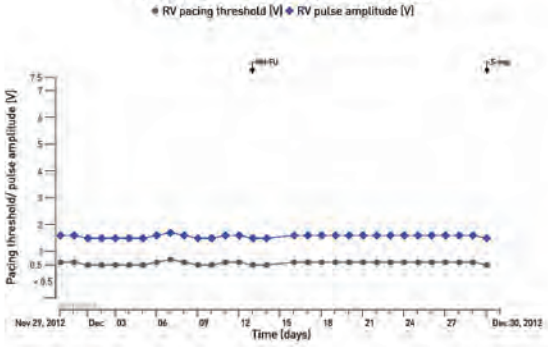
Status - Lead:

RA lead	**24 h**	**Since Nov 7, 2012 1:43:30 AM Mean values, ** Min values**
Sensing amplitude (daily mean) [mV]	4.8	3.9
Sensing amplitude (daily min.) [mV]	4.3	2.2**
RV lead		
Pacing impedance [ohm]	680	554
Pacing threshold [V]	0.5	0.6
Pulse amplitude (AUTO) [V]	1.5	1.6
Sensing amplitude (daily mean) [mV]	5.4	6.5
Sensing amplitude (daily min.) [mV]	4.9	3.3**
Shock lead		
Daily shock lead impedance [ohm]	105	81
Latest available impedance of a delivered shock [ohm]	---	measured on ---

Pacing impedance



RV pacing threshold and pulse amplitude



Status report - Dec 30, 2012

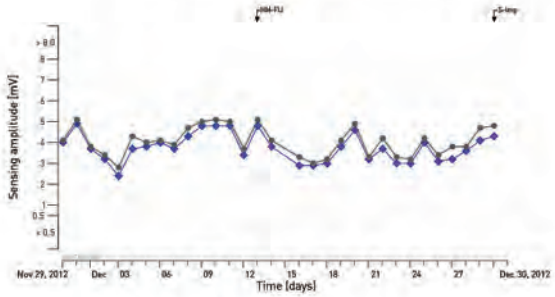
To: Service TélécØrdiologie

BIOTRONIK excellence for life

Name:	DOB:	Lumax 740 VR-T DX (SN 60639943)	Last message: Dec 30, 2012
Patient ID:	Phone: -	ICD implanted Jul 27, 2012	Last clinic follow-up: Nov 6, 2012

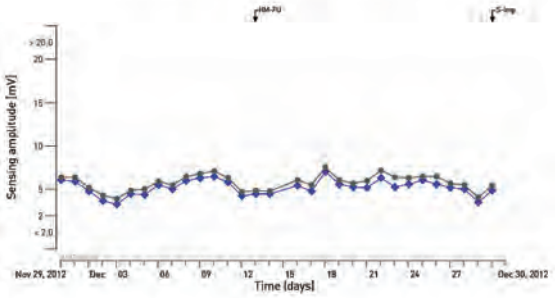
RA sensing amplitude

Mean RA sensing amplitude [mV] Min. RA sensing amplitude [mV]



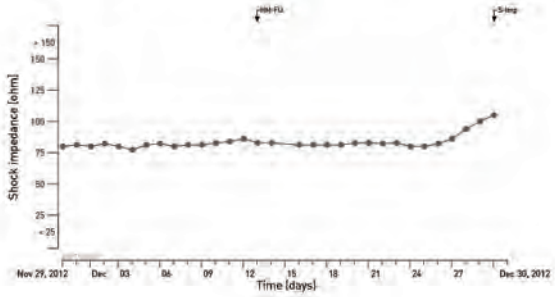
RV sensing amplitude

Mean RV sensing amplitude [mV] Min. RV sensing amplitude [mV]



Shock impedance

Daily shock lead impedance [ohm] Standard shock impedance [ohm]



Implatable Cardioverter Defibrillator - chapter 4

Discrimination

Tracing 23 ↘ VT and single-chamber discrimination

Patient

48-year-old man implanted with a Lumax 540 VR-T single-chamber ICD for ischemic cardiomyopathy with altered ejection fraction; event report (yellow color) in the setting of a classified VT1; programming of a VT1 zone (400-250 ms) with effective discrimination (onset 20%, stability 24 ms).

Telecardiology tracing

3 channels are available: the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the right ventricular sensing channel (RV).

① spontaneous rhythm;

② ventricular doublet;

③ sudden onset tachycardia initially sensed in alternation between the VT1 and VF zones; the calculation of the abrupt onset is carried out over 8 sliding intervals, the average of the last four RR intervals is compared with the average of the ensuing 4 RR intervals; the criterion is fulfilled when the difference between these two averages is greater than the programmed sudden onset value (20% in this patient); in this episode, this criterion is fulfilled since measured at 61%;

④ the morphology criterion is not integrated into the discrimination (old platform); it can be seen however that the morphology is different during the tachycardia relative to the spontaneous rhythm in the sensing channel and the far-field channel;

⑤ stabilization of the tachycardia; the stability criterion is fulfilled (rhythm considered as stable) when, for a ventricular cycle, the difference between the RR interval and one of the 3 preceding RR intervals is less than the programmed value (24 ms in this patient); for this episode, the criterion is fulfilled (the difference between 1 interval and the 3 previous intervals never exceeds this threshold of 24 ms); the 7 ms value found in the table corresponds to the measurement over the last 4 intervals before the classification of the VT;

⑥ classification of the VT1 episode; the average RR for the initial classification corresponds to the average of the 4 intervals preceding the classification;

⑦ a burst is delivered (not displayed);

⑧ termination of the arrhythmia.

Comments

The initial detection of an arrhythmia is based on frequency and duration criteria. The notion of frequency is essential but too simplistic to differentiate ventricular rhythm disorders from supraventricular arrhythmias: when considered individually, the sole management of this criterion yields a sensitivity of 100% but a specificity of only 60%. The improvement in sensing is based on discrimination, which is the ability of an ICD to specify the supraventricular or ventricular origin of a tachycardia episode based on the characteristics of the arrhythmia such as the stability of the RR intervals, the onset mode, the state of the atrium-ventricle (AV) association, all of which are programmed separately or in combination. Discrimination algorithms are only used in VT zones where the sensing of an episode must be confirmed by the VT/SVT discriminators in order for the programmed therapies to be delivered. In the VF zone, the safety criterion prevails and the sensing of a high ventricular rate entering the « sensed VF » zone by the ICD triggers the programmed therapies without the episode being « filtered » by the discrimination algorithms. Discrimination algorithms should only be programmed in patients who are likely to have supraventricular tachycardia and should therefore be deactivated in patients with complete and permanent atrioventricular block.

A single-chamber ICD cannot analyze the atrial rate. Up until the very latest generation of Biotronik™ single-chamber devices, discriminating the origin of the arrhythmias was based on the analysis of the onset

(sudden or progressive) of the tachycardia and on the stability analysis of the rhythm (stable or unstable). None of these 2 parameters allows a perfect discrimination of all tachycardias. Specificity improves when the latter are associated. Depending on the setting, each parameter can be rendered more or less sensitive and more or less specific. In this example, the sudden onset and the regularity of the rhythm are suggestive of VT. Similarly, the variation in the morphology of the ventriculograms (not integrated in the discrimination algorithm of the device) is also suggestive of a VT.

The sudden onset criterion prevents the treatment of tachycardias with a progressive acceleration while enabling the discrimination of sinus tachycardias. It is based on the principle that a sinus tachycardia accelerates progressively as opposed to a ventricular tachycardia which begins suddenly. On the other hand, this parameter does not allow the discrimination of atrial fibrillation or flutter from ventricular tachycardia. To search for the presence of a sudden onset, the average of the last four RR intervals is compared with the average of the next 4 RR intervals. The calculation is therefore carried out over 8 sliding intervals. The criterion is fulfilled when the difference between these two averages is greater than the programmed « sudden onset » value. The programmed default value is 20%. When the sudden onset criterion is verified, it remains valid for the entire episode including during redetection.

The stability criterion theoretically allows discriminating between atrial fibrillation (usually irregular) and ventricular tachycardia (usually regular). On the other hand, this parameter does not discriminate sinus tachycardia, atrial tachycardia or atrial flutter, from ventricular tachycardia. The stability criterion is fulfilled when, for a ventricular cycle, the difference between the RR interval and one of the 3 preceding RR intervals is less than the programmed value: the rhythm is considered as stable. The default value is 24 ms. The stability value can be programmed differentially in the VT1 and VT2 zones. The stability criterion is used during the detection and redetection phases.

Status report - Oct 11, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

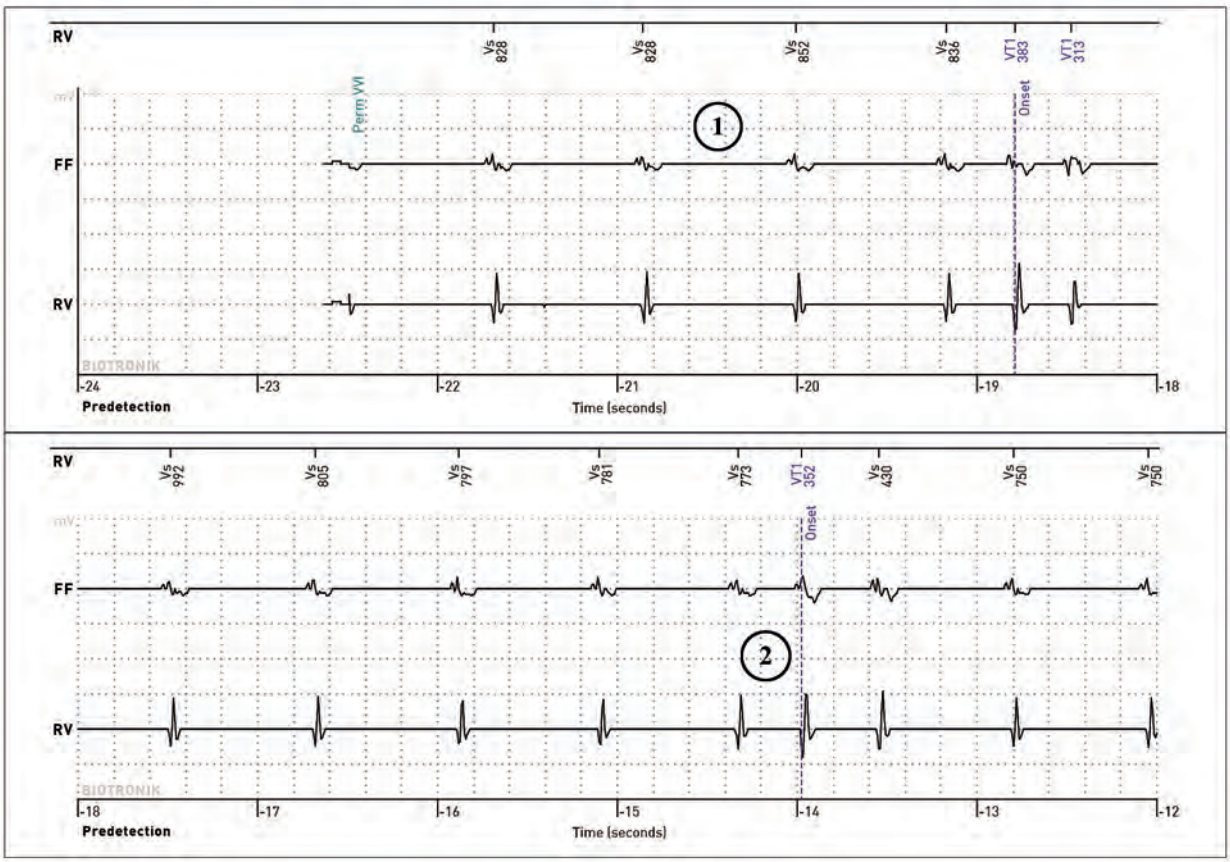
Name:	DOB:	Lumax 540 VR-T (SN 60467517)	Last message: Oct 11, 2013
Patient ID:	Phone: -	ICD implanted Jun 14, 2010	Last clinic follow-up: Feb 7, 2013

Recordings

Recordings - Episode 33:

General	
Episode number	33
Episode type	VT1
Detection	Nov 19, 2012 4:29:31 AM
Termination	Nov 19, 2012 4:29:43 AM
Duration	12s
Device settings no.	9
Detection	
Mean RR at initial detection [ms]	277
Onset [%]	61, fulfilled
Stability [ms]	7
Redetection	---

Therapy	
ATP in VT/VF delivered	1
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	0
Maximum energy [J]	---
Termination	
Mean RR at termination [ms]	861
Remark	
none	

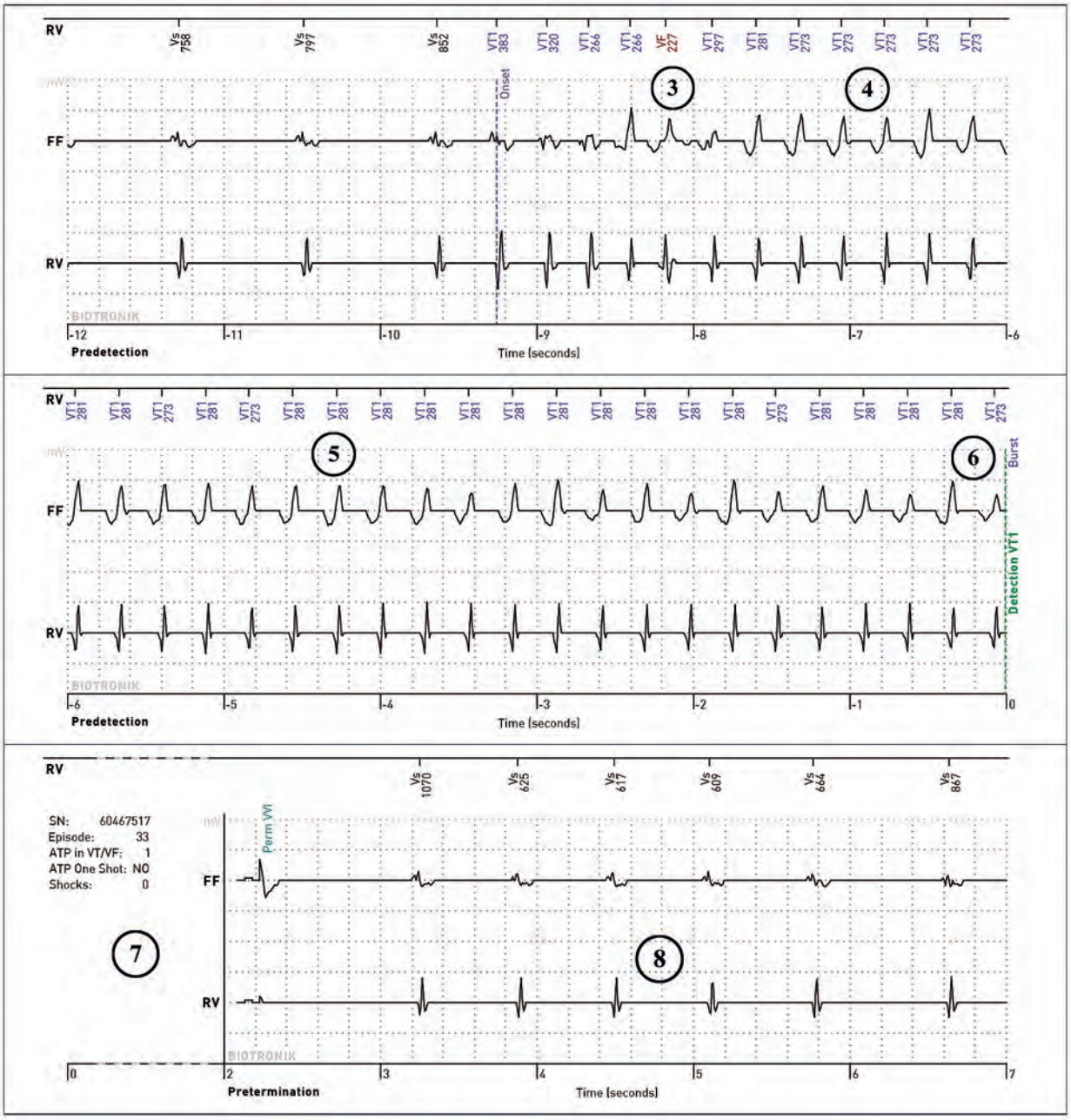


Status report - Oct 11, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

Name:	DOB:	Lumax 540 VR-T (SN 60467517)	Last message: Oct 11, 2013
Patient ID:	Phone: -	ICD implanted Jun 14, 2010	Last clinic follow-up: Feb 7, 2013

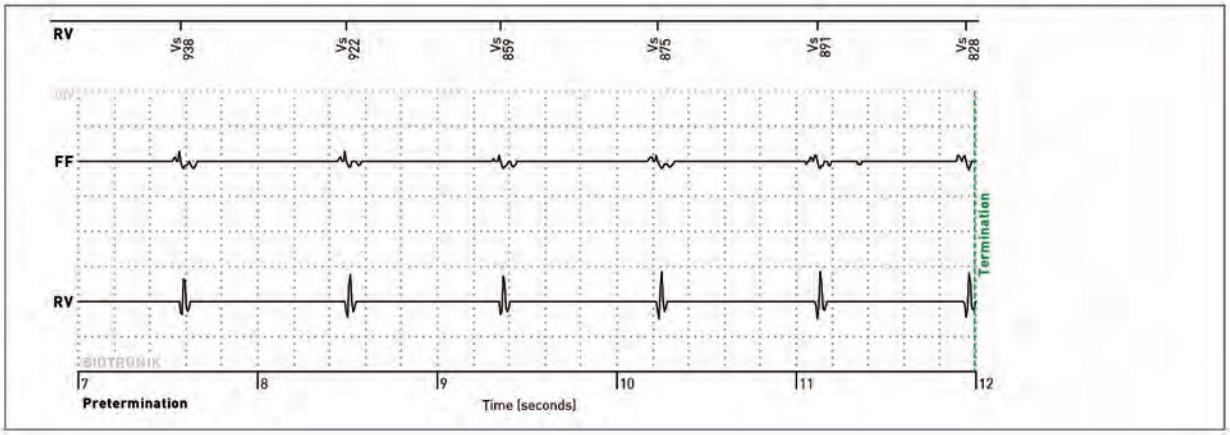


Status report - Oct 11, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

Name:	DOB:	Lumax 540 VR-T (SN 60467517)	Last message: Oct 11, 2013
Patient ID:	Phone: -	ICD implanted Jun 14, 2010	Last clinic follow-up: Feb 7, 2013



Tracing 24 ↘ Atrial tachycardia and single-chamber discrimination

Patient

76-year-old man implanted with a Lumax 540 VR-T single-chamber ICD for dilated cardiomyopathy with ejection fraction of 25%; event report (yellow color) in the setting of a classified VT1; programming of a VT1 zone (350-290 ms) with effective discrimination (onset 20%, stability 24 ms).

Telecardiology tracing

3 channels are available: the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the right ventricular sensing channel (RV).

① spontaneous rhythm with probable sinus tachycardia;

② sudden onset tachycardia detected in the VT1 zone; on this episode, the sudden onset criterion is fulfilled since measured at 38% (> threshold of 20%);

③ the morphology criterion is not integrated in the discrimination; it can be seen however that the morphology is the same during the tachycardia and during the slow spontaneous rhythm on the sensing channel and on the far-field channel;

④ the tachycardia is stable and the stability criterion is fulfilled (8 ms);

⑤ classification of the VT1 episode in the presence of a sudden onset and a steady rhythm;

⑥ a burst is delivered (visualization of the last 2 beats);

⑦ effective burst and termination of the arrhythmia.

Comments

This tracing illustrates the challenges in the discrimination of an atrial tachycardia or flutter with a single-chamber ICD. Typically, during an atrial tachycardia or a flutter, as in the case of a VT, there is a sudden onset and a stable rhythm. In this patient, the morphology of the signal (not integrated in the discrimination algorithm for this platform) is clearly suggestive of a supraventricular origin (identical morphology). The antitachycardia pacing sequence may therefore be considered inappropriate. It nevertheless allowed terminating the arrhythmia. The termination of an atrial tachycardia stemming from a ventricular antitachycardia pacing is relatively common; the termination of the tachycardia by ATP cannot therefore be considered as an element suggestive of a ventricular origin of the tachycardia. It was therefore chosen for this patient not to modify the programming (no possibility in terms of discrimination but possibility of reducing the intervention zones) despite the inappropriate nature of the therapies.

Status report - Oct 11, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

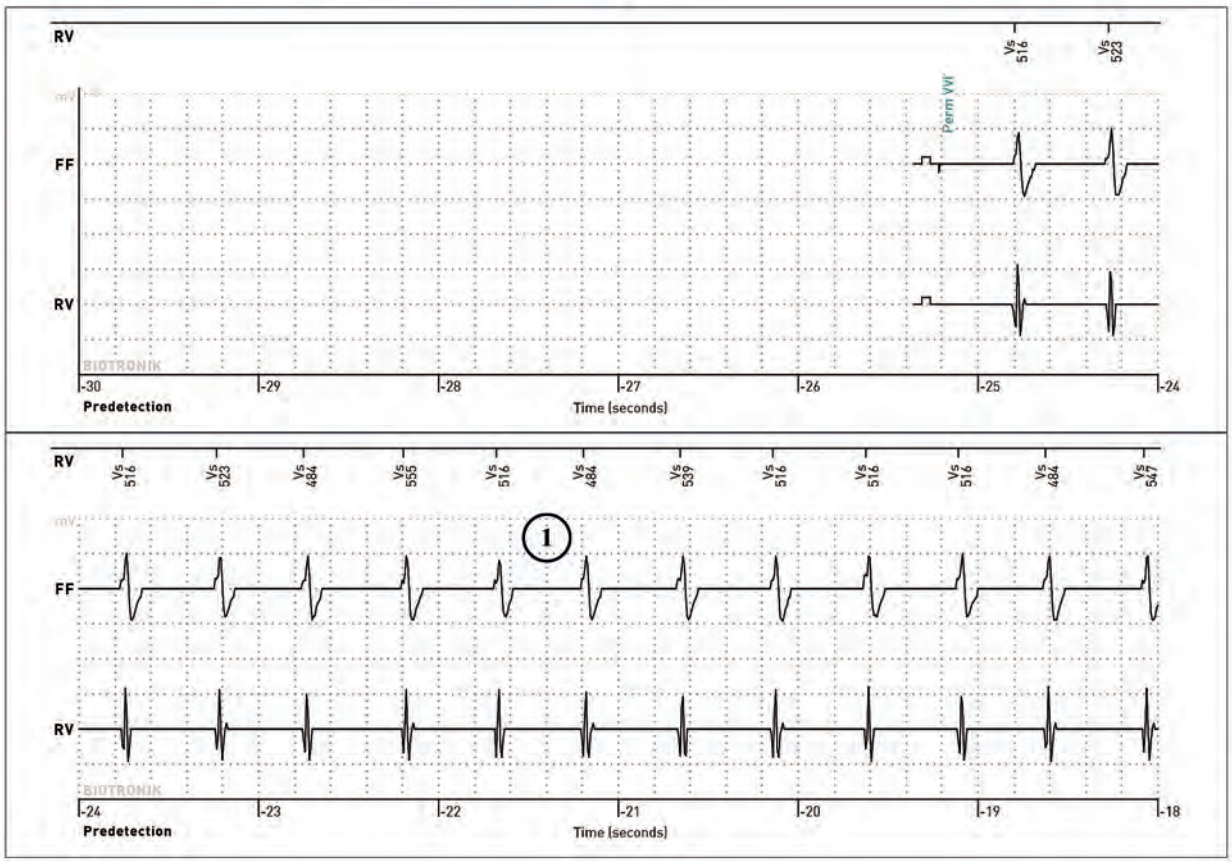
Name:	DOB:	Lumax 540 VR-T (SN 60640442)	Last message: Oct 11, 2013
Patient ID:	Phone:	ICD implanted Mar 18, 1936	Last clinic follow-up: Jun 10, 2013

Recordings

Recordings - Episode 6:

General	
Episode number	6
Episode type	VT1
Detection	Feb 28, 2013 4:34:01 PM
Termination	Feb 28, 2013 4:34:11 PM
Duration	10s
Device settings no.	4
Detection	
Mean RR at initial detection [ms]	329
Onset [%]	38, fulfilled
Stability [ms]	8
Redetection	---

Therapy	
ATP in VT/VF delivered	1
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	0
Maximum energy [J]	---
Termination	
Mean RR at termination [ms]	530
Remark	
none	

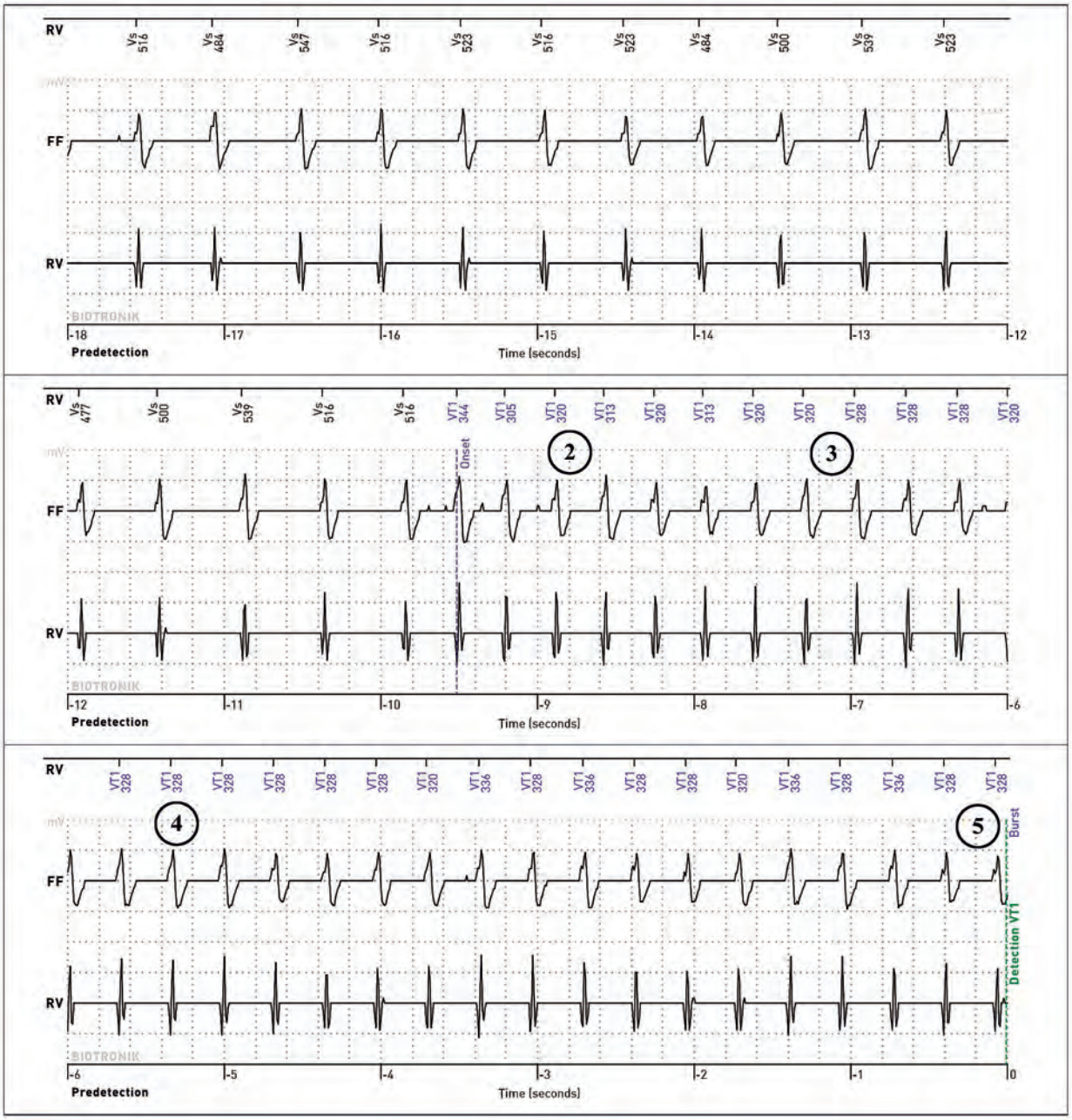


Status report - Oct 11, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

Name:	DOB:	Lumax 540 VR-T (SN 60640442)	Last message: Oct 11, 2013
Patient ID:	Phone:	ICD implanted Mar 18, 1936	Last clinic follow-up: Jun 10, 2013

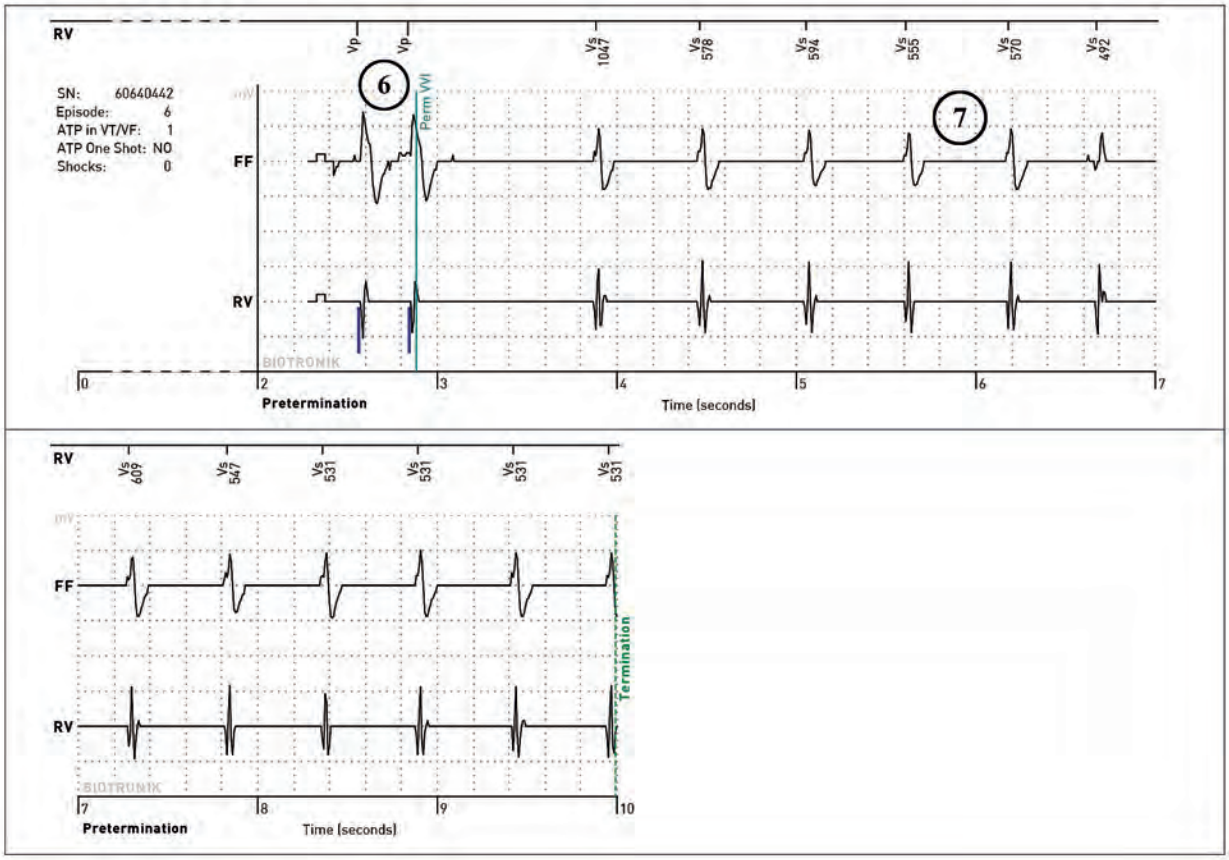


Status report - Oct 11, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

Name:	DOB:	Lumax 540 VR-T (SN 60640442)	Last message: Oct 11, 2013
Patient ID:	Phone:	ICD implanted Mar 18, 1936	Last clinic follow-up: Jun 10, 2013



Tracing 25 ↘ Atrial tachycardia and new single-chamber discrimination

Patient

Patient implanted with an Itrevia 5 VR single-chamber ICD; programming of 3 discrimination parameters (sudden onset 20%, stability 24 ms, MorphMatch ON); episode diagnosed as SVT in the device memory.

Tracing

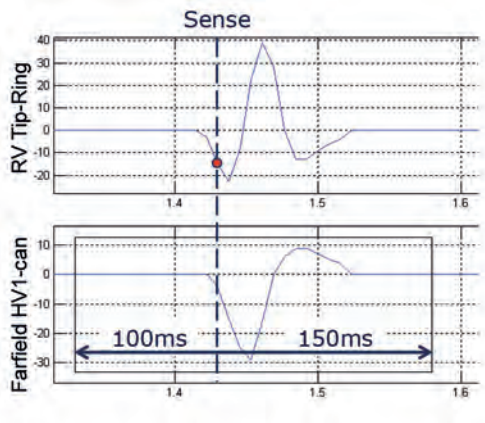
① the diagnosis of SVT was made owing to the morphology analysis (MorphMatch);
② sinus rhythm;
③ onset of tachycardia with sudden onset and stable rhythm but with a morphology very similar to that in sinus rhythm;
④ the VT counter is full, however the device diagnoses a SVT based on the analysis of the morphology;
⑤ spontaneous termination.

Comments

This tracing illustrates the value of a discrimination based on the morphological analysis that is now available on the latest Biotronik™ ICD platforms. This patient had episodes of atrial tachycardia (sudden onset + stable rhythm) that would have been poorly discriminated with the older devices.

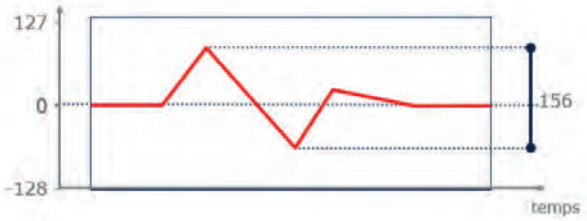
The operation of this new discrimination parameter can be divided into several key points:

1) the analysis of the morphology of the QRS complexes is performed during a calculation window of 250 ms; the right ventricular bipolar sensing channel triggers the analysis since the window begins 100 ms prior to the sensing of a spontaneous QRS complex and ends 150 ms thereafter;

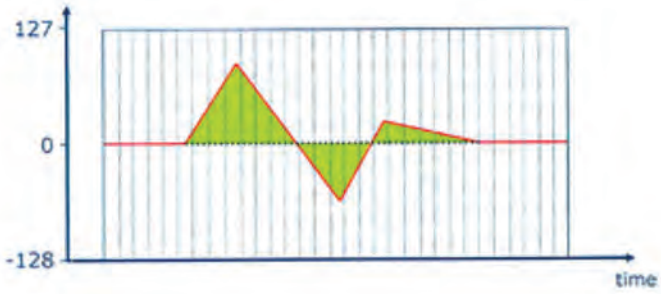


2) while the bipolar channel serves as a trigger for the analysis, the morphology calculation is subsequently exclusively performed from the far-field channel (RV coil - pulse generator) with measurement of the following 3 morphological characteristics:

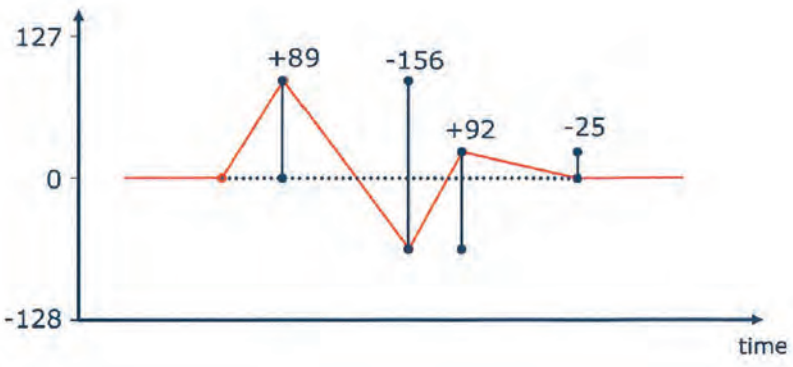
- maximum amplitude



- area



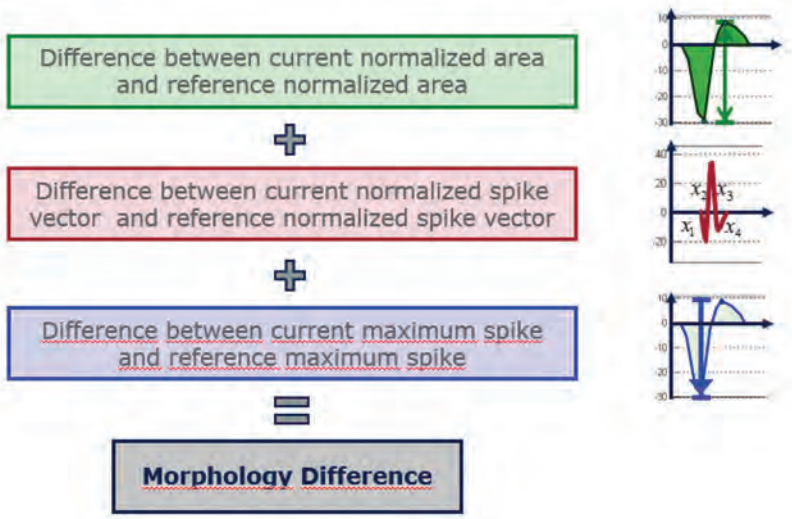
- vector



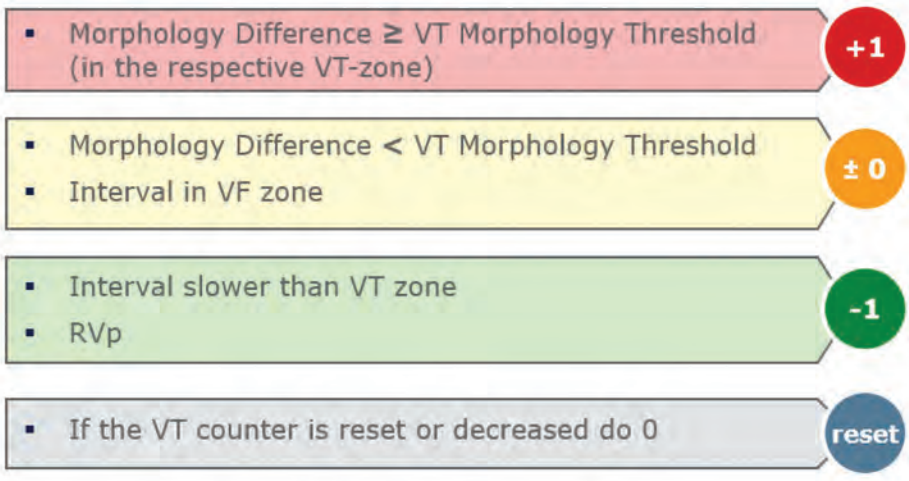
$$\vec{X} = \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{pmatrix} \cdot \frac{1}{X_{\max}}$$

3) a reference signal, which will be subsequently compared to the tachycardia signals, is determined from the signals classified as VS with a rate under 100 beats/minute; at least 32 QRS complexes are needed; this reference signal is reset to zero every night and after each delivered therapy; the variance of the average QRS complex is also calculated from all the spontaneous complexes of lower frequency than the lowest VT zone;

4) the analysis of the morphology is performed in the VT zone but not in the VF zone; it should be noted that this analysis cannot be performed on complexes classified as VT with a rate higher than 230 beats/minute (if the VF zone is programmed very high), the 250 ms analysis window limiting the analysis capacity for very fast rhythms; the comparison with the reference signal is based on the sum of the differences between the three morphological characteristics:

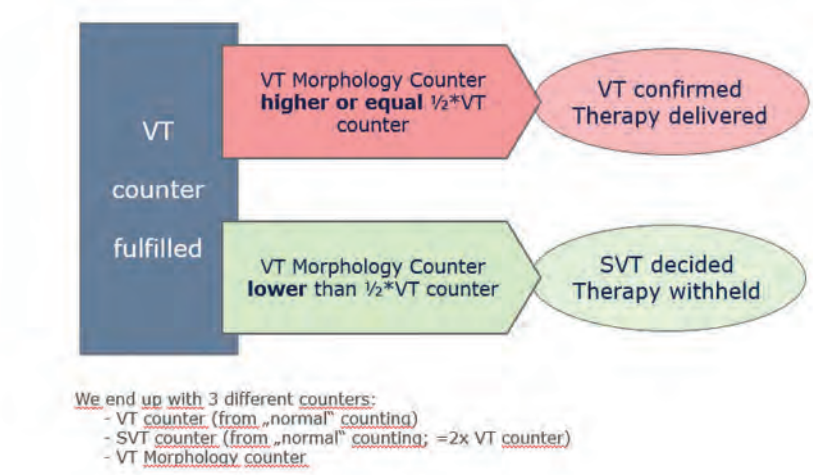


5) according to the analysis of the morphology, the up and down counter of the VT zone is more or less incremented;



6) when the VT counter is full, the device uses its VT morphology counter to make a decision:

Discrimination



We end up with 3 different counters:
- VT counter (from „normal" counting)
- SVT counter (from „normal" counting; =2x VT counter)
- VT Morphology counter

7) the morphology (MorphMatch) parameter is available on all new devices (single-, dual- or triple-chamber) and can be programmed to ON, OFF or Monitoring; it should be noted that for the dual- or triple-chamber ICDs, it is necessary to chose between the analysis by the SMART algorithm or by MorphMatch (SMART OFF).

Recordings - Episodes

No.	Time	Zone	RR [ms]	Description	RR [ms]
1	15/09/14 15:09	SVT	287		584

Recordings - Details

Episode: 1

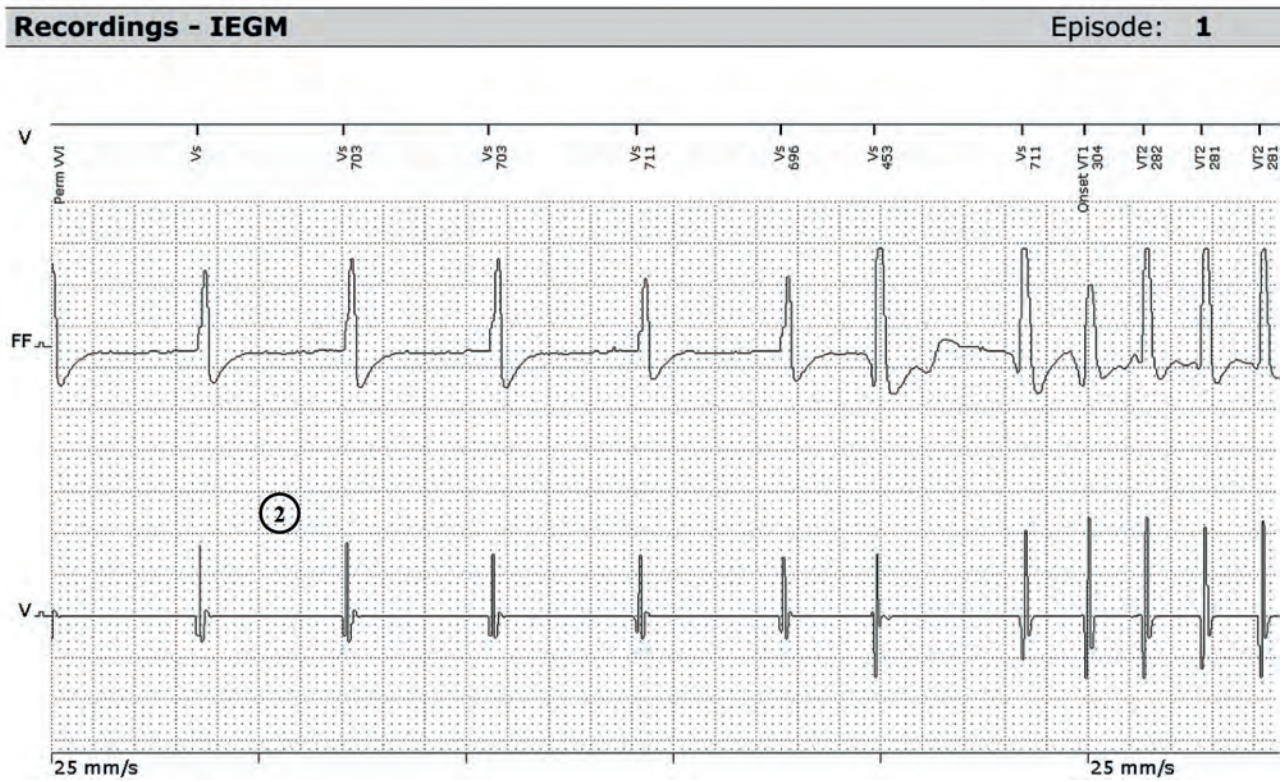
EGM of episode No.		1
Detection		
Zone		SVT
Measured Onset in V [%]	(fulfilled)	55
Measured stability in V [ms]		2

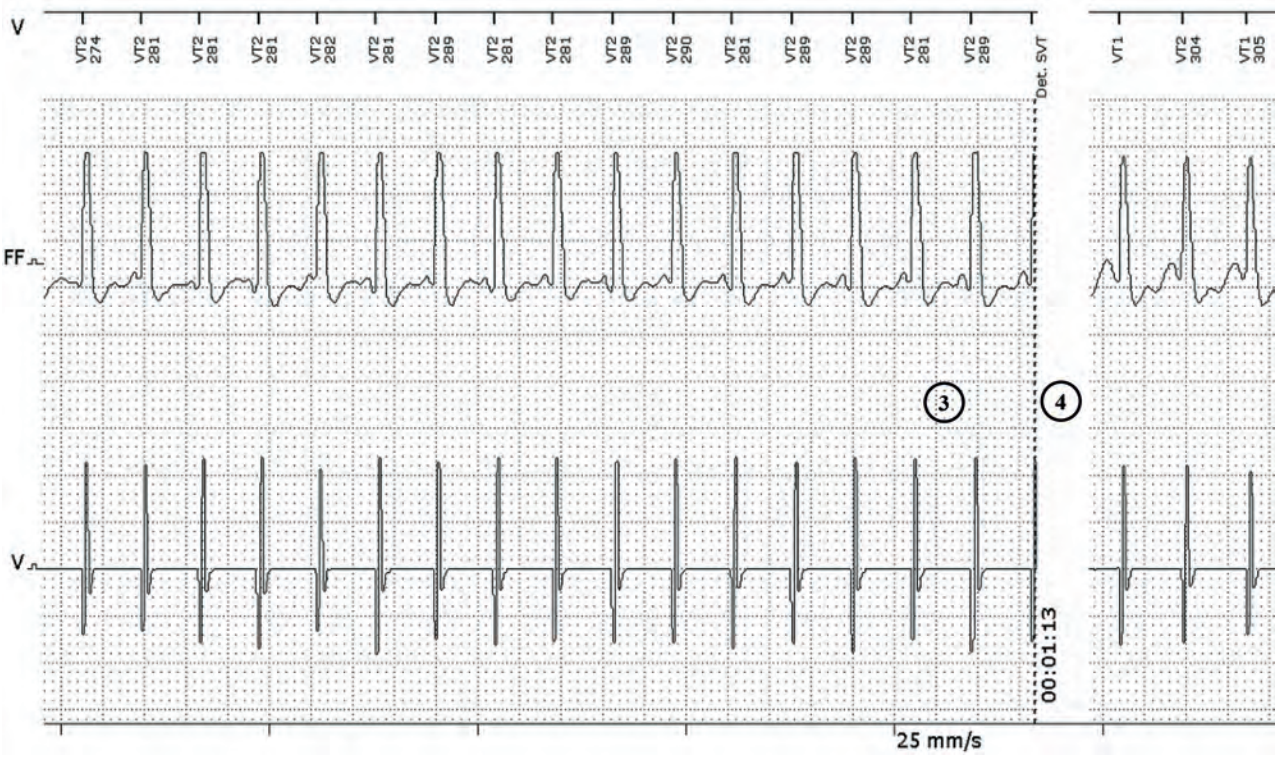
	VT1	VT2	VF
Redetections	0	0	0

Therapy	
ATP	0
Shocks	0
Max. energy [J]	***
ATP One Shot	NO
Times	
Detection	15/09/2014 15:09:13
Termination	15/09/2014 15:10:36
Duration	0:01:23
Program No.	3

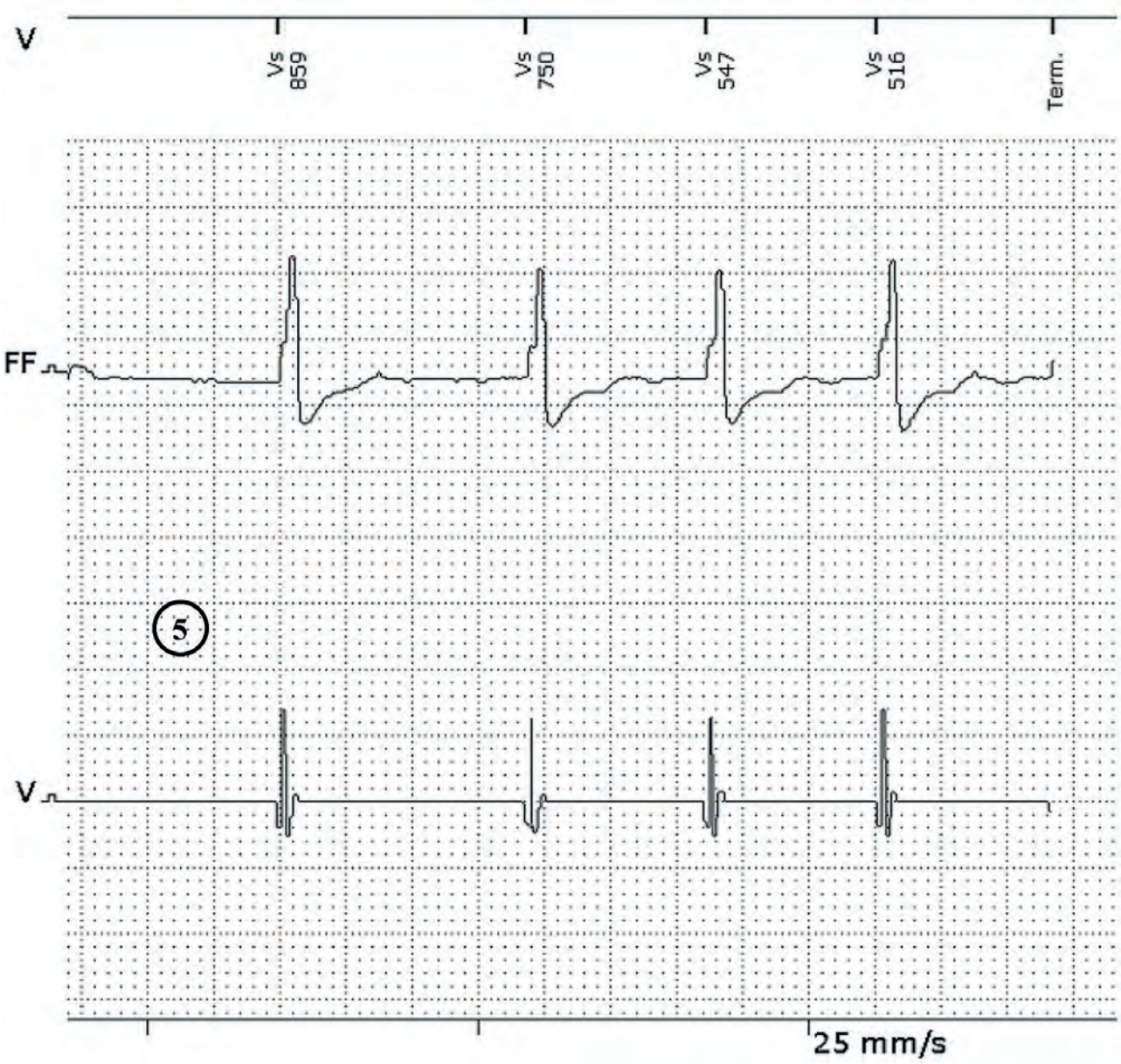
Remark
SVT (MorphMatch) (1)

Discrimination




V
VT2 274
VT2 281
VT2 281
VT2 281
VT2 282
VT2 281
VT2 289
VT2 281
VT2 281
VT2 289
VT2 290
VT2 281
VT2 289
VT2 289
VT2 281
VT2 289
Det. SVT
VT1
VT2 304
VT1 305
FF
3
4
V
00:01:13
25 mm/s

Discrimination



Tracing 26 ↘ Accurate discrimination of VT by a dual-chamber ICD

Patient

63-year-old man implanted with a Lumax 740 DR-T single-chamber ICD for ischemic cardiomyopathy; recording of a VT episode treated with an ATP burst; programming of a VT1 zone with SMART discrimination.

Telecardiology tracing

4 channels are available: the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the atrial sensing channel (A) and the right ventricular sensing channel (V).

① sinus rhythm;

② onset of a ventricular arrhythmia with a clear modification of the morphology of the QRS complexes; sensing in the VT1 zone; initially probable 1:1 retrograde atrial conduction;

③ slight acceleration of the ventricular rhythm and sensing in the VT2 zone; atrioventricular dissociation with ventricular rate faster than the atrial rate;

④ sensing of a VT2 episode; discrimination in the PP > RR arm; the average PP during the initial classification (594 ms) is calculated based on the average of the 4 PP intervals prior to classification; the average RR for the initial classification (298 ms) is calculated based on the average of the 4 RR intervals prior to classification; an ATP burst is delivered

⑤ termination of the arrhythmia and return to sinus rhythm.

Comments

The addition of an atrial lead opens an additional and valuable sensing window: dual-chamber discrimination is based on the combined analysis of atrial and ventricular electrograms. The SMART algorithm uses various criteria to discriminate between VT and SVT: rate (atrial and ventricular), rate stability (atrial and ventricular), multiplicity (n/1 A and V ratio) and presence or absence of a sudden onset of the arrhythmia. Depending on the analysis of these parameters, the arrhythmia is classified as VT or SVT. For each interval corresponding to one of the VT zones, the discrimination algorithm carries out a series of analyses to arrive at the diagnosis of VT or SVT. An interval classified as VT is labeled VT1 or VT2 depending on the rate zone to which it belongs. An interval classified as SVT is labeled AFib for atrial fibrillation, AFlut for atrial flutter, SinT for sinus tachycardia or 1:1 for atrial tachycardia.

The SMART algorithm uses sliding windows of 4 intervals in the atrium and in the ventricle to compare these 2 rhythms. This allows determining whether the ventricular rhythm is faster, identical or slower than the atrial rhythm. For each new interval, the average is recalculated by eliminating the first of the 4 previous intervals. .

This analysis is essential since, as in this example, if the ventricular rhythm is deemed to be faster than the atrial rhythm, the device determines a diagnosis of VT without any additional discrimination.

Status report

BIOTRONIK
excellence for life

Lumax 740 DR-T

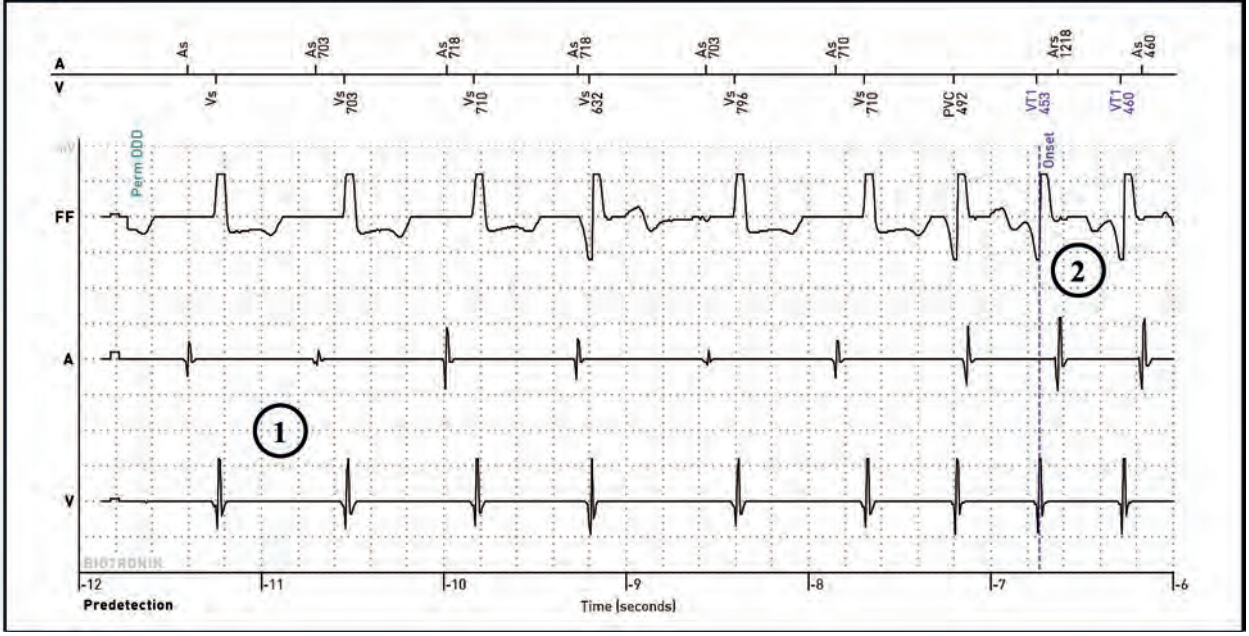
Recordings

Recordings - Episode 377:

General	
Episode number	377
Episode type	VT2
Detection	Dec 1, 2015 4:52:11 AM
Termination	Dec 1, 2015 4:52:21 AM
Duration	10s
Device settings no.	6
Detection	
Mean PP at initial detection [ms]	594
Mean RR at initial detection [ms]	298
Onset [%]	37, fulfilled
Stability [ms]	16
Redetection	---

Therapy	
ATP in VT/VF delivered	1
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	0
Maximum energy [J]	---
Termination	
Mean PP at termination [ms]	641
Mean RR at termination [ms]	641
Remark	
Therapy	ATP optimization in VT2 applied

IEGM



Status report

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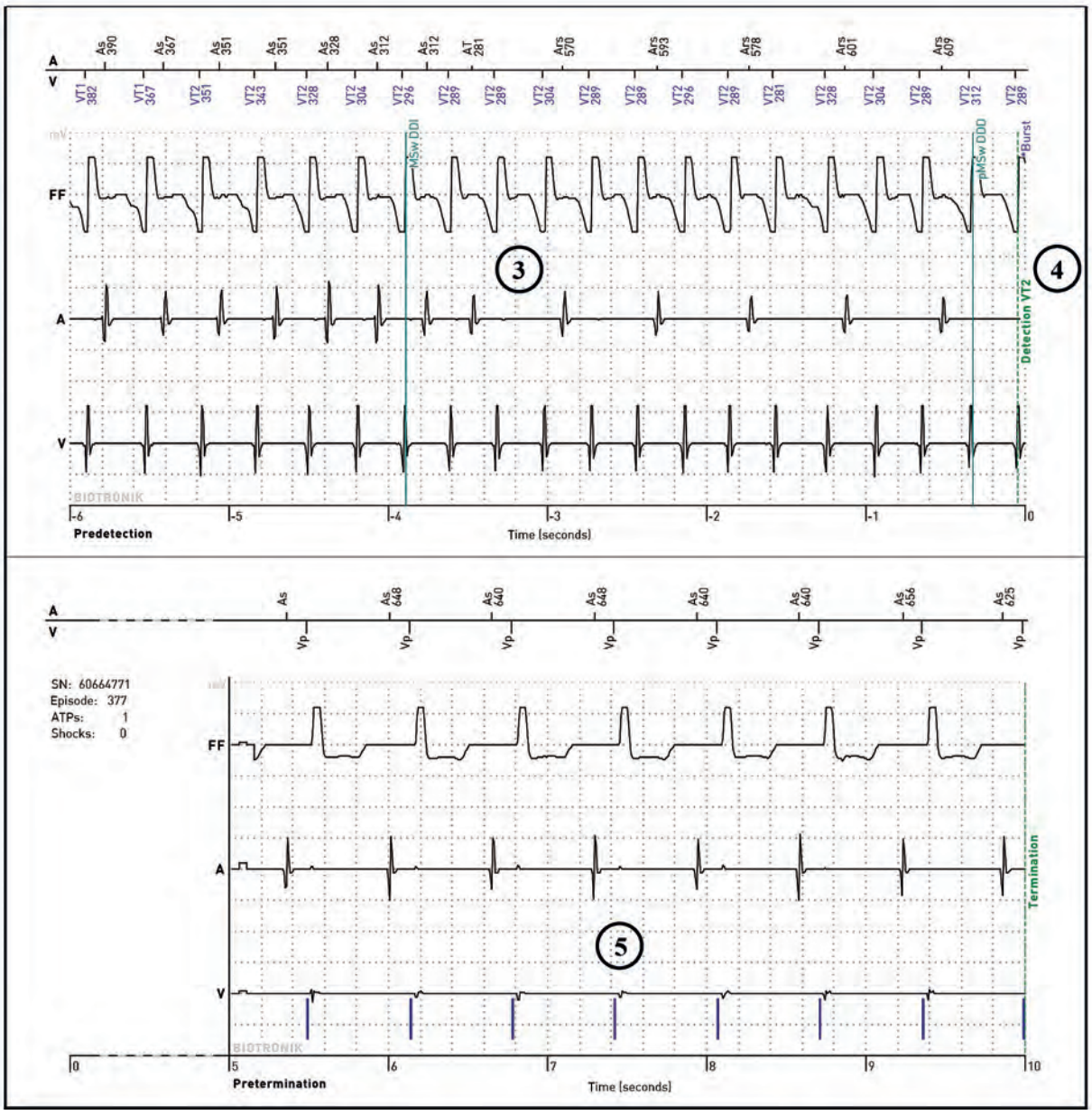
Lumax 740 DR-T



Tracing 27 ↘ Accurate discrimination of ventricular tachycardia despite atrial undersensing

Patient

60-year-old man implanted with a Lumax 340 DR-T dual-chamber ICD for dilated cardiomyopathy with VT episodes; event report (yellow color) in the setting of a classified VT2.

Telecardiology tracing

4 channels are available: the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the atrial sensing channel (A), the right ventricular sensing channel (RV).

① spontaneous rhythm in the atrium and ventricle;

② tachycardia initially sensed in the VT1 zone;

③ atrioventricular dissociation; atrial activity visible on the atrial EGM but without markers since occurring within the post-ventricular atrial blanking period;

④ better visualization of atrial activity;

⑤ VT2 classification after 16 intervals classified as VT2; discrimination in the PP> RR arm; average PP for initial classification 683 ms and average RR for initial classification 314 ms;

⑥ non-visible burst;

⑦ effective burst and termination of the arrhythmia;

⑧ end of the episode after 12 VP or VS intervals.

Comments

The first discrimination level of the SMART algorithm is the comparative analysis of atrial and ventricular rhythm. In this patient, the discrimination of the episode is correct (VT) in spite of an error in the count of the atrial electrograms (P wave in the post-ventricular atrial blanking period). Accurate sensing at the level of both chambers is essential for the proper operation of this dual-chamber discrimination algorithm. Atrial lead dislodgement, crosstalk with atrial oversensing of the R wave, undersensing of atrial activity due to low-voltage AF activity, and occurrence of atrial activity in the post-ventricular atrial blanking period can be associated with inaccurate dual-chamber discrimination. The post-ventricular atrial blanking period should be programmed sufficiently long to avoid crosstalk but not too long to avoid errors in the atrial electrogram counts. It should be noted that the atrial intervals falling within the PVARP (Ars) are integrated in the evaluation of the atrial rate.

Status report - Oct 10, 2013

To: Service TéléCardiologie

BIOTRONIK excellence for life

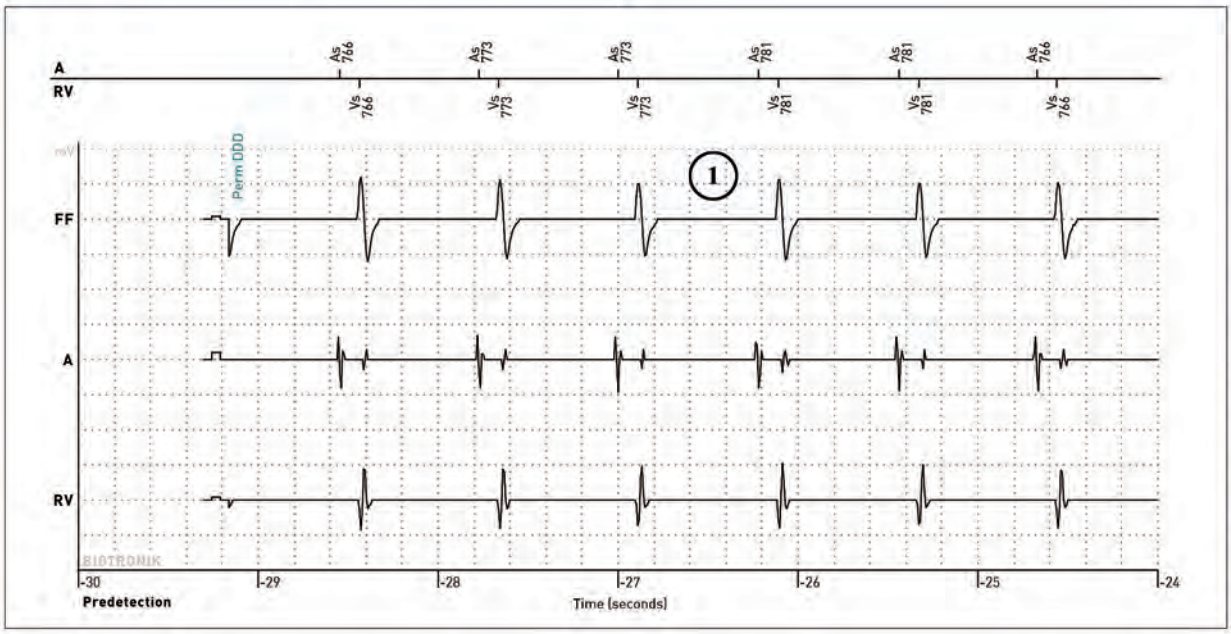
Name:	DOB:	Lumax 340 DR-T (SN 60428125)	Last message: Aug 3, 2013
Patient ID:	Phone:	ICD implanted Dec 8, 2008	Last clinic follow-up: Jun 25, 2013

Recordings

Recordings - Episode 20:

General	
Episode number	20
Episode type	VT2
Detection	Dec 3, 2011 12:16:43 PM
Termination	Dec 3, 2011 12:16:54 PM
Duration	11s
Device settings no.	7
Detection	
Mean PP at initial detection [ms]	683
Mean RR at initial detection [ms]	314
Onset [%]	40, fulfilled
Stability [ms]	8
Redetection	---

Therapy	
ATP in VT/VF delivered	1
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	0
Maximum energy [J]	---
Termination	
Mean PP at termination [ms]	782
Mean RR at termination [ms]	782
Remark	
none	

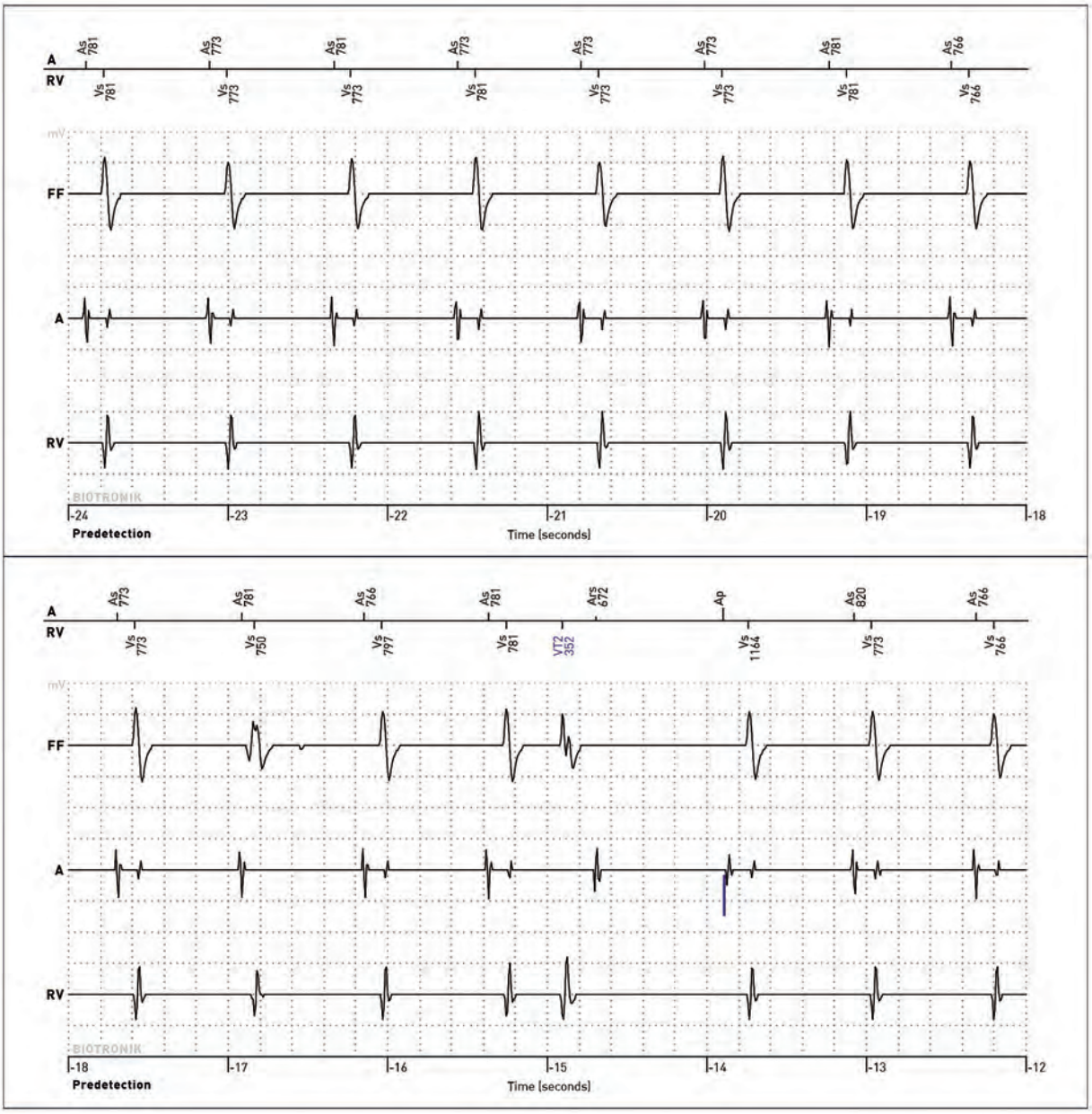


Status report - Oct 10, 2013

To: Service Téléc@rdiologie

BIOTRONIK excellence for life

Name:	DOB:	Lumax 340 DR-T (SN 60428125)	Last message: Aug 3, 2013
Patient ID:	Phone:	ICD implanted Dec 8, 2008	Last clinic follow-up: Jun 25, 2013



Status report - Oct 10, 2013

To: Service Télécardiologie

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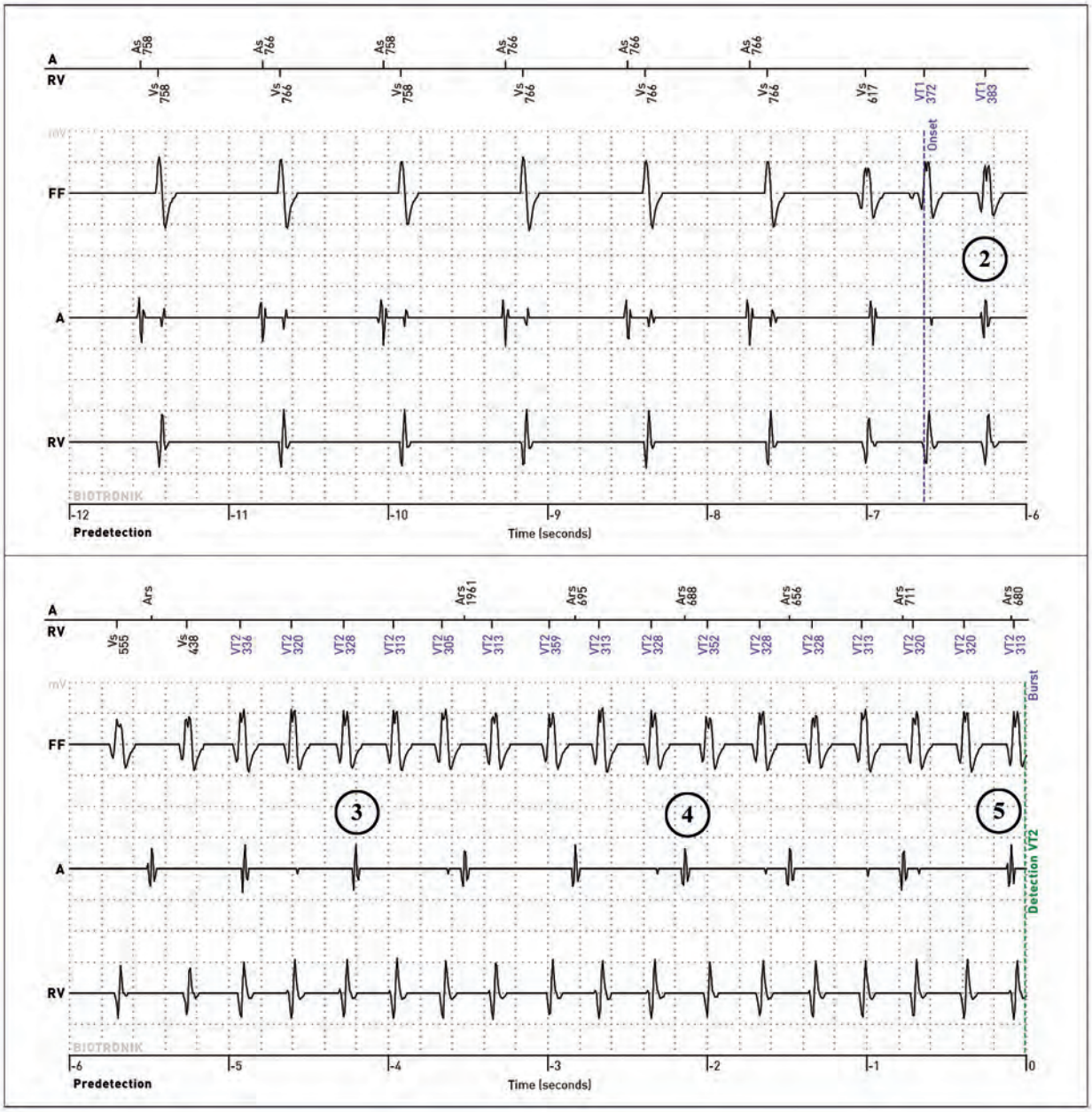
Patient ID:	Phone:	ICD implanted Dec 8, 2008	Last clinic follow-up: Jun 25, 2013

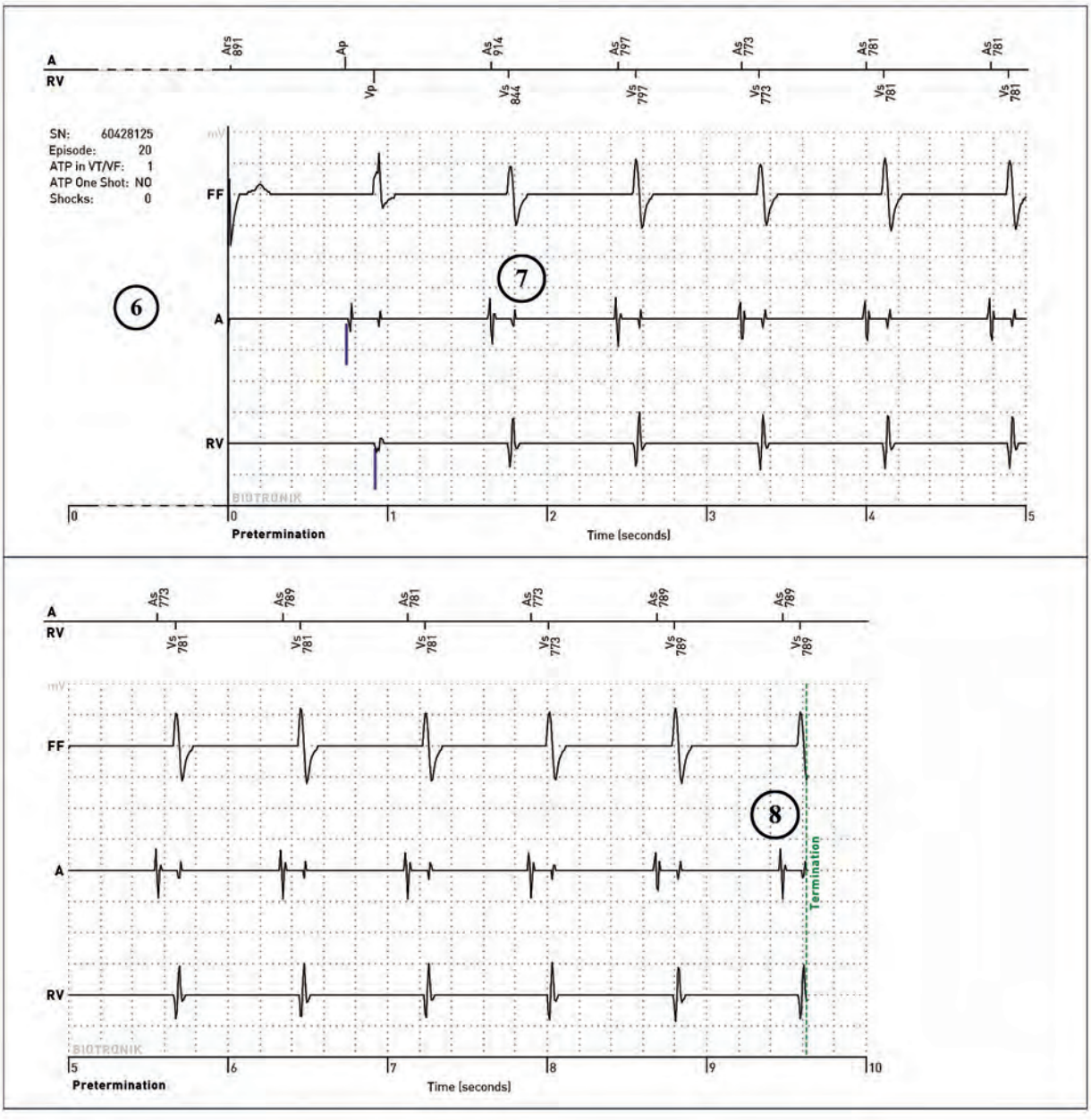


Status report - Oct 10, 2013

To: Service Téléc@rdiologie

BIOTRONIK excellence for life

Name:	DOB:	Lumax 340 DR-T (SN 60428125)	Last message: Aug 3, 2013
Patient ID:	Phone:	ICD implanted Dec 8, 2008	Last clinic follow-up: Jun 25, 2013



Tracing 28 ↘ Accurate discrimination of sinus tachycardia by a dual-chamber ICD

Patient

61-year-old man implanted with a Lumax 740 DR-T dual-chamber ICD for ischemic cardiomyopathy with altered ejection fraction; event report (yellow color) in the setting of a classified SVT.

Telecardiology tracing

4 channels are available: the markers with the time intervals, the shock channel (FF: far field) between the ventricular lead coil and the pulse generator, the atrial sensing channel (A) and the right ventricular sensing channel (RV).

① tachycardia in the VT1 zone with 1:1 atrioventricular ratio; the ventricular events are classified as Tsin (sinus tachycardia);

② SVT classification in the PP=RR arm; average PP at initial classification 379 ms, average RR at initial classification 379 ms; stable rhythm, with measurement of the stability criterion at 2 ms for a 24-ms programmed threshold; stable PP intervals; stable PR interval without monotonous change; in this instance, the sudden onset criterion is not fulfilled (measured at 1% for a 20% programmed threshold, the diagnosis made by the device is thus that of SVT (sinus tachycardia);

③ gradual slowing of the heart rate at the end of the exertion and exit from the VT1 zone (VS intervals).

Comments

The vast majority of 1:1 tachycardias are of supraventricular origin (sinus tachycardia, 1:1 atrial tachycardia). VTs with 1:1 retrograde conduction constitute only 10% of these tachycardias. This episode corresponds to an accurately discriminated sinus tachycardia.

As explained previously, the first discrimination step when the SMART algorithm is programmed is a comparison between ventricular and atrial rates. In this example, the two rates are strictly identical (column RR=PP). The device analyzes the stability of the RR intervals and considers in this example that the ventricular rhythm is stable followed by the stability of the PP intervals which is also deemed stable (difference between an atrial interval and the preceding three intervals does not exceed the programmed value).

When the atrial and ventricular rhythms are stable and similar, different arrhythmias may coexist (dual tachycardia, VT with retrograde conduction and sinus tachycardia). Different parameters are analyzed to discriminate these arrhythmias: 1) monotonous variation of the PR interval: when the atrial and ventricular rhythms are deemed stable and identical, the device looks for the PR intervals to evolve according to a characteristic profile. The PR intervals are classified as monotonous if on a rolling window of 4 intervals, the PR intervals increase or decrease with respect to each other in a constant manner (AV n < AV n-1 < AV n-2 < AV n-3 or AV n-> AV n-1 > AV n-2 > AV n-3) indicating the presence of atrioventricular dissociation. Indeed, if there is a trend in terms of the PR interval (if there is a prolongation or a progressive shortening of the PR interval measured by the device), the atrial and ventricular rhythms certainly have a similar rate but can be considered as independent. The small but constant difference between the 2 rates induces a steady variation of the PR interval and the device concludes to a dual tachycardia; 2) if, as in this example, the atrial and ventricular rhythms are stable without monotonous variation in PR interval, the algorithm uses the Onset criterion (same operation as described for single-chamber devices) to differentiate VT from 1:1 retrograde conduction (abrupt onset) and sinus tachycardia (progressive onset as in this example). The intervals classified as sinus tachycardia are labeled SinusT and decrement the VT counter by -1/4.

Status report - Oct 11, 2013

To: Service TélécØrdiologie

BIOTRONIK excellence for life

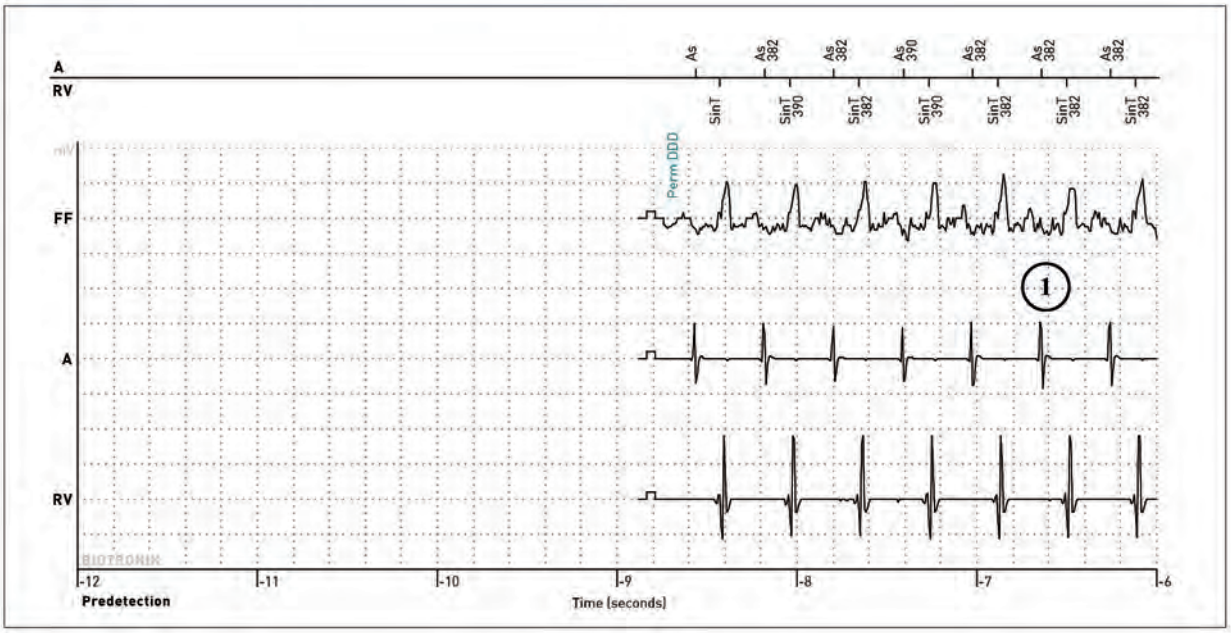
Name:	DOB:	Lumax 740 DR-T (SN 60664422)	Last message: Oct 11, 2013
Patient ID:	Phone:	ICD implanted Jan 16, 2013	Last clinic follow-up: Jun 13, 2013

Recordings

Recordings - Episode 5:

General	
Episode number	5
Episode type	SVT
Detection	Feb 10, 2013 7:08:20 AM
Termination	Feb 10, 2013 7:08:24 AM
Duration	4s
Device settings no.	5
Detection	
Mean PP at initial detection [ms]	379
Mean RR at initial detection [ms]	379
Onset [%]	1
Stability [ms]	2
Redetection	---

Therapy	
ATP in VT/VF delivered	0
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	0
Maximum energy [J]	---
Termination	
Mean PP at termination [ms]	408
Mean RR at termination [ms]	409
Remark	
Detection	Sinus tachycardia (PP = RR, PP and RR stable, onset not fulfilled)

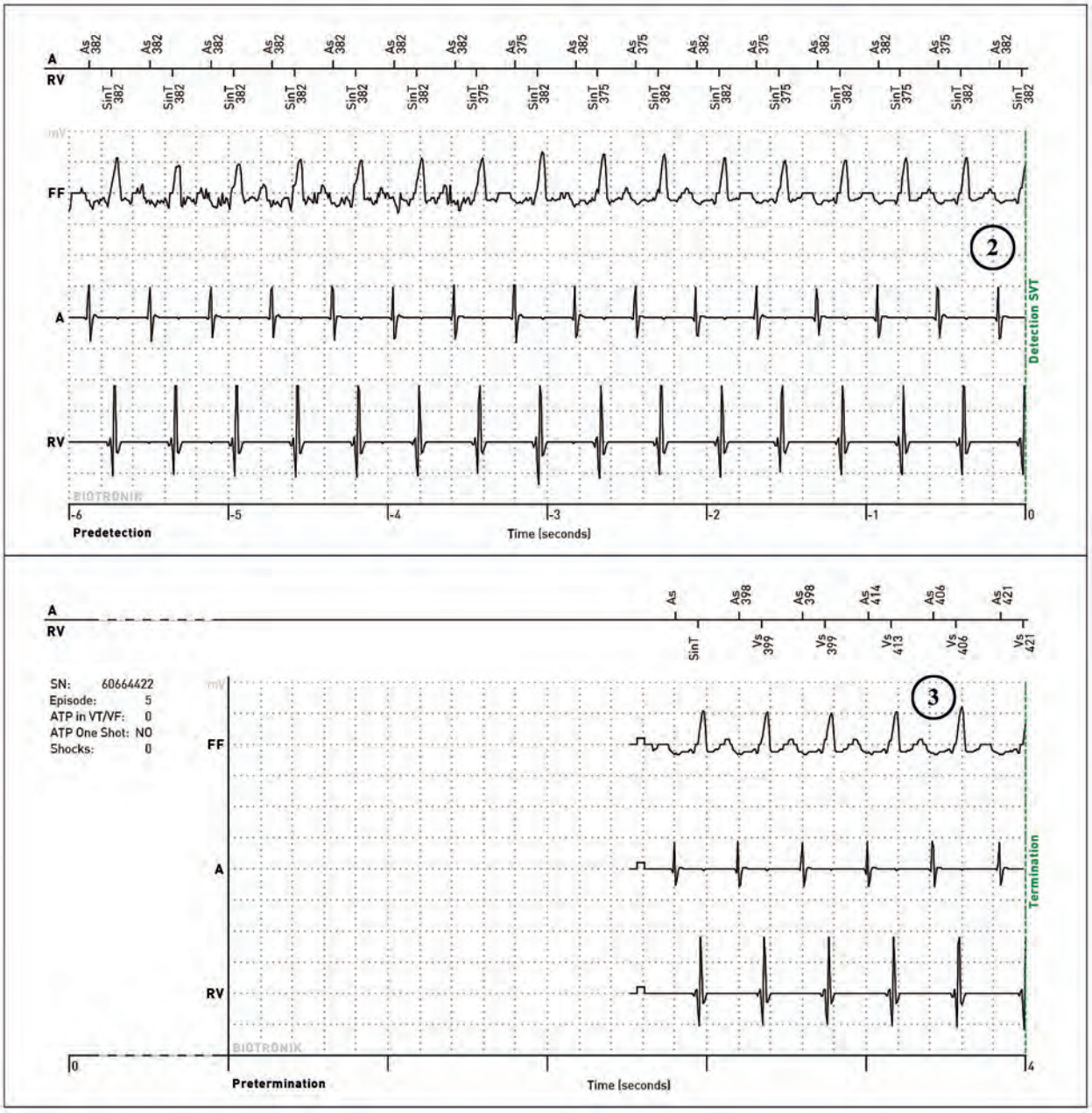


Status report - Oct 11, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

Name:	DOB:	Lumax 740 DR-T (SN 60664422)	Last message: Oct 11, 2013
Patient ID:	Phone:	ICD implanted Jan 16, 2013	Last clinic follow-up: Jun 13, 2013



Tracing 29 ↘ Accurate discrimination of atrial fibrillation

Patient

61-year-old man implanted with a Lumax 340 HF-T triple-chamber ICD for dilated cardiomyopathy with left bundle branch block; event report (yellow color) in the setting of a classified SVT.

Telecardiology tracing

4 channels are available: the markers with the time intervals, the atrial sensing channel (A), the right ventricular sensing channel (RV) and the left ventricular sensing channel (LV).

① mode switching for atrial arrhythmia (MSw DDI);

② rapid and irregular atrial rhythm with rapid and irregular ventricular conduction: AF; at the atrial channel, intervals classified As or Ars; at the ventricular channel, Vs markers for intervals outside the VT1 zone (limit at 370 ms) and FibA marker for the faster intervals;

③ classification of the SVT episode in the PP=RR arm; indeed, at the end of the tracing, 1 out of 2 atrial activities falls within the post-ventricular atrial blanking period and is therefore not sensed; the device classifies the episode as a sinus tachycardia and no therapy is delivered.

Comments

When the atrial rate is faster than the ventricular rate, two groups of arrhythmias must be discriminated: dual tachycardias (VT + SVT) and conducted SVT (atrial flutter, AF, atrial tachycardia).

As explained previously, the first discrimination step upon programming of the SMART algorithm is a comparison between ventricular and atrial rates. When the atrial rate is faster than the ventricular rate (RR>PP), the device analyzes the stability of the RR intervals.

When the ventricular rhythm is deemed unstable, the device concludes to SVT (conducted AF). An interval classified AFib decrements the VT counter by 4.

When the ventricular rhythm is deemed stable, the differentiation between dual tachycardia (VT + flutter) and conducted atrial flutter is difficult for an algorithm which does not include the morphology criterion. In both instances, the RR intervals > PP intervals and the RR intervals are generally stable. To discriminate the latter, the device uses the relationship between atrial and ventricular signals. If there is an N:1 relationship (2:1, 3:1 or 4:1), the ventricular interval is classified as atrial flutter with an AFlut marker and decrements the VT counter by 1. If this relationship N:1 does not exist, a dual tachycardia is identified with a VT marker.

Status report - Oct 11, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

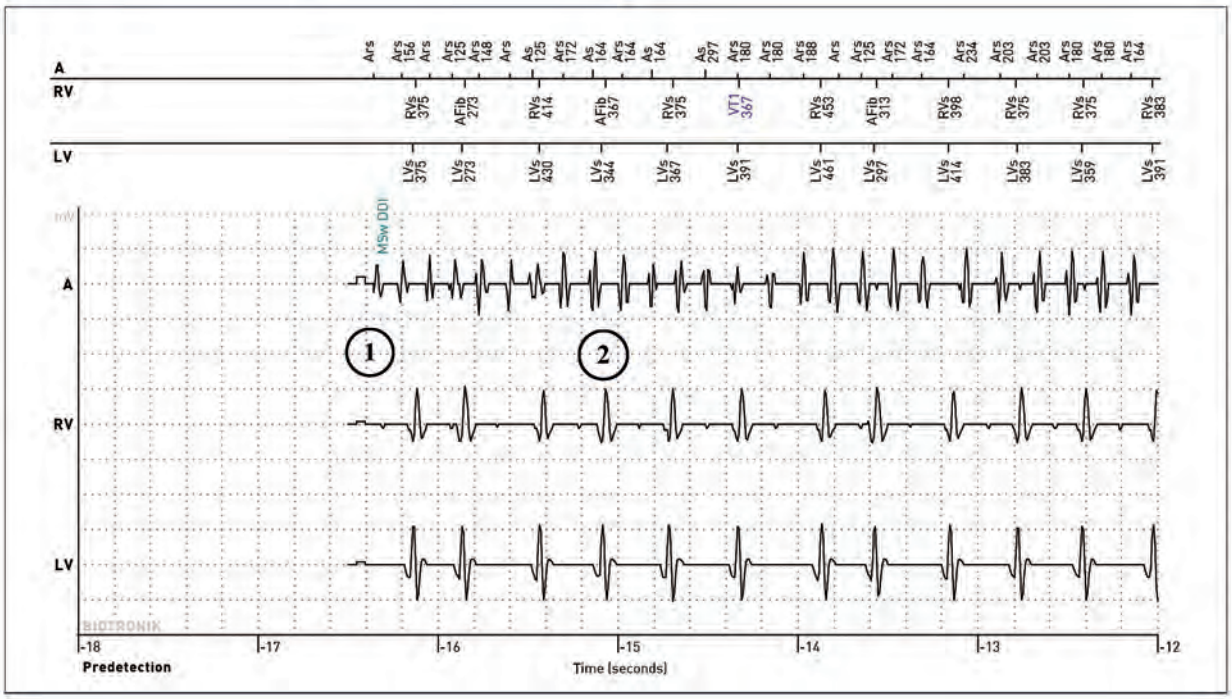
Name:	DOB:	Lumax 340 HF-T (SN 60464365)	Last message: Oct 11, 2013
Patient ID:	Phone: -	CRT-D implanted May 31, 2010	Last clinic follow-up: Sep 17, 2013

Recordings

Recordings - Episode 30:

General	
Episode number	30
Episode type	SVT
Detection	Dec 14, 2010 12:58:33 PM
Termination	Dec 14, 2010 12:59:28 PM
Duration	55s
Device settings no.	50
Detection	
Mean PP at initial detection [ms]	360
Mean RR at initial detection [ms]	361
Onset [%]	21
Stability [ms]	13
Redetection	---

Therapy	
ATP in VT/VF delivered	0
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	0
Maximum energy [J]	---
Termination	
Mean PP at termination [ms]	201
Mean RR at termination [ms]	383
Remark	
Detection	Atrial fibrillation (PP < RR, RR unstable)



Status report - Oct 11, 2013

To: Service Télécardiologie

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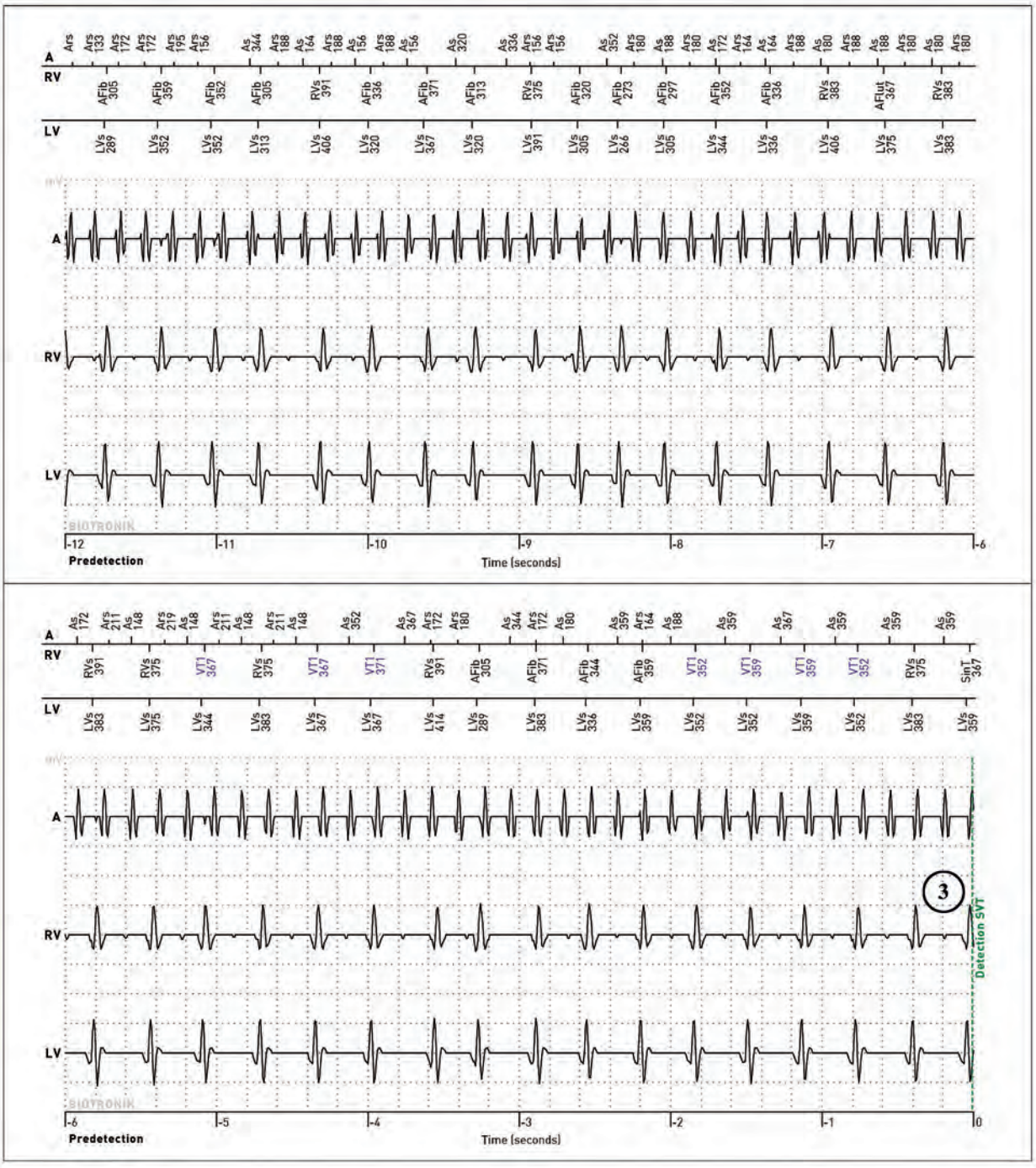
Name:	DOB:	Lumax 340 HF-T (SN 60464365)	Last message: Oct 11, 2013
Patient ID:	Phone: -	CRT-D implanted May 31, 2010	Last clinic follow-up: Sep 17, 2013



Status report - Oct 11, 2013

To: Service Télécardiologie

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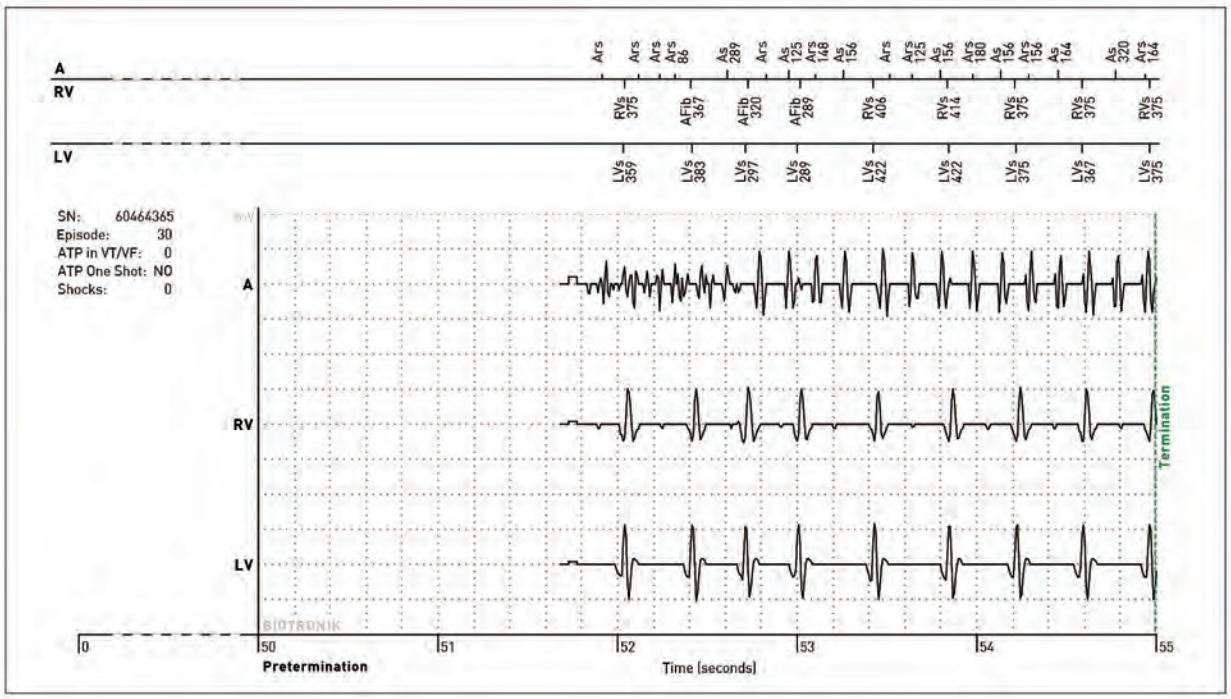
Name:	DOB:	Lumax 340 HF-T (SN 60464365)	Last message: Oct 11, 2013
Patient ID:	Phone: -	CRT-D implanted May 31, 2010	Last clinic follow-up: Sep 17, 2013



Tracing 30 ↘ Poorly-discriminated ventricular tachycardia

Patient

59-year-old man implanted with a Lumax 740 DR-T dual-chamber ICD for dilated cardiomyopathy with VT episodes; event report (yellow color) in the setting of a classified VT1 and a SVT.

Telecardiology tracing 1

① tachycardia in the VT1 zone initially with a 1:1 atrioventricular ratio; the ventricular events are classified Tsin (sinus tachycardia);

② interruption of retrograde conduction with ventricular rhythm faster than the atrial rhythm (pathognomonic of a VT); discrimination in the PP>RR zone;

③ diagnosis of VT1 in the PP>RR arm;

④ delivery of 6 ATP sequences;

Telecardiology tracing 2

⑤ tachycardia in the VT1 zone with a 1:1 atrioventricular ratio; the ventricular events are classified Tsin (sinus tachycardia); note that the ventricular morphology is perfectly similar to that of the previous episode;

⑥ SVT classification in the PP=RR arm; average PP at initial classification 332 ms, average RR during at classification 336 ms; stable rhythm, with measured stability at 8 ms for a 24-ms threshold; stable PP intervals; stable PR intervals without monotonous change; the sudden onset criterion is not fulfilled (measured at 18% for a programmed threshold of 20%); the diagnosis made by the device is therefore that of SVT (sinus tachycardia).

Comments

During a 1:1 tachycardia, a transient retrograde ventriculo-atrial block allows confirming the diagnosis of VT. The second episode is misdiagnosed as SVT by the device (sinus tachycardia). The differential diagnosis between VT and sinus tachycardia is highly challenging, if not impossible, on the basis of the analysis to this tracing alone. The first episode allows a diagnosis of certainty. Indeed, the interruption of retrograde conduction (V>A) reveals the ventricular origin of the tachycardia. In a patient presenting multiple episodes of 1:1 tachycardia, it is very important to analyze all of the tracings in search of an anterograde (SVT) or retrograde block (VT), which provides a diagnosis of certainty.

As with a single-chamber ICD, it is possible to program on the latest generation of dual-chamber devices, a discrimination based on the morphology analysis. This criterion is not featured as an addition to the SMART algorithm, the physician having to choose between discrimination based on the morphology or on SMART.

Status report - Oct 11, 2013

To: Service Télécardiologie

BIOTRONIK excellence for life

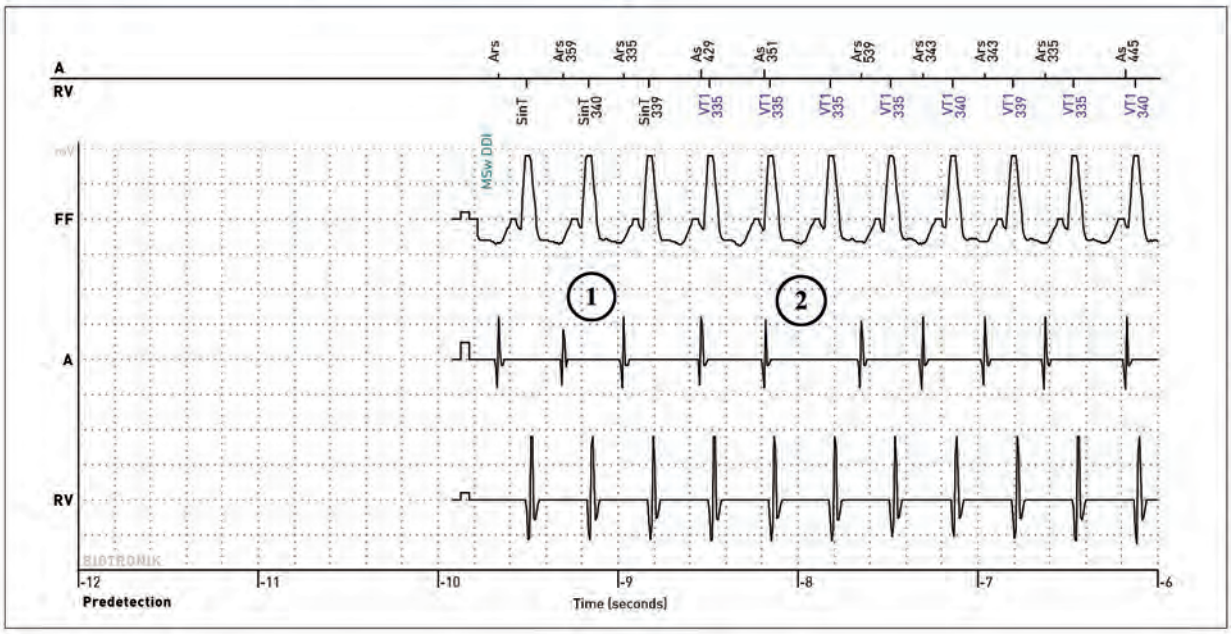
Name:	DOB:	Lumax 740 DR-T (SN 60660128)	Last message: Oct 11, 2013
Patient ID:	Phone:	ICD implanted Nov 20, 2012	Last clinic follow-up: Jul 1, 2013

Recordings

Recordings - Episode 20:

General	
Episode number	20
Episode type	VT1
Detection	Dec 2, 2012 4:59:29 PM
Termination	Dec 2, 2012 5:02:47 PM
Duration	3min 18s
Device settings no.	4
Detection	
Mean PP at initial detection [ms]	371
Mean RR at initial detection [ms]	337
Onset [%]	20
Stability [ms]	4
Redetection	VT1: 5

Therapy	
ATP in VT/VF delivered	6
ATP One Shot delivered	NO
Shocks delivered	0
Shocks aborted	0
Maximum energy [J]	---
Termination	
Mean PP at termination [ms]	425
Mean RR at termination [ms]	336
Remark	
Termination	forced termination



Status report - Oct 11, 2013

To: Service Télécardiologie

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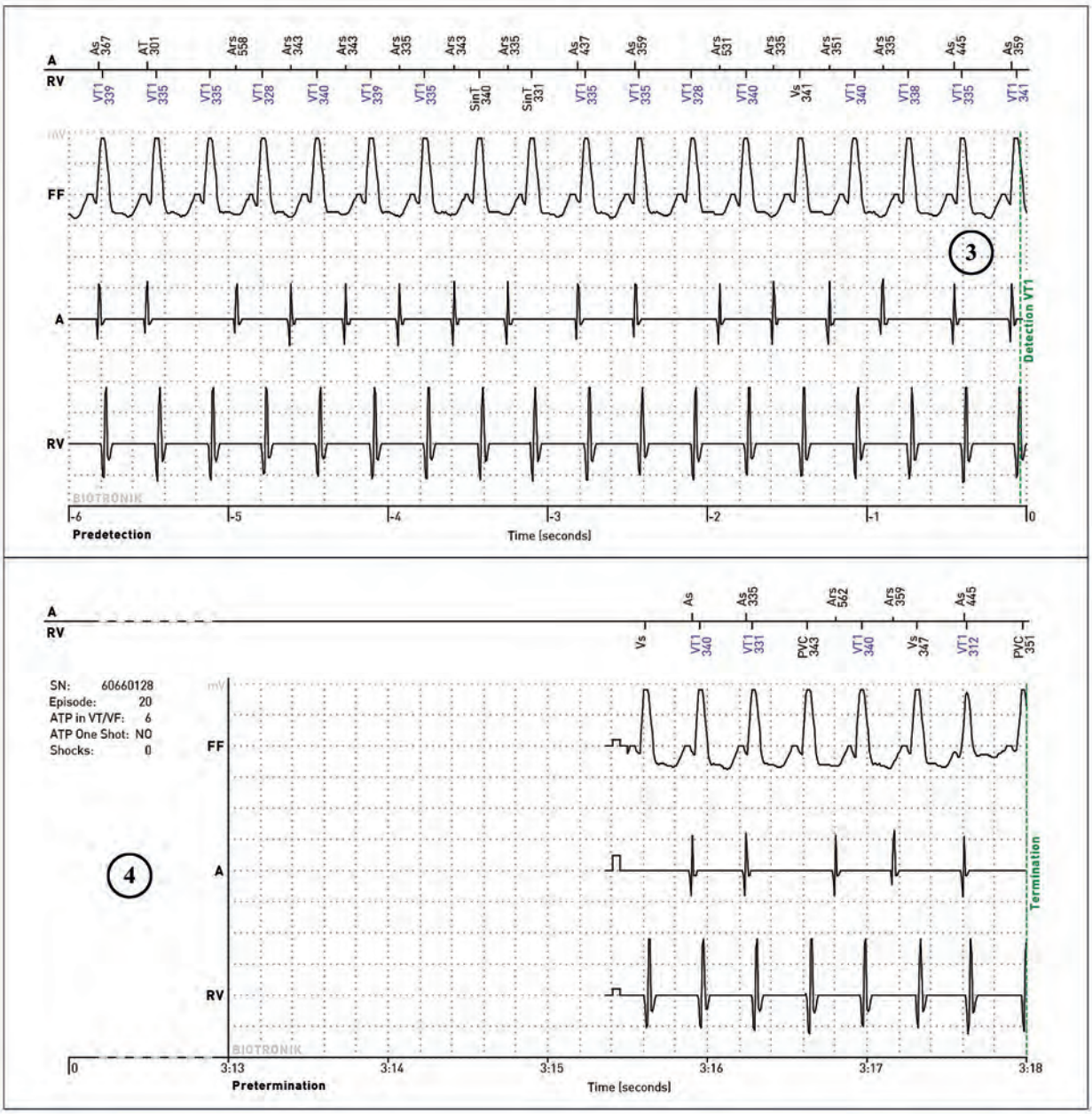
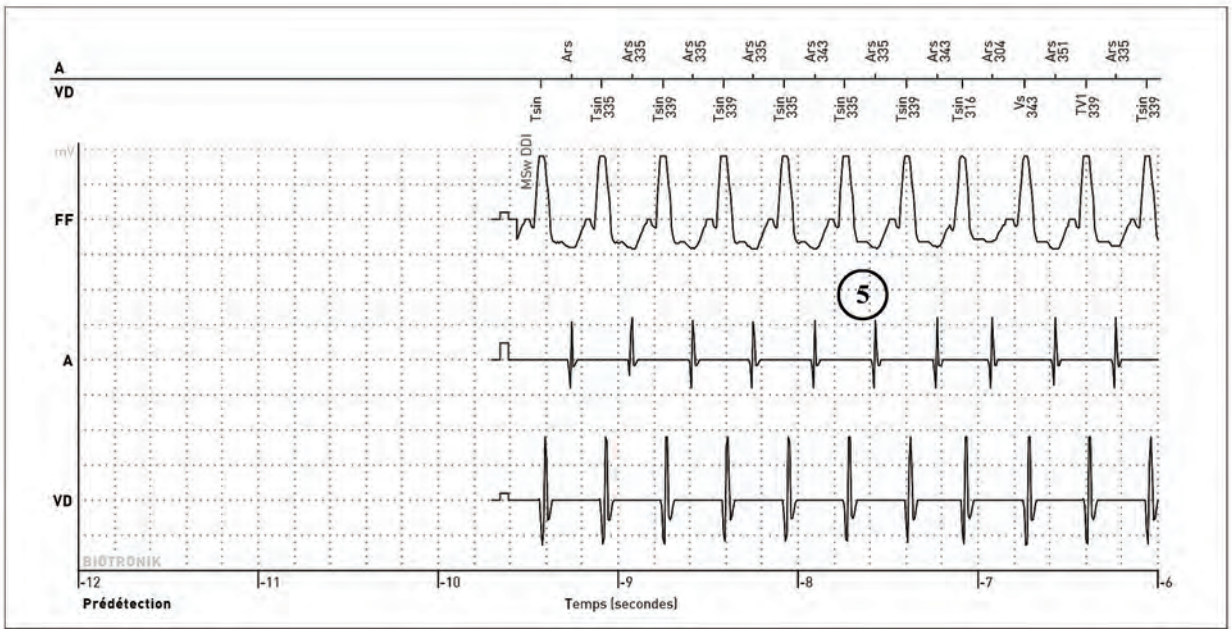
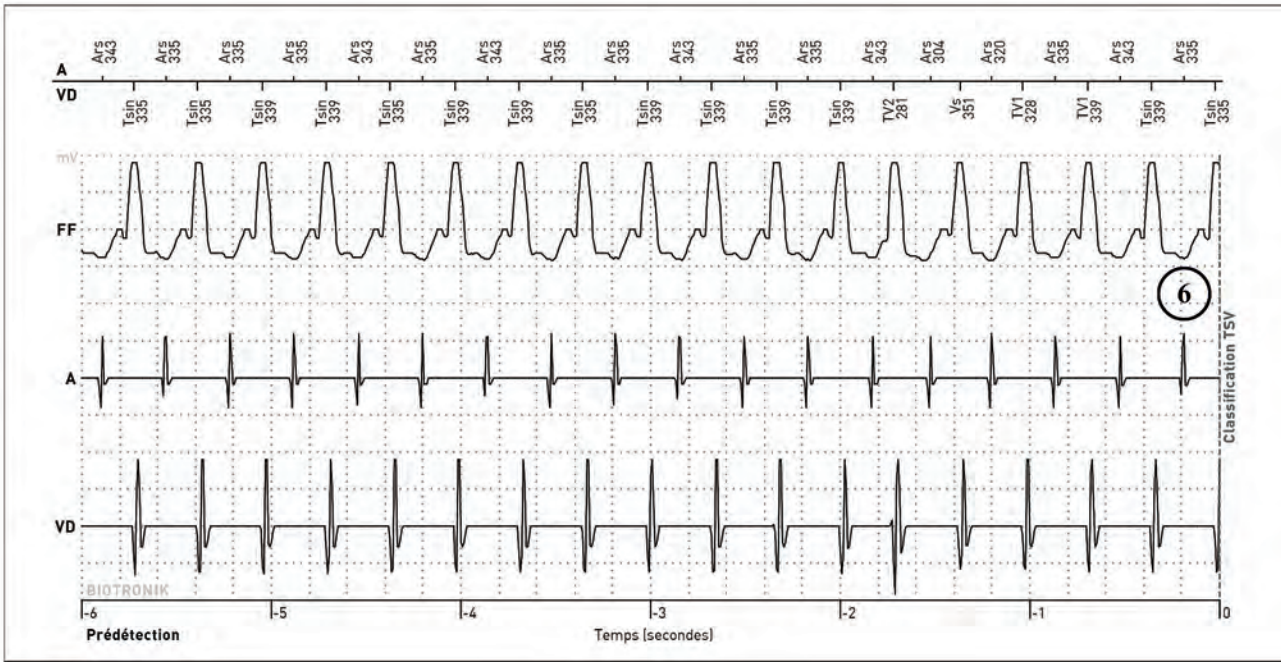
Name:	DOB:	Lumax 740 DR-T (SN 60660128)	Last message: Oct 11, 2013
Patient ID:	Phone:	ICD implanted Nov 20, 2012	Last clinic follow-up: Jul 1, 2013




A
VD
Ars
Ars 335
Ars 335
Ars 335
Ars 343
Ars 335
Ars 343
Ars 304
Ars 351
Ars 335
Tsin
Tsin 335
Tsin 339
Tsin 339
Tsin 335
Tsin 335
Tsin 339
Tsin 316
Vs 343
TV1 339
Tsin 339
mV
MSw DDI
FF
5
A
VD
BIOTRONIK
-12
-11
-10
-9
-8
-7
-6
Prédétection
Temps (secondes)

Discrimination



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