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Implantable Cardioverter Defibrillator

Clinical cases from
patients with **MicroPort™** ICDs

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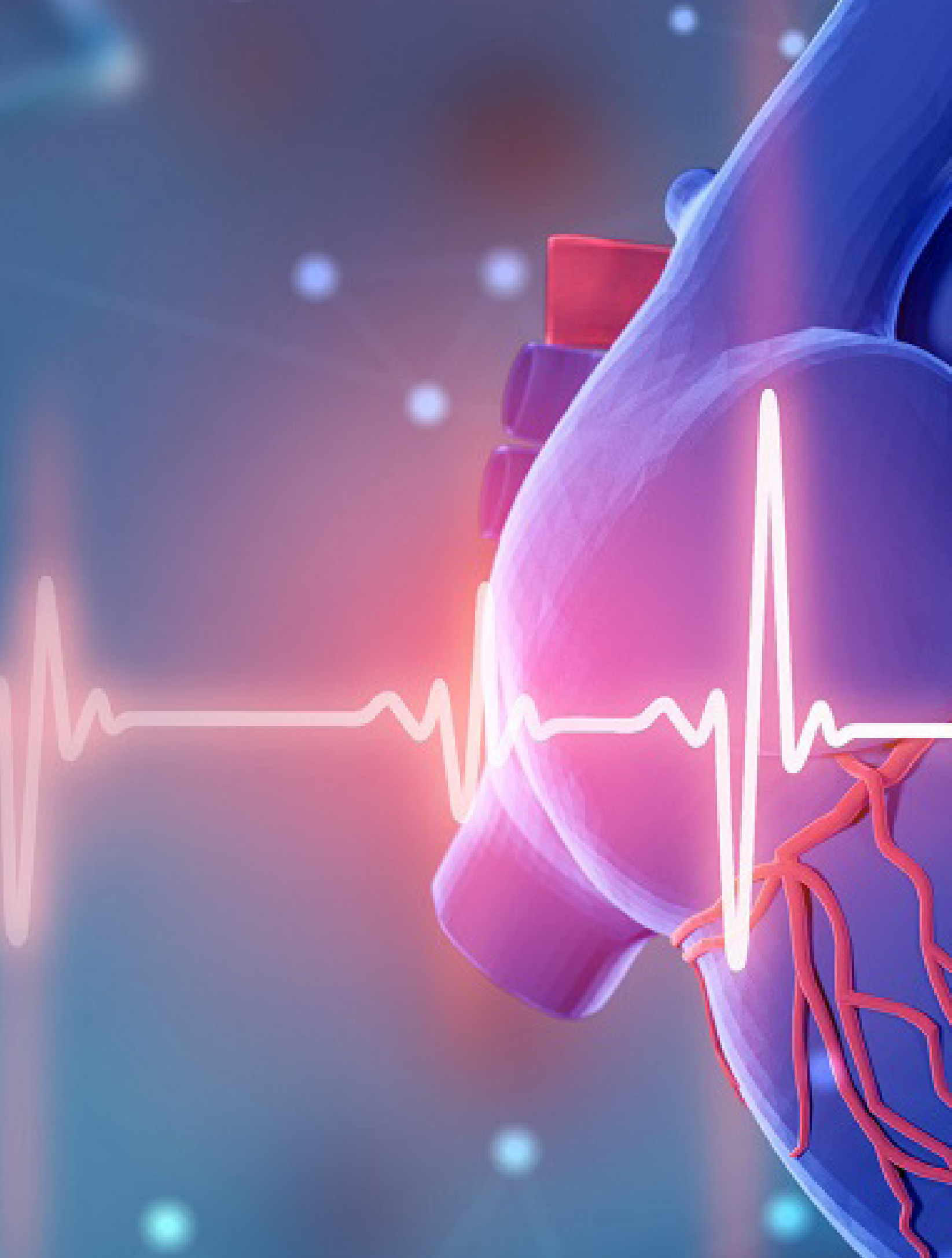
L'institut des maladies du rythme cardiaque

STIMUPRAT Editions



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Préface

This book is the result of collaboration between reference rhythm cardiologists at CHU Haut-Lévêque (Bordeaux, France) and MicroPort™ engineers. It is aimed at all professionals involved in the management of patients with automatic implantable defibrillators (ICDs), particularly those using MicroPort™ devices. Designed as an illustrated clinical guide, this book offers an in-depth analysis of **over 25 real-life cases**, organized into five main teaching sections:

Counting and diagnosing ventricular arrhythmias: You'll discover the detection rules specific to MicroPort™ ICDs, illustrated by tracings explaining majority logics (6/8 cycles), tachycardia zones (VT, slow VT, VF) and persistence counters. These elements are essential for understanding why a therapy is - or is not - delivered.

Anti-tachycardia pacing and shocks: through a series of case studies, the reader learns to interpret the programming of ATPs (bursts, ramps) and shocks, the commitment of therapies to rhythm stability, and the criteria that differentiate an appropriate shock from an inappropriate therapies.

Discrimination : The book details the PARAD+ and Stability+/Acc algorithms, specific to MicroPort™, enabling fine discrimination between ventricular and supraventricular tachycardias, even in the absence of reliable atrial signals.

Oversensing : Cases of T-wave oversensing, lead dysfunction or noise are analyzed, highlighting current system limitations and suggesting ways of reprogramming to avoid inappropriate therapies.

Remote monitoring : Remote monitoring is an essential aspect of ICD monitoring. The most important alerts will be discussed, including the new lead noise alert.

Each case is accompanied by an annotated electrogram, explanatory tachogram, guided diagnosis and take-home messages for everyday clinical practice. The authors provide both a technical reading and a critical clinical analysis, enriched by their own experience.

This volume is part of a series dedicated to the different ICD manufacturers. It does not claim to impose a single truth, but rather to share structured expertise in a formative approach. Whether you're a beginner in rhythmology or an experienced user, you'll find concrete lessons to help you optimize your patients' care.

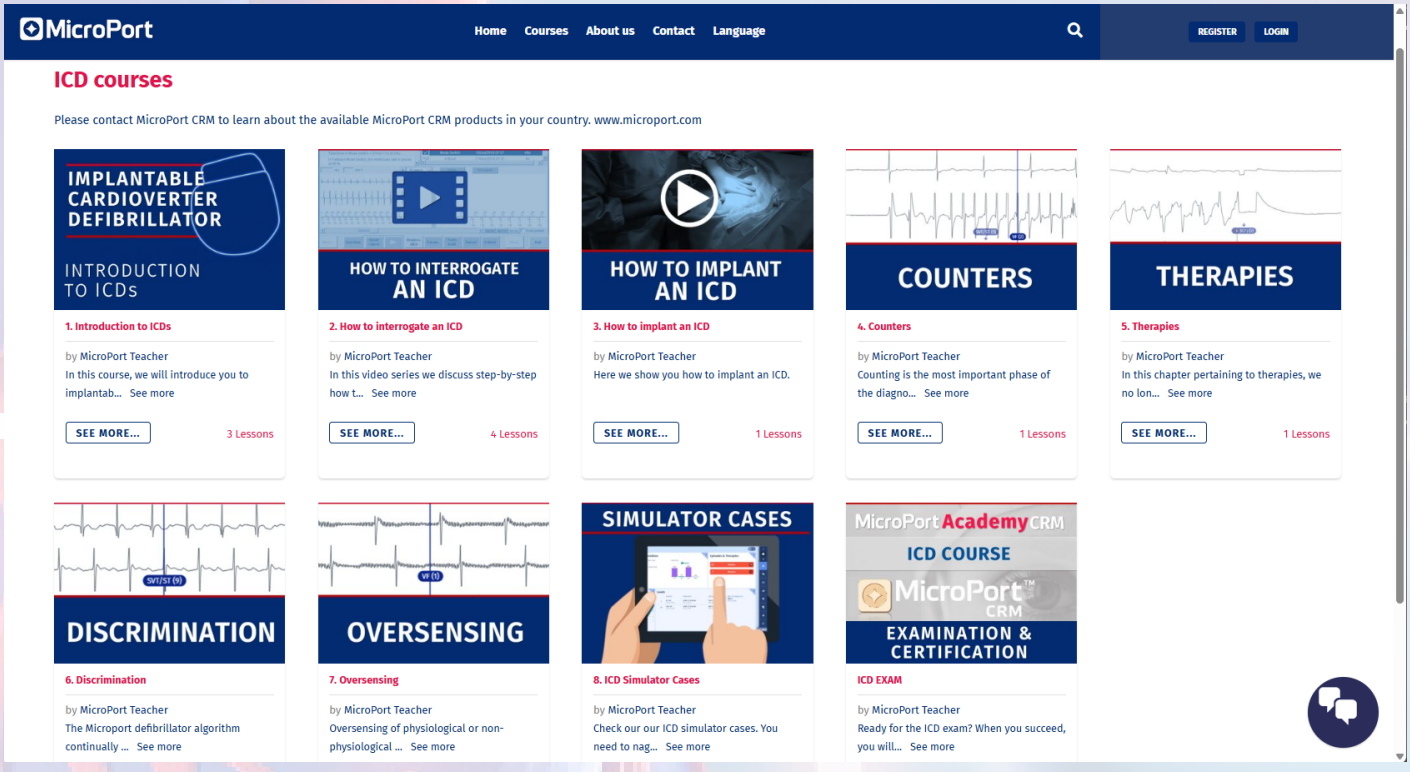
An indispensable tool for any professional faced with the analysis of MicroPort™ ICD tracings.

This book is also the perfect complement to the e-learning site:

www.microportacademycrm.com

We invite readers to check out the website for content not possible in a written book :

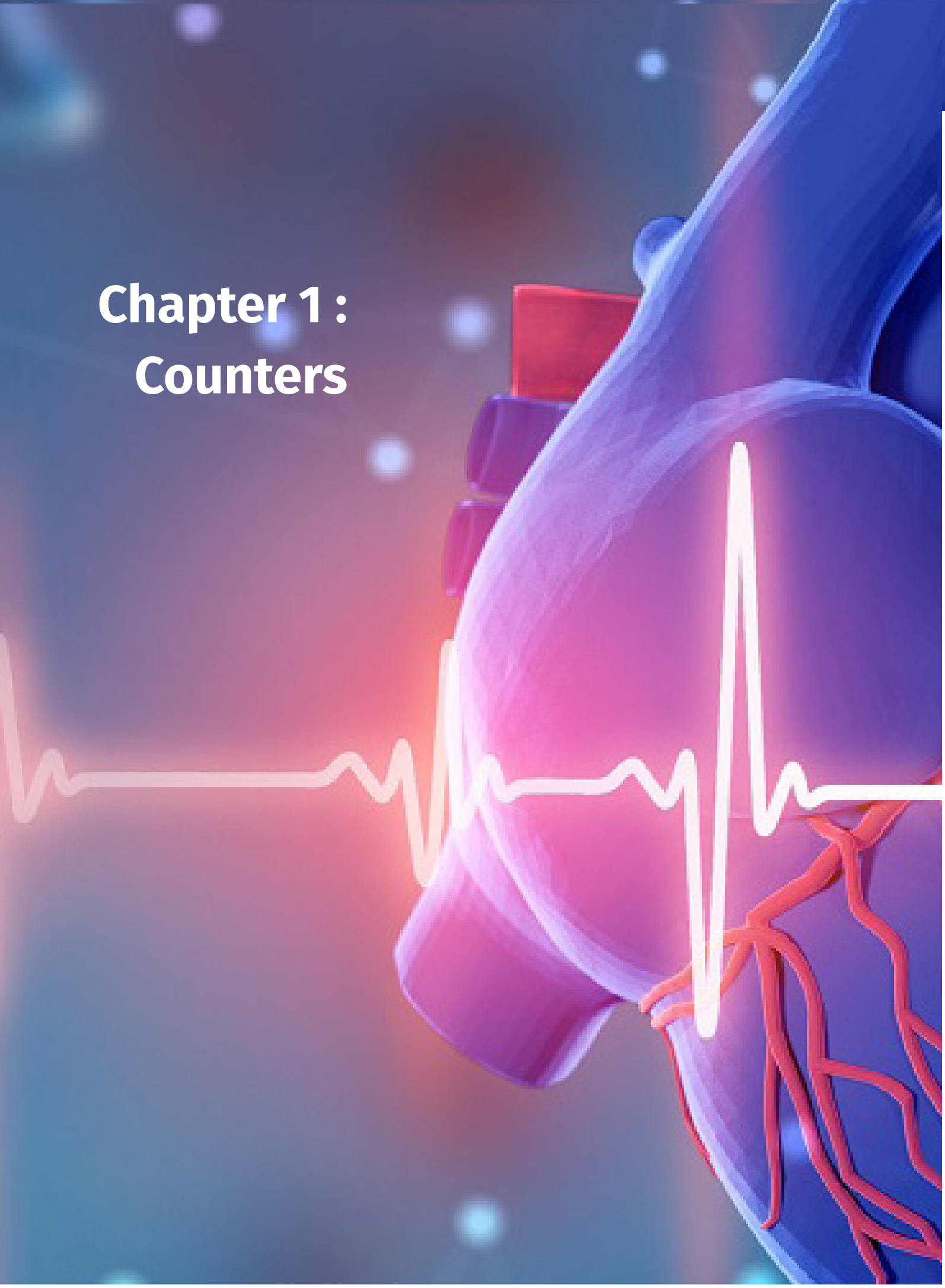
- **Implantation video tutorials**
- **Interrogation video tutorials**
- **Interactive simulator cases**
- **Exams with personal certificates**



An essential tool for students, young rhythmologists and experts wishing to deepen their mastery of MicroPort™ ICDs in a structured, evolutionary framework.

Marc Strik

Chapter 1 : Counters



In this first chapter dedicated to counting, the first two tracings pertain to ventricular fibrillation, the first involving an induction performed in the electrophysiology room at the time of defibrillator implantation, which will allow discussing the indication, advantages and disadvantages of the induction of ventricular fibrillation. The second is the spontaneous occurrence of ventricular fibrillation, enabling to explain the basic counting process of ventricular events.

The following cases illustrate the methods used to count ventricular events when entering the different programmed zones in order to explain the reasons for the observed delays in analysis of the tachycardias and the type of therapy generated according to the counting mode.

Indeed, counting is the most important phase of the diagnosis, even before application of the discrimination rules. Likewise, in the event of failure of a given therapy, the counting rules during the redetection phase, in addition to influencing the progression of the therapies already performed, also influence the therapies that will follow.

The interpretation of the various tracings will allow explaining the sequence of therapies available in MicroPort defibrillators. We will begin with the VF zone, followed by explanation of the therapies in the VT zone, then those in the Slow VT zone. After presenting the first cases, we will not systematically comment the counting of the cycles in the ensuing cycles, nor necessarily address the discrimination.

At the end of this chapter, the reader should be able to understand the process of events counting and the sequence of therapies based on the tachycardia zones and programmed therapies. At each tracing, the authors will endeavour to provide not only technical comments, but also a clinical analysis of the given situations encountered.

Fundamentals on the counting of ventricular events with MicroPort™ defibrillators.

Rule n°1 : Eight consecutive sliding cycles are analysed to determine « a majority rhythm » or « Majority ». This is the basic unit for incrementing counters. The algorithm tests the conditions listed below in order. The first condition that is fulfilled will determine the type of rhythm for this group of 8 sliding cycles analysed:

1. If 75% or more of these 8 cycles (at least 6) have coupling intervals less than or equal to the Fibrillation Detection Interval (ventricular cycles within the VF zone, including those within the Fast VT section (if enabled) of the VF zone), then the rhythm is classified “VF majority”.
2. If 75% or more of these 8 cycles (at least 6) have coupling intervals lower than or equal to the Tachy Detection Interval (ventricular cycles within the Slow VT zone (if enabled), the VT zone and the VF zone), then the rhythm is classified “VT majority”.
3. If less than 75% of these 8 cycles (less than 6) have coupling intervals less than or equal to the Tachy Detection Interval, and the majority rhythm is not classified as Slow, then the rhythm is classified as having “No majority”.
4. If 75% or more of these 8 cycles (at least 6) exhibit coupling intervals greater than the Tachy Detection Interval or are paced, then the rhythm is classified as “Slow rhythm”.

Note, the first 2 coupling intervals in the VT zone and the pacing coupling intervals are not used for this analysis

A majority rhythm is assessed on each cycle (sliding analysis over the last 8 cycles).

Rule n°2 : When the majority rhythm is classified VT, the PARAD+ criteria for dual-chamber and resynchronization defibrillators, or the Stability+/Acc criteria for single-chamber defibrillators, intervene to formally classify this rhythm. The classification then becomes binary: VT (programmed therapy) or SVT/ST (no therapy).

PARAD+ criteria:

1. RR stability (stability of V intervals)
2. PR association (stability of PR "As-Vs" or AR "Ap-As" intervals)
3. Association level (1:1 or N:1)
4. A or V acceleration (origin of the first sudden acceleration)
5. Long V cycle (medium term instability) (this is the + of PARAD+)

Stability+/Acc criteria:

1. RR stability (stability of V intervals)
2. Acceleration
3. Long V cycle (medium term instability) (this is the + of Stability+/Acc)

These criteria will be specifically analysed in the chapter dedicated to discrimination.

Persistence (counter) \ Majority	VF	VT (VTLC)	SVT	No Majority
VF	Increments	Resets	Resets	Maintains
VT	Increments	Increments	Resets	Maintains
SVT	Resets	Resets	Increments	Maintains

Direction of reading

Rule n°3 : Persistence counters either increment, maintain or reset their value in the following manner depending on the "majority" rhythm assessed at each cycle.

The incrementing of the counter for the fastest zone also increments the counter for slower zones.

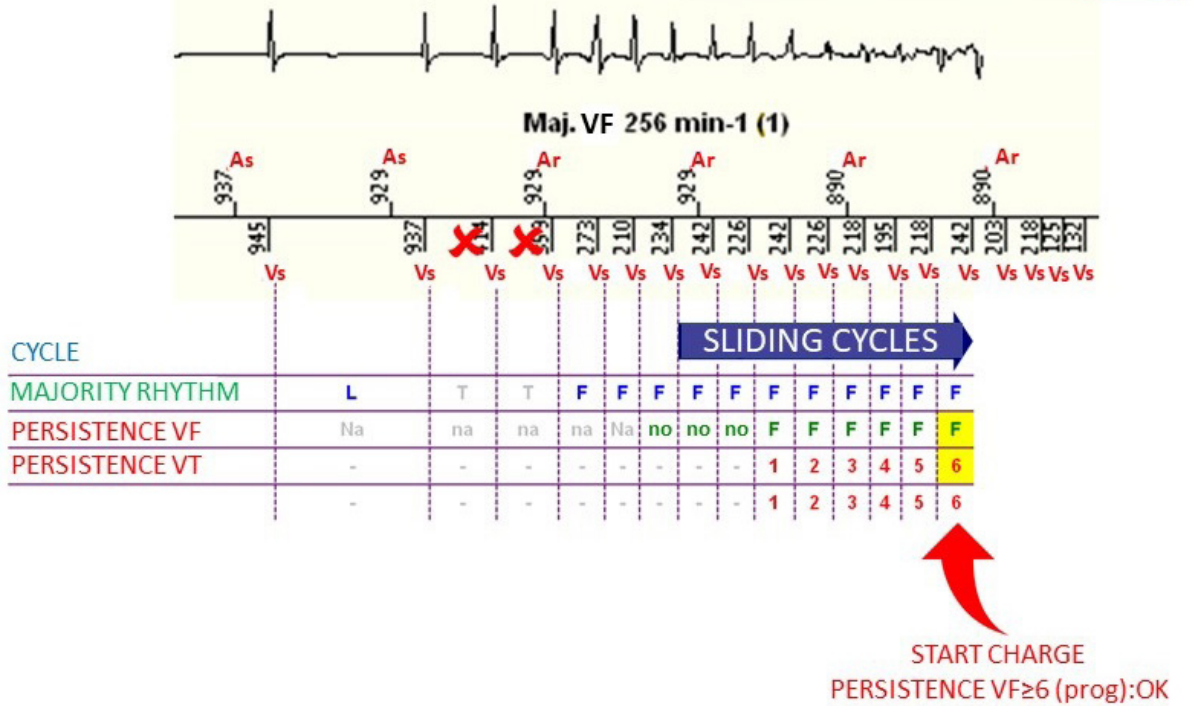
Rule n°4 : Once the first VT or VF majority rhythm is determined, a persistence phase begins (programmed in number of cycles per programmed zone).

The persistence counters for the VT and VF zones are independent. The classification of the episode (VF, VT, Slow VT, VT->SVT/ST or SVT/ST) occurs when the first persistence criterion is fulfilled for the first time. Even if the rhythm evolves and a different classification is obtained thereafter, the classification of the episode will remain that of the initial classification.

Therapies are triggered (delivered in the case of ATP) when the « arrhythmia persistence » counter has reached the programmed threshold.

Rule n°5 : The classification of the episode (VF, VT, Slow VT, VT->SVT/ST or SVT/ST) occurs when the first persistence criterion is fulfilled for the first time. The tachycardia rate is determined once the persistence is reached, and calculated as the average of the last 4 cycles available in the Tachy/VF zone. This rate determines the type of action triggered according to the programming of the zones.

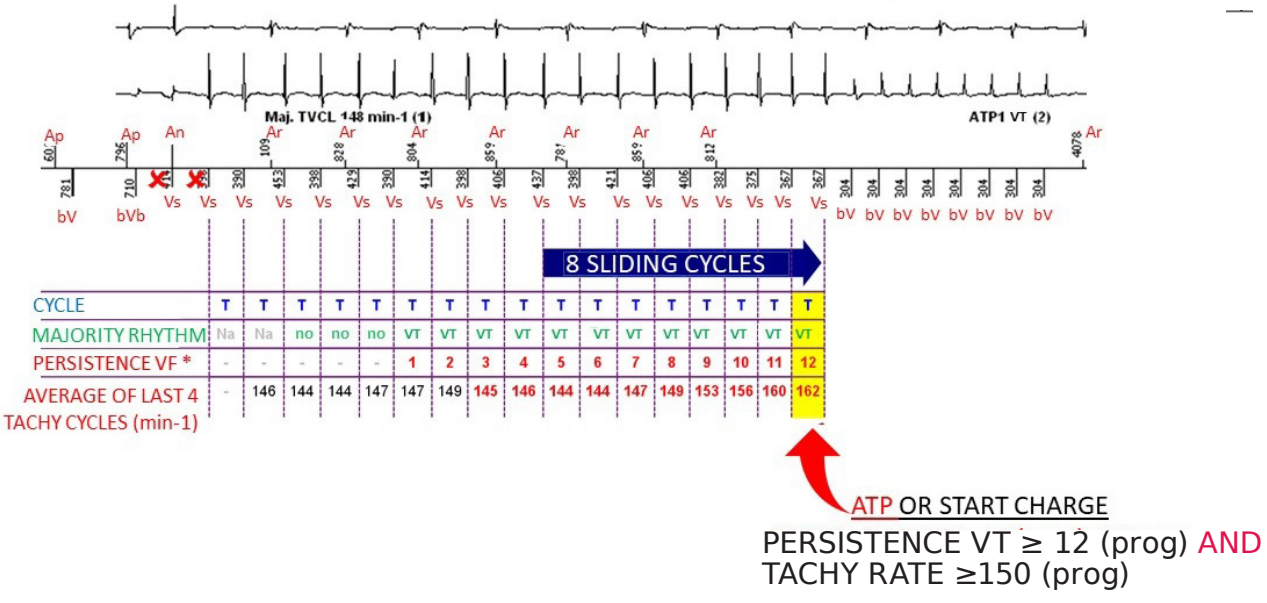
1 - Example for a VF: the VF majority is obtained after 6 consecutive cycles, and if the latter continues for a programmable number of persistence cycles (6 in this instance) for the VF zone (persistence fulfilled), the defibrillator starts charging the capacitors (which is the therapy programmed for a VF rate greater than 240/min in this example). If the tachycardia rate in the VF zone had been between 200 and 240/min, then a Fast VT therapy would have been induced.



Note 1: In this example, the two first cycles are detected in the VT zone, and are not considered (see note of rule n°1), whereas the next cycles are in the VF zone and are all used for the diagnosis of VF. No VF cycles are excluded in the counting process of VF.

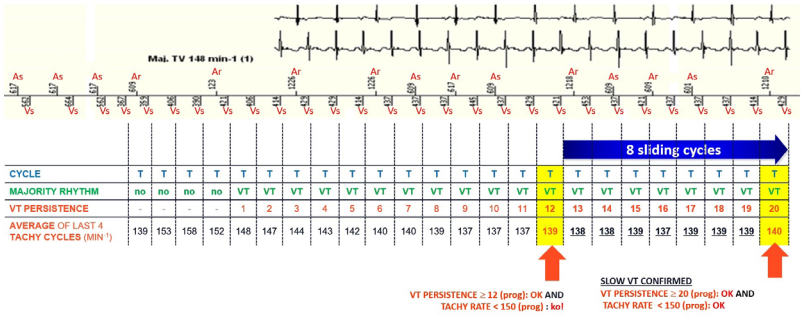
Note 2: Once the very first majority is obtained and displayed (in this instance: VF Maj.) on the markers, as long as the diagnosis of the majority rhythm remains unchanged, there is no new repetitive display of the majorities (VF Maj.) at each cycle.

2 - Example for a VT: the VT majority is obtained after 8 cycles and if this majority continues for a programmable number of persistence cycles (12) for the VT zone (persistence fulfilled), the defibrillator initiates the ATP. At this stage, at least 6 of the last 8 cycles (8/8) are in the VT zone, have coupling intervals lower than or equal to the Tachy Detection Interval, the persistence is reached in the VT zone and the averaged rate of the last 4 Tachy/VF cycles is in the VT zone. It is therefore the first programmed therapy of the VT zone that is induced (an ATP sequence).



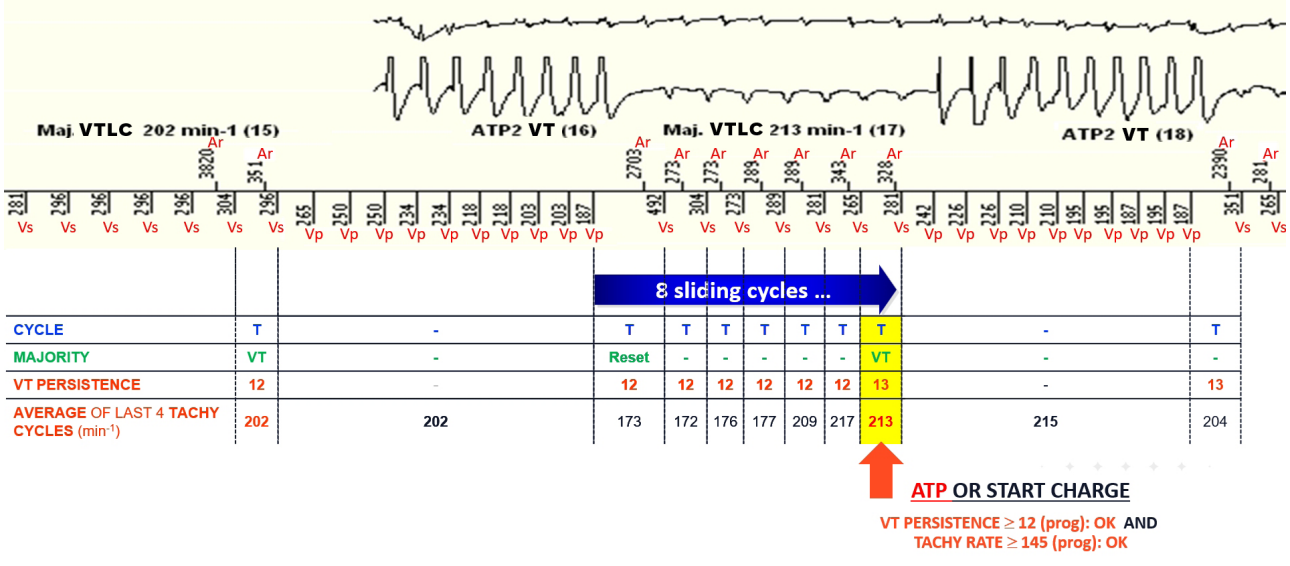
Note: Once the very first majority is obtained and displayed (VT Maj. in this instance) on the markers, given that the diagnosis of the majority rhythm remains unchanged, there is no new repetitive display of the majorities (VT Maj.) at each cycle.

3- Example for a Slow VT: the VT majority is obtained after 8 cycles, and the majority counter continues during the persistence, although at the end of this persistence, the tachycardia rate is not in the VT zone, but in the Slow VT zone: the Slow VT persistence continues to the programmed number of cycles (20 in this instance) which fulfils the persistence in the Slow VT zone. Upon completion, the VT majority is still detected and the average of the last 4 intervals is in the Slow VT zone, the persistence is fulfilled, the defibrillator just starts recording the episode without delivering therapy because no therapy is programmed in the slow VT zone in this example. Otherwise, the therapys available in this area would have been applied.



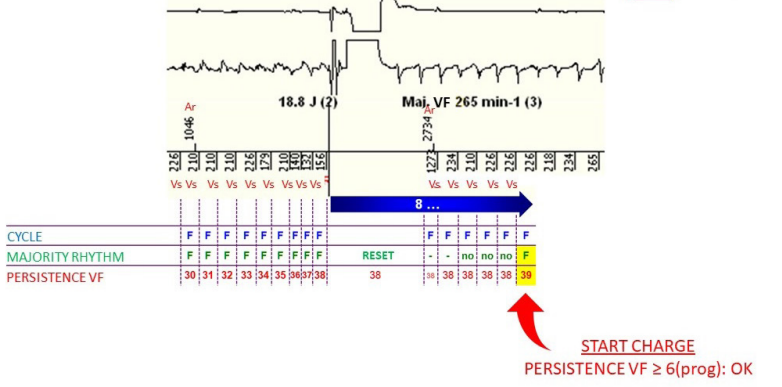
Rule n°6 : After a therapy, a redetection phase is initiated. The majority criterion is then reset to 0, although the persistence counters are not reset. Their value remains that of the persistence values prior to the therapy. A new VT or VF majority (at least 6 out of 8 cycles) is therefore required to deliver the next therapy while respecting the other stated rules, namely the number of programmed persistence cycles, the averaged rate of the last 4 Tachy/VF cycles in the VT zone, and the zone-specific programmed therapies. Note that the first post-ATP cycle in the VT zone is not used.

1 - Example of tachycardia redetection in the VT zone. The first cycle is not taken into account after the therapy, thereafter the 6/8 cycles criterion fulfills the VT majority, the persistence is maintained at 12 (not reset after the therapy) and is incremented on the last cycle regaining the majority rhythm, with the averaged rate of the last 4 Tachy/VF cycles is in the VT zone; the second available therapy programmed for the VT zone is triggered.



2 - Example of a VF majority redetection in the Fast VT zone (150 – 240 bpm): After delivery of the shock due to ventricular fibrillation, a tachycardia appears. After the post-shock blanking period (1s), a VF majority appears immediately following 6 VF cycles. The persistence is the same as that observed before the shock and is maintained. Then, the averaged rate of the last 4 Tachy/VF cycles is in the Fast VT zone; hence it is the next therapy programmed in the Fast VT zone that is triggered, i.e. a shock.

3 - In detection or redetection, when the Slow Rhythm majority criterion is fulfilled, the episode is considered terminated, and all tachycardia and fibrillation counters are reset. The current status of the therapy programs is also reset.



Conclusion and reminder:

1. The prevailing element in the counting of ventricular events by MicroPort defibrillators is a basic analysis on 8 sliding cycles with a search for the majority rhythm (or diagnosis) (at least 6 out of 8 cycles).
2. The duration of a persistence phase (programmed in number of cycles) is dependent on the zone in which the tachycardia was diagnosed. During the course of obtaining this persistence, the diagnosis can evolve, with this analysis of majority cycles in the fastest zone also leading to the counting in slower zones.
3. If 3 zones have been programmed (Slow VT, VT, and VF), a VF majority also causes incrementation of the counters in the slower zones of the Slow VT and VT. A VT or Slow VT majority also causes the increment of the VT of Slow VT zone counter, but resets to 0 the VF zone counter.
4. The first attained persistence carries the definite diagnosis of tachycardia, and consequently the eventual programmed therapy.
5. A diagnosis of SVT/ST during VT or VF persistence resets the persistence counter to zero, which resumes only if a new diagnosis of Slow VT, or VT, or VF has been established and for the required number of cycles corresponding to the zone of the new tachycardia event.

The delivery of a therapy, in particular a shock, is subject to conditions (a verification cycle):

- At the time of delivering the VF therapy, the VF persistence counter is always equal or higher than the programmed threshold, the majority rhythm analysis is still VF and the current cycle is in the VF zone.
- At the time of delivering the VT therapy, the VT persistence counter is always equal or higher than the programmed threshold, the majority rhythm analysis is still VT and the current cycle is in the VT zone.

If these conditions are not fulfilled, the device will verify the next cycle in order to deliver its programmed therapy.

Case 1

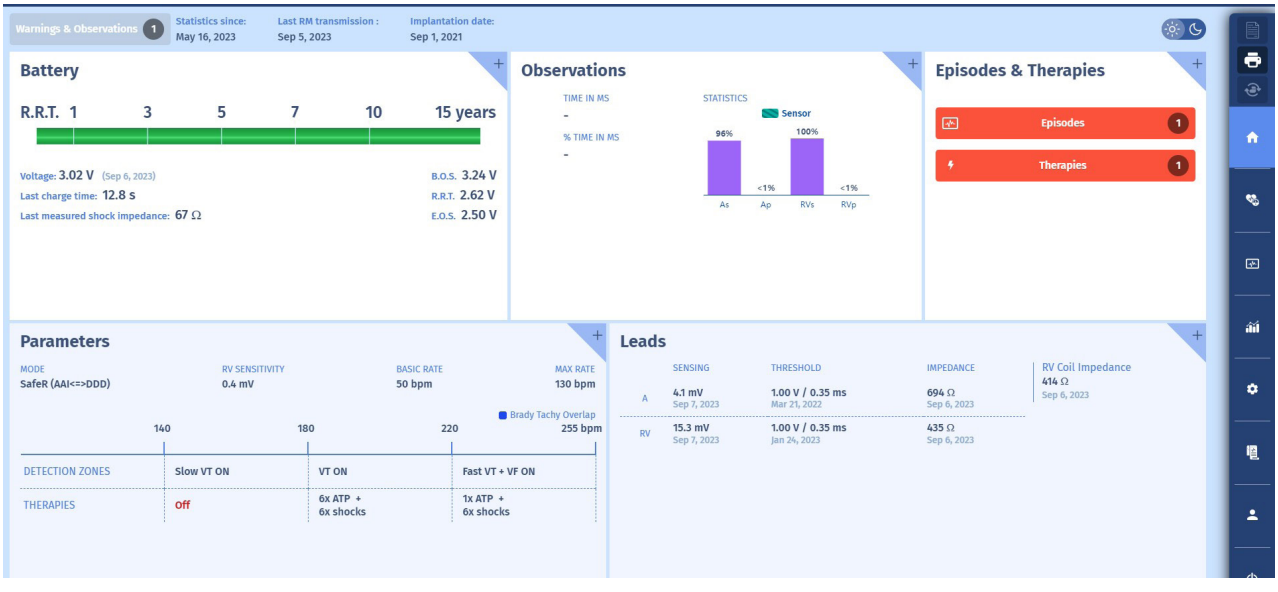
Counting and diagnosis of ventricular fibrillation

Patient

A 66-year-old man, implanted with a dual-chamber defibrillator for secondary prevention due to ischemic heart disease in the absence of infarction, with an ejection fraction of 27%, presenting initially with decompensated heart failure with narrow QRS complexes. The patient came in for a consultation because he had experienced an electric shock preceded by palpitations and presyncope.

Summary screen

Here is the first screen when interrogating the defibrillator:



What is your opinion? (multiple answers possible)

1 The battery is new

2 The impedance of the shock electrode is not satisfactory

3 The programming of the therapies is in keeping with the recommendations

4 There appears to be a problem with the atrial lead.

5 There is a high probability that certain atrial arrhythmias are not detected.

Interpretation

1 At interrogation, and after verification of the leads, we can see that they function perfectly, that the battery is new, that the patient has received at least one shock since the shock impedance was measured, with a value of 67 Ohm. The anti-bradycardia programming attempts to abide to AV conduction by the SafeR-R mode; the ventricular pacing rate is <1%. For tachycardias, a Slow VT zone, from 140 to 180/min, is a monitoring

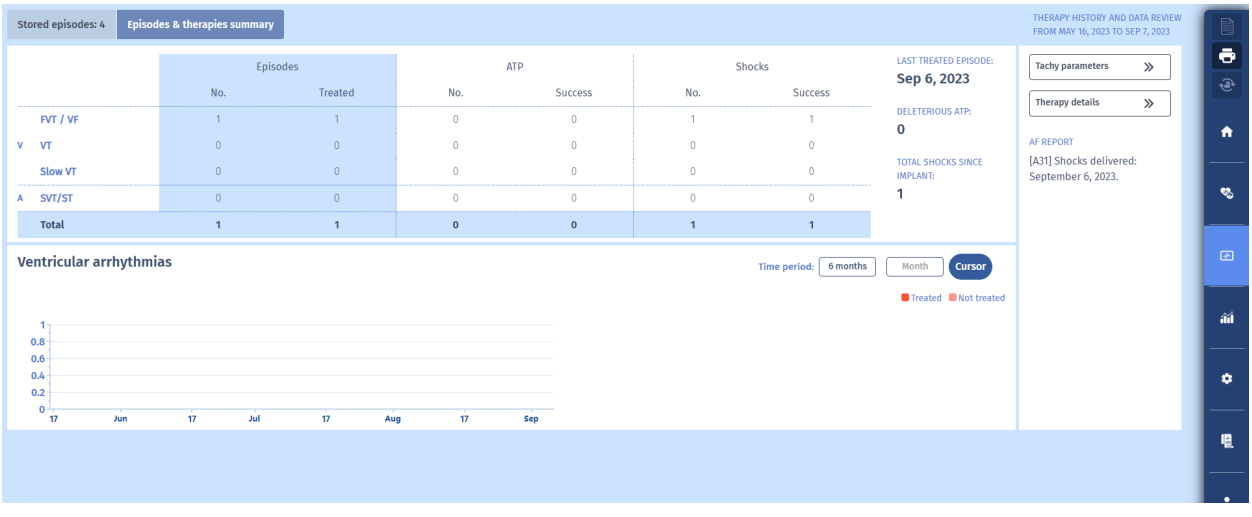
zone; between 180 and 220, a VT zone with therapies comprised of 6 ATPs and 6 shocks (all at maximum energy of 42 Joules not visible on this screen); above 220/min, a Fast VT zone + VF, with up to 255/min, 1 pre-shock burst if the tachycardia is stable, followed by maximum energy shocks, and maximum energy shocks alone beyond 255/min. The programming is in keeping with recommendations.

2 In the Observations section, there was no mode switch, suggesting the absence of atrial rhythm disorders, especially since the atrial detection in sinus rhythm is very good (4.1mV), suggesting a good detection of AF when occurring (simple presumption since there is limited correlation between the amplitude of the sinus signals and the atrial arrhythmia signals).

3 In the Episodes & Therapies section, we can that there has been 1 episode with therapies. On the old user interface, there would have been more information presented in the form of a table. But for the sake of clarity, it has been decided to consolidate this information and present the details elsewhere.

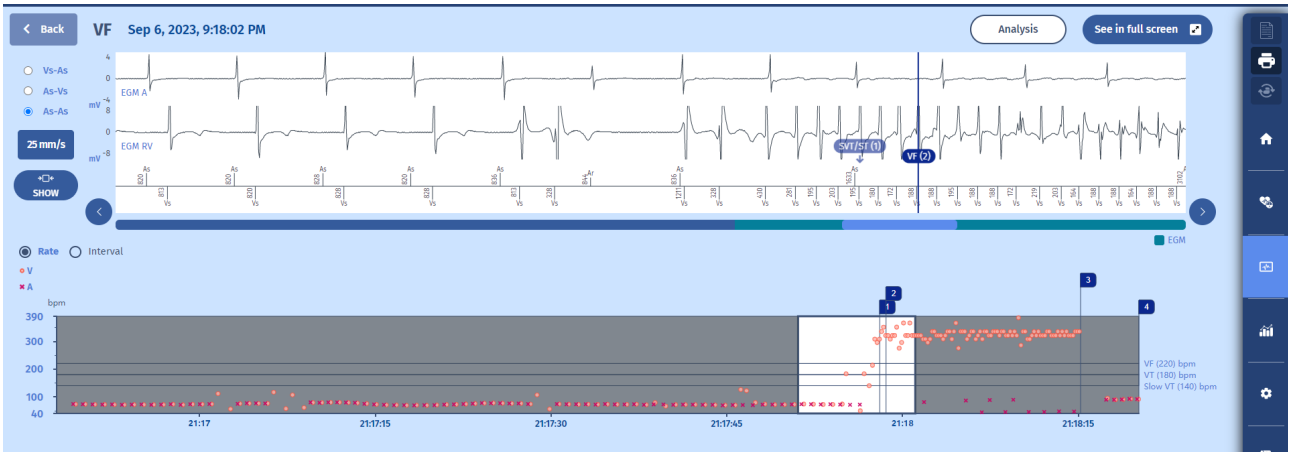
When we click on one of those red buttons (or when we go to the “episodes” screen we will access the following episode list. The list of memorized episodes appears with their respective type, date, duration and therapy applied.

When we click on “Episodes and Therapies summary”, we can observe a table with episodes and therapys. We can see that there has been 1 VF episode with therapy.



Episode review

Let's review the most recent episode, diagnosed as VF, resulting in a shock. We will get a combined screen showing the EGM corresponding with the highlighted area on the tachogram displayed below.



The interval plot reveals the following elements:

1 On the right of the graph, the following zones are noted: a monitoring Slow VT zone from 140 to 180/min, a VT zone from 180 to 220/min with bursts, ramps and shocks, and VF above, with a FVT zone from 220 to 255/min with 1 burst followed by maximum shocks.

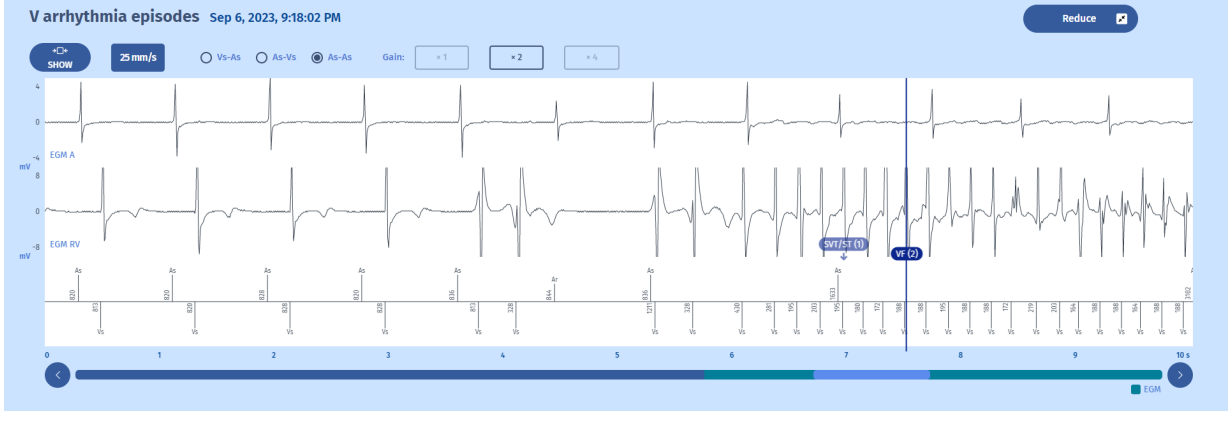
2 Initially, the rhythm is 1:1 in a Slow rhythm zone with some premature ventricular complexes (the higher orange dots) and compensatory pauses (lower orange dots).

3 Suddenly, a chaotic tachycardia occurs in the VF zone. The diagnosis of VF was made (at marker 2), after which a 41.8 Joule shock was delivered (marker 3) with immediate effectiveness.

4 Return to slow rhythm. The episode is terminated (marker 4).

Electrogram: beginning

While the interval plot allows for a quick overview of the episode with possibility of making the diagnosis in most cases, it is essential to analyze the electrogram (EGM) to verify proper functioning of the ICD. The EGM can be expanded by clicking on « See in full screen ».



Case 1

Tracings: The tracing at the top entitled EGM A is the atrial electrogram, the tracing underneath entitled EGM RV is the ventricular electrogram, lastly, at the bottom, the atrial markers above the line and ventricular markers below, along with the time intervals. The gain can be changed at the top (now set at X 2). The running speed can also be changed, ranging from 12.5 to 100 mm/sec.

The EGM shows the following elements

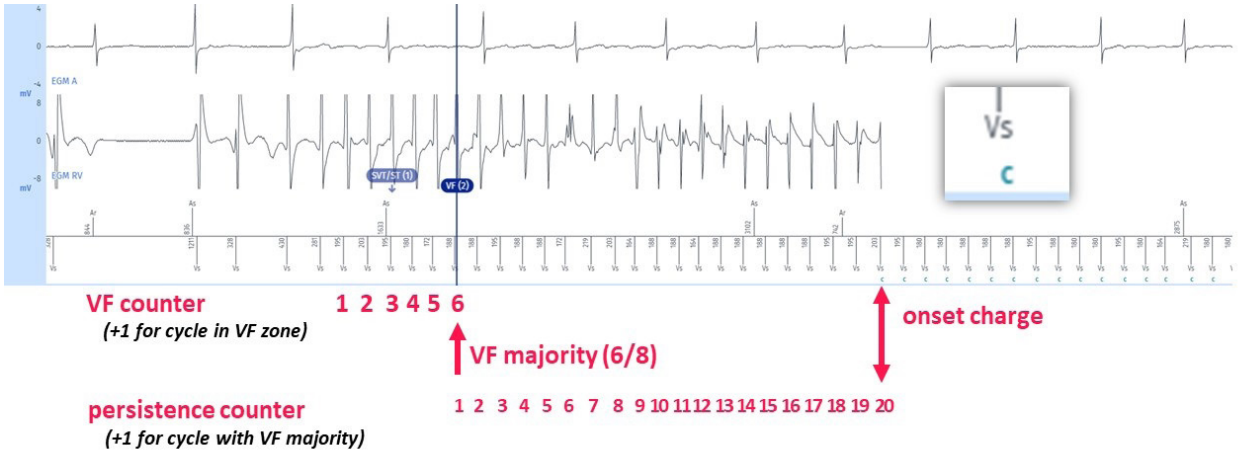
1 An intrinsic rhythm with spontaneous atrioventricular conduction rhythm at baseline;

2 A few ventricular extrasystoles which seem to be associated with the onset of a polymorphic tachycardia above 220/min, perfectly detected, with a slow and regular atrial rhythm, and small amplitude signals on the atrial channel which are far-field signals of ventricular origin and not detected by the atrial chain;

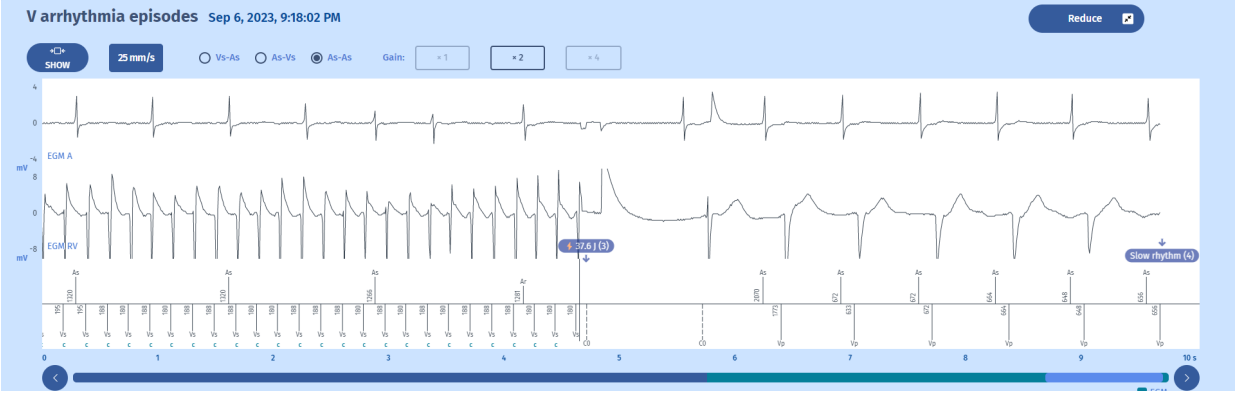
3 After 6 out of 8 cycles in the VT zone, the diagnosis of SVT/ST is made (marker 1); this is often seen in VF episodes and is caused by the “warming” up of many ventricular arrythmias. The combination of fast cycles (PVCs and the onset of VF) and slow cycles (compensatory pauses or differences in cycles often seen during “warming up” period) results in the VT criteria being fullfilled before the VF criteria. As the rythm is unstable, it is considered SVT by the discrimination algorithm, therefore we see a first marker SVT/ST, rather than VT of VF.

4 After a majority of 6 out of 8 cycles in the VF zone, the diagnosis of VF is made shown by the marker VF (2). It should be pointed out, even before the course on discrimination, that the discrimination criteria (PARAD+) are not active because it is the VF zone.

5 After diagnosis of VF, therapys are not directly delivered as we want to give the tachycardia the chance to self-terminate. The tachycardia needs to complete the persistence counter before therapies are delivered. After 20 persistence cycles, as programmed (and as recommended), during which the diagnosis of VF is confirmed at each cycle, according to the 6/8 majority, the capacitor charges (« C »). Indeed, no burst was triggered because the rate is above the 220 – 255/min zone. (If the tachycardia had been within this aforementioned zone, and if it had been stable, then a burst would have been triggered. If the tachycardia had been within this zone but conversely unstable, then an immediate shock would have been delivered without a prior burst).



Electrogram: end



1 Once charged, the defibrillator sends a shock on the next cycle which is in the VF zone; shown by the marker: 37.6J (3).

2 After the shock, there is a 1-second blanking period (between C0 markers). After six cycles out of tachycardia zones the Slow rhythm majority is met (6/8) and the episode is terminated.

Correct Answers - n° 1 and 3

Comments

The EGMs show normal functioning of the defibrillator. The counting of the events is carried out as follows:

1 Each ventricular cycle detected outside refractory periods is classified as: Slow, VT or VF, depending on the programming of the tachycardia zones.

2 In a sliding window of 8 cycles and for each cycle, the device classifies RR cycles with a 16-ms margin in a histogram. Paced cycles do not enter into the constitution of the histogram.

3 In the present case, 75% of the 8 cycles, hence 6, must be in the VF zone for the diagnosis to be established. For a therapy to be triggered, it is necessary that the persistence of the programmed number of cycles is fulfilled (in this instance 20 cycles, according to the recommendations), with the VF majority detected for each cycle. The last 4 cycles determine the initiation of therapy due to FVT or VF: each of the last 4 cycles are analysed and if any of the latter is in the VF zone above the FVT zone, the assigned therapy will be a 42 J shock (depending on the programming), and the charge of the capacitors begins.

4 All tachycardia cycles are in the VF zone during the charge which is therefore continuous. It is on the ensuing cycle which follows the end of the charge and which is in VF zone that the shock is delivered.

5 After the shock, 6 out of 8 cycles are in the Slow zone, the rhythm is deemed slow and the episode is terminated.

A systematic approach must be used to read the follow-up data:

1 Make sure that the leads are working properly and repeat the tests systematically. Leads in perfect condition report reliable signals to the defibrillator and the stored data are interpretable. If the leads do not work properly, the reading of the memories will need to be with much more caution.

2 Make sure you analyse the programming of the device properly to correctly interpret the memories. The device only records events according to what it is asked to do and record !

1 To correclty interpret EGMs, a sound knowledge of the programmed algorithms is required.

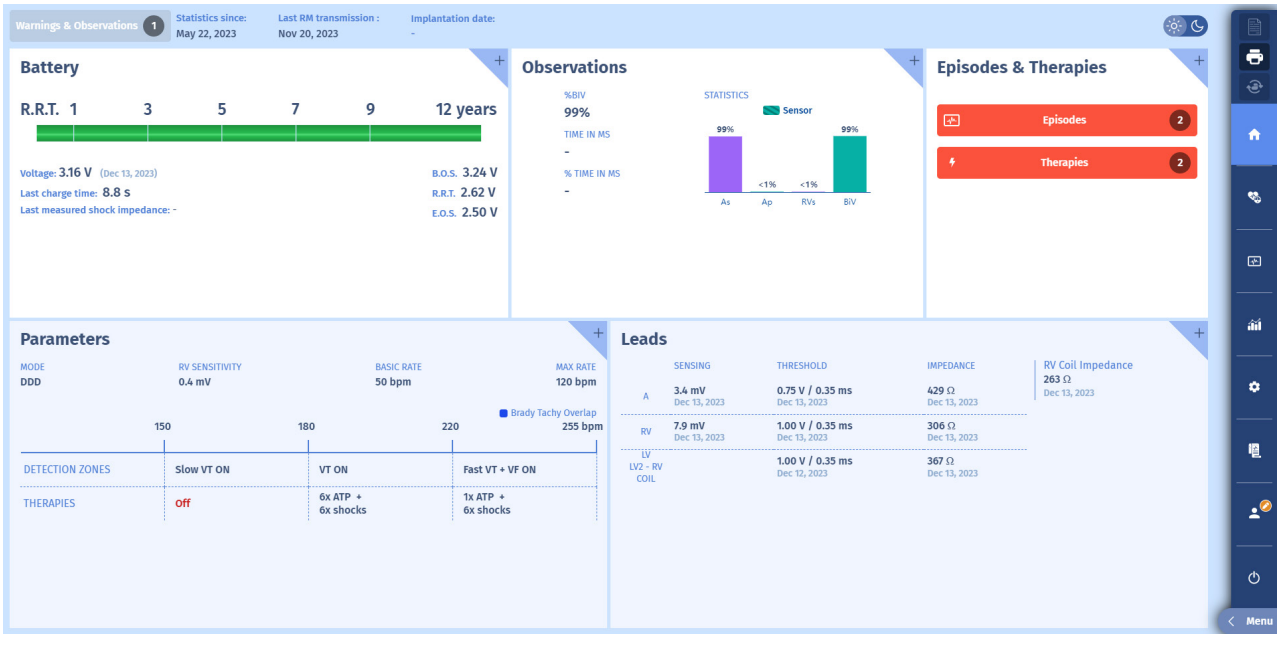
Case 2

Counting in the VT zone

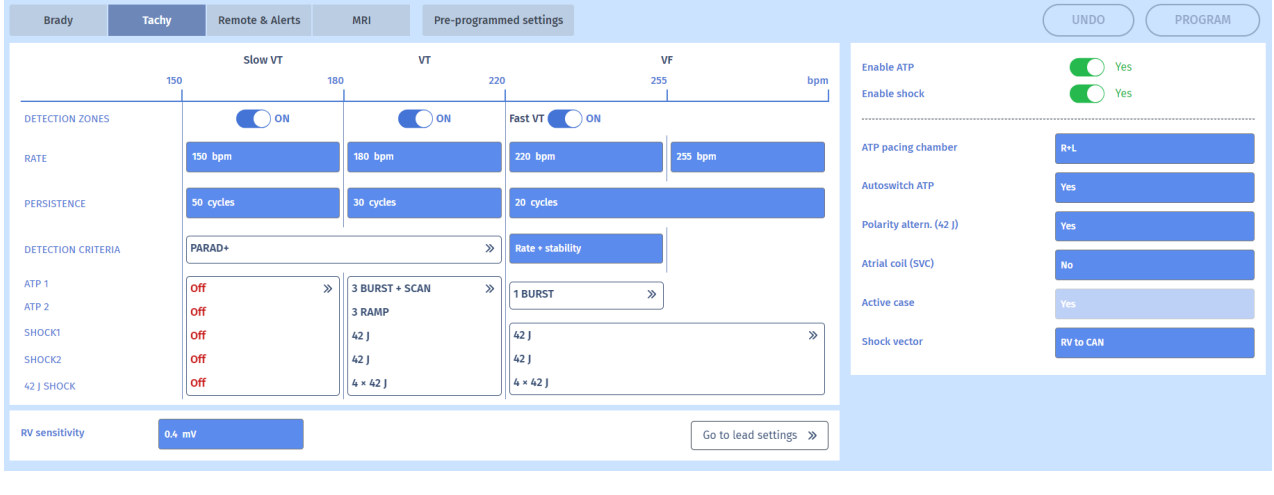
Patient

A 61-year-old male was implanted with a dual-chamber device for dilated coronary heart disease with compensated heart failure and an ejection fraction between 30 and 35%. The patient consults for a systematic follow-up control.

Overview screen

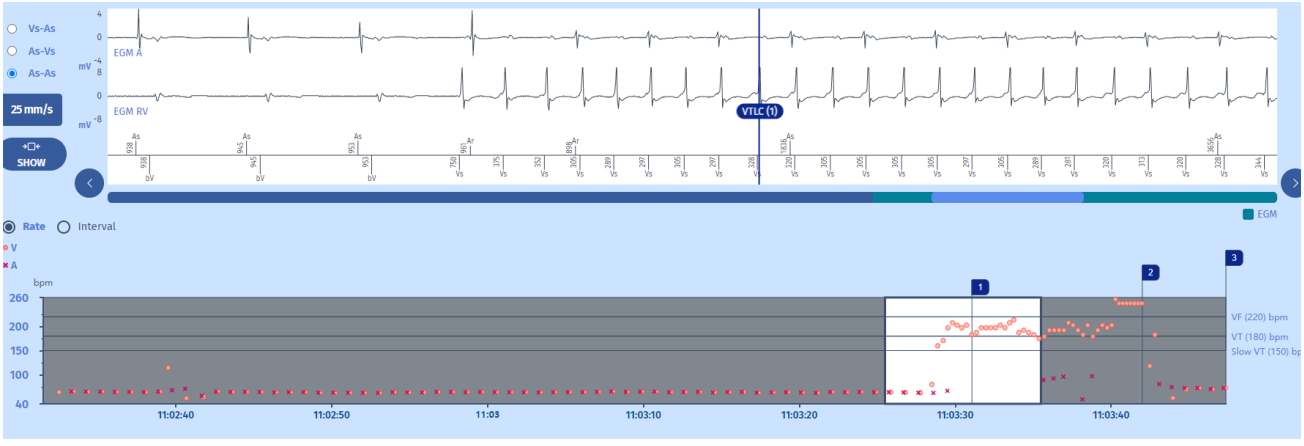


Programming



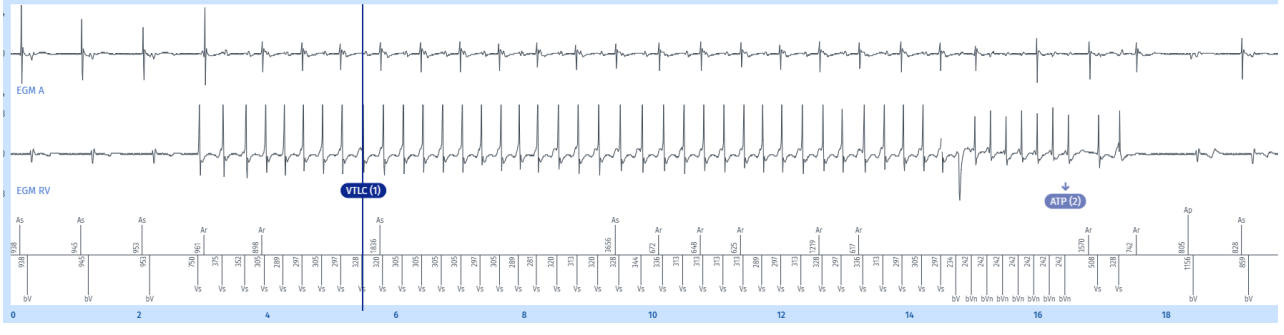
Case 2

Episode (first screen)



Overview of the full EGM

Tracings: The tracing at the top is the atrial electrogram, underneath, the ventricular electrogram, and lastly, at the bottom, the atrial markers above the line and ventricular markers below, along with the time intervals.



What is your diagnosis ?

1 Ventricular tachycardia diagnosed in the VT zone

2 VT diagnosed in the Slow VT zone

3 The antitachycardia pacing is a ramp

4 The antitachycardia pacing terminates the tachycardia.

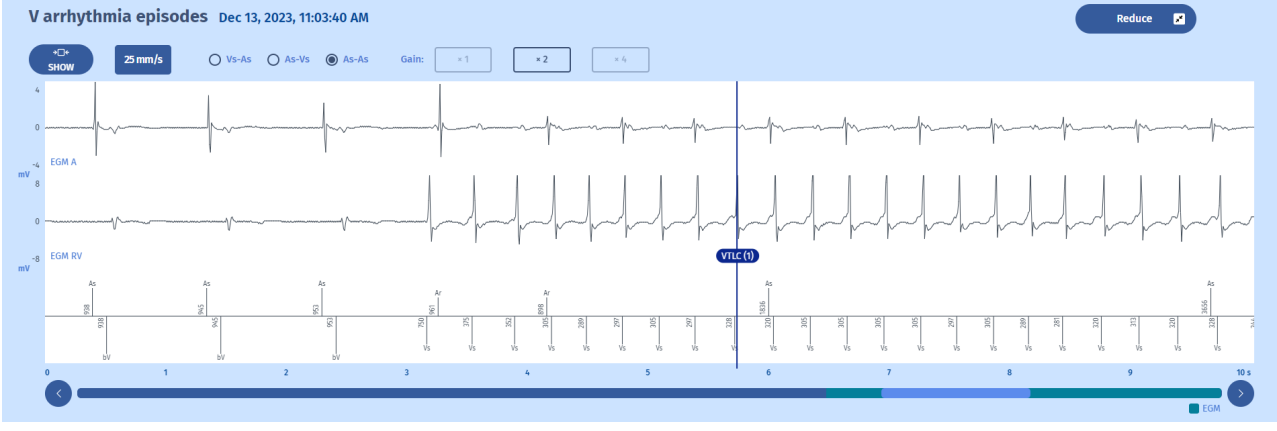
Interval plot

1 The rhythm is sinus with biventricular resynchronization.

2 Ventricular tachycardia begins in the VT zone (orange dots), while the atrial rate remains slow (purple crosses (x)).

3 An ATP is delivered with a return to sinus rhythm in the Slow zone.

EGM



1 The rhythm is sinus with synchronized biventricular pacing

2 Ventricular tachycardia begins. The first tachycardia cycle (750 ms) is outside the tachycardia zone (400 ms). For the defibrillator, the tachycardia begins at the next cycles which are in the VT zone (375 ms, 352 ms < 400 ms). In the VT zone, the first 2 cycles are excluded. The next 6 cycles are all in the VT zone and count towards the majority. The rate is on average 200/min so well within the VT zone (>180/min). The 6 out of 8 cycles in the VT zone criterion is fulfilled. The ventricular rhythm is stable and there is an atrio-ventricular dissociation (more ventricular than atrial signals). The marker is: VTLC (1). The persistence phase begins.

3 After 30 persistence cycles during which all cycles are in the VT zone, an anti-tachycardia pacing burst is initiated for 8 fixed cycles (this is the first therapy programmed in this zone), shown by the second marker: ATP (2).

4 The ATP is effective with termination of the tachycardia, and after 6 slow cycles (and a PVC at 328 ms), the episode is terminated (label: Slow Rhythm).

Case 2

Correct answers - n° 1 et 4

Comments

1 This episode shows the perfect detection of a ventricular tachycardia. The counting is carried out according to the 6 of 8 cycles rule: 75% of cycles in a programmed VT zone triggers a persistence phase that is programmable in cycles (in this instance 30) during which the cycles must validate a majority rhythm (6 out of 8 cycles) in a VT zone and are analysed for diagnosis. If a Slow cycle (excluding VT zones) is detected, it does not reset the persistence counting to zero. The VT persistence counting is set to zero if a majority of Slow cycles is detected or a majority of SVT/ST rhythm. In addition, there is no distinction between VT and Slow VT during the counting of VT persistence: it is only at the end of the VT persistence (the shortest) that the device calculates the averaged rate of the last 4 cycles to determine if the rhythm is in the VT zone or in the Slow VT zone. In the present example, all of the cycles are in the VT zone. If the cycles enter in VF, the diagnosis of VF is made if the majority rate (6/8) is VF.

2 The averaged rate of the last 4 cycles in the Tachy/VF zone calculated at the time of persistence determines the type of therapy that will be initiated after the persistence phase. The first therapy programmed in the VT zone of our patient is therefore launched (an 8-cycle burst with a pacing interval equal to 80% of the average coupling interval of the tachycardia). In this case the average RR interval was 305 ms (197/min) resulting in an ATP of 242 ms (248/min).

3 Note: not all atrial events are sensed given that, due to atrio-ventricular dissociation, some fall into the post-ventricular atrial blanking period; during the ATP, the ventriculograms are only captured completely from the 2nd cycle of the burst.

4 The therapy was effective, and thus the programming will not be changed.

Take-home-messages

1 The counting follows the rules of the majority rhythm. At least 6 out of 8 cycles must be in a programmed zone for an initial diagnosis to be made.

2 The persistence phase must be completed to establish a final diagnosis and is recommended at 30 cycles.

3 In the VT or Slow VT zone, the last 4 persistence cycles determine the type of therapy of the tachycardia zone that will be applied.

Case 3

Competing counters

Patient

A 70-year old patient is implanted with a dual chamber ICD (ULYS DF4) in the context of secondary prevention (VF) in ischemic cardiomyopathy. You interrogate the device in the emergency department after sensation of a shock.

Why are there three markers (SVT, VT and FV) before the diagnosis is made ?

1 Because there is intermittent undersensing, which delays the diagnosis of VF

2 Because it is a supraventricular tachycardia, initially correctly diagnosed (SVT) but then the diagnosis changed inappropriately to VF.

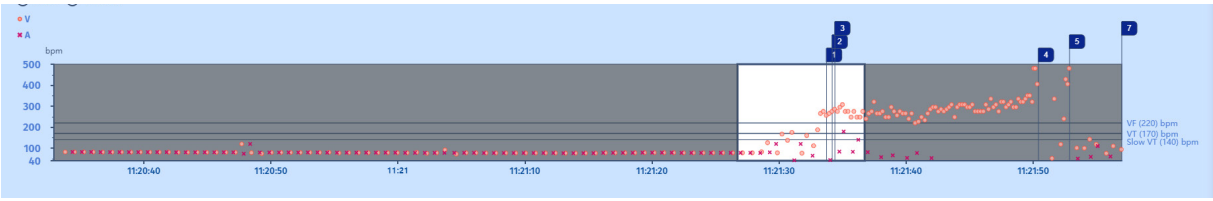
3 Because it's how the counters work: first VT zone but irregular (SVT marker), then VT zone and stable (VT marker) and then in VF zone (VF marker).

4 Because there is oversensing of the VT which fills the VF counter.

Case 3

Interpretation

This is a typical example of a tachycardia in the VF zone which shows multiple markers before the final diagnosis is made.

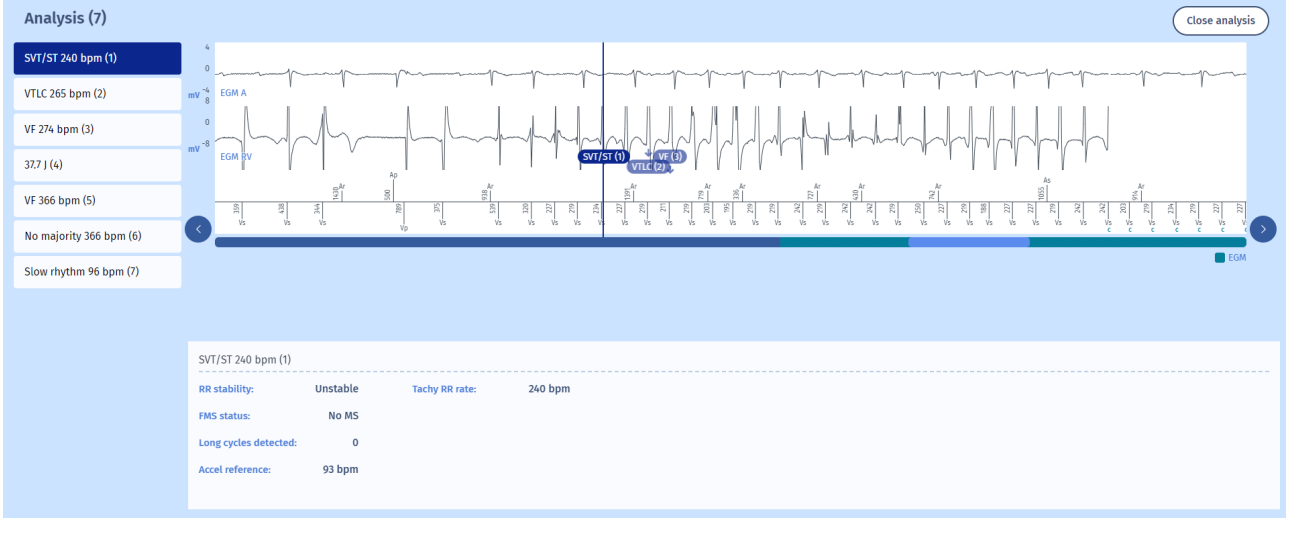


The interval plot shows a stable atrial and ventricular rhythm (probably paced as the intervals seem fixed) with a sudden acceleration of ventricular events, beginning with extrasystoles and continuing with a more organized tachycardia in the VF zone. After the shock (marker 4), there are again a few extrasystoles before the return to slow rhythm).

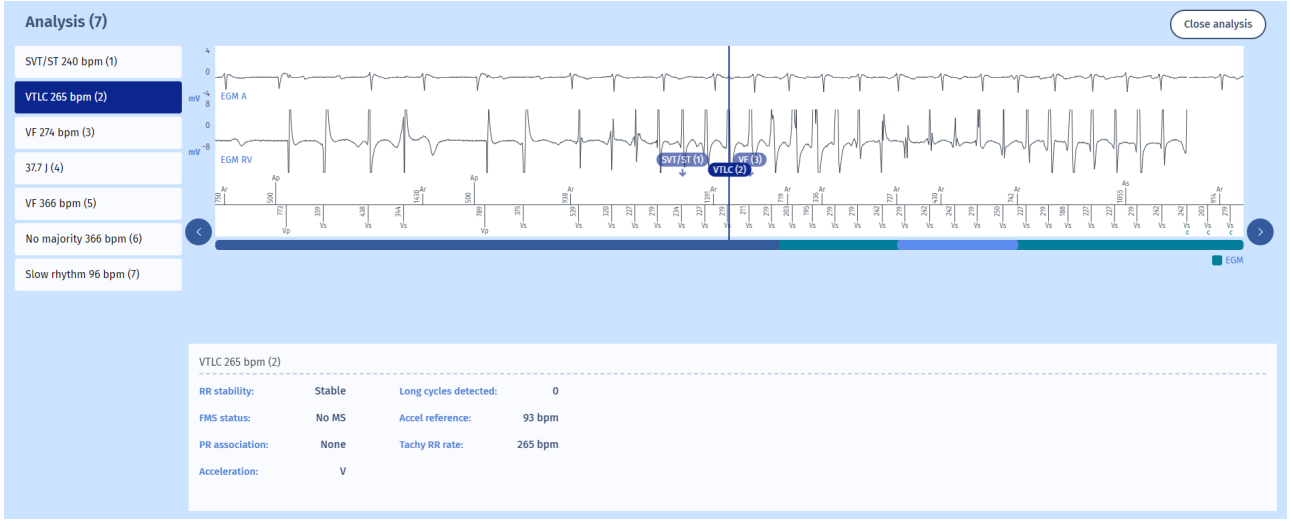
EGM

The beginning of the tachycardia is very typical with first extrasystoles disturbing the rhythm and then an organized ventricular arrhythmia which speeds up and becomes more organized after a few cycles. This is called “warming-up” and is often seen in the beginning stage of a fast ventricular tachycardia.

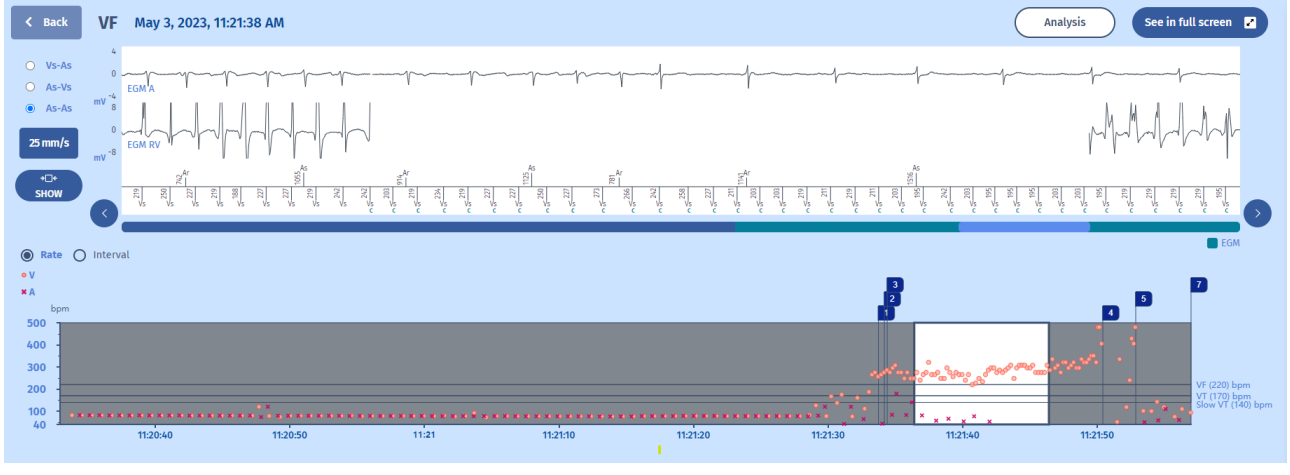
As MicroPort ICDs use a very fast counter (6 out of 8), we often see an early SVT marker during this period as there are 6 cycles in the VT zone (including 2 extrasystoles) but these cycles are unstable and therefore the discrimination algorithm classifies the events as “supraventricular” (SVT). When we click on the marker, in the window we find the word: Unstable, which confirms the normal algorithm behavior.

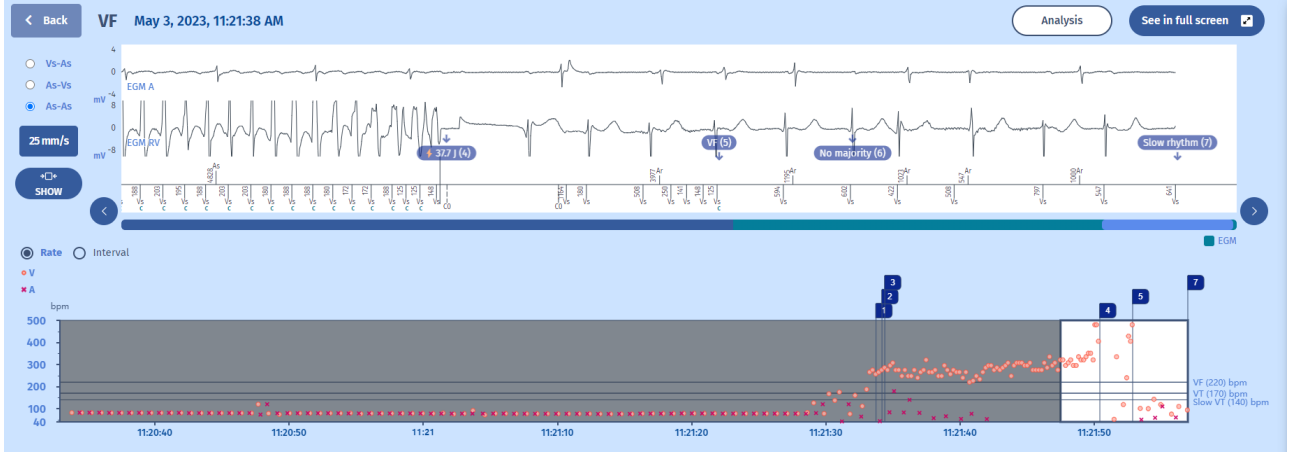


The next marker is the VT marker which is after the 6th stable cycle in the VT zone and therefore the rhythm becomes stable and the diagnosis changes from SVT to VT. The marker is actually VTLC which means VT but with consideration of “Long Cycles”, more about this later in the Discrimination section. It is important to realize that at this moment, the VT persistence starts counting at a value of 1.



As the arrhythmia speeds up into the VF zone, there is fast appearance of the VF marker and the VF persistence starts (at a value of 1) while the VT persistence increases to 2 (it was 1 during the previous cycle at the same time as the VTLC marker). There is no discrimination in the VF zone in MicroPort ICDs so any 6/8 events in the VF zone will result in a VF marker. There is however another check of stability which is required to make the choice between Fast-VT or FV therapies but more about this later. After filling of the VF persistence (20 cycles), the charge begins.





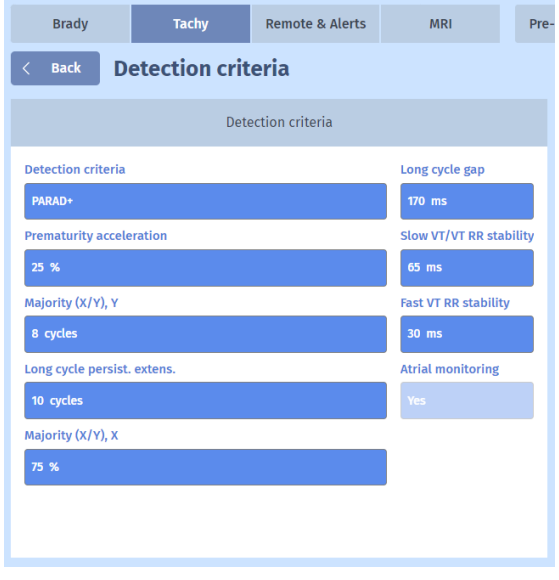
Case 3

After the charge has completed, there is confirmation of the tachycardia and the shock is delivered. The shock terminates the VT. Interestingly, there is a new VF marker which is caused by some low amplitude noise on the ventricular channel, associated with some late post-shock artifacts. But the persistence is reset soon after when the VF majority is lost (No majority marker). The episode is concluded when the Slow majority is reached.

Correct Answer: 3

Comments

As only 6 fast events (in a window of 8 events) are required to make a diagnosis, MicroPort ICDs have the shortest counters on the market. Therefore, the ICDs delivers checks on each cycle to confirm the rhythm still has the same majority. If the majority changes, there will be a new marker displayed. It is very informative to click on “Analysis” to show more information about each marker in order to understand why the ICD has made certain decisions. And so you will often see multiple markers before the first therapies are delivered as ventricular arrhythmias start with extrasystoles, as they speed up and become stable after a few seconds. A quick fix to this could be to prolong the 6/8 counter and while this is possible to do in MicroPort ICDs, the engineers strongly advise against changing this parameter because it is the core of ICD fonctioning.



Under “Tachy” parameters, we can find and modify the X out of Y Majority. By defaut, Majority is set to 75% (X) out of 8 cycles (Y) and these parameters should not be changed.

Take-home message

MicroPort ICDs have very short majority counters. As ventricular arrythmia’s often “warm-up”, we often see SVT or VT markers before the VF marker.

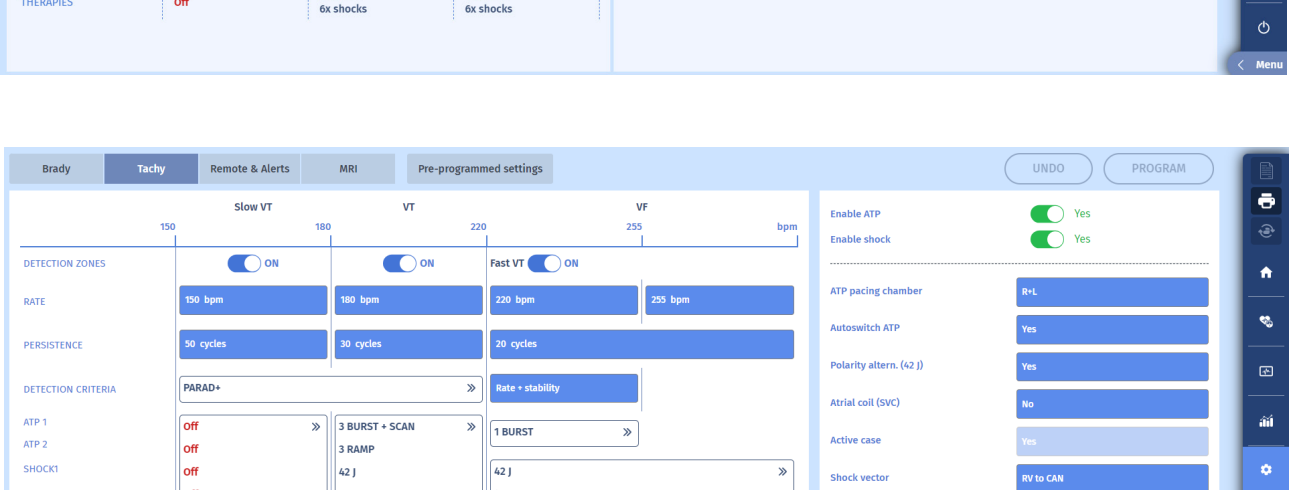
Case 4

Persistance

Patient

62-year old patient with dilated cardiomyopathy with left bundle branch block and reduced LV ejection fraction, implanted with a Gali CRT-D, comes for a check-up after an episode of palpitations.

Overview sceen



Case 4

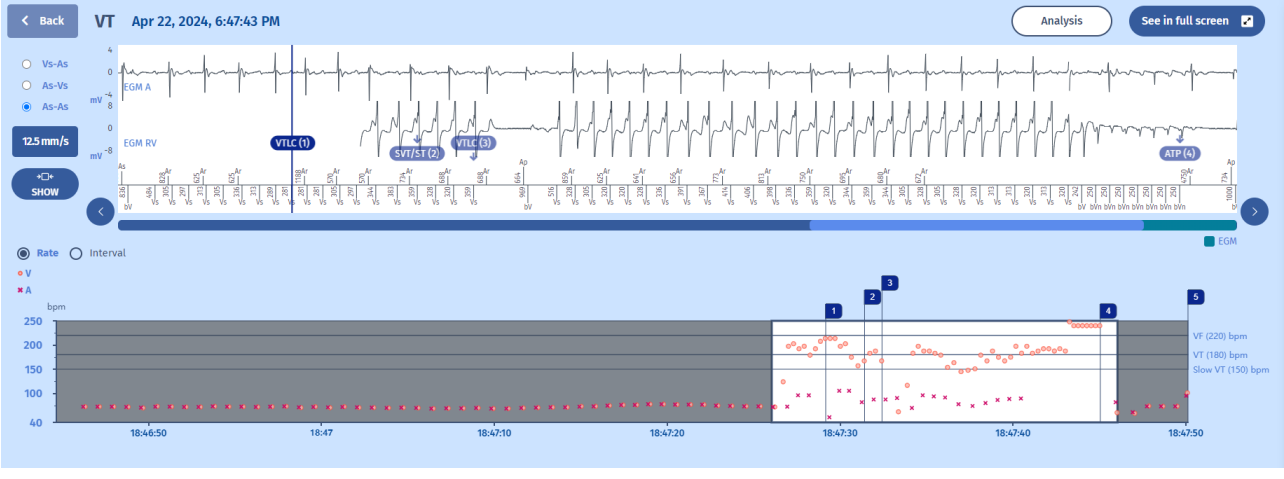
Which of the following statements are correct?

1 The persistence in the VT zone is programmed at 30 cycles
2 The persistence in the VF zone is programmed at 30 cycles
3 The persistence in the VT zone is programmed at 20 cycles
4 The persistence in the VF zone is programmed at 20 cycles

Interpretation

The programmer screen shows well functioning leads and a single episode which received therapy.

This is the episode:



Tachogram

After an slow and regular rhythm suggesting atrial sensing and biventricular pacing, there is a sudden acceleration of ventricular cycles. As there are more ventricular events than atrial events, the episode is highly suspicious of ventricular tachycardia, in the VT zone. Marker 1-3 are related to counters and marker 4 is an ATP, which is succesful.

EGM

1 The rate of the initial rhythm around 70 beats per minute

2 Then the diagnosis of VT (Marker 1: VTLC) is made after 6 out of 8 cycles in the VT zone.

3 The rhythm becomes irregular, the ICD suspects atrial fibrillation and so displays the second marker: SVT/ST

4 After a few more cycles, the rhythm again stabilises and the third marker shows: VT

5 When the persistence counter is completed (more details about this later), an ATP is delivered (burst with 8 pulses) which terminates the VT

6 After 6/8 slow events, marker 5 marks the end of the episode

Correct answer - n° 1 and 4

Comments

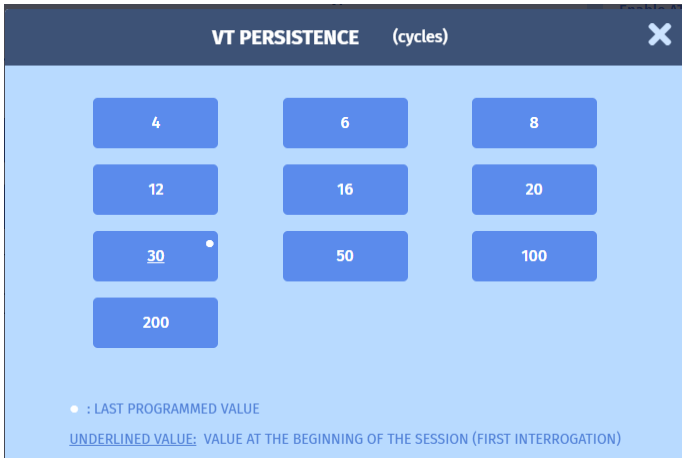
The persistence counter is essential for two reasons.

1 It prevents unnecessary therapy by allowing nonsustained ventricular arrhythmias to self terminate. Multiple studies have shown that therapy of ventricular tachycardias by shocks is deleterious for the patient. Shock may be delivered because ATPs are not successful but also because ATP may even accelerate the arrhythmia into the VF zone. All efforts need to be made to avoid ICDs treating VT and programming a long persistence is probably the most efficient method. In the VT zone the persistence should be programmed at 20 or 30 but it can even programmed to 200.

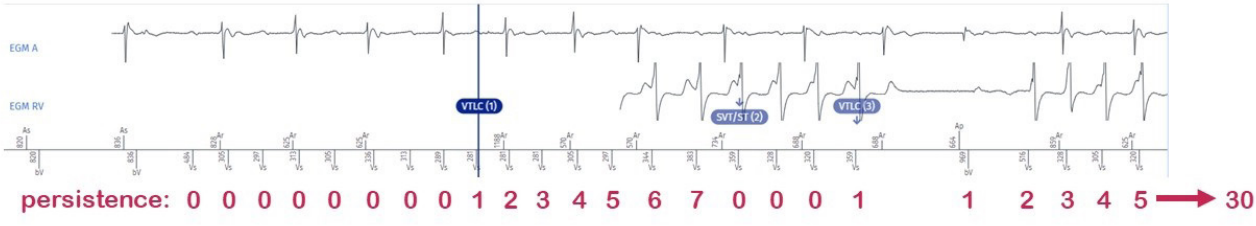
2 It prevents inappropriate therapy by allowing for supraventricular arrhythmia or noise to self terminate before the wrong diagnosis (VT or VF) is made. Noise is often expressed as short bursts of ventricular oversensing and programming a persistence of 20 cycles or more is very efficient in preventing the filling of the persistence counter during bursts of noise. Supraventricular arrhythmias can be errounously diagnosed as VT for many reasons and a longer persistence counter gives the ICD more chance to rediagnose the arrhythmia as supraventricular. In MicroPort ICDs, the discrimination algorithms work continuously, also during the persistence, which is why long persistence counters greatly reduce inappropriate therapies in case of supraventricular arrhythmias.

Case 4

The menu showing the possible options for persistence in the VT zone:



Here is a figure going in depth of the working of the persistence counter in this case:



The persistence counter starts every time when the VT/VF majority is filled and starts at a value of 1. As we can see in this figure, the persistence counter is reset to 0 when the diagnosis is no longer VT (but SVT/ST in thise case). The persistence counter restarts at 1 when the diagnosis of VT (VTLC 3) is again made. Interestingly, there is a short interruption of the VT. While the VT majority remains filled (meeting the 6/8 criterium), the persistence counter is frozen (+0) until there are new events in the VT zone (+1). In this case, the persistence counter needed to reach 30 before the first therapy is launched (ATP in this case).

Take-home message

Persistence counters are essential in MicroPort ICDs as they significantly decrease the amount of unnecessary and inapropriate therapies. One of the most important reasons why we see a lot less therapies the last decade, is due to the systematic programming of longer persistence counters than in the past.

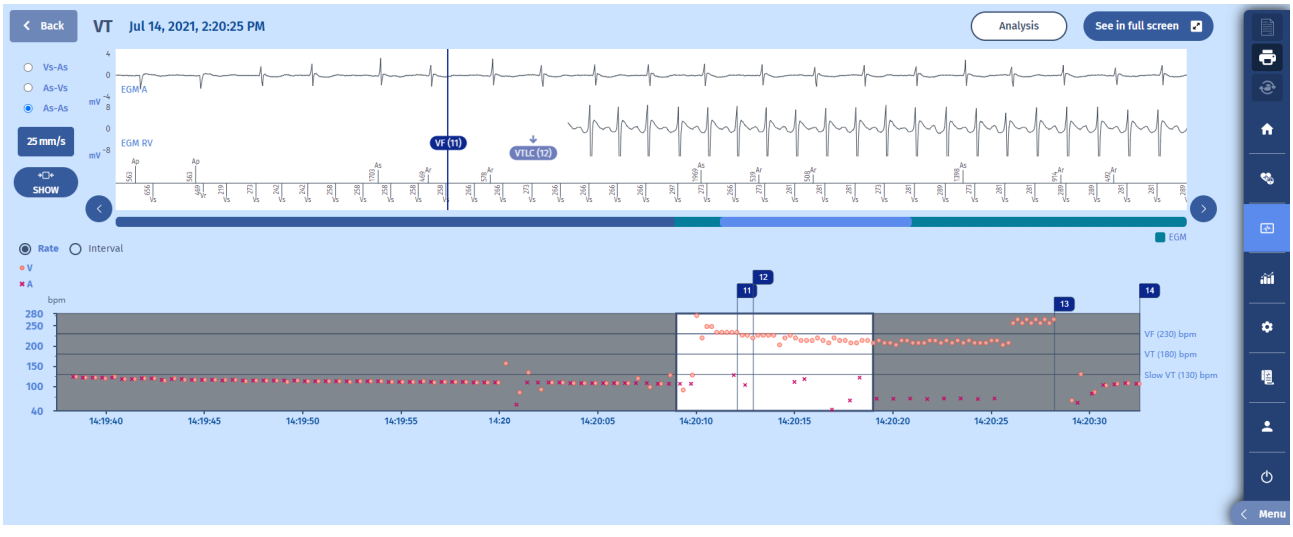
Case 5

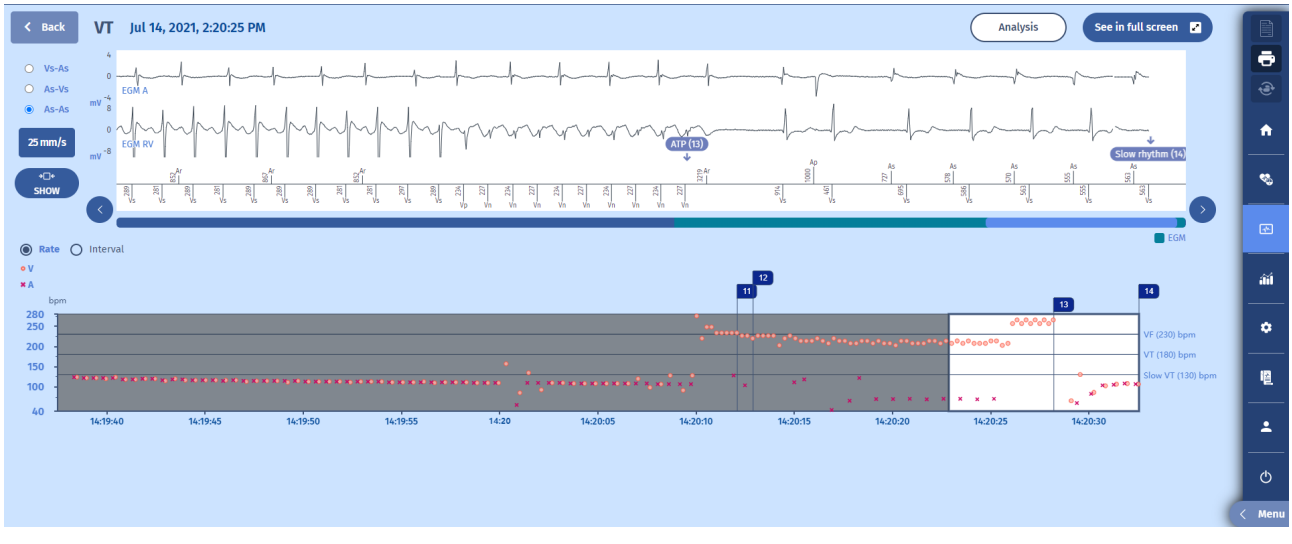
Long VT

Patient

A 50-year old patient with dilated cardiomyopathy with commonly well tolerated VTs comes in for a regular device check.

The newest episode with therapy is the following:





Case 5

Why does it take so long (over 15 seconds) for the ATP to be delivered?

1 VT majority has been increased from 6/8 to 30/40.

2 Persistence has been increased to 50 cycles

3 The VT self-terminates and than starts up again, delaying the diagnosis.

4 There has been wrongful labelling of the episode as supraventricular arrhythmia, thereby delaying the therapy.

Interval plot

The episode begins with an elevated heart rate at around 110 beats per minute. There are multiple ventricular events with a shorter cycle, suggesting the existence of PVCs. There is a sudden acceleration of the ventricular rhythm into the VF zone but the arrhythmia stabilizes in the VT zone. After a period of 15 seconds of stable VT in the VT zone, an ATP is delivered, which terminates the arrhythmia. The last marker indicates filling of the “Slow Rhythm” majority, which means the end of the episode.

EGM

1 At the beginning of the episode we see atrial pacing at 100-110/min with preserved atrioventricular conduction.

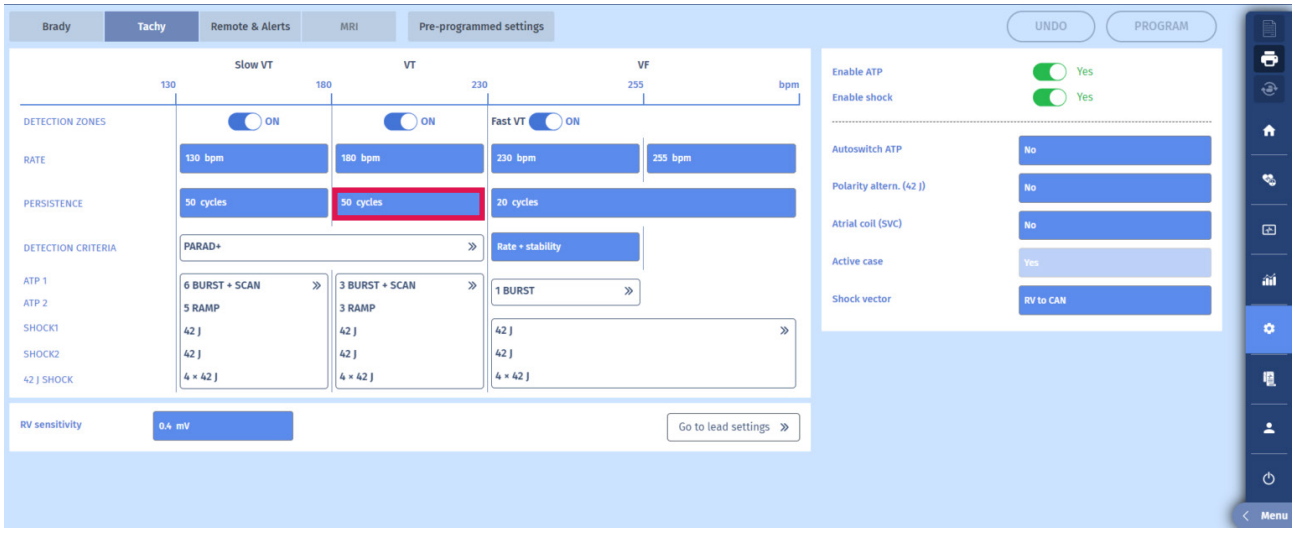
2 Suddenly there are rapid ventricular events which fill the VF counter, marker VF (11)

3 The ventricular events slow down and the VT counter is filled shortly after.

4 At this marker, VTLC (12), the persistence counter steadily increases with each ventricular event.

5 When the persistence counter is filled (50) after 15 seconds, an ATP is delivered

6 The ATP terminates the VT



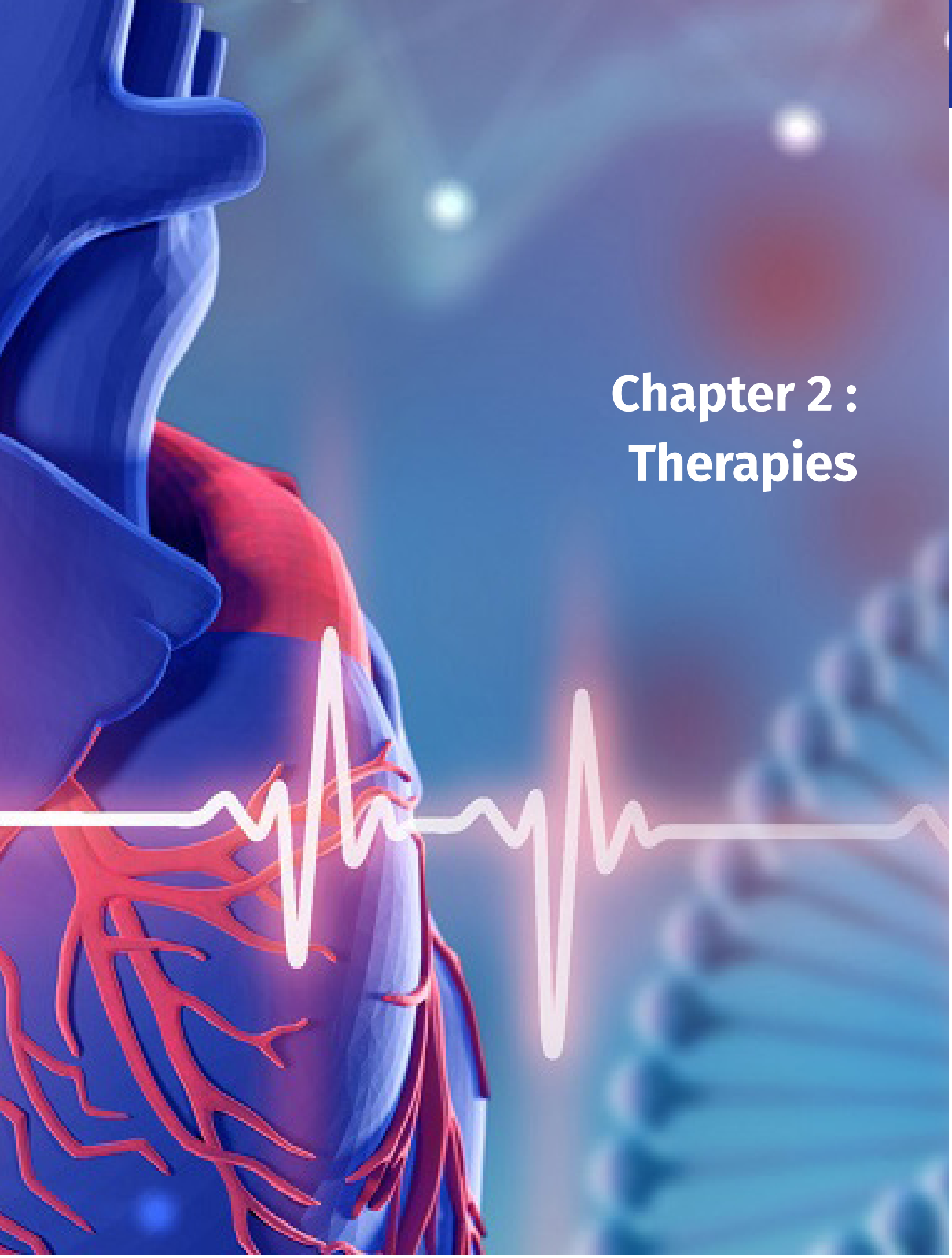
Correct answer = n° 2

Discussion

This episode shows correct sensing of a VT, terminated by a single burst. There is a substantial delay before the ATP is delivered which is caused by programming of a long persistence counter (at 50). This was decided after the patient had many nonsustained VTs which were well tolerated. Many of the VTs which are treated after a persistence counter of 20 or 30 could actually self terminate. This way there is no delivery of ATP, which is associated with a small risk of accelerating the rhythm into a faster VT or even VF, which would be more symptomatic and even dangerous for the patient. Up until a decade ago ICDs were programmed aggressively, making sure that VT and VF was quickly treated. The idea was to protect the patient from the deleterious effects of persisting VT or VF, which may degrade and become more symptomatic and harder to treat (risk of non-effective shocks). This dogma has been resolved by the publication of multiple studies (such as MADIT-RIT and Painfree) which show the deleterious effects of early therapy of VT due to dangerous side effects of ATP (acceleration) and shocks (which are harmfull to the heart).

Take-home message

When patients have many occurrences of VT and which suffer from the many therapies (ATP/shocks), it may be decided to program a longer persistence to allow for the VT to self terminate. For this patient this has lead to significant less therapys, but not all VTs self-terminated, as evidenced by this episode. It was agreed with the patient to keep the current programming.



Chapter 2 : Therapies

In this chapter pertaining to therapies, we no longer describe the counting of events which has been detailed in the corresponding chapter. Similarly, discrimination will not be discussed.

The tracings herein will be presented logically beginning with ventricular fibrillation, followed by tachycardias observed in the VT zone. We will describe the sequence of therapies that are called upon according to the programming of the device.

Functioning principles

1 - Initiation of therapies

A VF zone therapy is initiated when the VF majority and the VF persistence are reached.

a. For stable rhythms in the Fast VT zone, the ATP is applied in first intention rather than a shock according to the following additional criteria:

- The rhythm is stable to within 30 ms, and
- The last 4 coupling intervals are all in the Fast VT section

If the ATP is effective, there is no unnecessary charge of the capacitors.

b. For unstable VF or rhythm, the first-line therapy is shock

A therapy in the VT zone is initiated when the VT majority and the VT persistence are reached. The tachycardia rate (average of the last 4 tachycardia cycles) directs the therapy in either the Slow or “conventional” VT zone.

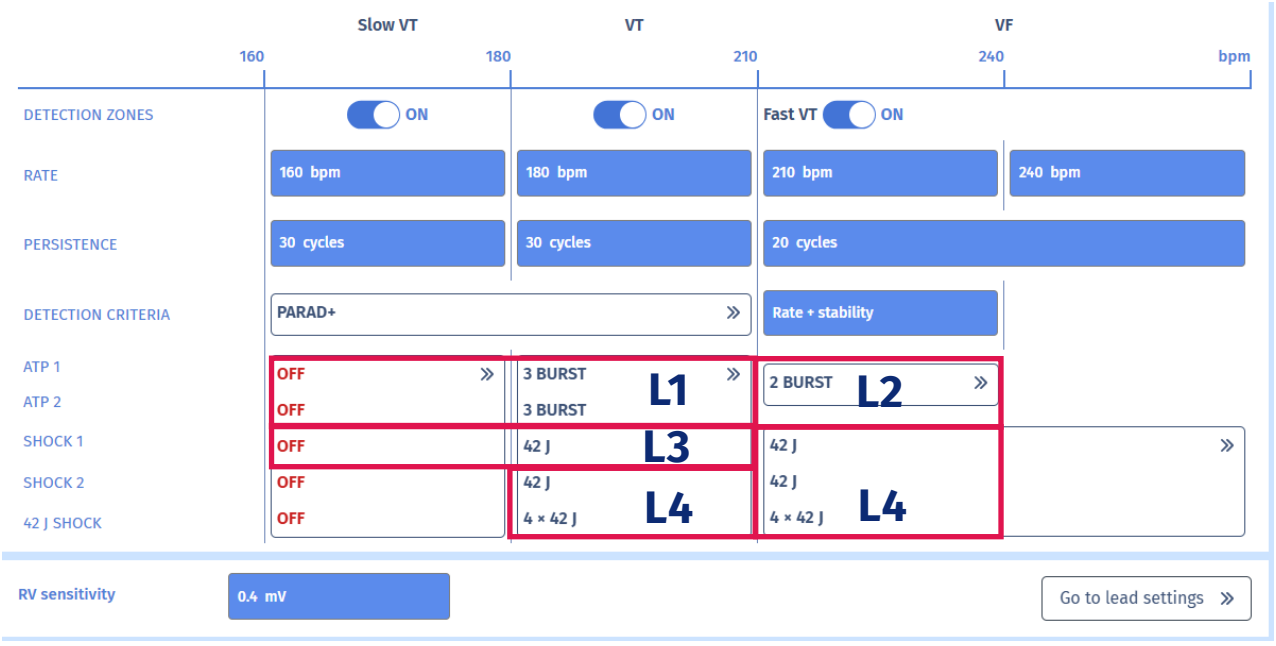
c. VT persistence + Rate in conventional VT zone - > Initiation of a conventional VT therapy.

d. VT persistence + Rate in the Slow VT zone -> Initiation of a Slow VT therapy.

2 - Level of aggressiveness of the therapies

In a same episode, the ensuing initiated therapy program should always have a degree of aggressiveness greater than or equal to that of the previously called upon therapy program. The increasing order of aggressiveness is as follows:

- Level 1: the 2 ATP in the Slow VT zone and the 2 ATP in the conventional VT zone (ATP 1 and ATP 2).
- Level 2: ATP in the Fast VT zone.
- Level n: Shocks in order of increasing energy.



3 - Management of ATP program interruptions and capacitor charge interruptions

An ATP program is interrupted and/or ended by:

- The return to “Slow Rhythm” (Slow Rhythm Majority identified), or
- The complete delivery of the program, or
- The exceeding of the ATP Minimum cycle length or the ATP Time limit, or
- A change of zone:
  - acceleration of the rhythm (Other therapy available in the “new” zone -> initiation of this therapy)
  - deceleration of the rhythm (Other therapy available in the “new” zone -> initiation of this therapy).

A temporary interruption of the charge occurs if:

- A cycle outside of the Tachy/VF zone (Slow) has just been detected (the charge can be resumed after detection of a Fast cycle), or
- A SVT/ST Majority, No Majority or VTLC Majority with at least one long cycle over the last 24 cycles.

The charge is definitely halted when:

- The Slow Rhythm Majority is identified, or
- the stored energy level has reached the programmed value, or
- the charging time reaches 40 seconds.

Note: The calculation of the charge time is measured from the time of the last charge onset (without interruption) up to the cycle preceding the delivery of the shock. The measurement accuracy is = 0.125 ms.

4 - Delivery of therapies

An ATP (other than the ATP in the Fast VT zone) is delivered when:

- The cycle is VT, the majority rhythm is VT and the VT persistence counter reaches the programmed limit *, and
- The tachycardia rate (average of the last 4 tachycardia cycles) corresponds to that which led to the initiation of therapy.

A shock is delivered when:

- The capacitors are no longer charging and have reached a charge level corresponding to the programmed energy, and
- The cycle is VF, the majority rhythm is VF and the VF persistence counter reaches the programmed threshold *, or the cycle is VT, the majority rhythm is VT and the VT persistence counter reaches limit programmed limit *.

*: Avoids the inappropriate application of therapy for an accelerating or slowing rhythm.

5 - Post-shock redetection

After a shock, a blanking period is triggered for one second. The persistence counters are not reset. The first RR cycle is not taken into account in the stability and association criteria. The acceleration is forced to “Ventricular”. It takes a minimum of 6 redetection cycles to obtain a “Majority”. If the latter corresponds to VT or VF, associated with its persistence counter which has exceeded the threshold, the device can then initiate the remainder of the therapy program or the following program.

The management of available therapies is based on an increasing order of aggressiveness. The next called-upon therapy program should always have a level of aggressiveness greater than or equal to that of the previously called-upon therapy program.

6 - Post-ATP redetection

After an ATP, the persistence counters are not reset. Acceleration is forced to “Ventricular”. A minimum of 6 redetection cycles are required to obtain a “Majority”. If the latter corresponds to VT or VF, associated with its persistence counter which has exceeded the threshold, the device can then initiate the remainder of this therapy program or the next therapy program.

The management of available therapies is based on an increasing order of aggressiveness. The next called-upon therapy program should always have a level of aggressiveness greater than or equal to that of the previously called therapy program.

7 - 'Special' post-therapy redetection (rejection of sinus tachycardias)

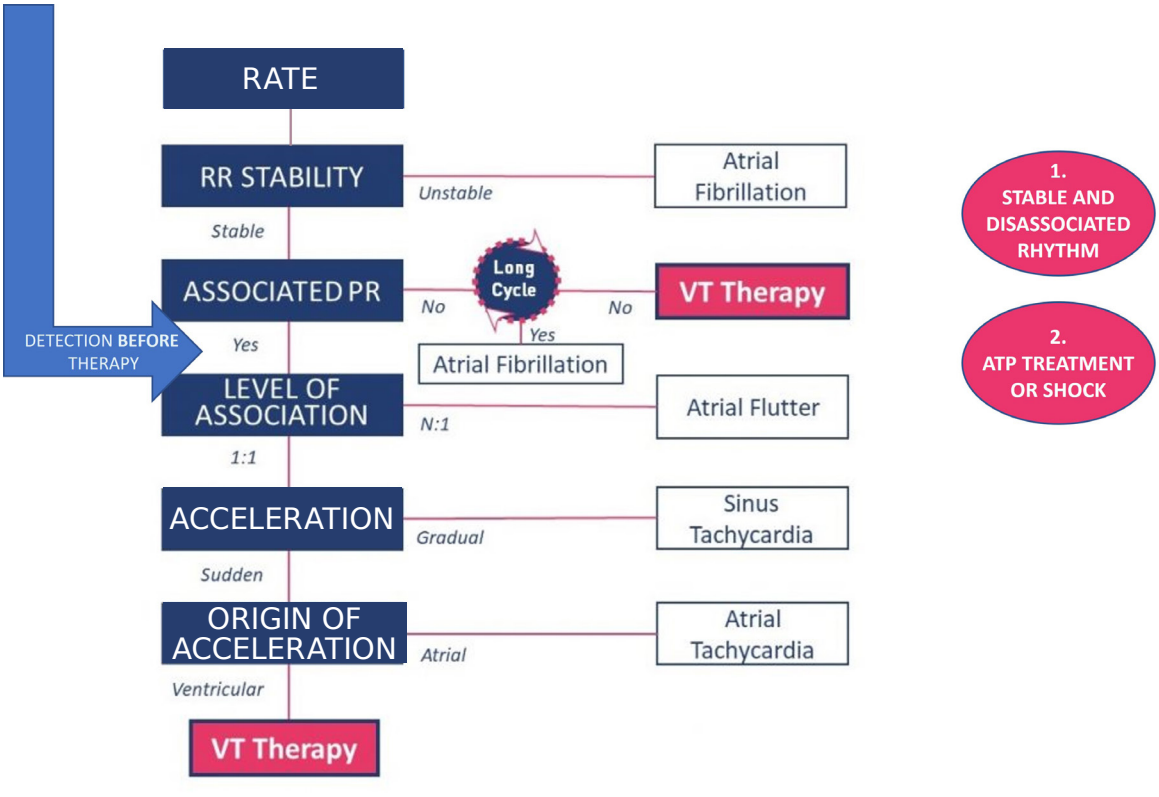
The purpose of this function (which does not have a name) is to not continue to treat a dissociated ventricular arrhythmia during a return to normal, albeit tachycardia, rhythm.

The following two situations can be identified:

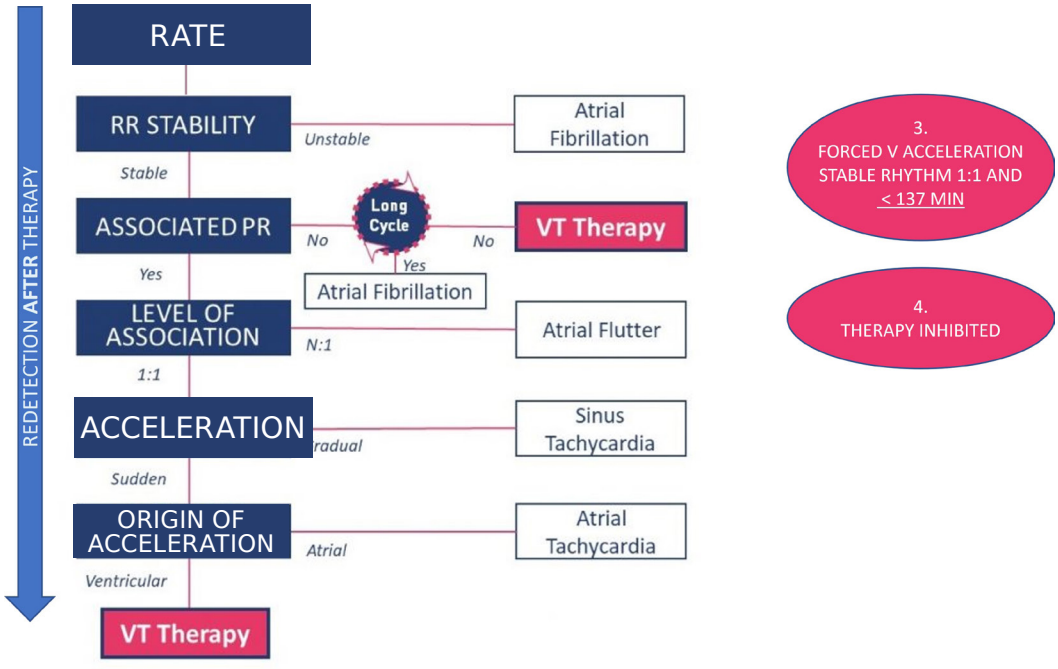
- A dissociated VT treated and followed by a stable 1:1 associated rhythm is most likely a VT followed by a ST (and not followed by a 1:1 VT which is less likely). This situation does not require further therapy.
- A VT with retrograde 1:1 conduction treated and followed by a stable 1:1 associated rhythm is most likely a VT followed by a ST or by this 1:1 VT (treated ineffectively). This situation requires further therapy.

The therapy inhibition rule is therefore the following. If a stable and dissociated ventricular tachycardia rhythm is treated (ATP or shock) (acceleration is forced to V) and is followed by a stable tachycardia rhythm which is 1:1 associated and below 137 bpm, then the therapy programs are inhibited as long as these last 2 conditions persist.

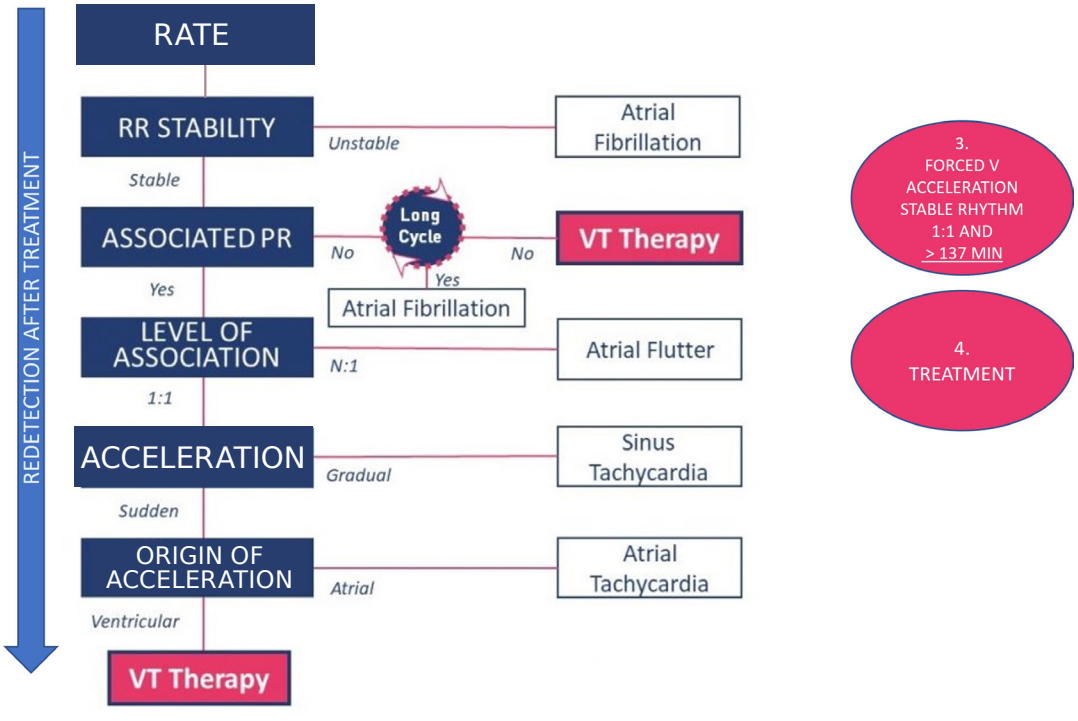
Situation before therapy:



Situation 1 after therapy: inhibition



Situation 2 after therapy: new therapy



8 - Return to sinus rhythm

The return to sinus rhythm is obtained when at least 75% of the last 8 cycles are slower than the tachycardia zones or are paced (even those paced in the Tachy zone). The episode is terminated and stored in memory.

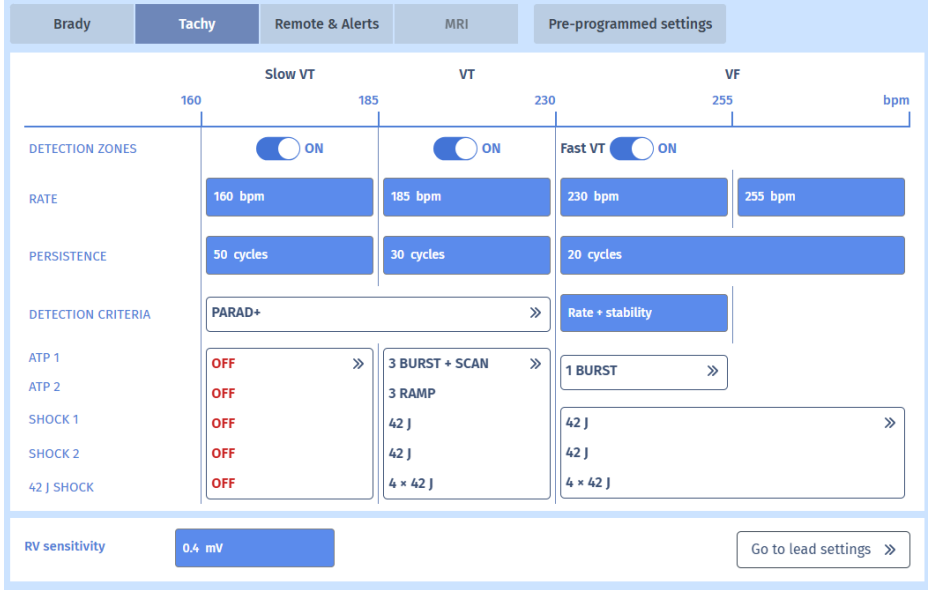
Case 1

Tachycardia treated with a shock

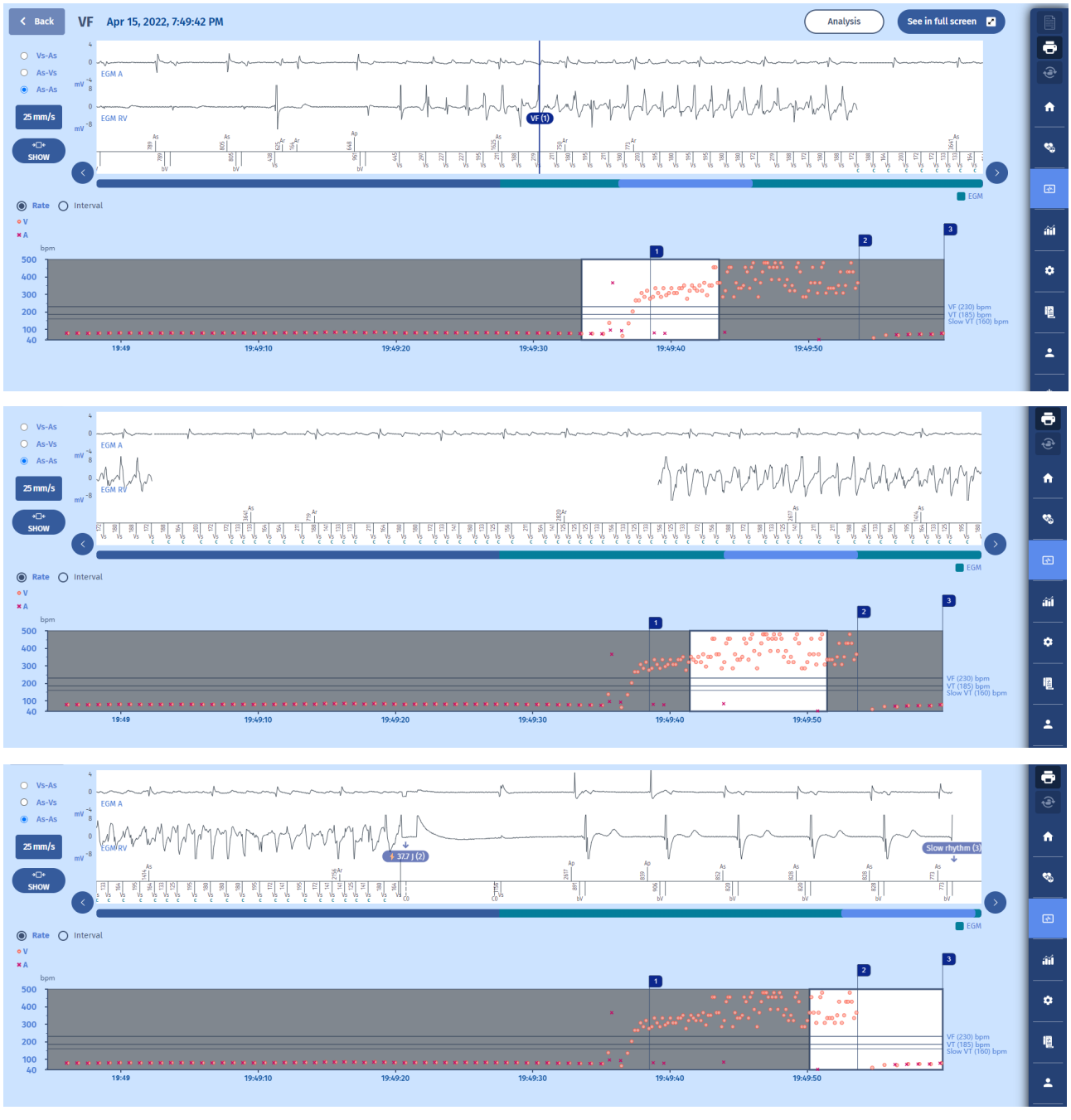
Patient

68-year old patient has been implanted with an ICD in the context of primary prevention for ischemic cardiomyopathy. A telemedicine transmission led us to call the patient for an emergency consultation, the latter having experienced a syncope and received a shock.

Here is the overview screen, notice that there has been one episode with therapies



The following three screens show the episode:



What is your diagnosis?

1 Inappropriate shock due to lead fracture artifacts

2 Inappropriate shock due to atrial fibrillation

3 Appropriate shock due to ventricular fibrillation in the VF zone

4 Appropriate shock due to unstable ventricular tachycardia in the FVT zone

5 The tachycardia is poorly detected

Case 1

Interpretation

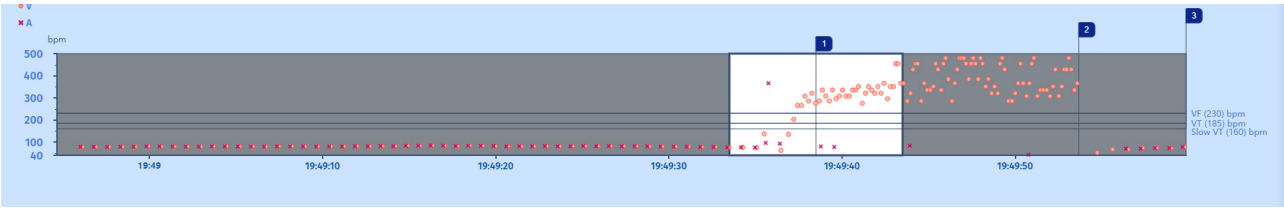
This clinical case illustrates the basis of the functioning of a defibrillator and its intended purpose: the termination of a fatal ventricular rhythm disorder by a shock.

In the summary screen, we can see that the leads are working perfectly, and that the device battery is new with an output voltage of 3.16 V.

Programming is consistent with current recommendations. Three zones are programmed: a Slow VT monitoring zone, without therapy; a VT zone with bursts, ramps and maximum shocks; and a VF zone with a FVT section up to 255/min, with a burst if the FVT is stable, followed by max shocks, and a pure VF section with maximum shocks.

Based on the stored memory, the device reports no mode switches, and there is 1 episode with therapy . The last shock provided an impedance value of 65 Ohm.

Interval plot



Onset of a very fast tachycardia in the VF zone with high cycle variability, for which a quick diagnosis of VF is made with delivery of a shock restoring the slow rhythm.

EGM

1 The tracing confirms the onset of a very fast ventricular fibrillation (VF (1)) detected above 255/min at nearly 300/min, and triggering a charge of the capacitors (C markers) after a persistence of 20 cycles. The VF episode is perfectly detected.

2 Throughout the charge, the VF majority is analysed cycle-by-cycle and the charge continues as long as the VF majority does not change to SVT/ST or SR (Slow Rhythm).

3 Upon completion of the charge of the capacitors at 42 J, the shock (37.7 J) is delivered after a confirmation cycle which is also in the VF zone. The slow rhythm is restored with atrial sensing and biventricular pacing.

4 The functioning herein is a textbook case: perfect detection of all the signals, correct diagnosis, quick initiation of the therapy, effective shock, memorization of the episode.

Correct answer - n° 3

Take-home message

A ventricular fibrillation detected in the VF section of the VF zone immediately calls for a shock therapy.

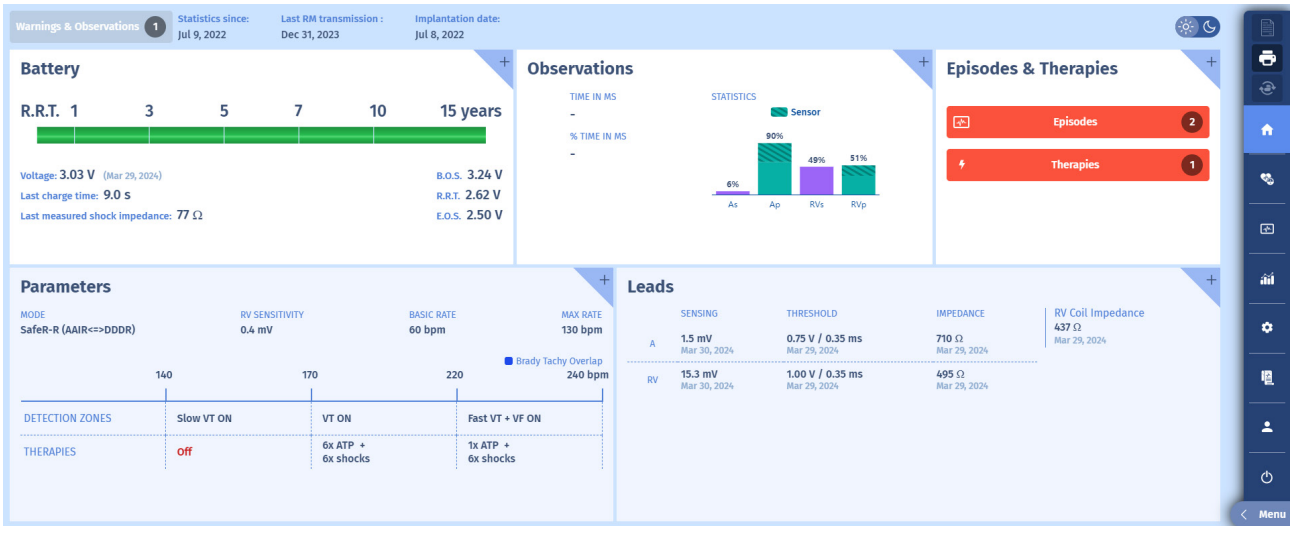
Case 2

Tachycardia treated with a shock, or is it?

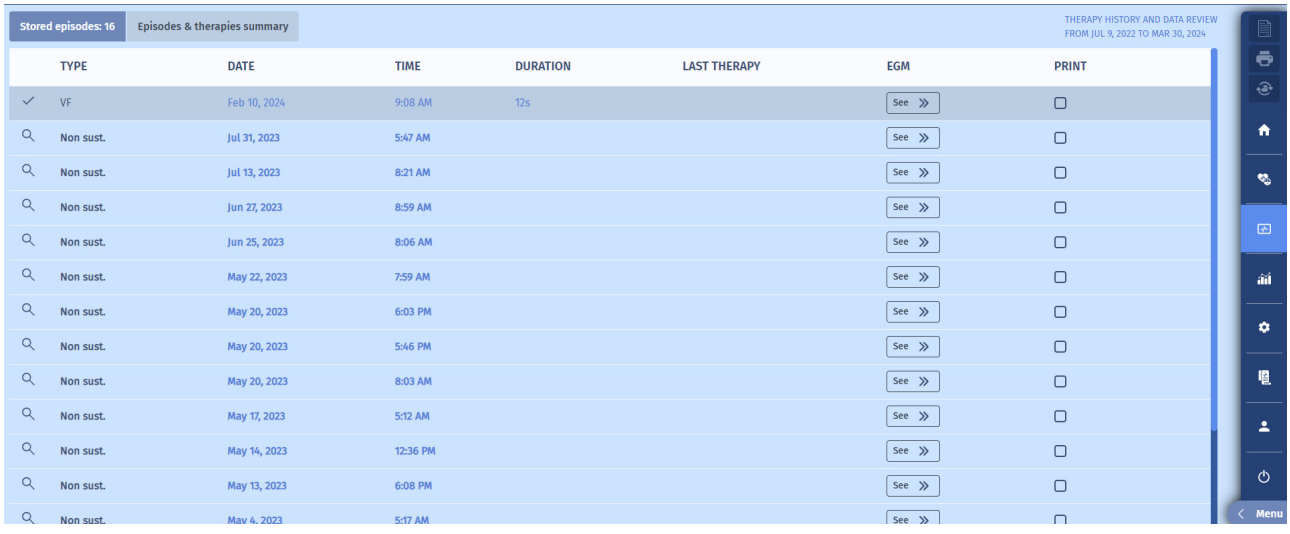
Patient

A 70-year old patient is implanted with a dual chamber ICD (ULYS DF4) in the context of secondary prevention (VF) in ischemic cardiomyopathy.

You interrogate the device in the emergency department after sensation of lightheadedness:



Case 2



What is the correct observation ?

1 The latest episode is a VF treated with a shock

2 The latest episode is a VF treated with an ATP

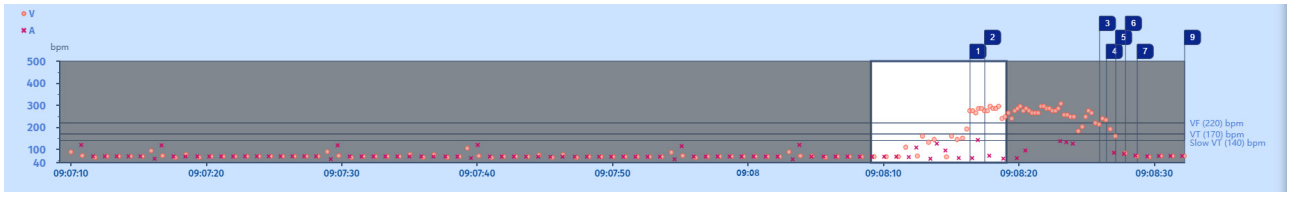
3 The latest episode is a VF without any therapy

4 The latest episode is a VT without any therapy

Interpretation

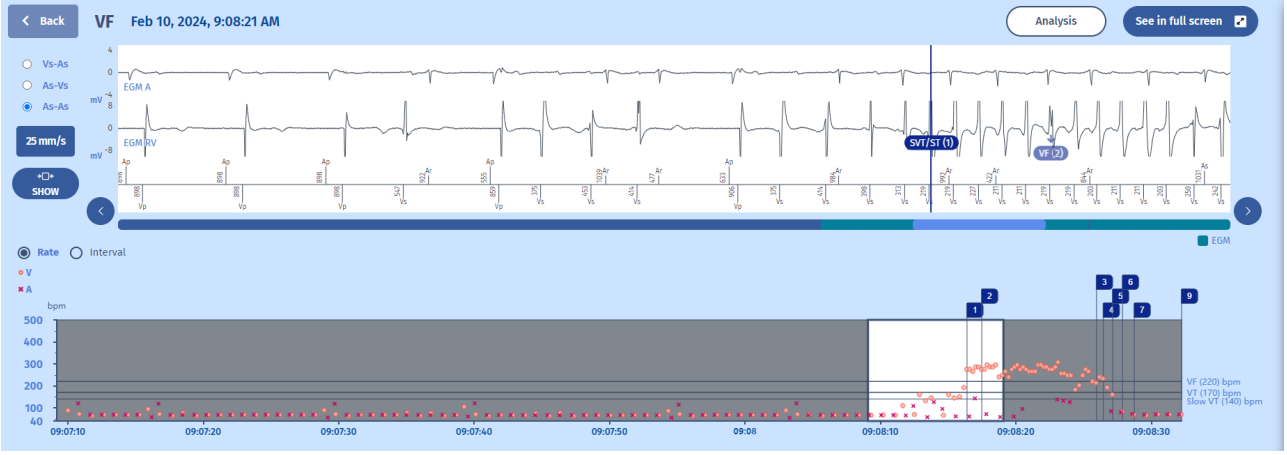
This case shows an episode of very fast polymorphic ventricular arrhythmia, which self terminates before the delivery of a shock.

Interval plot

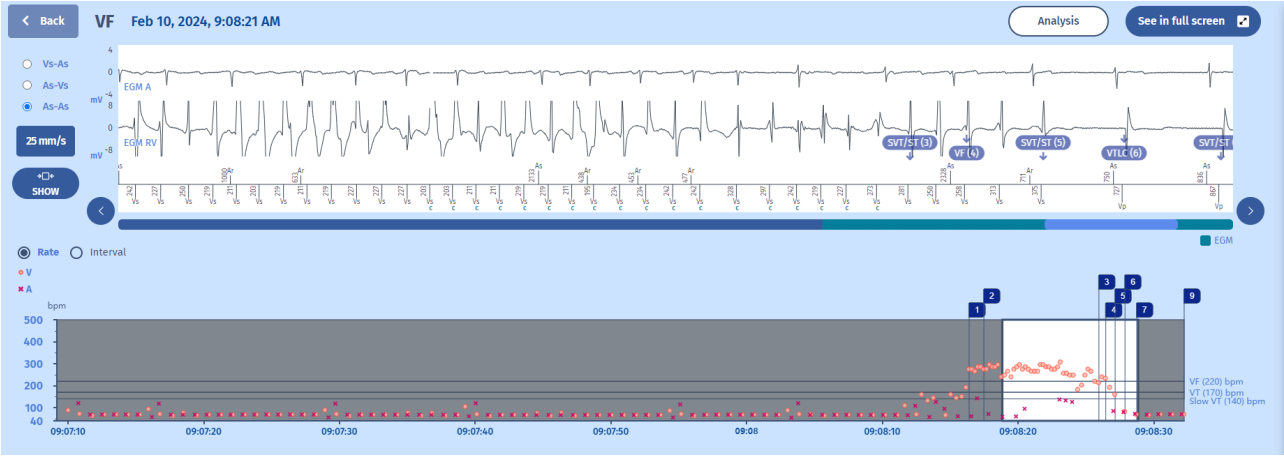


The interval plot shows a stable and slow rhythm (probably paced) with some extrasystoles when suddenly there is a ventricular arrhythmia in the VF zone (>220/min). As the ventricular arrhythmia accelerates into the VF zone, after a while the arrhythmia slows down, becomes more irregular and self-terminates.

EGM



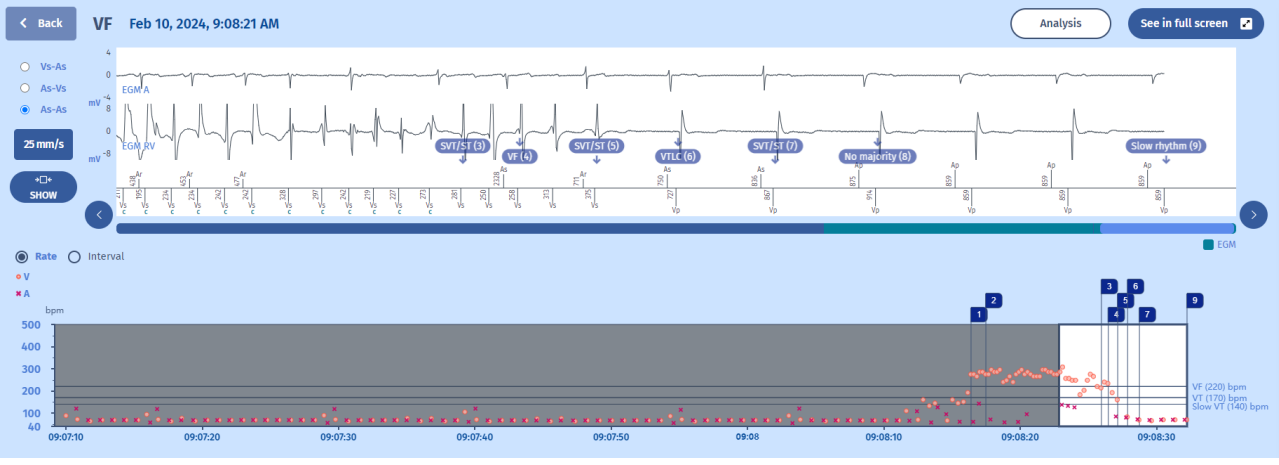
The VT majority is first filled but as it is irregular, it is classified as SVT by the PARAD discrimination algorithm. Soon after, the VF majority is filled with 6 ventricular events in the VF zone and the persistence counter starts.



When the persistence counter is filled (20) and as the arrhythmia is too irregular to deliver ATP (Fast VT therapy), the ICD starts to charge in order to deliver a shock.

Case 2

In order for the ICD to continue charging, the VF majority must be met. As soon as we see the SVT marker, the ICD stops charging as the VF majority is lost. On the EGM we can confirm that the ventricular arrhythmia slows down into the VT zone but also becomes irregular (which is why we see a SVT marker). Soon after we see multiple markers as the arrhythmia is flirting with the VT (but unstable therefore SVT) and VF zones. Note also that while we see a new VF marker, there is no continuation of the charge (no blue c). This is because while the VF majority is filled, the persistence counter is not met and therefore the charge remains aborted. Soon after, the arrhythmia self terminates and no shock is delivered.



Comments

While at the dawn of ICD therapy, we were most worried about correctly sensing the episode and delivering the shock as fast as possible, the dogma has completely changed. Today, we demand of our contemporary ICDs not only to correctly detect episodes and deliver fast and efficient therapies, we also demand a near-zero rate of unneeded or inappropriate therapies. Therefore, the counters must seamlessly work together with the other existing algorithms and past mistakes make for good learning. Today, we see that counters are getting longer and longer, mostly with the goal to decrease therapies which are not needed or not appropriate. In this case, we see a good example of an aborted charge for good reasons: the self-termination of the ventricular arrhythmia. We now understand why for the charge to continue, the majority and persistence of VF (or VT when in VT zone) must be met. When the patient will again suffer from a ventricular arrhythmia soon after, the charge will be faster as the consensators will not actively dump the charge. This is why we can see surprisingly fast charge times during some episodes.

Correct answer - n° 3

Take-home message

A full charge of an ICD can consume multiple weeks of battery capacity and therefore major efforts must be taken to prevent charges and shocks which are not needed or inappropriate. This is why the VT/VF majority and persistence must be met for each cycle for the charge to continue.

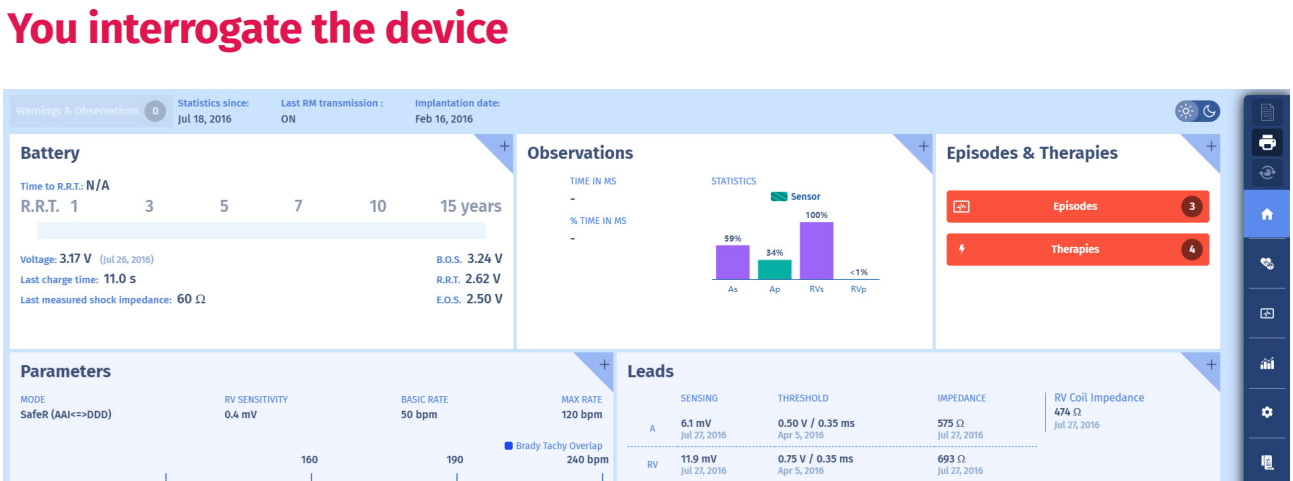
Case 3

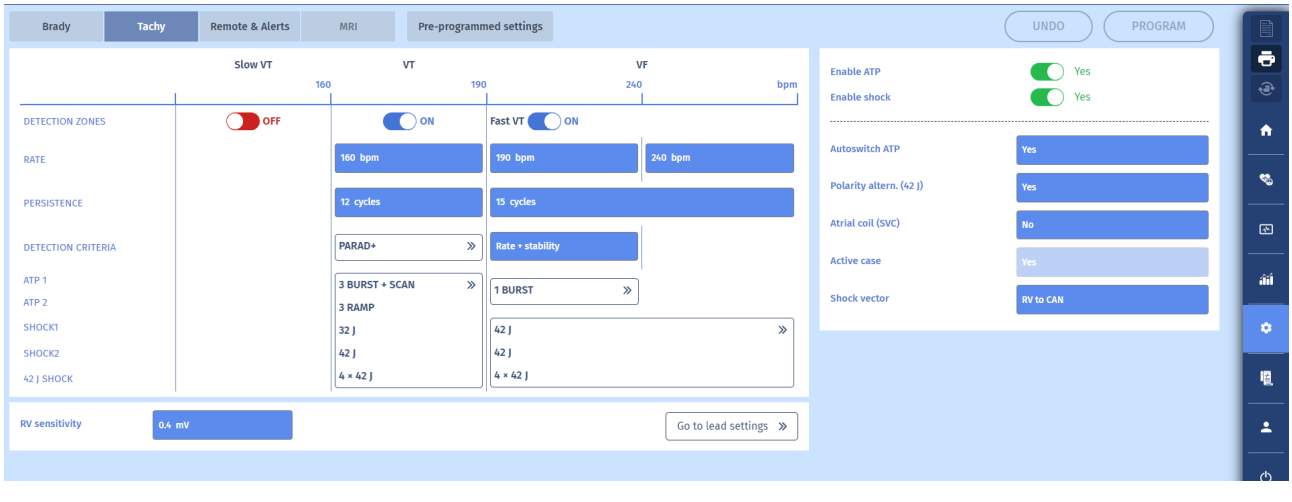
Tachycardia treated by an ATP burst

Patient

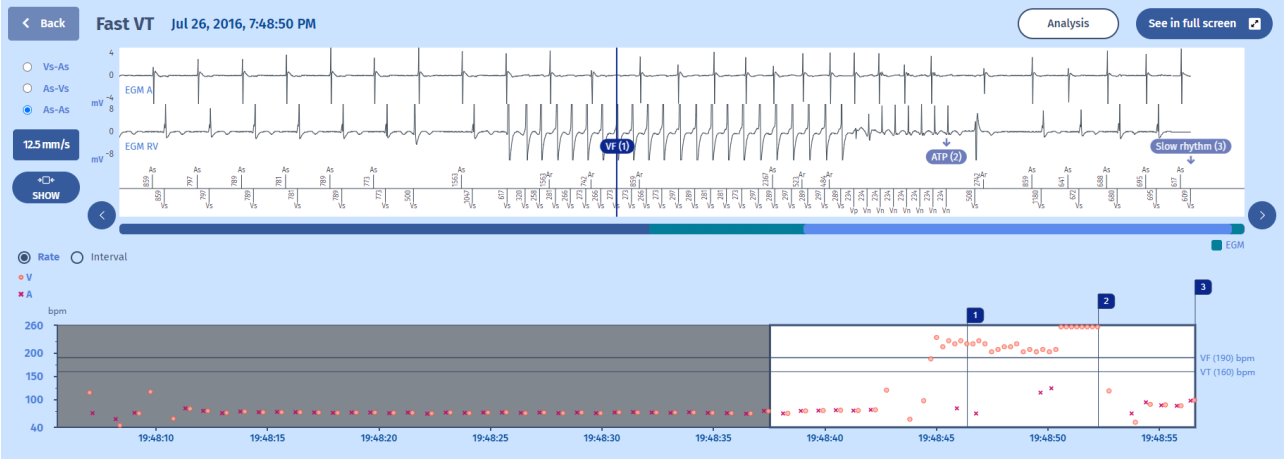
An 83-year-old man implanted with a Platinium DR in secondary prevention for sustained syncopal VT due to sequelae of inferior necrosis. The ejection fraction is maintained at 40%. This is a routine follow-up control, patient being asymptomatic. However, the patient has already received a shock due to sustained ventricular tachycardia.

You interrogate the device





Case 3



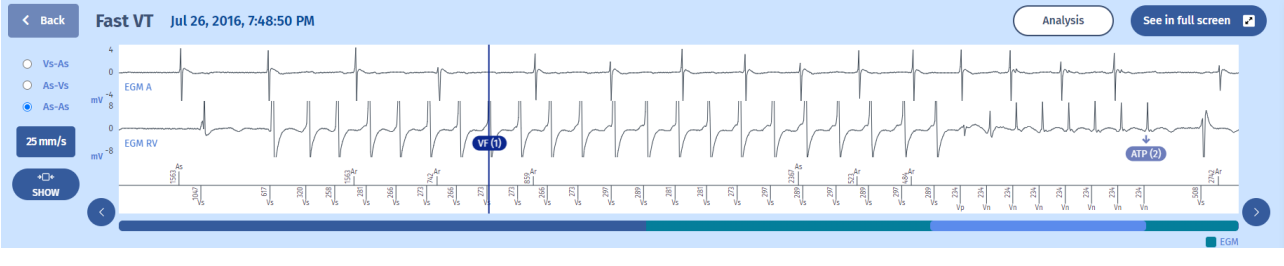
What is your opinion ?

1 Ventricular fibrillation treated by a burst
2 Fast VT treated by a burst
3 VT treated by a burst
4 Ventricular fibrillation treated by a ramp
5 Fast VT treated by a ramp

Interval plot

Sinus rhythm with A-V association

1 Beginning of a ventricular rhythm in the VF zone
2 Triggering of an ATP
3 Return to the slow zone



EGM

1 The rhythm is sinus, conducted (As-Vs);

2 Sudden onset of ventricular tachycardia detected in the VF zone. The first 6 cycles immediately indicate a VF majority. The next 15 are the persistence cycles as programmed.

3 The tachycardia is stable and situated between the programmed values of 190 and 240 per minute. An ATP burst is delivered with 8 cycles and a coupling interval equal to 80% of the tachycardia coupling (292 ms for the VT, hence 234 ms for the burst).

4 The rhythm is slow over 6 cycles outside the VT/VF zone confirming the end of the episode.

Comments

1 This case demonstrates the benefit of antitachycardia pacing in the VF zone. This very fast tachycardia is not ventricular fibrillation but rather monomorphic ventricular tachycardia, treatable by rapid pacing.

2 As always, the problem remains whether the ATP will be effective and thus avoids the delivery of a shock, or whether it will delay this shock after the ineffectiveness of the ATP. In this example, the ATP is effective.

3 The burst did not generate capture during the first cycle. During the first three cycles, there is a fusion between the spontaneous depolarization of the tachycardia circuit and the depolarization generated by the pacing from the implantation site of the right ventricular defibrillation lead. As a result, only the last cycles of the burst have a chance to penetrate the tachycardia circuit and influence the heart rate. It may therefore be necessary to program a larger number of cycles during the burst which may render it more effective. The risk is that, on the contrary, the increase in the number of cycles transforms the tachycardia into fibrillation that will need to be shocked. The result is thus case by case and cannot be predicted before trying it. In the present example, there is no reason to change the therapy.

4 The tachycardia episode is very short, thus raising the question of whether it would have terminated spontaneously. In order to allow this opportunity, it would be necessary, in this instance, to increase the number of persistence cycles. On the other hand, given that we are in the VF zone, extending the duration of the analysis may also delay the start of effective therapy. However, it has been shown that lengthening the analysis time prior to therapy does not change the prognosis.

Correct answer - n° 2

Take-home message

Programming an antitachycardia burst prior to the charging of the capacitors on a fast monomorphic tachycardia provides an opportunity to avoid delivering a defibrillation shock

Programming a large number of cycles before initiating therapy may allow spontaneous termination of the tachycardia without defibrillator intervention.

In the VF zone, in the fast VT zone, if the tachycardia is stable, an ATP sequence is called upon before the shocks.

Case 4

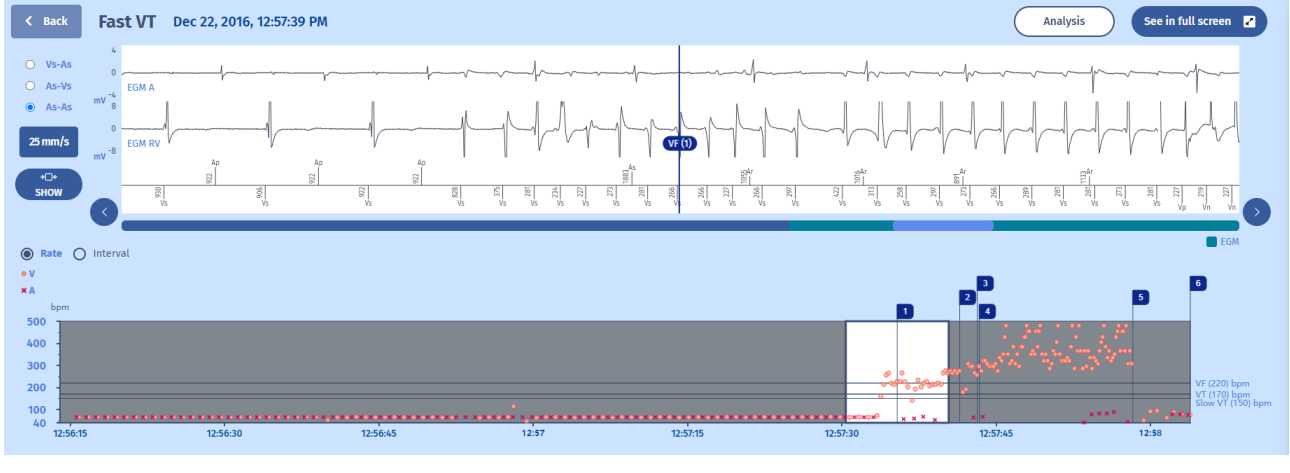
Fast tachycardia accelerated by therapy

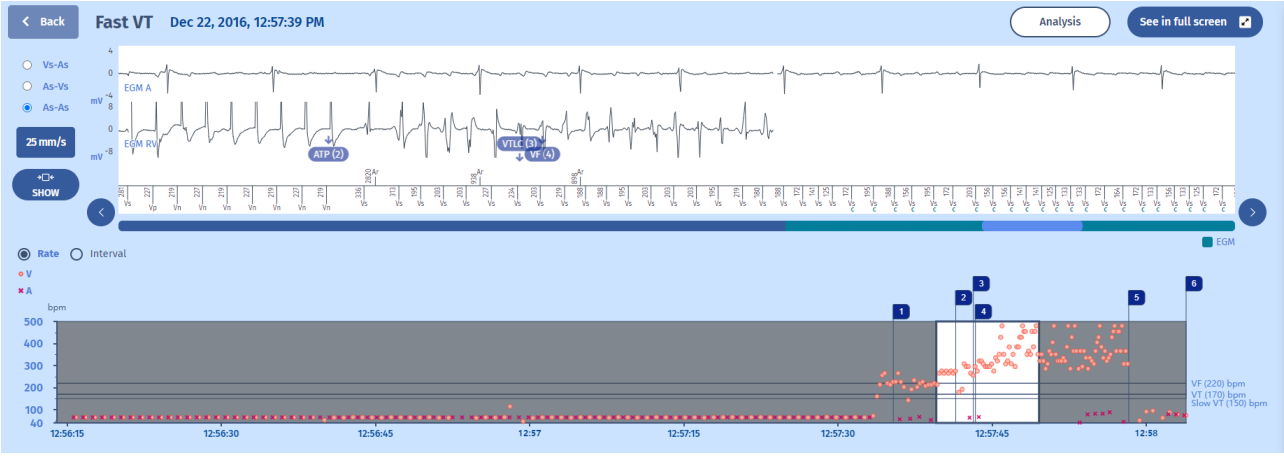
Patient

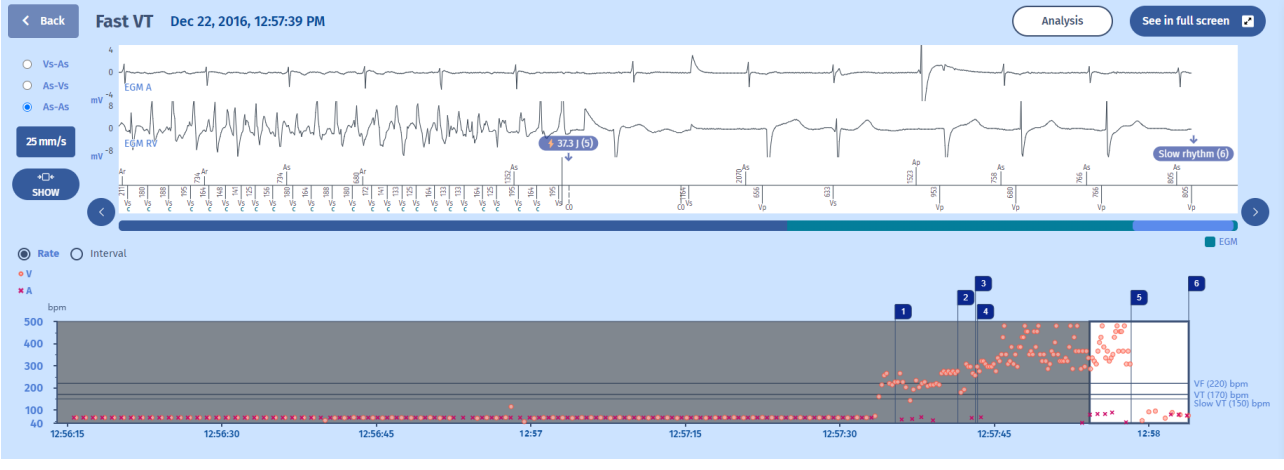
A 66-year-old man implanted with Platinium DR for dilated ischemic heart disease without prior infarction and ejection fraction of 28%, narrow QRS, in secondary prevention. Follow-up control. Asymptomatic patient.

Device interrogation

EGM







Which observation is correct?

1 This is a ventricular fibrillation from the outset, and the ATP has no chance of being effective.

2 This is an atrial fibrillation with inappropriate therapy

3 This is a very fast ventricular tachycardia observed in the VF zone and treated in the FVT section by a burst

4 The ATP degrades the tachycardia into VF

5 The return to slow rhythm should have been achieved one cycle earlier

Case 4

Discussion

This example explains the sequence of therapies in the FVT/VF zone.

1 The tachycardia is immediately detected in the VF zone after 8 tachycardia cycles. We can see that the tachycardia is not stable at the outset

2 A persistence of 16 cycles is therefore triggered at the end of which

3 The first therapy in the FVT zone is initiated since the tachycardia is still in the VF zone at the end of the persistence with a stable rhythm: the therapy delivered is an 8-cycle burst

4 This degrades the tachycardia into a ventricular fibrillation, first observed in the VT zone (VTLC marker) since the first two cycles after the ATP are longer and diagnosed as VF in the next cycle (VF marker), hence a new persistence of 16 cycles is triggered.

5 The second line of therapy consists in shocks, hence the charge of the capacitors.

6 The VF continued throughout the charge, the device was able to confirm the charge cycle-to-cycle, and at the end of the charge, a 195 ms cycle confirms that the VF continues, and thus a shock is delivered (37.3 J).

7 The first signal after the shock is the opening of the detection chains (for the implant, the coupling interval of this cycle is 164 ms: the post-shock interval is 1164ms that equals the one-second blanking period plus 164 ms), the ensuing 6 cycles are slow which terminate the episode.

Comments

Here we have the example of a burst causing the degradation of a fast ventricular tachycardia into a VF and which requires a shock. This tachycardia is fast and rather unstable at the outset. One can therefore raise the question of programming a longer persistence duration to allow the tachycardia the opportunity to terminate spontaneously before the response of the defibrillator. The programmed persistence in the VF zone is 16 cycles. An increase in the number of persistence cycles should therefore be discussed.

Correct answers - n° 3 et 4

Take-home messages

An ATP burst in the VF zone can allow terminating the rhythm disorder without the need for a defibrillation shock at the outset.

The programming of a long persistence duration is recommended to allow the tachycardia to terminate spontaneously without defibrillator intervention.

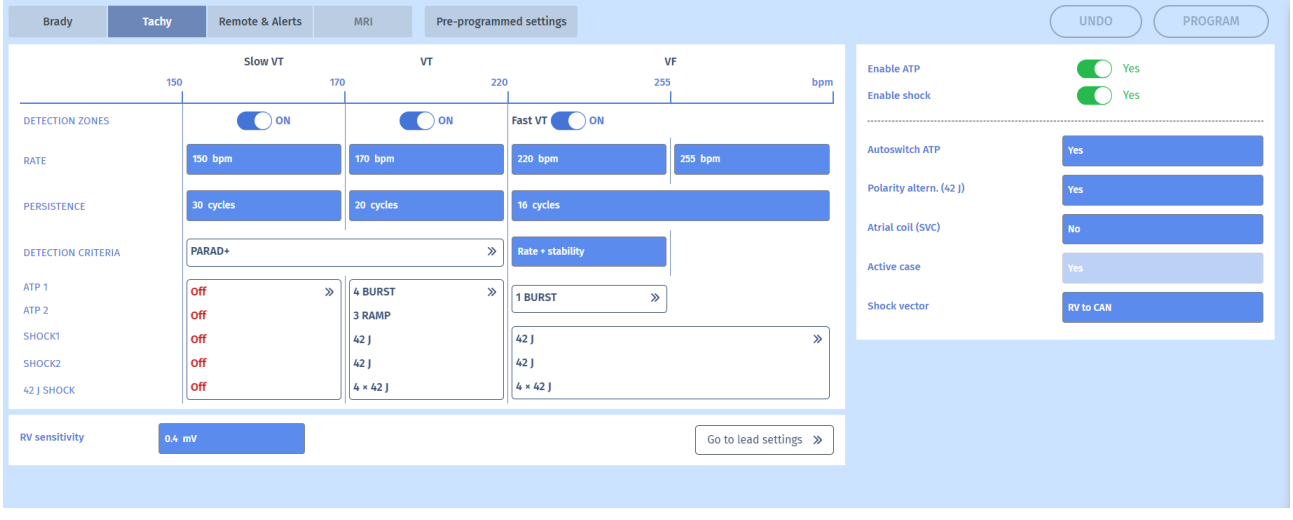
Case 5

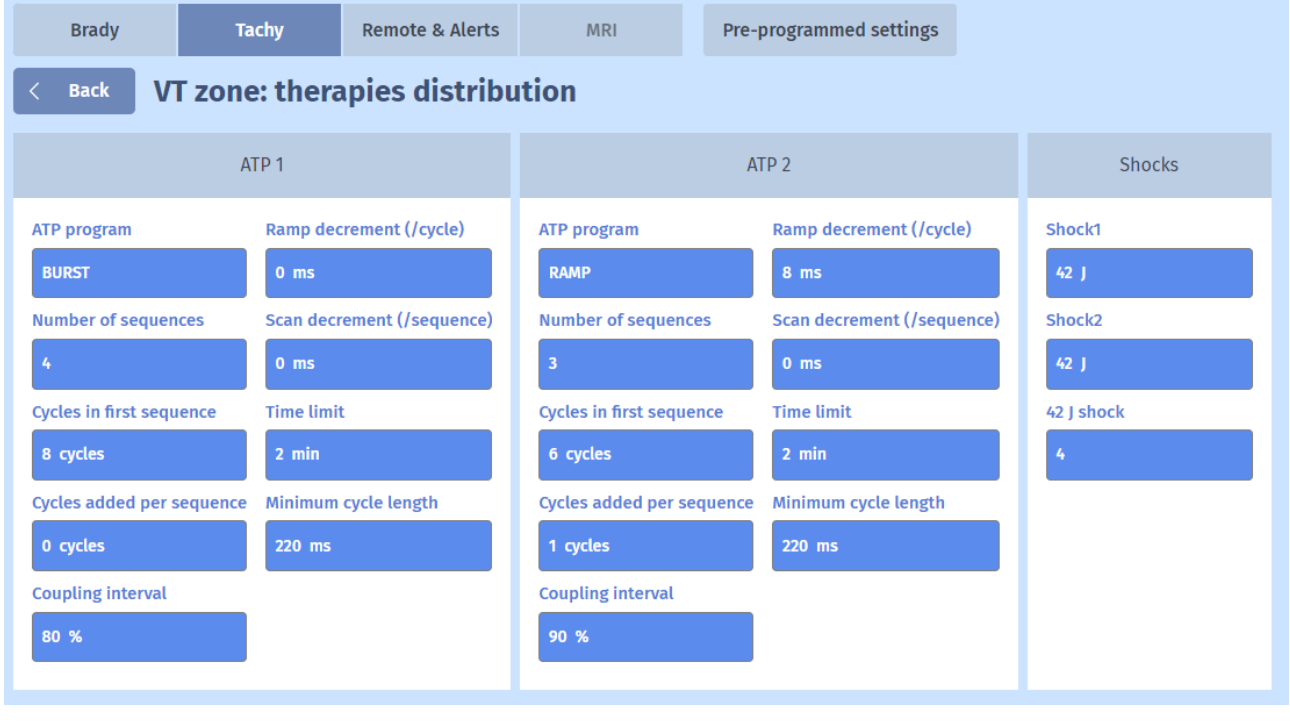
Tachycardia treated by an ATP burst

Patient

A 66-year-old man implanted with Platinium DR for dilated ischemic heart disease without prior infarction and ejection fraction of 28%, narrow QRS, in secondary prevention. Follow-up control. Asymptomatic patient.

Programming

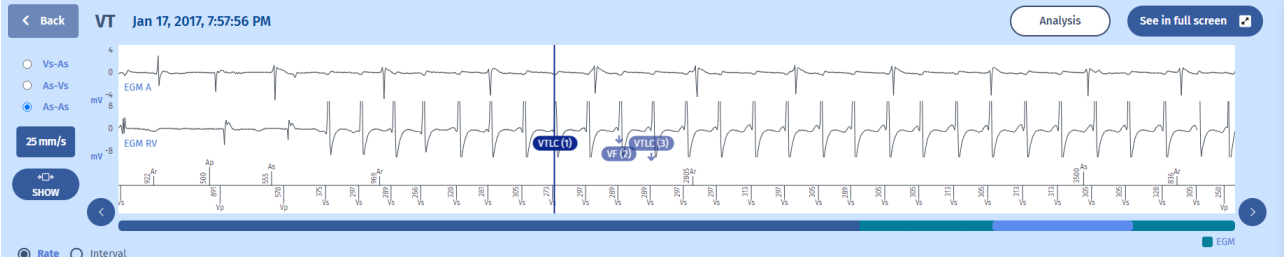


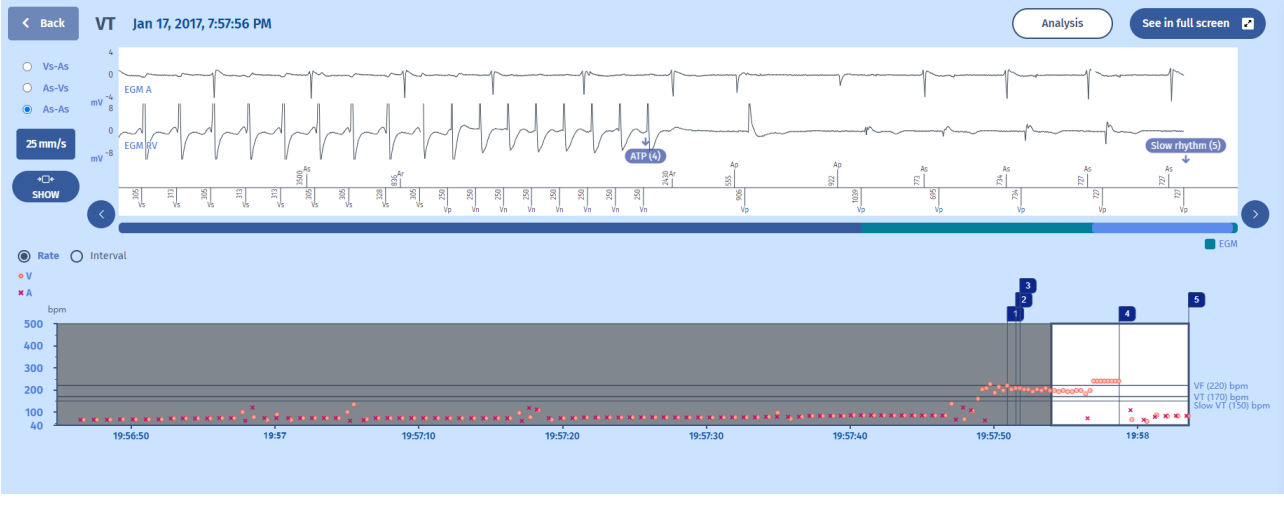


Case 5

EGM

The following 2 EGMs highlight the episode; the first is the beginning, followed by the second EGM, both at 25 mm/sec.





Which observation is correct?

1 Effective ATP burst in the Fast VT zone

2 Effective ATP burst in the VT Zone

3 The burst rate is determined by the last 4 cycles of the first VT diagnosis

4 The burst rate is determined by the last 4 persistence cycles

5 The VF cycles also increment the VT counter

Explanation

1 The rhythm is sinus and stable.

2 A tachycardia begins, ventricular in nature since the atrial rate remains slow, with some cycles in the VF zone, although the rhythm is predominantly VT with a first VTLC marker, and therefore, a persistence of 20 cycles is started.

3 Then, after 3 cycles, the rhythm becomes predominantly VF, hence a VF persistence is started while the VT counter continues to be incremented by the VF marker.

4 However an additional cycle triggers a return to VT majority (second VTLC marker), and remains as such throughout the persistence of 20 cycles

5 The average of the last 4 persistence cycles is in the VT zone, and it is the first therapy in this zone that is called upon: a burst whose coupling interval is 80% of that of the tachycardia. The ATP cycles are all identical. Not all sinus waves are detected since falling in the post-ventricular atrial blankings.

Comments

A few operating rules of the MicroPort algorithms:

1 The first two tachycardia cycles in the VT zone are excluded in the initial counting of events.

2 The majority rhythm of the initial 6/8 cycles determines the diagnosis of tachycardia and the number of triggered persistence cycles.

3 VF majority cycles (and the majority they generate) increment the persistence counter of the lower zones

4 The average rate of the last 4 persistence cycles determines the type of therapy that will be initiated based on the zone in which the ventricular tachycardia is located.

The first triggered therapy is the first therapy programmed for the designated zone of the tachycardia, or that previously determined by the Autoswitch ATP function.

Correct Answers - n° 2, 4 and 5

Take-home Message

The triggered therapy is dependent on the average rate of the last 4 persistence cycles that defines the zone in which the arrhythmia is classified, primarily for the VT and Slow VT zones, and in conjunction with other criteria for the FVT zone.

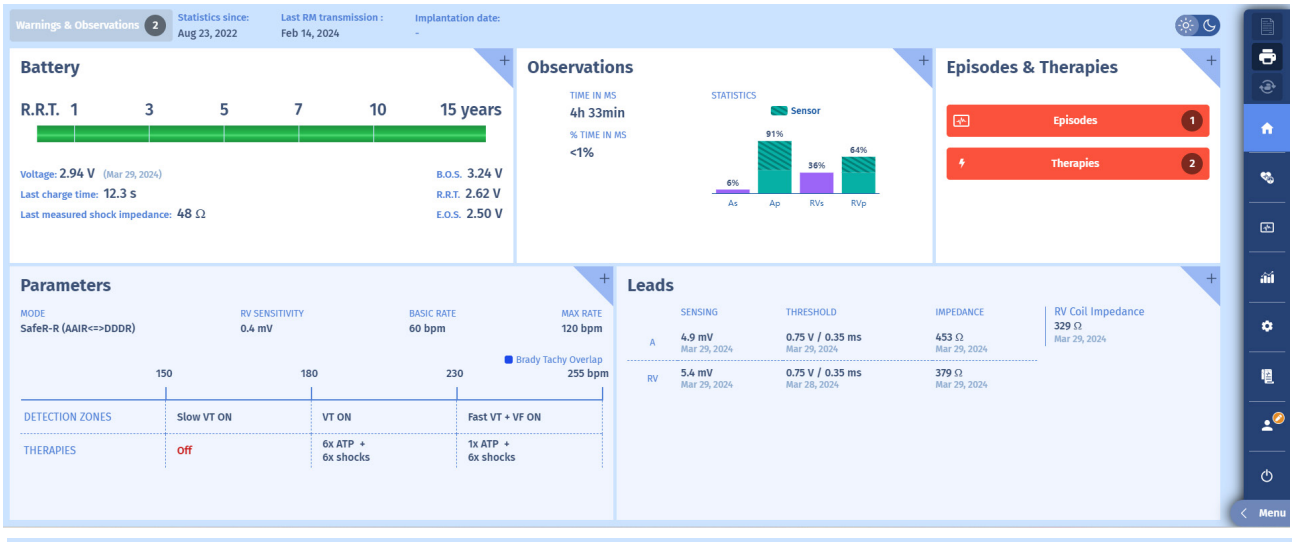
Case 6

Possible deleterious effect of antitachycardia pacing

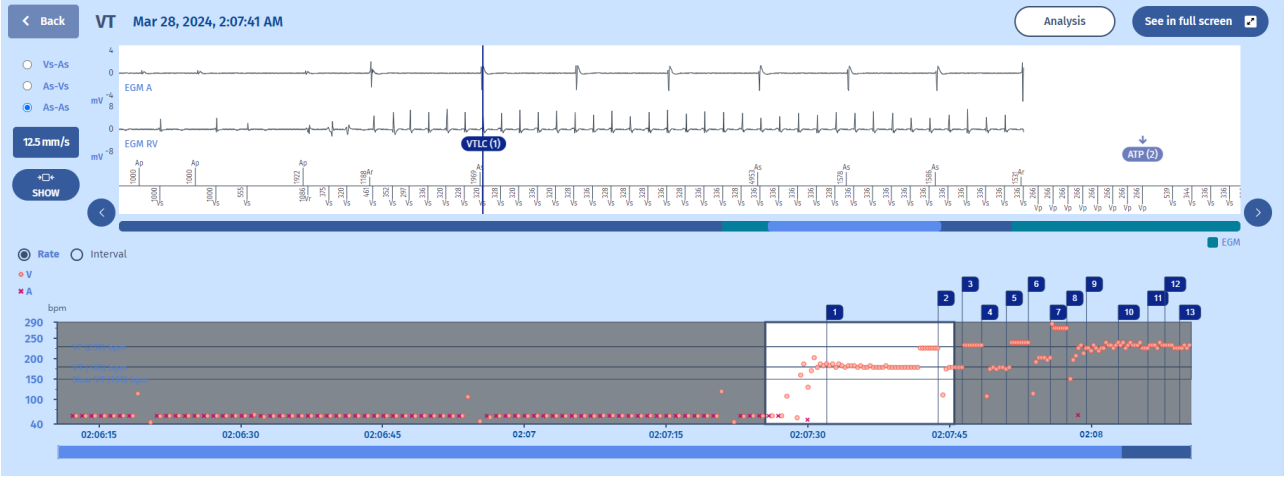
Patient

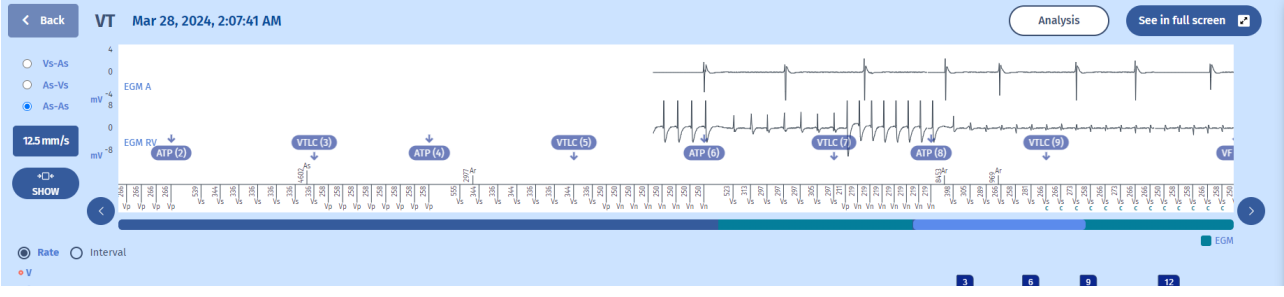
A 56-year-old ischemic patient, with ejection fraction of 30% and symptoms of heart failure, implanted with a dual chamber defibrillator, comes for a routine check.

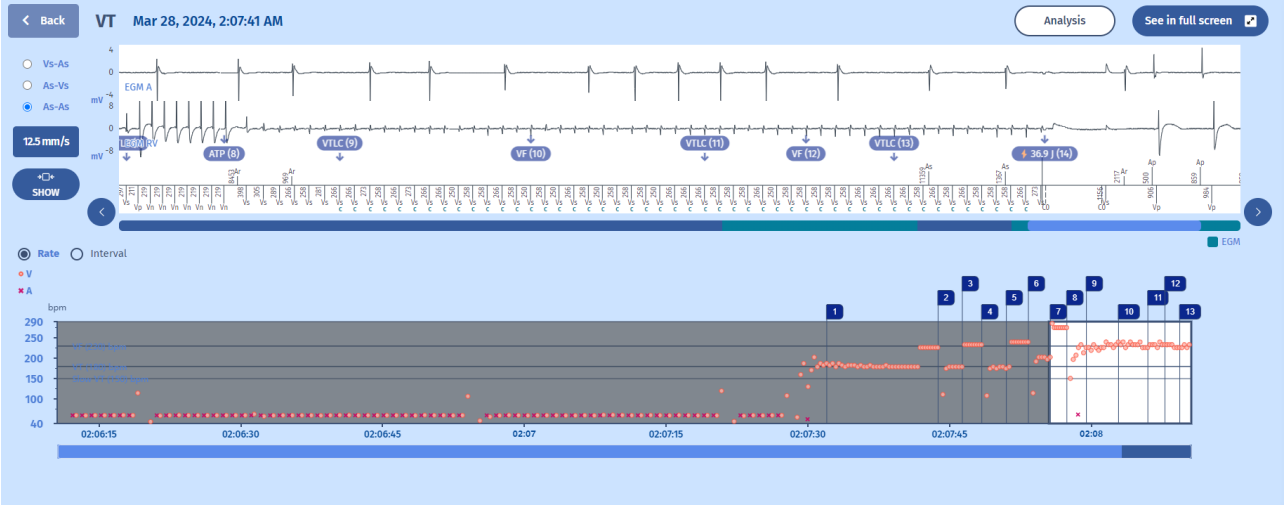
Programming



EGM







What is your opinion?

1 the first ATP was deleterious

2 the second ATP was deleterious

3 the third ATP was deleterious

4 the fourth and last ATP was deleterious

5 the shock was deleterious

Case 6

Explanation

This clinical case illustrates the escalation of the applied therapies according to the zones in which the tachycardias are located, and according to their transition from one zone to another.

- The episode starts with a stable rhythm at 60 bpm when suddenly there is an acceleration of ventricular cycles into the VT zone (>180/min).
- On the EGM we can clearly see that it is a monomorphic ventricular tachycardia with cycles around 330 ms. The diagnosis is made and the persistence is filled.
- The first therapy is an ATP (burst) which does not terminate or alter the VT.
- There is redetection of the VT (marker: VTLC 3) with another non-efficient ATP(4)
- There is again re-detection of the VT with another burst
- Notice that while the VT cycle length remains the same, the bursts accelerate slightly every time. This is due to programming of BURST + SCAN with a decrement of 8 ms for every sequence.
- The third ATP (marker: ATP 6) accelerates the VT, the cycles going from >330 ms to <300 ms but they are still in the VT zone with delivery of a fourth burst at the shortest possible cycle length; 220 ms.
- The fourth ATP again accelerates the VT with cycles as short as 258 ms
- The fourth ATP sequence was delivered with all cycles at the “minimum ATP cycle length.” This causes the ATP program to terminate (interrupt). Therefore, the next therapy is a shock, the ICD start charging.
- During the charge the VT cycles straddle between the VT zone and the VF zone
- At the end of the charge the majority is VT and the persistence is still full (not reset by VF majorities).
- The delivered therapy is the first shock in the VT zone which terminates the VT.
- Slow rhythm is quickly declared after 6 cycles outside any tachy zones (and not following blanking).

Discussion

- The ICD will apply therapies depending on the zone in which it is detected at the end of its persistence.
- For the Slow VT/VT transition, when the tachycardia rate accelerates and enters the upper zone with the average of the last 4 persistence cycles in this upper zone, it is the therapy of the upper zone which is applied; similarly, if, when slowing down, the tachycardia enters the lower zone with the average of the last 4 persistence cycles in this lower zone, it is the therapy of the lower zone that is applied «i.e. the therapy with equal or higher level of aggressiveness (all ATP programms have the same level whatever the Slow VT or the VT zone).»
- For the VT/VF transition, when the tachycardia rate accelerates and enters the upper zone (FVT/VF), the majority rhythm will change from VT to VF and after the counting of the FV persistence, it is the therapy of the upper zone that is

applied; similarly, if, when slowing down, the tachycardia enters the lower zone (VT), it is the higher or equal therapy in terms of level of aggressiveness that will be applied, the FVT/VF ATP being considered « stronger » than the VT/Slow VT ATP.

- After a therapy, and in redetection, the same diagnosis as determined before the therapy increments the persistence counter and triggers the therapy planned in the program; if the diagnosis changes from VT to VF, a new VF persistence counter is restarted.
- In this case we see that ATP accelerates the rate but as we remain in the same zone (VT), we will still apply another ATP. However even when the VT again accelerates and remains in the VT zone, the ATPs are limited at 220 ms (programmed ATP Minimum cycle length) and no longer deliverable. It is a shock which terminates this VT in the VT zone.
- The escalation of therapies, i.e. the progressive aggressiveness from one therapy to another in case of perpetuation of the tachycardia, applies in a same zone. It also applies from one zone to another: if the ATPs have been exhausted in a zone and the tachycardia changes zone, i.e. an upper zone or a lower zone, the called-upon therapy will necessarily be the next line programmed therapy in the new zone.

Are ATPs more dangerous than they are efficient?

As ramps are more aggressive than bursts (shorter pacing intervals), they are considered as more arrhythmogenic by most. However, in our study with over a 1000 confirmed VT episodes, we found no difference between burst and ramp arrythmogenicity or efficacy. Read the full article in Heart Rhythm 2020 (Strik et al). Also we found that the first burst (for any VT) is 63% efficient with low acceleration rate. As multiple ATPs are delivered, the chance of success increased but also the risk of acceleration. After the 6th ATP, new ATPs are unlikely to be effective. Delivering 6 ATPs terminates the VT in >80% of cases. While we cannot deny the risk of acceleration, the alternative has the same outcome: delivery of a shock.

Correct answer - n° 3

Take-home messages

Antitachycardia pacing may accelerate a monomorphic ventricular tachycardia into a faster VT or even VF.

Multiple ATPs decrease the risk of shocks, even though there is a slight risk of acceleration requiring shock(s).

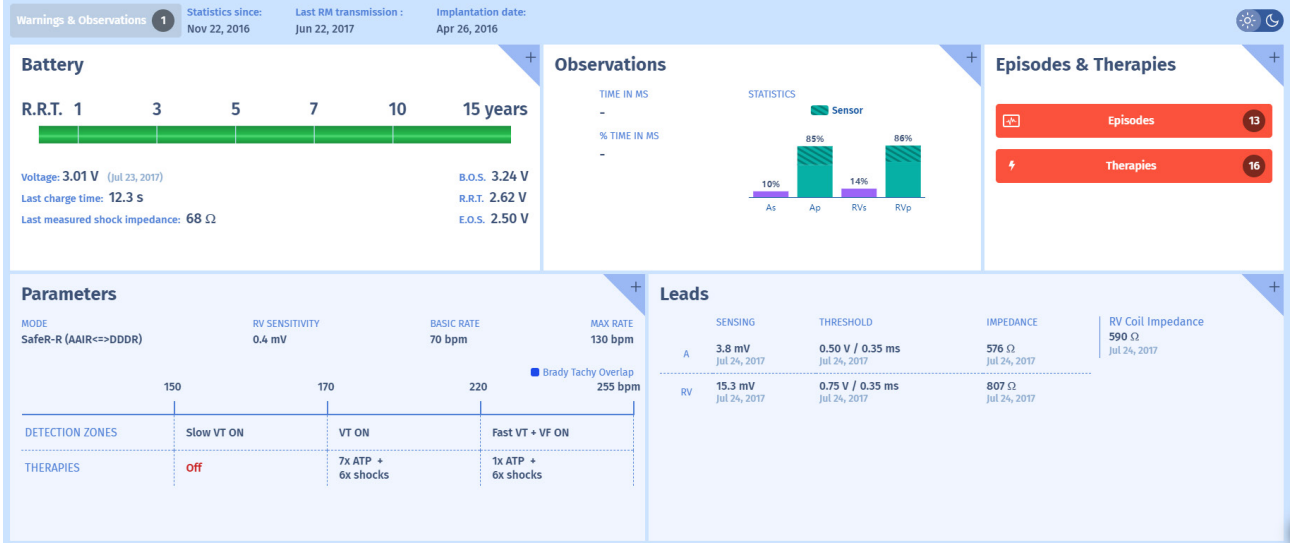
Case 7

Levels of aggressiveness

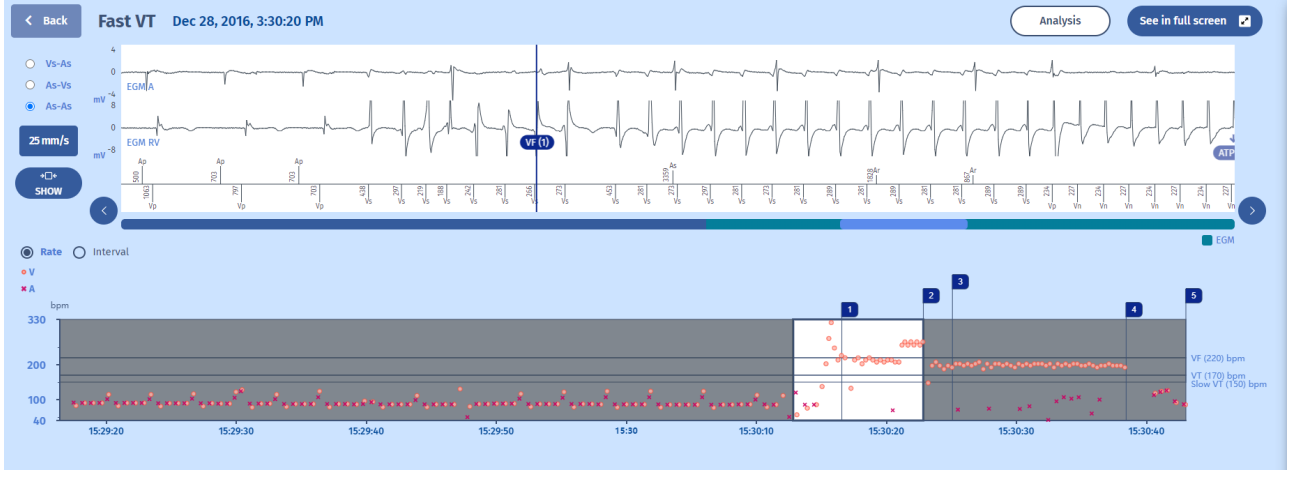
Patient

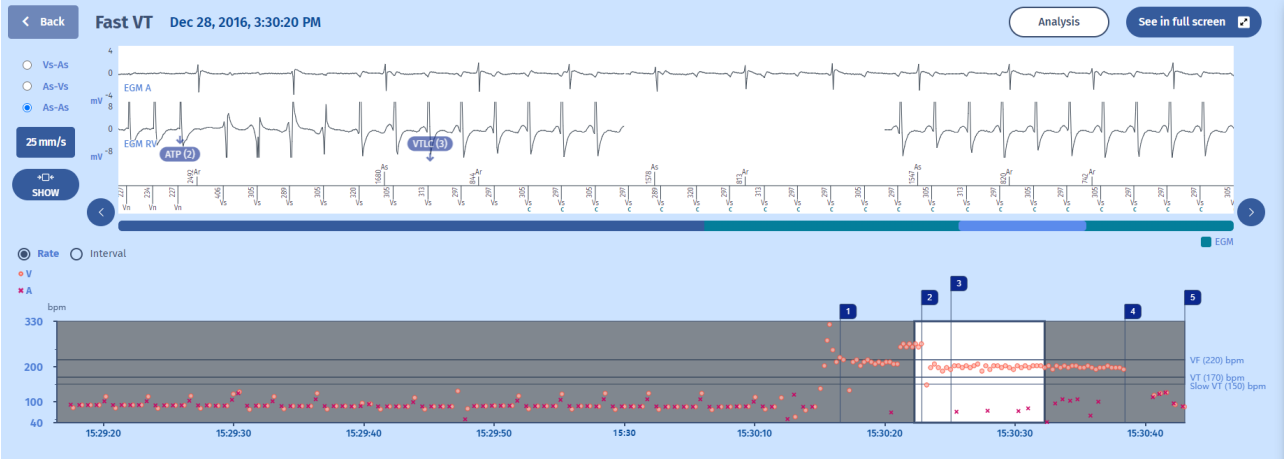
A 56-year-old ischemic patient, with ejection fraction of 30% and symptoms of heart failure, implanted with a dual chamber ICD, comes for a check-up.

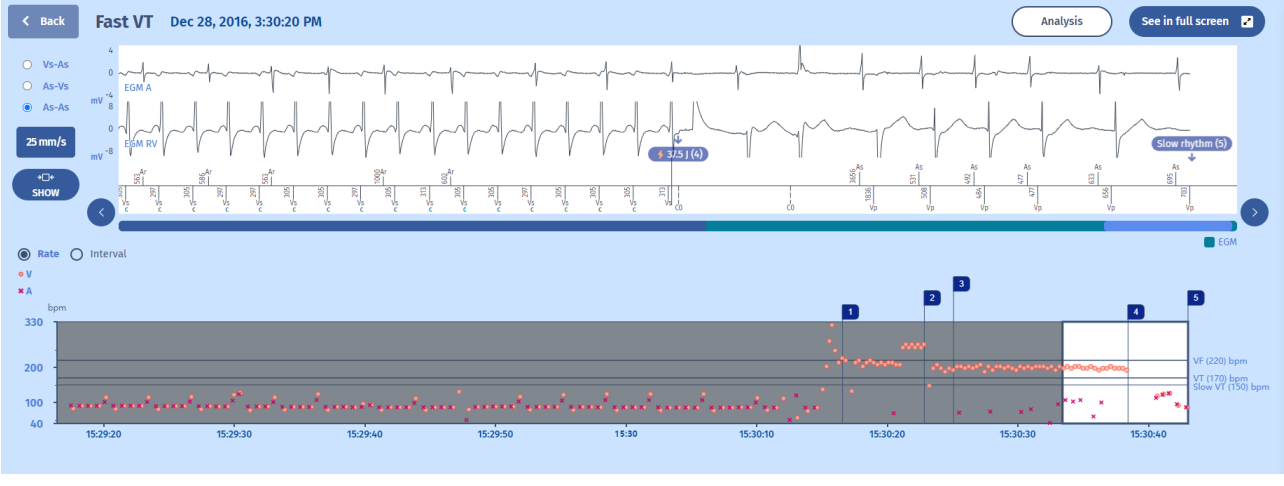
Programming



EGM







What is you opinion?

1 A ventricular fibrillation treated by a VF zone ATP followed by a VF zone shock
2 A VT treated by a VT zone burst followed by a VT zone shock
3 A VF treated by a Fast VT zone burst, then a VT zone shock
4 An inappropriate shock in response to a fast atrial arrhythmia
5 A longer ATP burst should to be discussed

Interval plot

Case 7

1 The onset of a tachycardia at the boundary of the VT and VF zones.

2 That the established diagnosis is VF

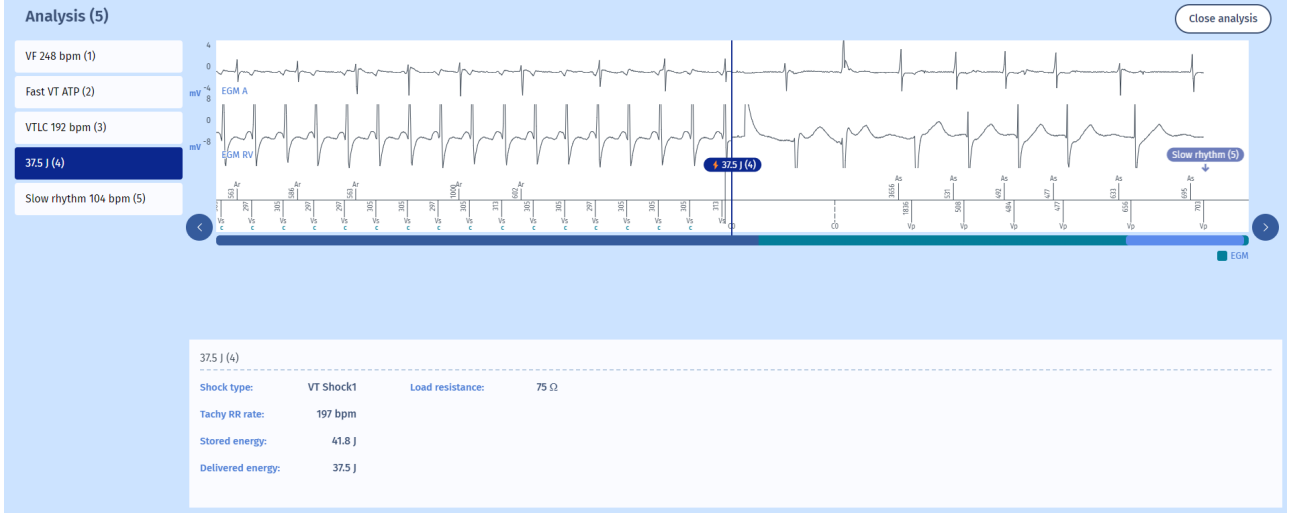
3 That an ATP burst is delivered which slows down the tachycardia and enters the latter into the VT zone

4 However it is a 42J shock that is called upon and not the ATP sequences programmed in this zone

5 With return to slow rhythm

Explications

- During the course of the electrically-driven atrioventricular rhythm, a ventricular tachycardia begins, detected in the VF zone (VF marker (1)).
- A persistence of 16 cycles is applied, and the diagnosis is not modified even if one of the cycles is of 453 ms, since this does not change the majority (at each cycle, at least 6 out of the 8 preceding cycles are in the VF zone) .
- At the end of this persistence, and because each of the last 4 cycles is in the Fast VT section of the VF zone and the rhythm is stable, the ATP sequence programmed in the Fast VT zone is triggered.
- During the redetection phase which follows the ATP, the first 4 cycles have a different morphology compared to the cycles preceding the ATP, suggesting the influence of this sequence on the tachycardia circuit, without however terminating it. Thereafter, the tachycardia is of the same morphology although a little slower, diagnosed as VT after 6 cycles in the VT zone.
- During the VF persistence, the VT counter has also increased. However, it nevertheless takes 4 additional cycles for the VT persistence counter to be fulfilled (since the number of VT persistence cycles is programmed to 20 cycles).
- It is a shock that is applied, the first of the VT zone.
- Indeed, the burst of the Fast VT zone has completed the first series of therapies for all of the zones. It is therefore the second line of therapy which is called upon, and thus



a VT Shock 1 is delivered as confirmed by the analysis corresponding to this shock in the EGM. The measured impedance is 75 Ohm.

Comments

- This episode occurs in a context of a nocturnal rhythmic storm since several ventricular tachycardias occurred in less than 24 hours, terminated by Fast VT ATPs. These resulted in palpitation symptoms and telemedicine alerts. The patient recalls a high consumption of alcoholic beverages during Christmas Eve... It should be remembered that the rhythmic risk is greatest in the 36 hours following the ingestion of alcohol, and which corresponds to the total elimination time of acetaldehyde, a breakdown product of ethanol by the liver, an agent known to damage cell membranes.
- All of the ATPs were effective at the first attempt on each episode, thus avoiding the occurrence of shocks which would have made the patient present earlier. Analysis of the transmissions the next morning, leads to convening the patient to come to the hospital. Unfortunately, the patient had an episode on route which resulted in a shock. However, we can surmise by this example the importance of having a remote transmission function that gave the alert and certainly avoided the patient from experiencing other additional shocks.
- The prognosis for patients who have had a rhythmic storm is very poor, and more than 50% of these patients will have died after one year of follow-up. These statistics are however those which preceded the era of ablation. This patient underwent a ventricular radiofrequency ablation session and to date has not had any recurrences while concomitantly refraining from the use of alcohol.

Correct answer - n° 3

Take-home messages

When a line of therapies is exhausted in a given zone, and that the ventricular tachycardia changes zone, it is the following line of therapies which is called upon in the new zone with an aggressiveness level always higher or equal to the previous level, and so forth. There is therefore a progressive escalation of the therapies without any fall-back as long as the event remains in the same episode.

This is the reason why we can immediately observe shocks in the new zone since an ATP in the Fast VT zone had already been delivered. In the present example, the Fast VT ATP burst was immediately applied. With the tachycardia slowing down into the VT zone, it is the first shock of the VT zone which is called upon, as the ATP therapies are concluded (albeit in the VT zone).

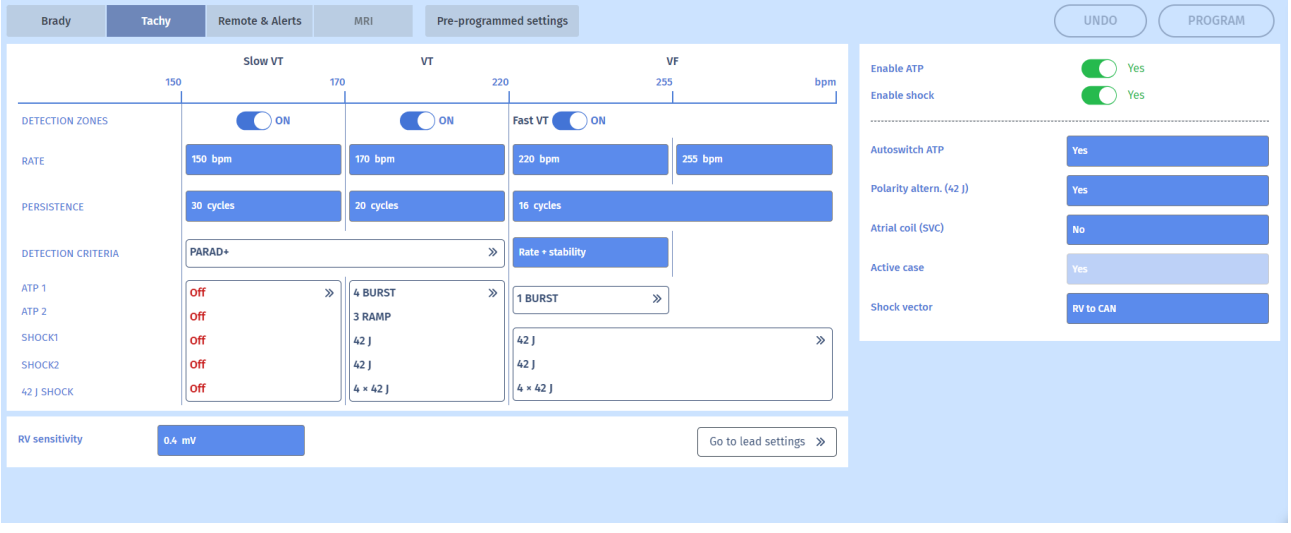
Case 8

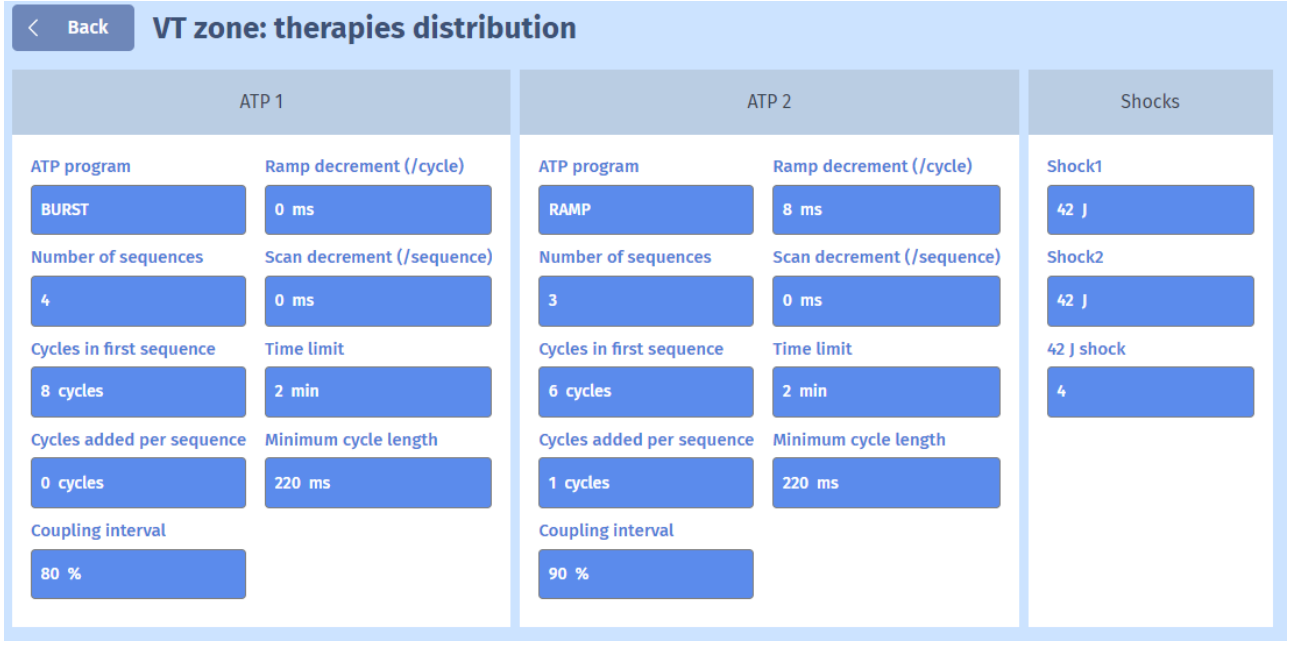
Tachycardia and zones

Patient

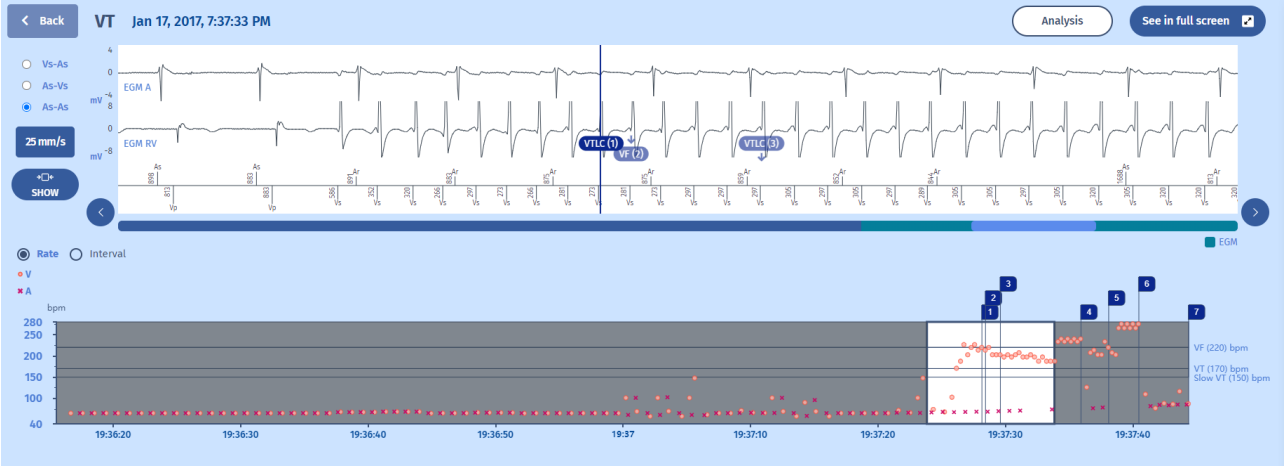
A 56-year-old ischemic patient, with ejection fraction of 30% and symptoms of heart failure, implanted with an atrio-biventricular defibrillator (narrow QRS but with frequent episodes of Mobitz I second-degree AV block).

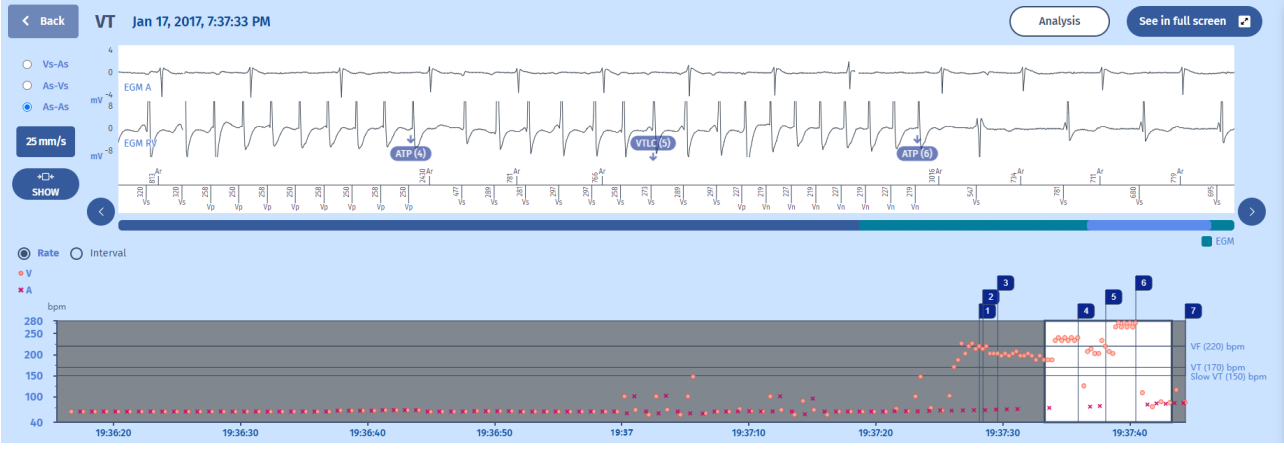
Programming





EGM





What is your opinion?

1 Ventricular tachycardia detected in the VT zone

2 Ventricular tachycardia detected in the VF zone, Fast VT section

3 The first ATP is a burst, the second is a ramp

4 Both therapies are bursts of the VT zone

5 There is an atrial flutter

Case 8

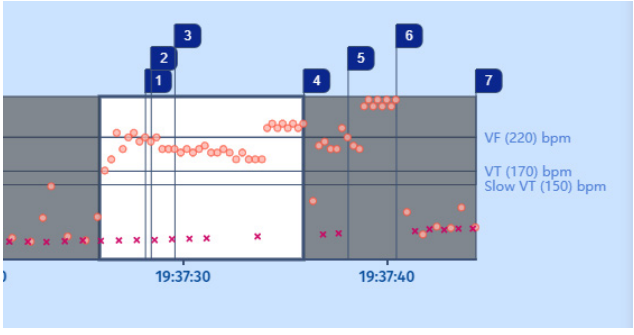
Interval plot

1 The rhythm is initially sinus, then appearance of premature contractions and the tachycardia begins

2 The tachycardia is in the VT zone, bordering on the FV zone,

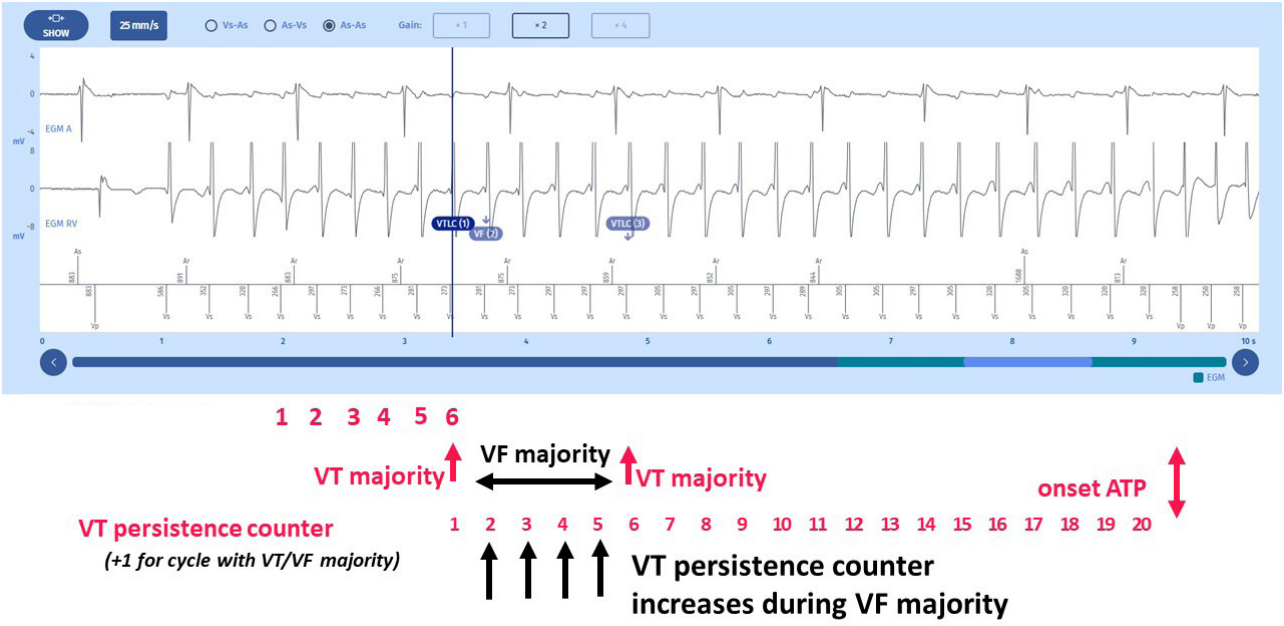
3 And an ATP burst is applied which leads to an acceleration of the tachycardia, which nonetheless remains in the VT zone

4 And at the end of redetection, a second faster burst terminates the tachycardia



EGM

- A monomorphic ventricular tachycardia begins abruptly with atrial dissociation
- Ventricular far-field signals are visible on the atrial EGM, but are not detected
- After excluding the first two tachycardia cycles in the VT zone, the following 6 cycles lead to a first VT diagnosis.
- There is a gradual acceleration at the onset of the tachycardia such that the diagnosis is quickly VF
- The tachycardia then stabilizes with a slight deceleration leading again to the diagnosis of VT
- From the first VT diagnosis (1st VTLC annotation noted on the tracing), the VT counter is incremented at each cycle, each validating the VT diagnosis. The VT persistence counter of 20 cycles (as programmed for this zone) therefore begins
- During the short time period where the tachycardia is noted VF, the VT counter continues to increment and VF counter starts to increment.
- The second VTLC annotation interrupts the VF counter, but continues to increment the VT counter until reaching the number of 20, which triggers the first therapy in the VT zone, a burst of 8 cycles with a coupling interval at 80% of the average of the last 4 persistence cycles (320 ms)
- The ATP does not terminate the tachycardia which is even faster than before the ATP
- After the ATP, the tachycardia continues. The 1st cycle post-ATP is not taken into account, and during the redetection cycles, the diagnosis of VT is obtained, and the second therapy of the VT zone is applied with a pacing coupling time of 80% of the average of the last 4 cycles of the redetection phase (281 ms)
- The cycles of this second ATP have a coupling interval at the limit of the minimum allowed coupling of 220 ms.
- This burst terminates the tachycardia



Comments

- This case illustrates the counting of cycles during the tachycardia with an increment of the VT counter when the cycles are labelled VF majority, with again, the risk of acceleration of the VT by the therapies. Here, the consequences are modest since the tachycardia is accelerating, obviously, but is quickly terminated by the next burst.
- The ATP coupling interval adjusts itself to the tachycardia rate which initiates the therapy. Each ATP will therefore have a rate depending on the average of the last 4 VT cycles prior to therapy.
- The ATP rate, whether it is a burst or a ramp, cannot be faster than the programmed minimum cycle length, in this instance 220 ms.
- A comment on the programming of the prosthesis. We can see that two types of therapies are programmed in the VT zone: bursts followed by ramps. We also note that no pacing cycle is added to each burst, while a cycle is added to each ramp. This means that the first ramp has 6 pacing cycles, the second has 6+1 cycles, the third 7+1 cycles, and so forth. This results in an increased aggressiveness of the ramps, which can cause acceleration, or the triggering of a VF thus necessitating a shock. It is better to increase the number of burst cycles rather than the number of ramp cycles.

Correct answers - n° 1, 4

Take-home messages

The ATP pacing rate is dependent on the average tachycardia rate prior to their delivery.

If successive therapies modify the tachycardia, the ATP rate adjusts itself to these changes.

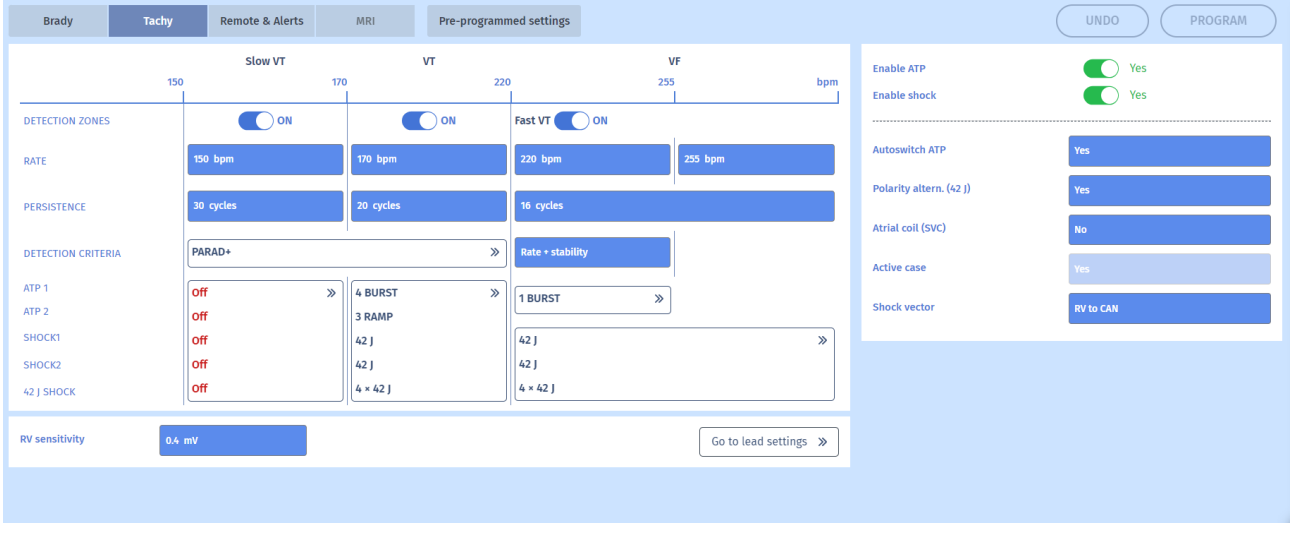
Case 9

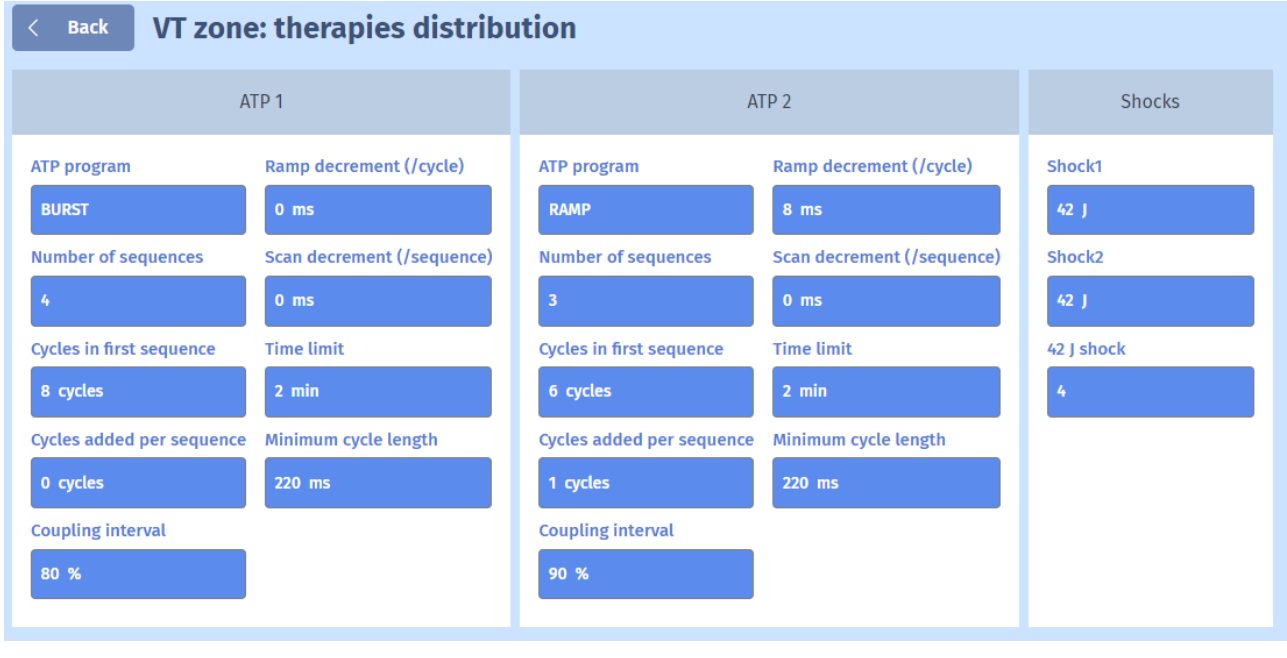
Termination by ATP?

Patient

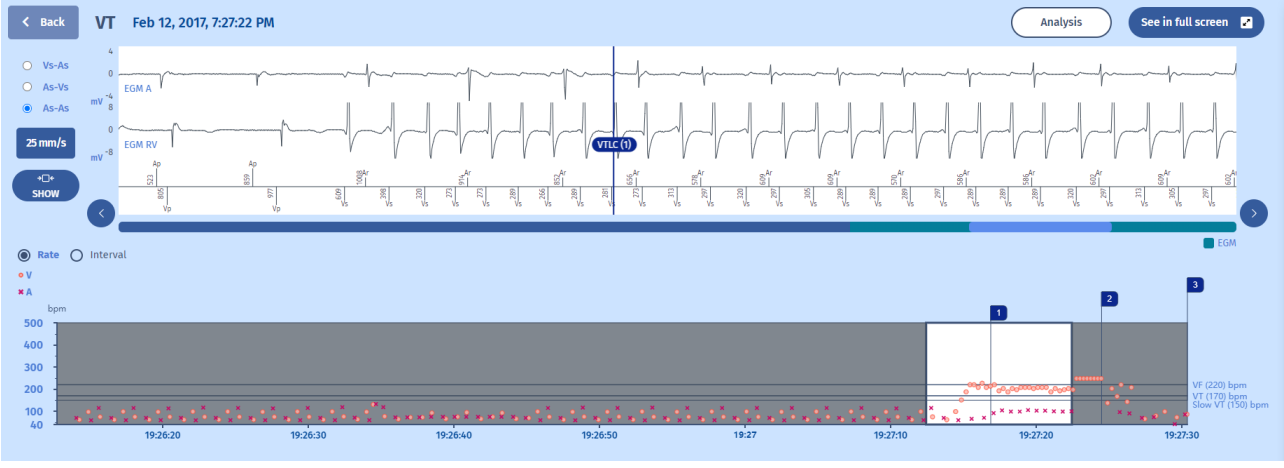
A 56-year-old ischemic patient, with ejection fraction of 30% and symptoms of heart failure, implanted with an atrio-biventricular defibrillator.

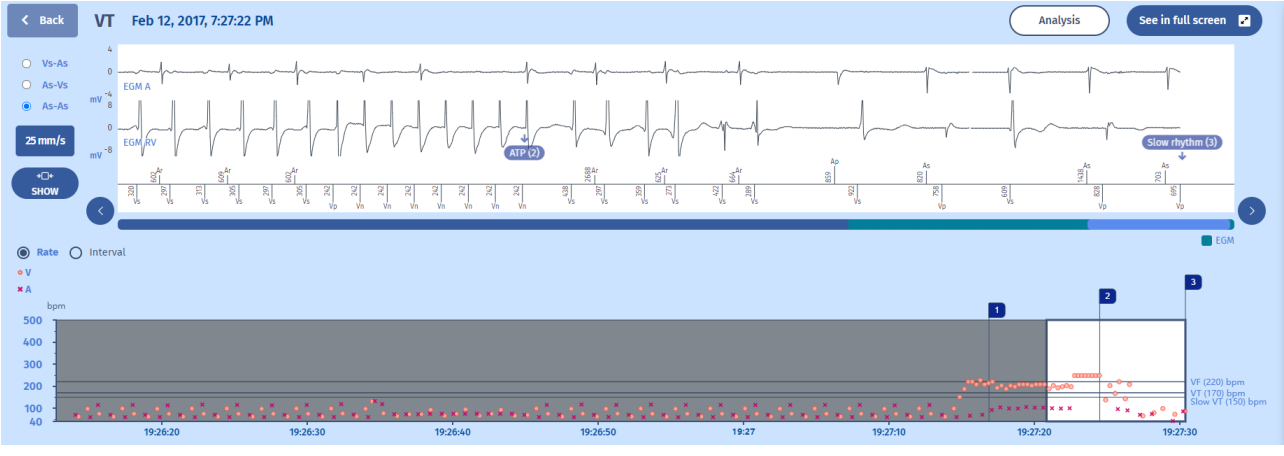
Programming





EGM





What is your opinion?

1 The tachycardia would probably have terminated spontaneously if the persistence had been programmed longer

2 The ATP therapy was definitely effective.

3 We cannot be completely sure the tachycardia was terminated by the ATP

4 A ramp would result in a faster termination

Case 9

Interpretation

- The counting of events is very clear in this example: The first tachycardia cycle is 609 ms and is therefore not in the VT zone. For the system, the tachycardia begins on the following cycle, the one noted 398 ms, which is excluded from the counting, as is the next cycle noted 320 ms
- The next 6 cycles are detected in the VT zone, and a first VT diagnosis is made (VTLC)
- Which triggers the persistence of 20 cycles, each cycle validating the VT majority, and perpetuating the persistence
- Once the persistence fulfilled, the first scheduled ATP sequence in the program is delivered, a burst
- The tachycardia terminated shortly after the second ATP but first we see a few premature contractions
- 6 out of 8 cycles are in the slow zone, and the episode ends.

Comments

- This tracing reveals the proper analysis behaviour of the defibrillator: the counting is simple, the discrimination correctly resulted in the diagnosis of VT with a persistence of exactly 20 cycles as programmed, the therapy of the zone was applied.
- This therapy is effective, certainly, but with a result that is not as clear-cut as in the previous example.
- One may wonder if a longer burst would have allowed to better penetrate the tachycardia loop and obtain a faster result. On the other hand, extrasystoles with varying cycle interval are often seen after ATP and may themselves be a sign of tachycardia destabilisaiton and ultimately termination. The exact number of fast ventricular events between ATP and termination to be tolerated and allow the therapy to be called succesful is not known.
- In addition, due to an onset mode seemingly always identical with the presence of many premature contractions which have a morphology ostensibly identical to that which triggers the tachycardia, an indication of ablation of the tachycardia should be discussed with this patient by targeting the triggering premature contractions circuit.

Correct answer - n° 3

Take-home messages

It takes several cycles before the paced cycles of a burst fully capture the ventricular events and have a chance to enter the tachycardia circuit.

It is recommended to program at least eight cycles for every burst.

Chapter 3 : Discrimination

Basics

The MicroPort defibrillator algorithm continually evaluates the criteria explained in the following paragraphs as soon as a ventricular cycle is detected in the Tachy/VF zone. Depending on the combination of criteria defined by the physician, some of these criteria will be taken into account in order to establish a classification (diagnosis) that will need to be maintained in order to lead to a binary result, namely therapy (VT) or no therapy (SVT). It should be remembered that in the VF zone (Fast VT zone included), no discrimination is made for differentiating between SVT and VT. The only criterion used is that of stability, in the Fast VT zone only, and not for the diagnosis, but rather to decide whether or not to administer an ATP prior to the capacitor charge if programmed.

Single-chamber discrimination

Once the majority rhythm is classified (6 of at least 8 sliding cycles in the Tachy zone: Slow VT or conventional VT), the following criteria are taken into account for VT/SVT discrimination:

- RR stability (stability of delays Vs-Vs)
- Sudden acceleration
- Long ventricular cycle (medium term instability)

The device analyses the rhythm according to different possible combinations:

- rate only: only the ventricular rate criterion is used (no discrimination)
- stability: use of the stability criterion
- stability+: stability criteria + long cycle search
- stability/acceleration: stability and sudden acceleration
- stability+/acceleration: stability, sudden acceleration and long cycle search (as-shipped setting)

The "+" specifies the search criteria and the taking into account of long ventricular cycles.

1. RR stability in VT zones (Slow VT and VT)

When a rhythm is detected in a VT zone (Slow VT or VT), the defibrillator evaluates the majority presence of RR intervals (Vs-Vs) in a given stability window. A majority (75%) of the 8 sliding cycles (6) analysed must have a « similar » coupling interval, namely 75% of the cycles must fit within a 65 ms window (programmable stability window).

2. RR stability in the Fast VT zone

When a rhythm is detected in the VF zone, but in the Fast VT section, the stability analysis is identical, however 75% of the cycles must fit within a 30 ms window (programmable stability window). It should be reminded that this discrimination is not used to differentiate SVT versus VT but to decide whether an ATP is to be administered prior to the capacitor charge.

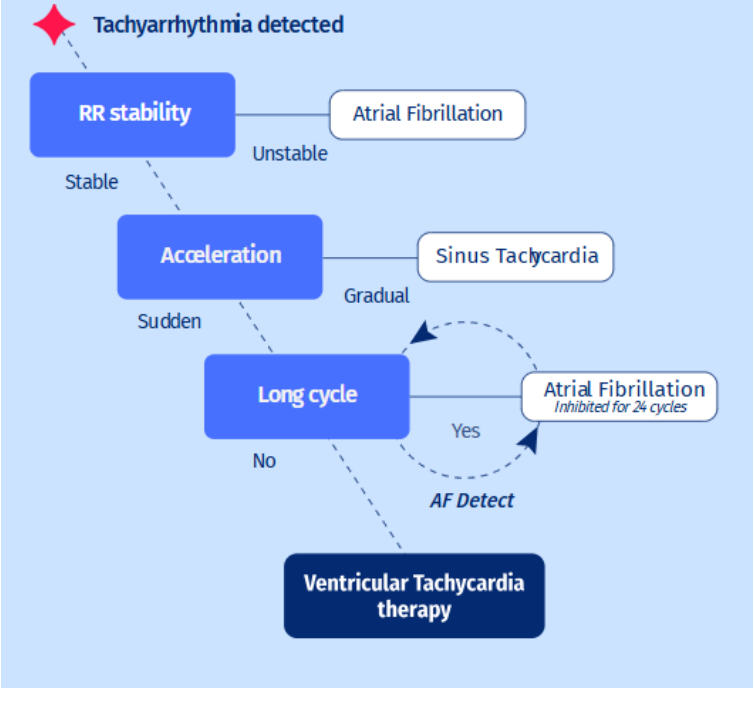
3. Sudden acceleration

The defibrillator defines a cycle as being accelerated when it is detected in a Slow VT, VT or VF zone, and its duration is shorter than the reference coupling interval (corresponding to the previous cycle if it is normal or the average of the 4 previous non-accelerated cycles) minus the

percentage of acceleration (19% nominal, programmable).

4. Long cycle search

When the stability criterion and acceleration criteria are is fulfilled, the defibrillator takes into account the presence of at least one long cycle over the last 24 cycles, starting from the first persistence. On subsequent persistence cycles (in the case of a charge, for example), the search for a long cycle is always carried out over the last 24 cycles or less in the case of post-therapy redetection. A long cycle is defined as a cycle whose duration is longer than the average of the last 4 cycles included in the Tachy/VF zone + a programmable duration, by default 170 ms. The long cycle search begins after the detection of 4 cycles classified as VT or VF.



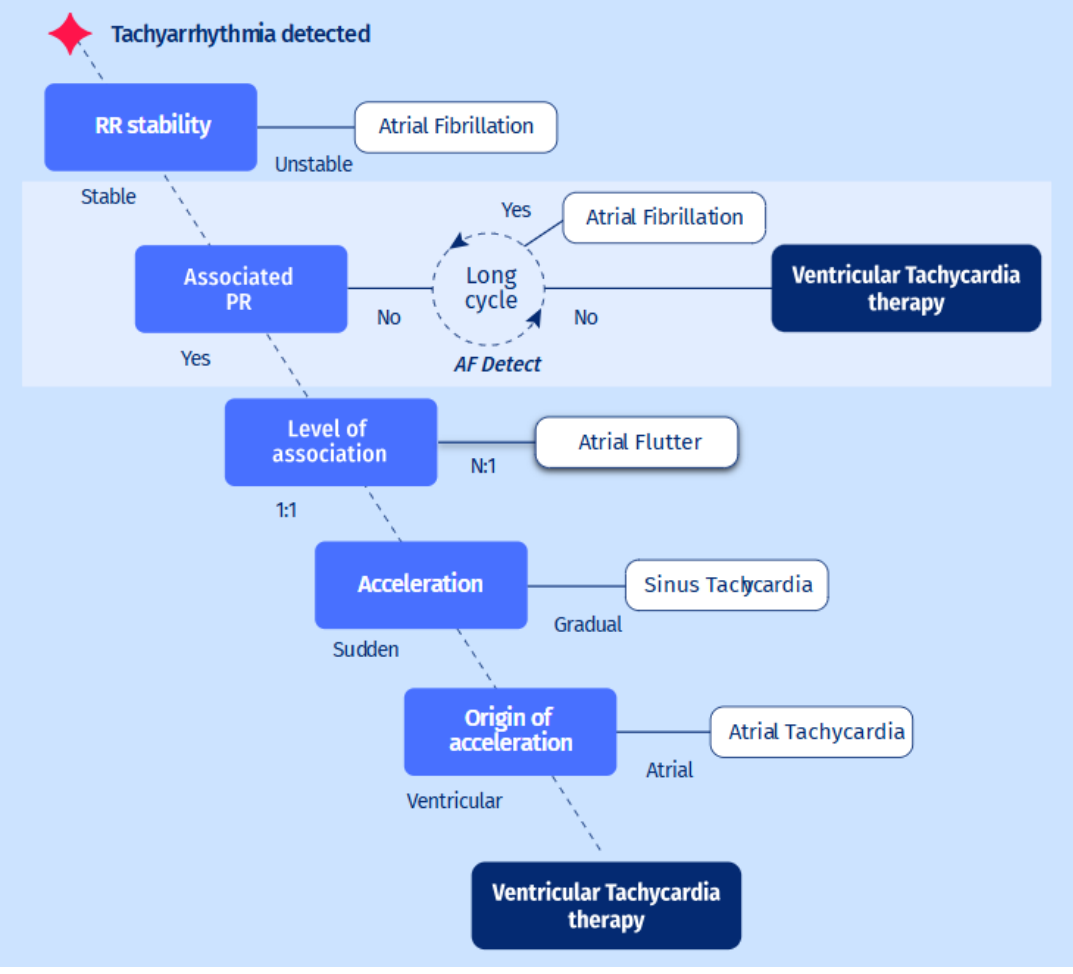
Dual Chamber Discrimination

Once the majority rhythm is classified, the following criteria are taken into account for VT/SVT discrimination in dual-chamber PARAD+ algorithm (as-shipped settings)

- RR stability (stability of delays Vs-Vs)
- PR association (stability of the PR (As-Vs or Ap-Vs) delays)
- Level of PR association (1:1 or N:1)
- Acceleration
- Originating chamber of the first sudden acceleration, A or V
- Long ventricular cycle (medium term unstability)

The decision tree for the PARAD+ algorithm

Classification of typical arrhythmias detected by the PARAD+ algorithm



For the functioning of the Stability, PR association and level of PR association parameters in the Slow VT and VT zones, the system divides the RR and PR intervals of the 8 sliding cycles into RR

Criterion / Typical rhythm	**Ventricular stability** (stable, unstable)	**Association AV** (No, 1:1 , N:1)	**Acceleration** (sudden, gradual)	**Origine of acceleration** (A, V)
Atrial Fibrillation (AF)	**unstable**			
Dissociated Ventricular Tachycardia (VT)	**stable**	**No**		
Atrial Flutter (A Fl)	**stable**	**N:1**		
Sinus Tachycardia (ST)	**stable**	**1:1**	**gradual**	
Atrial Tachycardia (AT)	**stable**	**1:1**	**sudden**	**A**
Ventricular Tachycardia (VT) with 1:1 retrograde conduction	**stable**	**1:1**	**sudden**	**V**

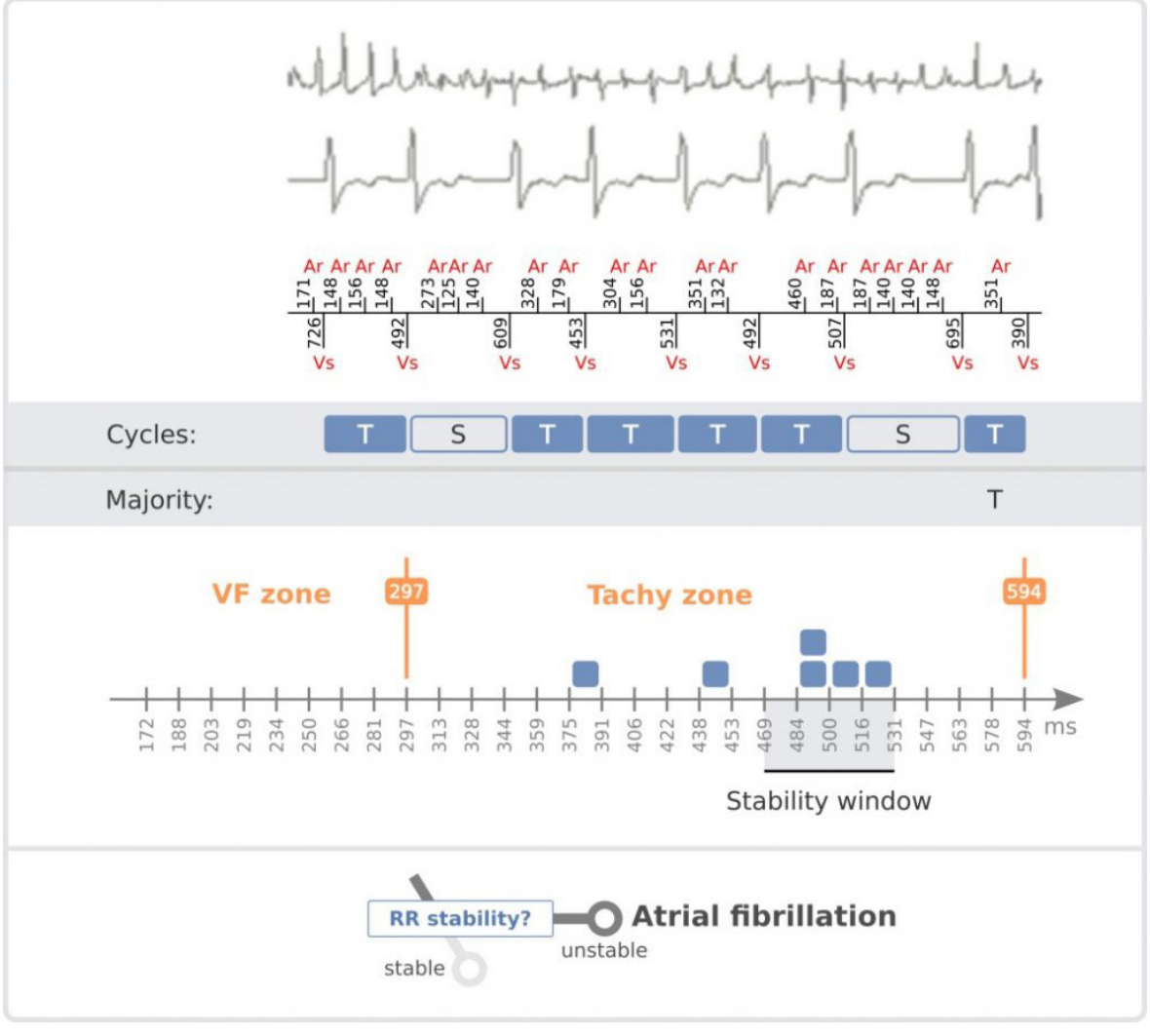
and PR histogram classes in 16 ms steps.

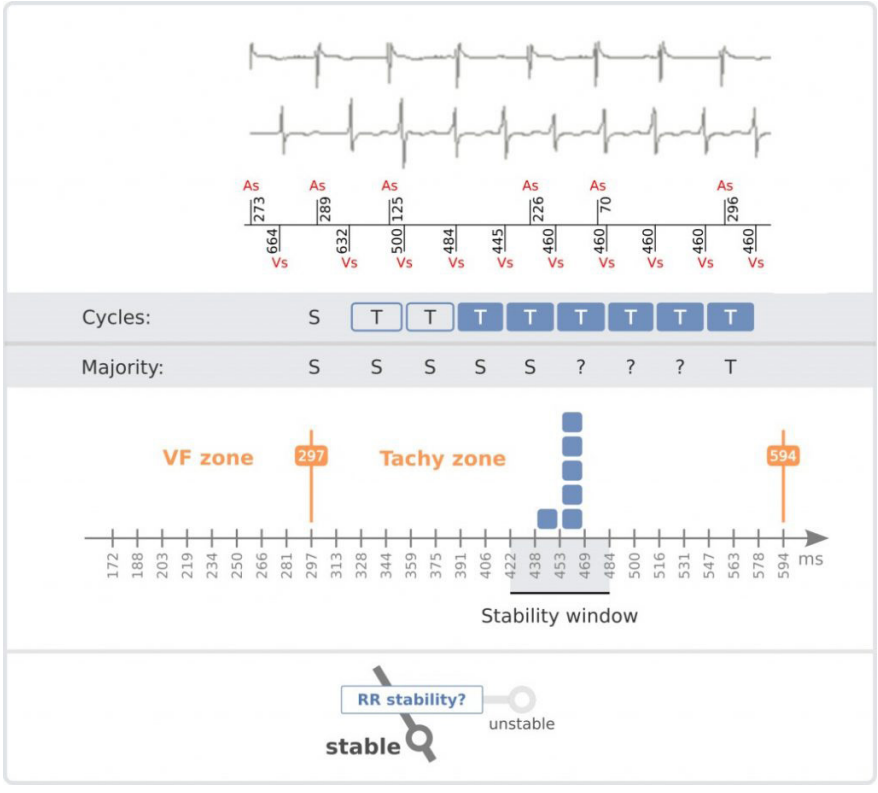
The number of RR and/or PR cycles of each RR and PR histogram class thus constructed is compared with the programmed values of the discrimination algorithm. The first two tachycardia cycles in the Slow VT and VT zones are ignored for the construction of the histograms.

1. RR stability

When a majority rhythm is detected in a VT zone (Slow VT or VT), the defibrillator evaluates the presence of majority of RR intervals in the stability window. A majority (75%) of the 8 analysed sliding cycles (6) should have a « similar » coupling interval, i.e. 75% of the cycles should fit within a 65 ms window (programmable stability window = 4 classes of 16 ms).

Here the stability criterion is not reached (4/6 < 75%), the rhythm is unstable and PARAD/ PARAD+ analysis is "Atrial fibrillation".



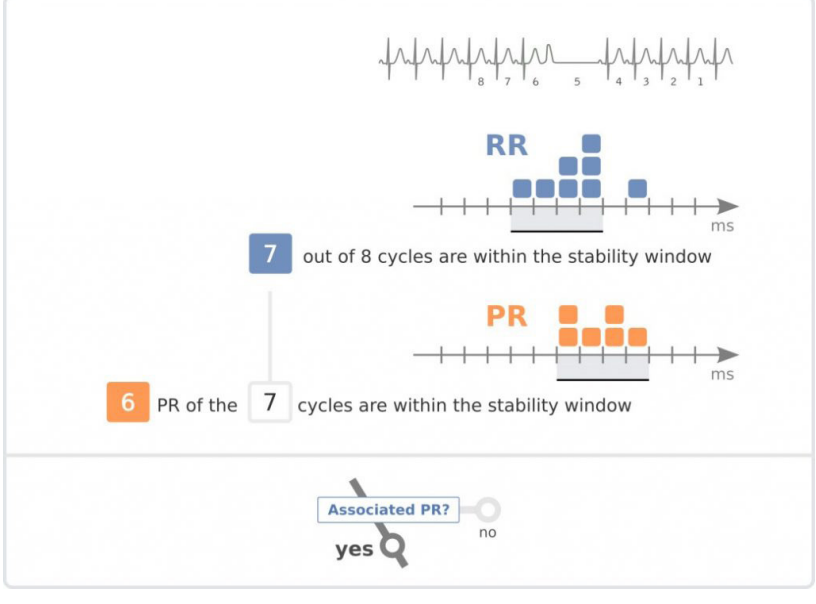


In this example, the rhythm is stable and PARAD/PARAD+ analysis will continue to identify the ongoing rhythm.

2. PR association (stability of the PR (As-Vs) or AR (Ap-Vs) delays)

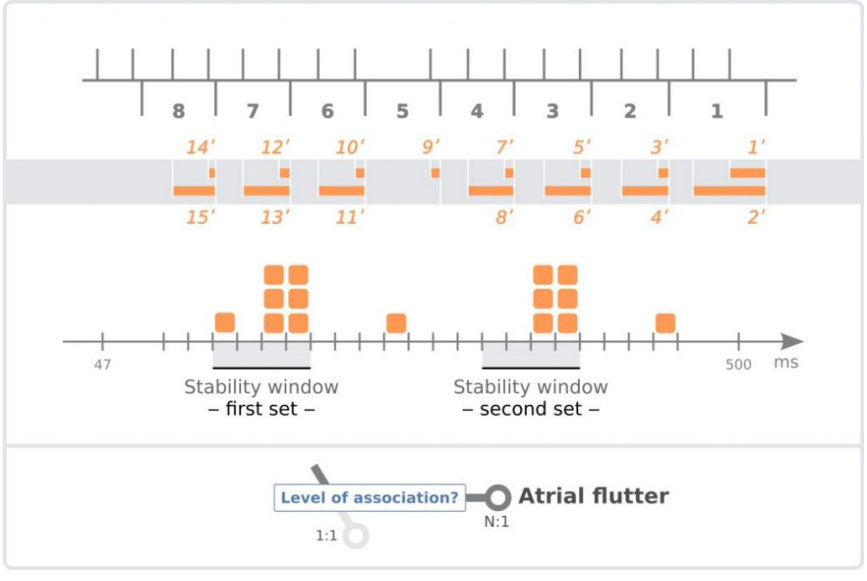
When the RR stability criterion is fulfilled, the defibrillator counts the number of PR or AR intervals in the association window.

A majority (75%) of solely stable V cycles must be preceded by an atrial event with a « similar » PR or AR interval fitting within a 65 ms window (association window = programmable stability window).

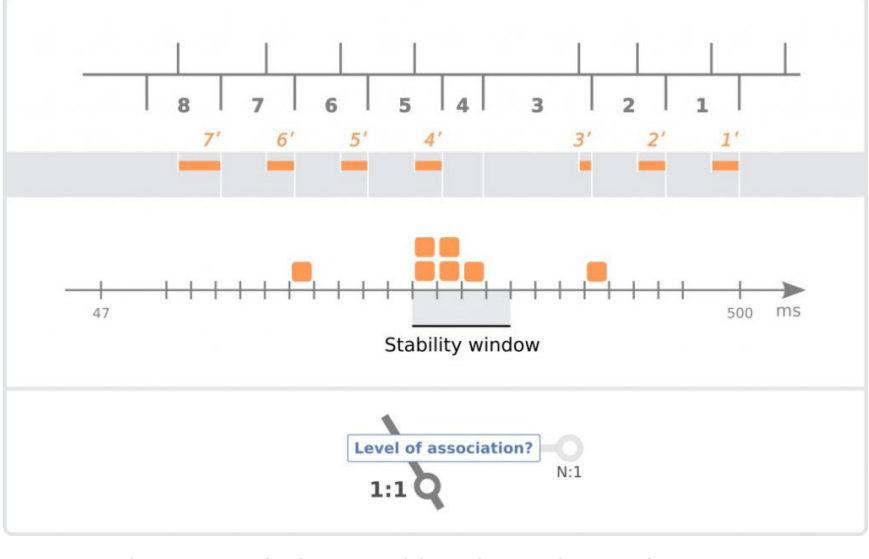


3. Level of PR association

When the RR stability criterion and the PR association criterion are fulfilled, the system searches for the presence of one or more PR groups with each having a « similar » coupling interval. In the distribution of the PR or AR intervals (i.e. As-Vs or Ap-Vs intervals),, when 75% of the PR or AR intervals fit within a 65 ms window (association window = programmable stability window), the level of PR association is 1:1. Otherwise, there is no 1:1 PR association, and the association level is said to be N:1.



The max number of PR intervals within a stability window is 7 (first set), which represents less than 75% of the total PR intervals (15): the association level is N:1.



The max number of PR intervals within a stability window is 5, which represents at least 75% of the total PR intervals (7): the association level is 1:1

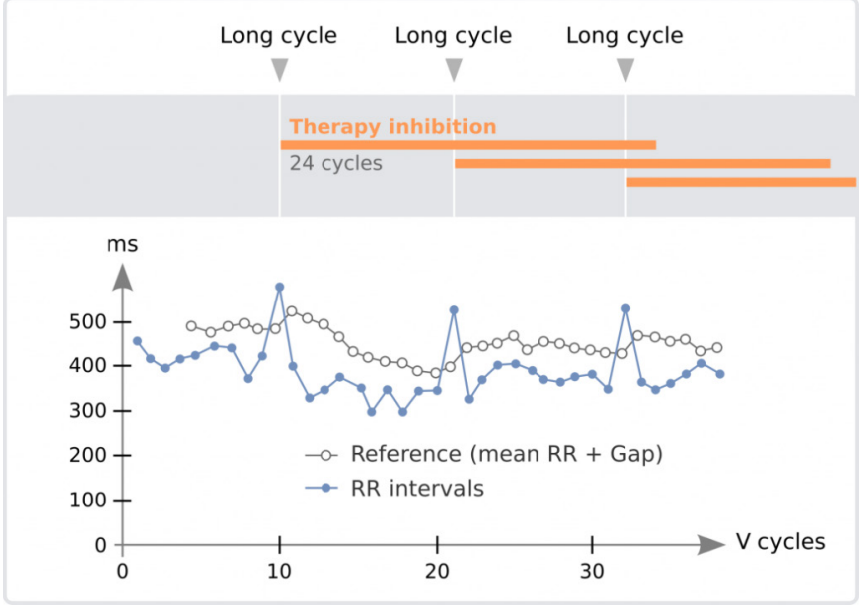
4. Search for a long cycle when the rhythm is stable and dissociated

VT therapies are inhibited for the 24 cycles following the detection of a long Vs-Vs cycle only when the rhythm is classified as stable and dissociated and the device is in mode switch. When the VT persistence counter is reached and, at this time, the majority rhythm ("the majority") is stable/dissociated VT, the device takes into account any long ventricular cycles detected during the last 24 ventricular cycles.

A cycle is long if its coupling interval is longer than the average of the last 4 cycles in the Tachy/VF zone + a programmable gap (170 ms nominal).

The search for a ventricular Long Cycle:

- begins as soon as 4 cycles in the Tachy/VF zone have been detected
- resumes after the delivery of a therapy



The average calculated of the last 4 cycles is re-initialized if the slow rhythm majority is reached, or after a therapy (ATP or shock).

5. A or V acceleration (chamber of origin of first sudden acceleration)

The defibrillator defines a ventricular cycle as accelerated when the cycle is detected in a Slow VT, VT or VF zone, and its duration is shorter than that of the reference cycle minus the programmed percentage of acceleration (25% nominal, programmable).

The reference cycle corresponds to:

- the previous RR interval, if the latter is « normal » (i.e. this cycle is not accelerated, nor considered as a pause, or a non-conducted cycle) or
- the average of the last 4 RR intervals which were not accelerated when the previous RR interval is: already accelerated (accelerated V or A), a ventricular pause (RR > 125% previous RR) or not conducted from the atria (premature ventricular contraction).

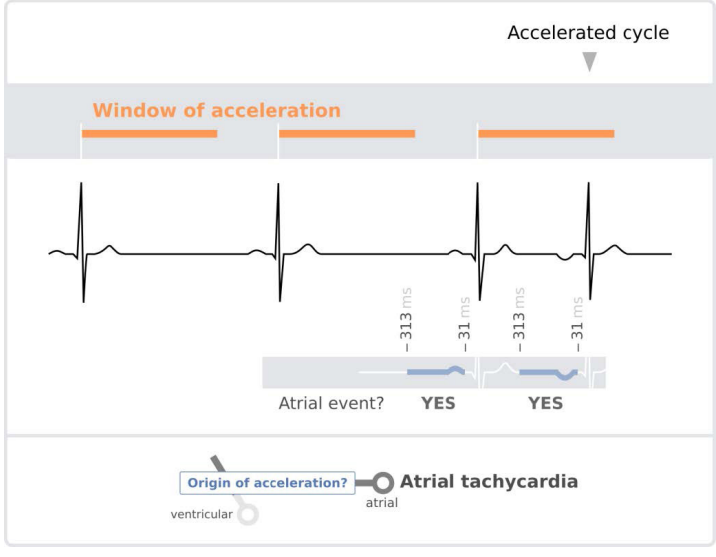
The origin of the acceleration is evaluated differently depending on the programmed pacing mode DDD, DDI or SafeR (AAI/DDD).

In DDD/DDI mode, in the Tachy/VF detection zone, the acceleration is atrial if both R's of the accelerated RR (Vs-Vs) cycle are conducted (the PR preceding each R is between 31 and 313 ms) otherwise, the acceleration is ventricular.

In SafeR mode in the Tachy/VF detection zone, the acceleration is atrial if the two ventricular events that define the first accelerated cycle are each preceded by an atrial event with a similar delay. That is, the RR interval must be at least 75%* of the PP interval, otherwise the acceleration is of ventricular origin.

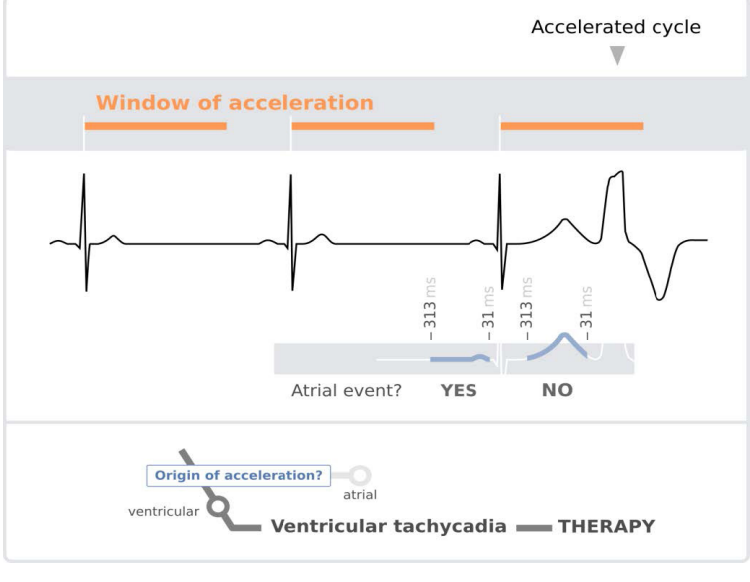
*: The percentage of shortening of the RR interval relative to the PP interval is dependent on the programmed prematurity (25% nominal). The percentage of shortening is = 1 – programmed prematurity = 75%.

In the next example, each of the RR intervals that define the first accelerated cycle are preceded by an atrial cycle event occurring in a time range of [31ms ; 313ms] : the acceleration is of atrial origin.



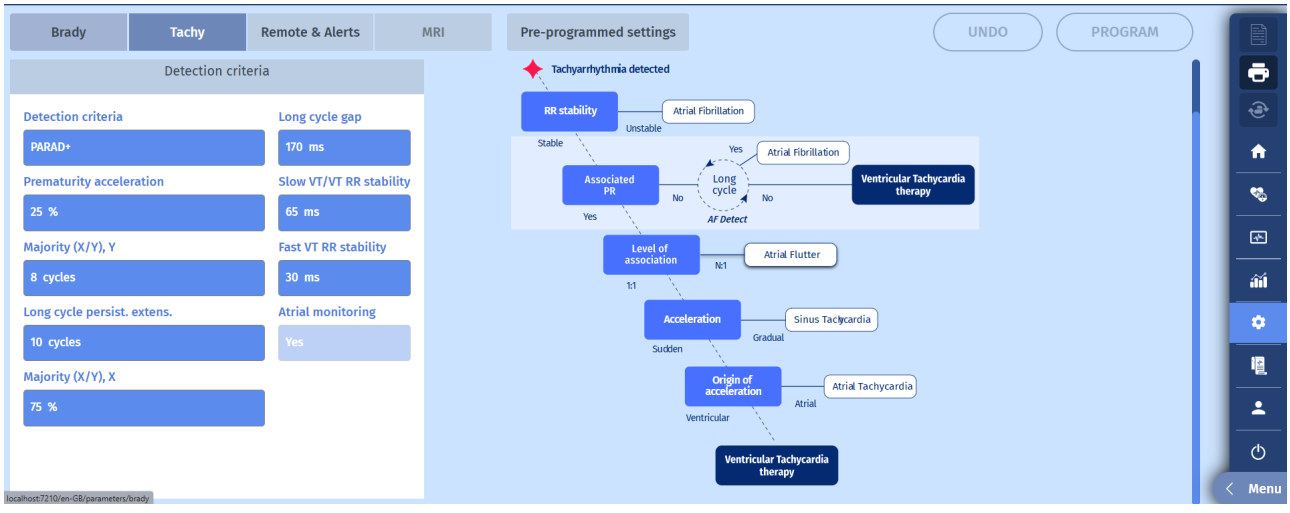
The acceleration is from ventricular origin if at least one of the 2 ventricular events which define the first accelerated interval is not classified as conducted ventricular beat. An example of non conducted beat is presented below.

In the following example, each of the RR intervals that define the first accelerated cycle are not preceded by an atrial cycle (second R wave not preceded by a P): the acceleration is of ventricular origin.

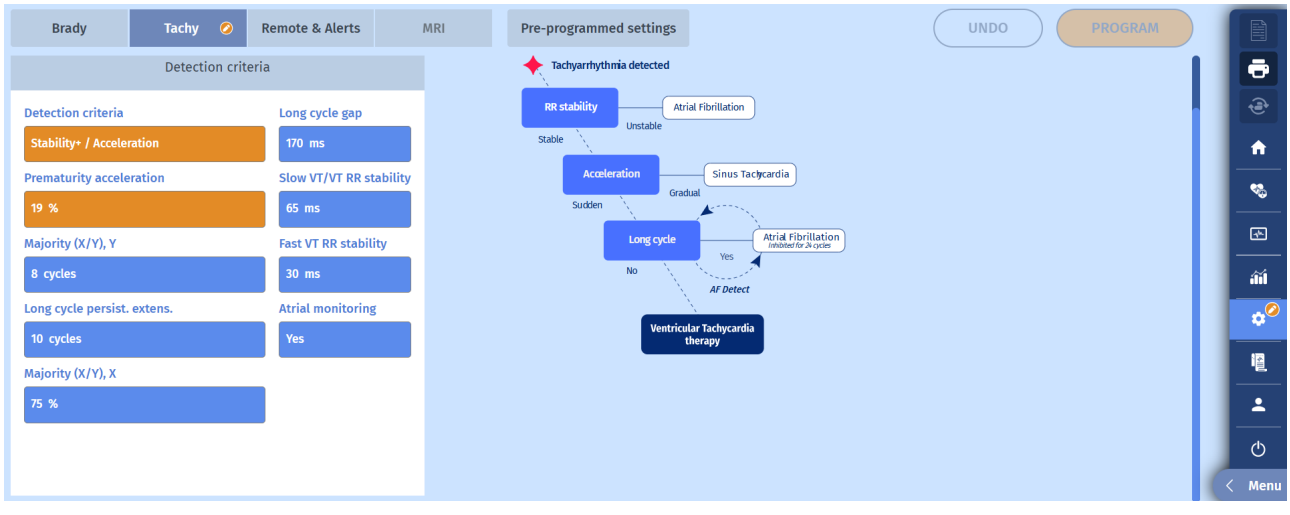


The V or A acceleration criterion is invalidated when 2 consecutive ventricular cycles lose the “accelerated cycle” criterion: the cycle times are longer than that of the reference cycle minus by the programmed percentage of acceleration (25% nominal, as shipped value).

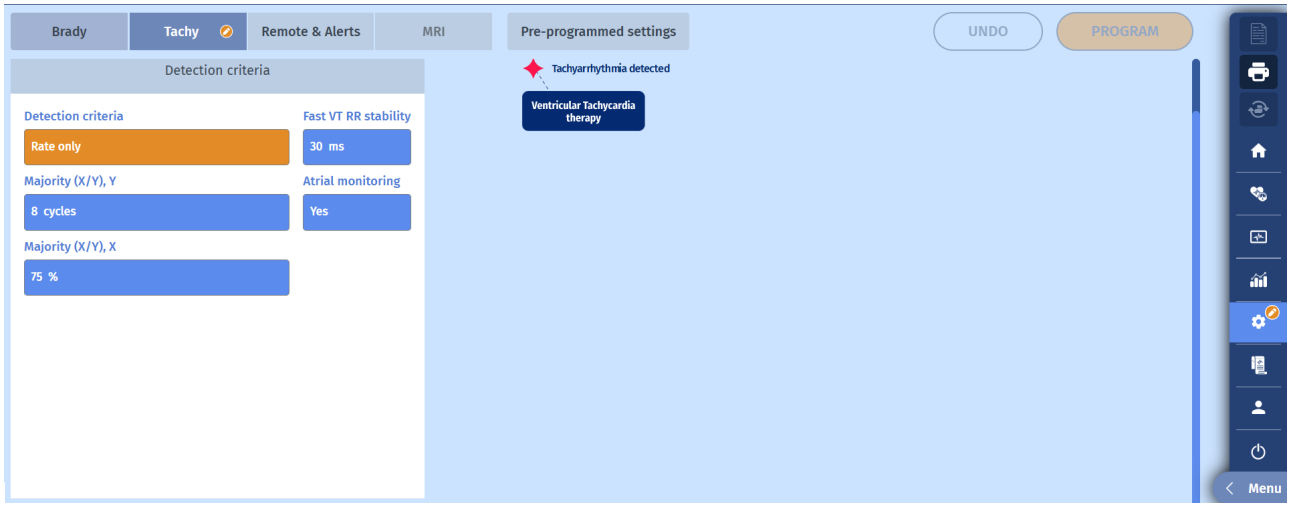
In MicroPort ICDs, don't forget that the discimination algorithm is displayed under the Tachy tab under the Detection criteria screen.



Any changes made to the discimination parameters directy show up on the programmer screen, like this following example when atrial lead dysfunction prompts switching to a single chamber discrimination algorithm:



Note: when a patient has complete AV-block, discrimination should be de-activated! Like so:



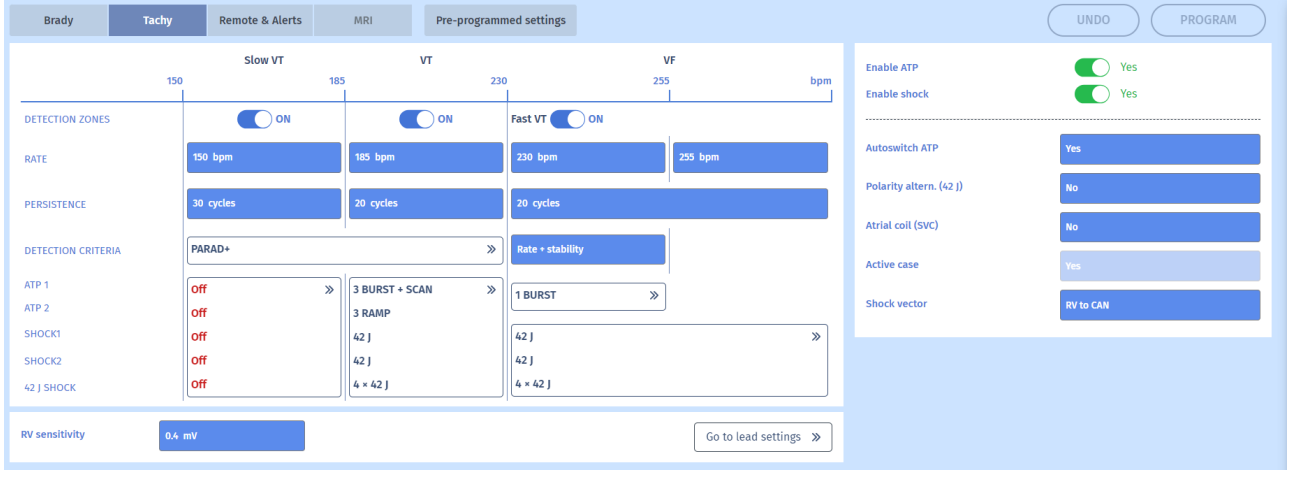
Case 1

Stability as the great discriminator

Patient

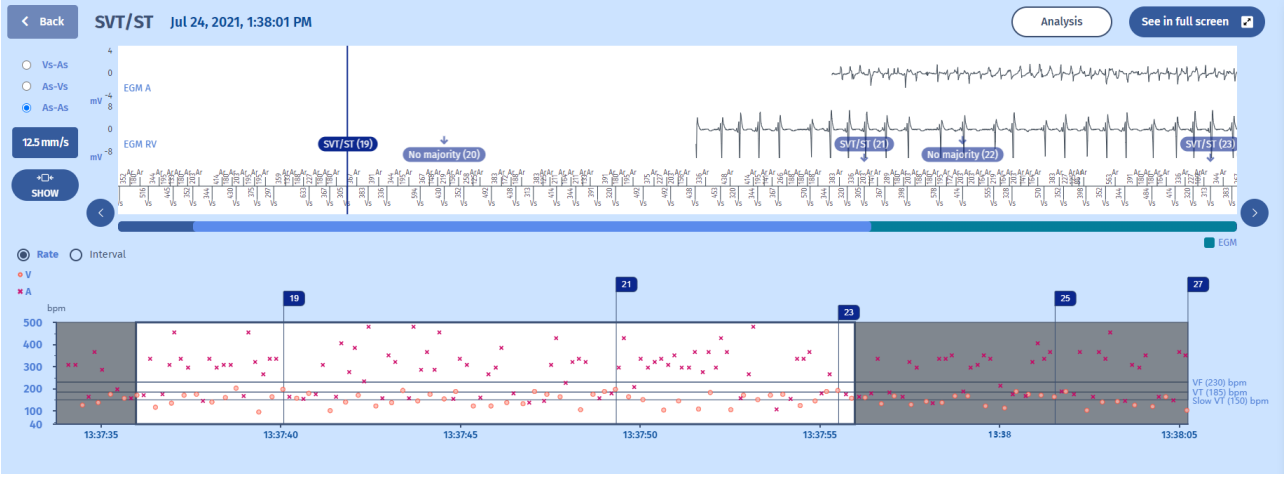
66-year old patient with ischemic cardiomyopathy implanted with a dual chamber defibrillator for primary prevention undergoes routine device interrogation.

Programming



Case 1

EGM



What is the correct diagnosis?

1 Ventricular tachycardia

2 Ventricular fibrillation

3 Atrial fibrillation with rapid ventricular response

4 Bitachycardia (atrial fibrillation + ventricular tachycardia)

5 Sinus tachycardia

EGM

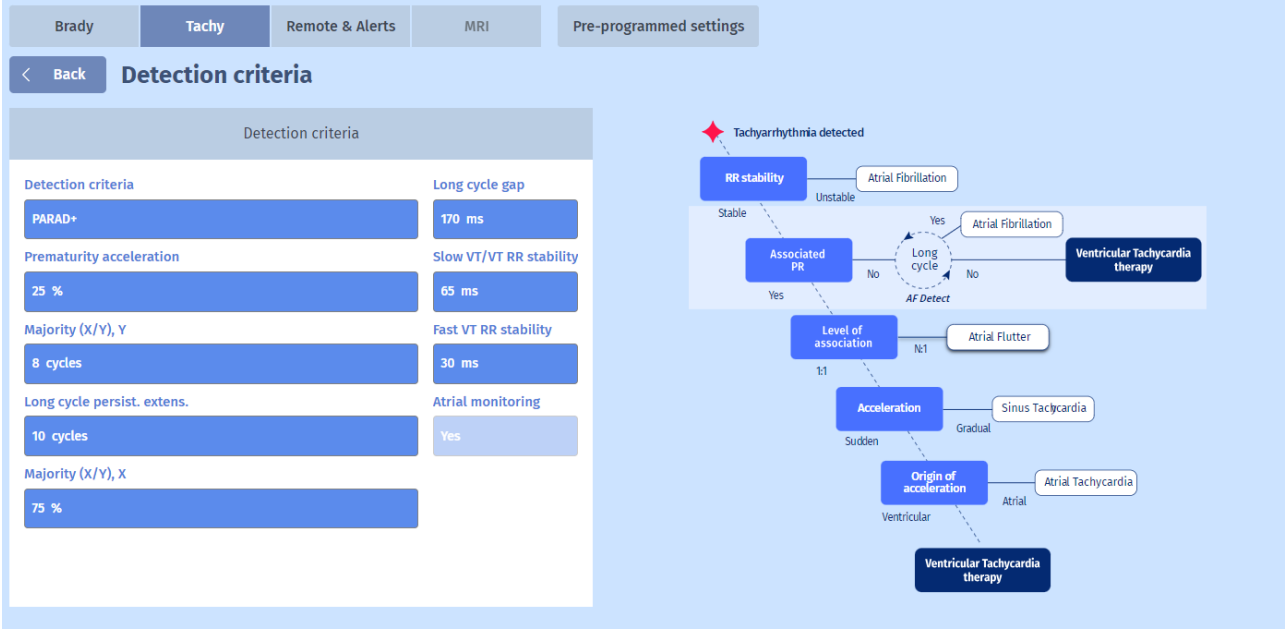
The interval plot and EGM show very rapid and irregular atrial arrhythmia on the atrial channel which confirms the diagnosis of AF. The ventricular EGM and markers also show rapid ventricular events which may give the suspicion of ventricular arrhythmia. However, the events are highly irregular and together with the co-existence of AF, the diagnosis of AF with rapid ventricular response can be made.

Discrimination

Discrimination in the context of ICDs is used to describe all efforts to exclude inappropriate diagnoses and therapys of supraventricular arrhythmia. While today, these algorithms are considered as being the most complicated onboard ICDs, in the past they were based mostly on stability (regularity of ventricular events) and sudden onset (to exclude sinus tachycardia). As AF is a major risk factor for inappropriate therapies and as it is most often irregular, the stability criterion is still considered as an important part of any discrimination algorithm. In MicroPort devices, it is even the first step of the PARAD+ algorithm.

When we click on Analysis we will find out which criteria were made to get to the conclusion of SVT/ST during the episode. As the analysis is continuous over a sliding window of 8 cycles, the diagnosis may change rapidly and it is therefore not uncommon to see multiple labels (“diagnoses”) during an episode in MicroPort ICDs.

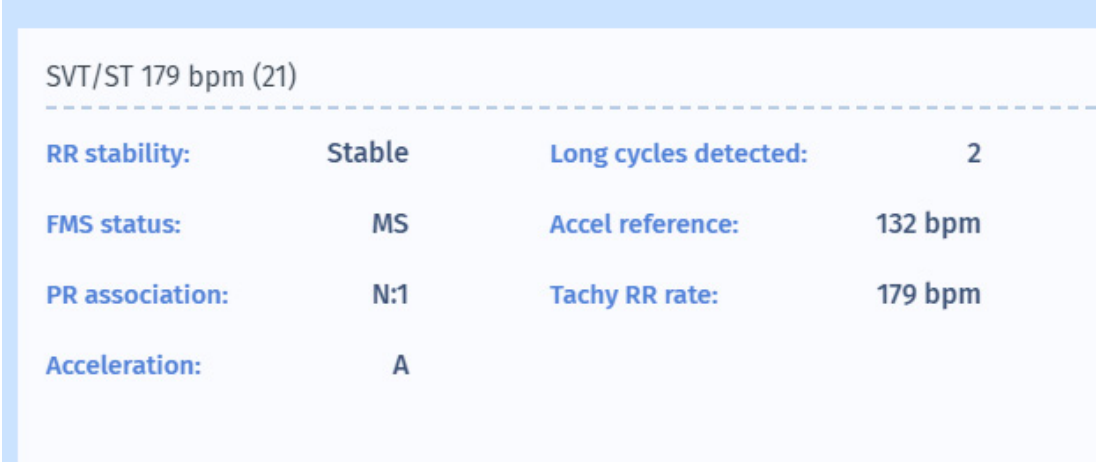
For marker 19, we can appreciate that the diagnosis of "SVT/ST" was made as the ventricular events were considered "unstable". Again working with the "majority" method, 6 out of 8 ventricular events surpassed the 65 ms threshold, as programmed in the discrimination screen:



We can appreciate the importance of "Stability" in the PARAD+ discrimination algorithm tree on the right of the figure, as it is the first step. When the VT criteria are met but RR is instable, it is considered as AF, the episode is saved as "SVT/VT" and therapy is withheld. This also holds true for slow VT zones without therapies, such as in this case.

As the episode continues, we can imagine that in some instances, the rapid ventricular events in fact become stable enough to not cross the 65 ms threshold. This is indeed true in this episode for example for marker 21.

Correct answer - n° 3



We can learn from the figure that marker 21 is considered as “Stable”. Fortunately, the PARAD+ has more criterion which protects against inappropriate diagnosis of VT in case of AF with rapid ventricular response. It is actually looking for atrioventricular association and in this case, finds that the relation is N:1, declaring it as supraventricular. It also correctly identified the origin of the tachycardia as atrial, which can also help in correctly discriminating the episode as supraventricular.

Take-home messages

Stability is one of the most common discriminators. While it has its pitfalls (as VTs may be unstable and ventricular response during AF may be stable), it is still quite powerful in distinguishing between VT and AF with rapid ventricular response.

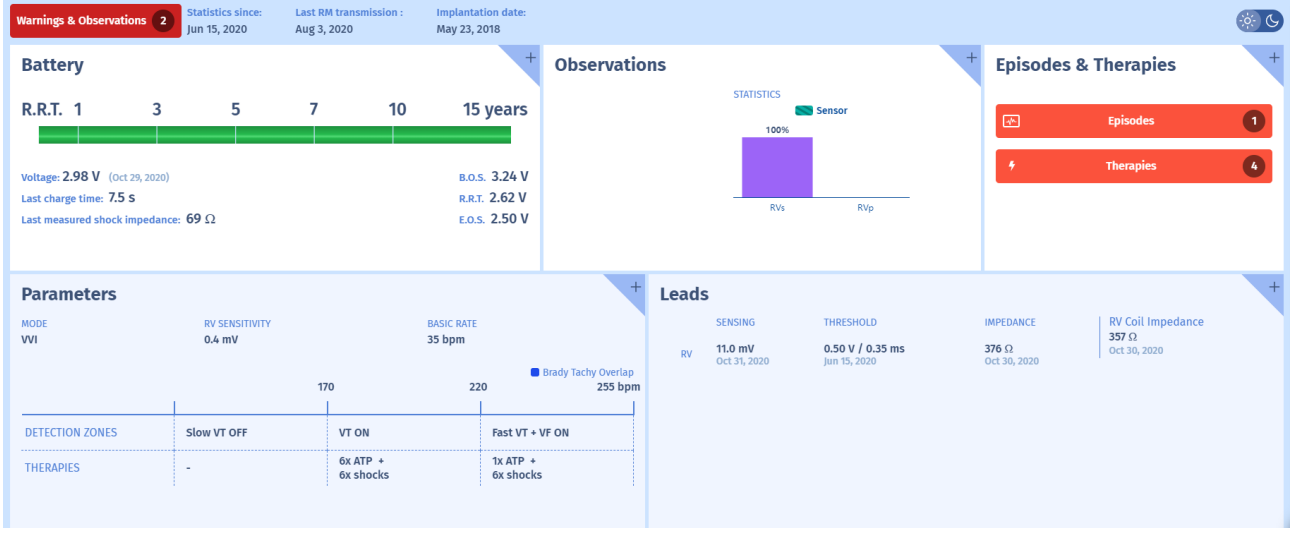
Case 2

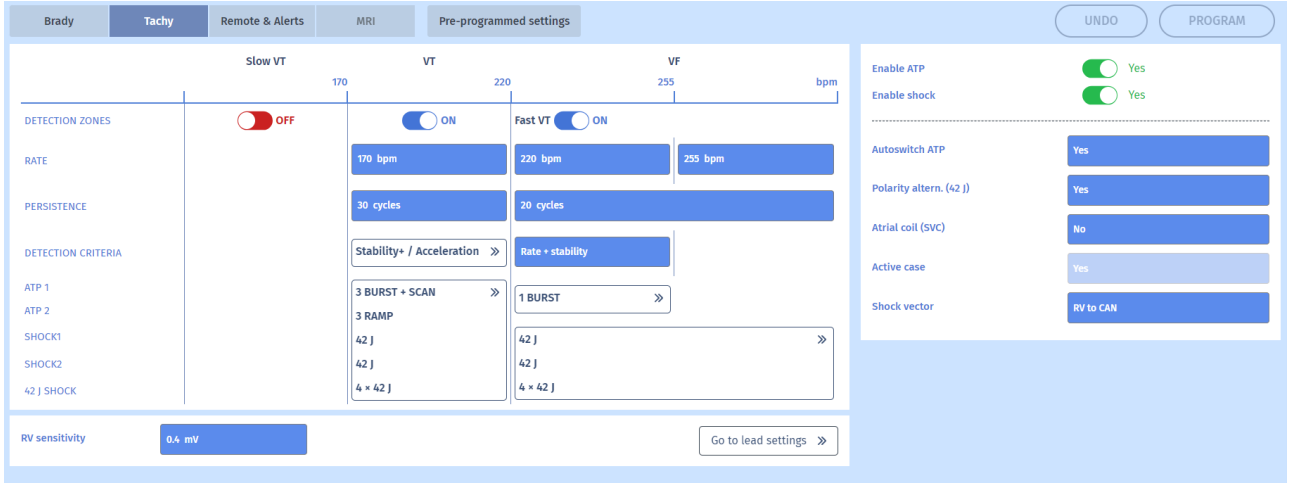
What about morphology?

Patient

58-year old patient with ischemic cardiomyopathy was implanted with a single-chamber ICD for primary prevention. He comes into office after receiving shocks during cycling.

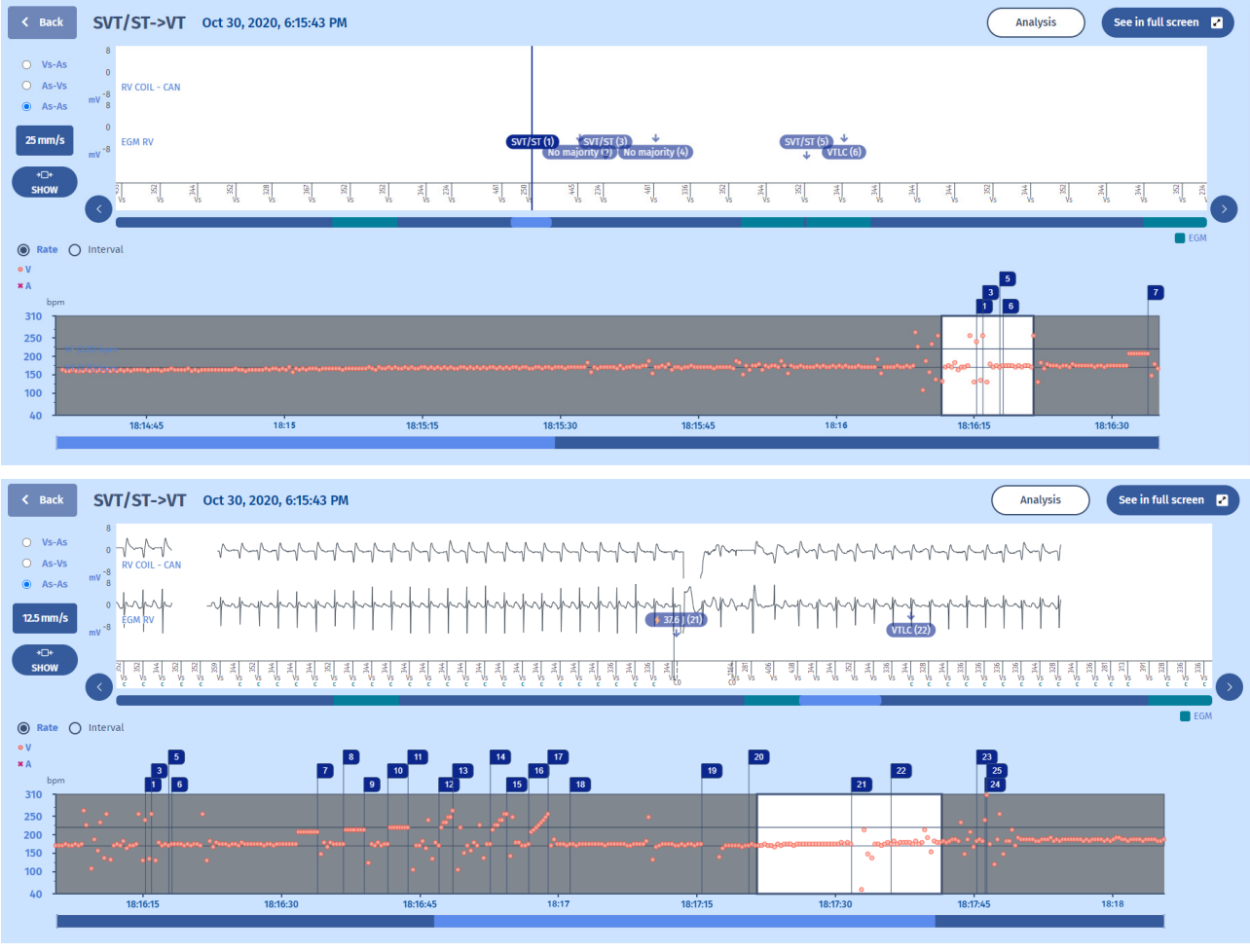
Programming





Case 2

EGM



What is the correct diagnosis?

1 Atrial fibrillation with rapid ventricular response

2 Ventricular tachycardia with appropriate therapies

3 Sinus tachycardia with inappropriate therapies

4 Dual tachycardia with appropriate therapies

Interval plot

On the bottom of the two figures we can appreciate the gradual onset of the tachycardia and the gliding into the VT zone. This is most typical for sinus tachycardia. After various markers, we see the therapies being delivered: bursts, ramps and shocks.

EGM

This is a long episode so only snippets of EGM are made available but it shows the same features as seen in the interval plot; the appearance of gradually faster ventricular events. As it is a single-chamber ICD with only a ventricular lead, we do not see an atrial channel. Where we would normally see an atrial channel, we now see a far field channel between the can and the RV coil, which is similar to a surface ECG. On this channel we can appreciate more of the QRS morphology and compare it to other episodes or live EGM which in this case is identical. This confirms the diagnosis of inappropriate therapies for sinustachycardia misdiagnosed as VT. While competitors use this information as a criterion for discimination (with varying results), it is not the case for MicroPort devices, which rely on atrial leads for discrimination, and in absence of atrial leads, rely on sudden onset and stability criteria.

In this case we can see that while initial diagnosis markers of SVT appear, the long intervals (post compensatory pauses after premature ventricular complexes) make the ICD believe that there is a sudden onset of VT (which is not the case). As the tachycardia is within the VT zone (>170/min), stable and considered as sudden onset, it is diagnosed as VT. As these three features do not change during the persistence, the therapies will keep being delivered until the ventricular rate slows down out of the VT zone. This is problematic as the sinus tachycardia tends to accelerate when a patient suffers from shocks.

Correct answer - n° 3

Case 3

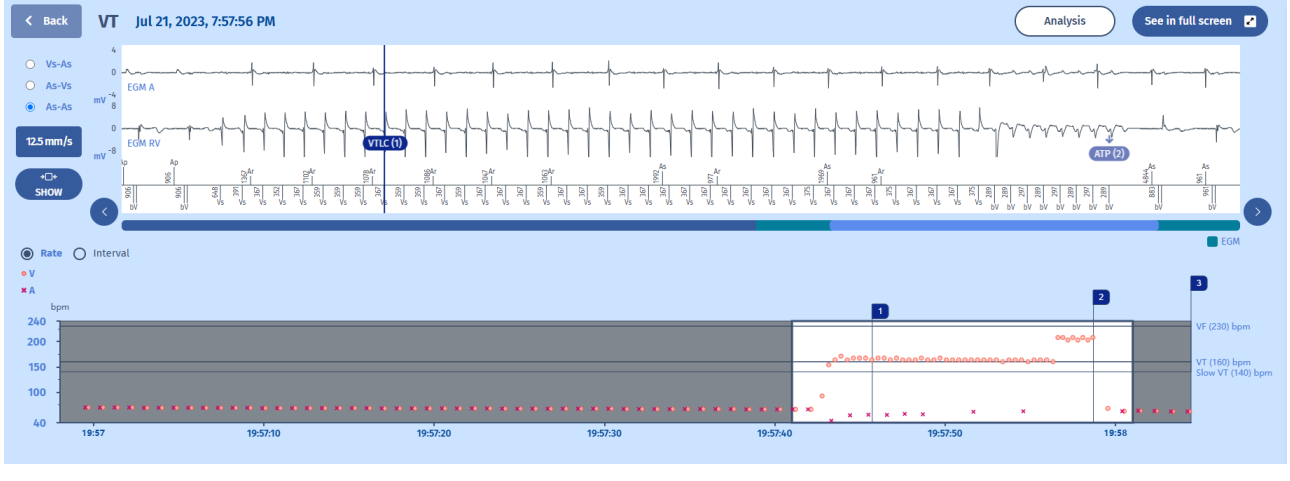
Preferred PARAD+ pathway

Patient

A 60-year old patient implanted with a CRT-D because of dilated cardiomyopathy with left bundle branch block, visits our clinic for a device check. The patient has sensed short bursts of palpitaitons lately.

You interrogate the ICD

This is one of the episodes responsible for palpitations, set to 12,5 mm/sec:



What is the correct PARAD+ statement?

1 As the rythm is stable, it checks for PR association, finds none, and therefore declares VT

2 As there are more ventricular events than atrial events, it declares VT direcly, without checking onset or stability

3 The morphology on the discrimination channel is different than the reference, therefore declaring VT

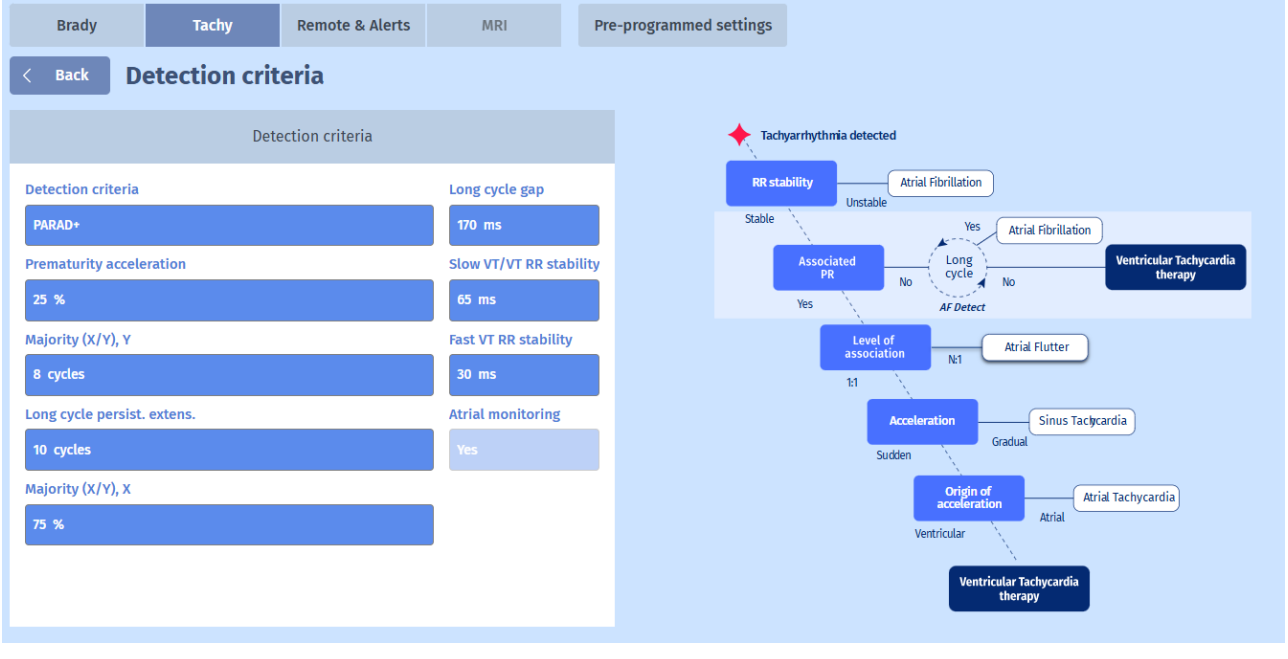
4 There is no discrimination for this zone, so the ICD declares VT immediately.

Interval plot and EGM

The initial rhythm (we only see two beats) is atrial pacing and biventricular pacing. We see two pacing markers as there is a significant interventricular delay in favor of the left ventricle. Suddenly a ventricular tachycardia initiates. For us, we diagnose VT quite easily since there are more ventricular events than atrial events. After the VT majority (VTCL marker) and persistence counter have been filled, an ATP is delivered which terminates the tachycardia.

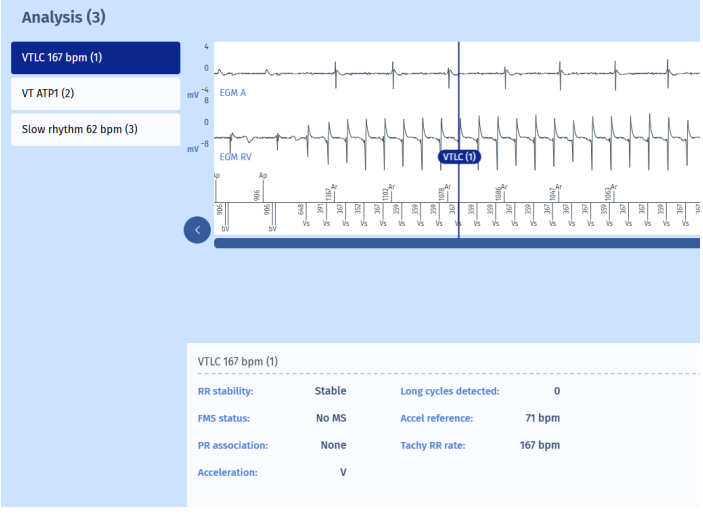
Comments

Most ventricular tachycardia episodes will be discriminated according to this example. To understand how the PARAD+ algorithm functions (only possible when atrial lead is present and reliable), it is always easy to go to Parameters, Tachy and then click on PARAD+ to acquire the following screen.



Case 3

We see that when a Tachyarrhythmia is detected, the PARAD+ will first check whether the rhythm is stable. Since AF is the most important supraventricular tachycardia to cause inappropriate therapies, this is the first step in the PARAD+ algorithm. The second step is to verify whether the atria and ventricles are associated. In the case of most VTs, there is no association and therefore this is a good criterion to distinguish between VT and SVT. To verify which route the PARAD+ algorithm took in this example, we can click on Analysis on the programmer screen and it will display the following information.



We can see that the ventricular rhythm was indeed considered as stable (PARAD+ step 1) and that there is no PR association (step 2). This is how the diagnosis of VT is made.

Why the “LC” in VTLC?

Stability and lack of PR association is a powerful combination for discrimination but the pitfal remains AF with soo rapid ventricular conduction that it may become quite “stable”. This is when the engineers decided to upgrade PARAD to PARAD+ with the search for long cycles. A cycle is considered long when it is 170 ms (programmable) longer than the mean coupling interval of the VT. This serarch is associated to an increase of the initial persistence counter by 10 cycles (programmable, see PARAD+ figure). If PARAD+ is programmed and the diagnosis of VT has been made following these steps, the VTLC marker appears to show that it has used the long cycle criterion. We can consider it as another safety measure against inappropriate therapies due to AF with fast ventricular conduction.

Correct answer - n° 1

Take-home messages

Most of the VT will follow the PARAD+ steps such as in this example: 1) it is considered stable, 2) there is no PR association. Long cycles extend the persistence counter, adding the + to PARAD+ algorithm.

Case 4

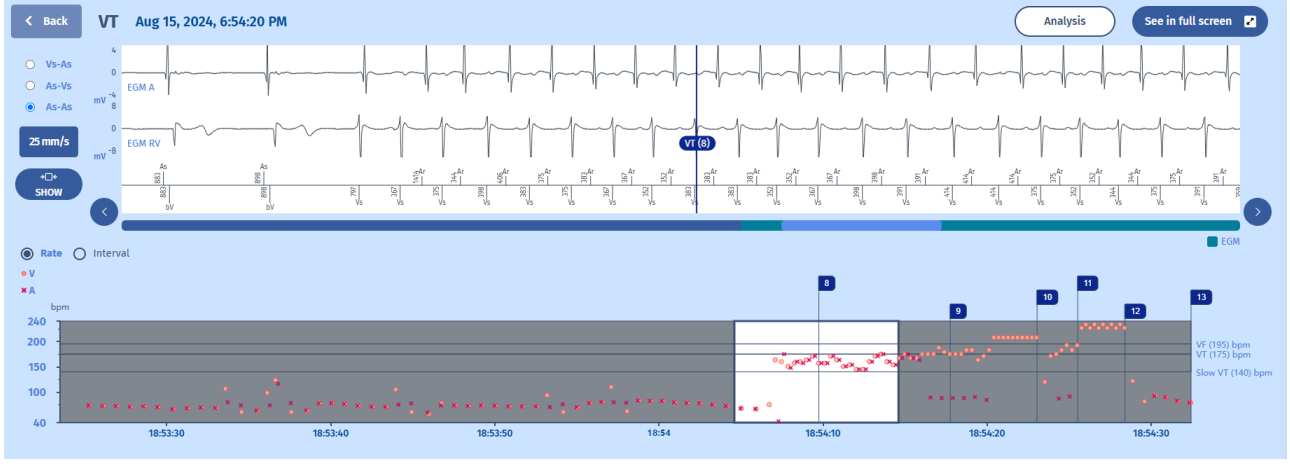
1:1 tachycardia

Patient

56-year old patient with ischemic cardiomyopathy and left bundle branch block has been implanted with a CRT-D.

You interrogate the device

This is the newest episode



Case 4

The ICD classifies the episode as VT because:

1 The arhythmia is stable and there is no PR association.

2 The arhythmia is stable, there is 1:1 PR association with onset of the ventricle

3 The arhythmia is stable, there is 1:1 PR association with onset of the atrium

4 The arhythmia is stable, and there are more ventricular events than atrial events (V > A).

Rate interval plot and EGM

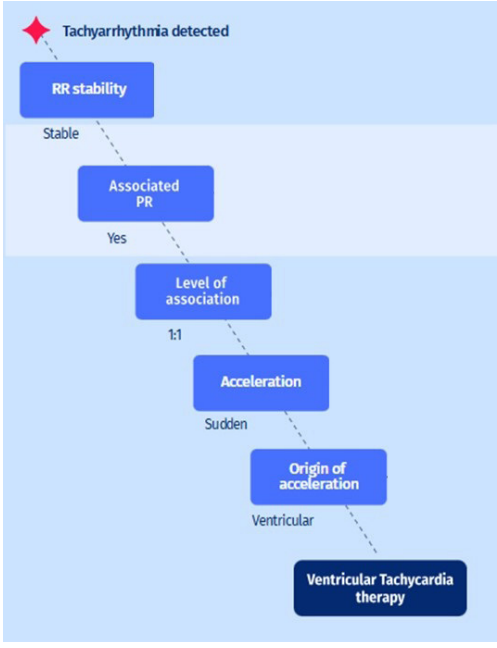
The initial rhythm is atrial sensing followed by biventricular pacing. Suddenly, a tachycardia initiates with fast ventricular and atrial rhythm with one-to-one (1:1) conduction. On the rate histogram we see that the VT continues and terminates after a second ATP.

Comments

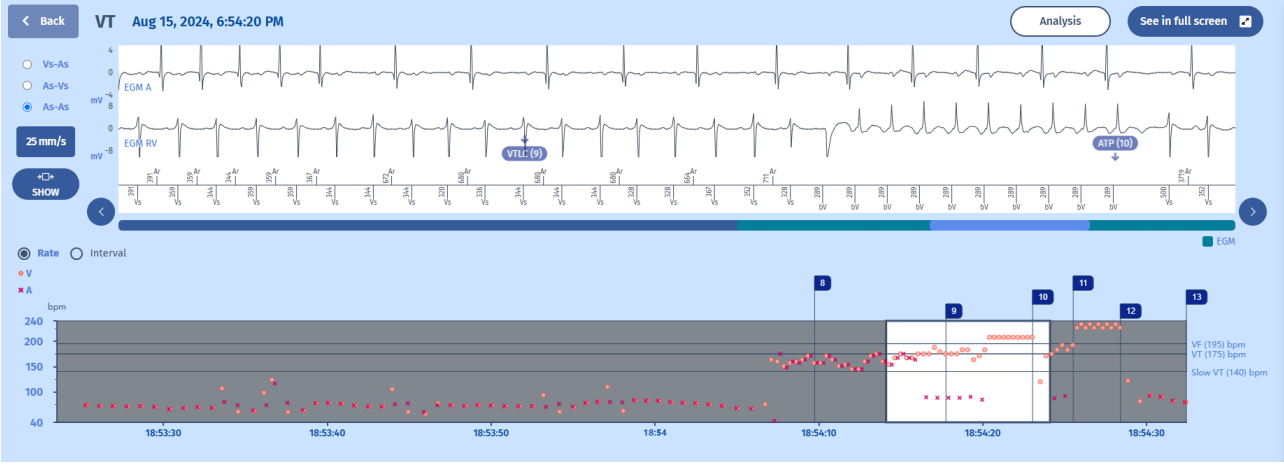
When we look closely at the onset of the arrhythmia, we can see that the first chamber to accelerate is the ventricle, driving the atrium. We can see that after 6 events in the VT zone (after discarding the initial two events from the RR stability, PR association and level of PR association criteria), the diagnosis of VT is made. Please note that the marker is VT, and not VTLC. This means that the tachycardia has followed another path in the decision tree than the previous cases. When we analyze the VT marker, we can see that the arrhythmia is indeed stable, but that because of PR association, the PARAD+ algorithm continues to look for criteria. There is 1:1 association according to the PARAD+ algorithm and therefore it proceeds to the next step. This is a check whether the acceleration is sudden, because sinus tachycardia is a stable tachycardia with 1:1 PR association and this needs to be excluded to diminish the risk of inappropriate therapies. In this case, the onset is sudden with an acceleration from 70 bpm (reference) to 163 bpm (tachy RR rate). When sinus tachycardia has been excluded, there is a last step. Which is exclusion of atrial tachycardia; a tachycardia with sudden onset, is stable, is associated in a 1:1 fashion. The best way to exclude atrial tachycardia is to analyze which chamber was first to accelerate. For atrial tachycardia this will be the atrium. For ventricular tachycardia, the first chamber to accelerate is the ventricle. In this case, the ventricle has been correctly identified as the first chamber to accelerate.

Therefore, the diagnosis is VT. Mentioned information is all displayed in the analysis figure below.

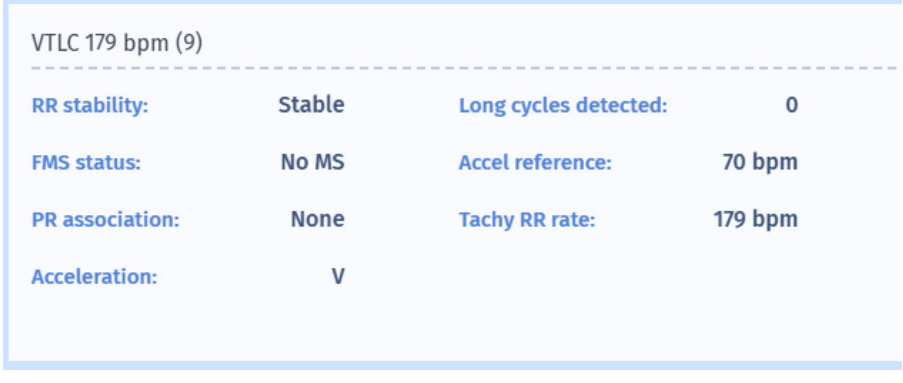
Illustration of the decision tree (PARAD+) of the beginning of the EGM:



The continuation of the EGM:

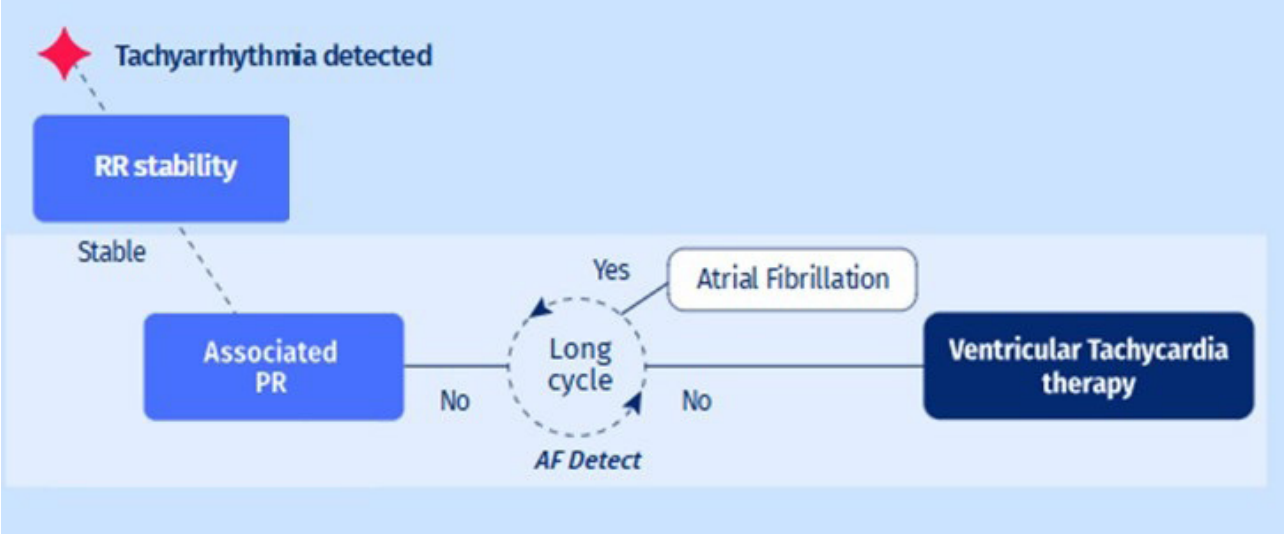


Notice how the marker changes from VT to VTLC. This is because the decision tree of the PARAD+ has changed. The retrograde (VA) conduction has diminished to a 2-to-1 fashion with loss of PR association. Therefore, the discrimination goes back to checking whether the ventricular rate is stable and VT is diagnosed. Again, the analysis button may help to better understand the PARAD+ algorithm, as it will display that the PR association is lost ("none").

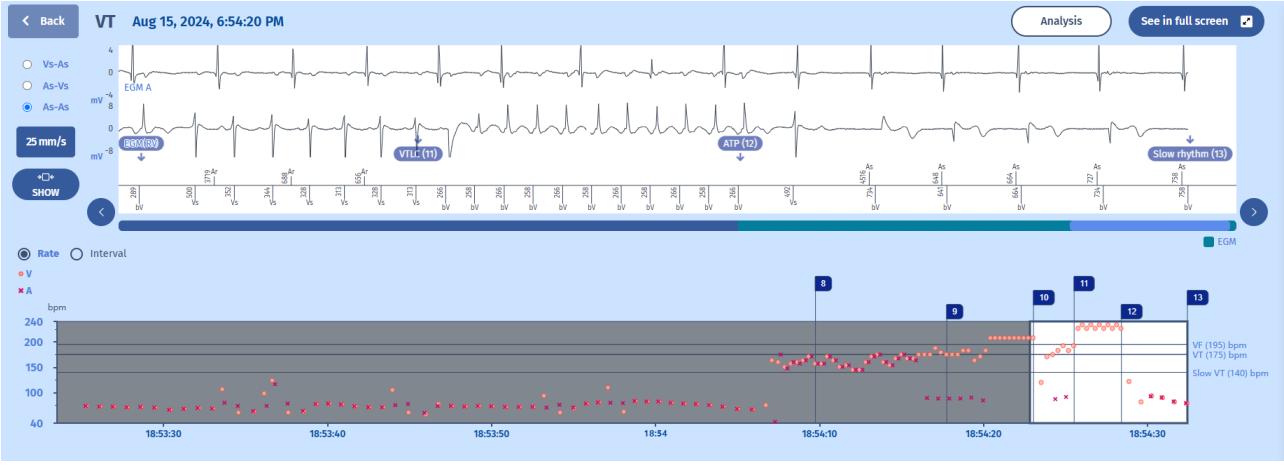


Case 4

Therefore, we may illustrate the decision tree (PARAD+) of the second part of the EGM like so:



The continuation of the EGM:



The persistence counter is not reset when the VT markers changed from VT to VTLC as the diagnosis is still VT. A first ATP sequence is delivered which does not terminate the VT (not shown on this page). The VT is terminated by a second ATP sequence.

Correct answer - n° 2

Take-home messages

Ventricular tachycardias with one-to-one retrograde conduction to the atrium (1:1 VA conduction) are quite rare and difficult to distinguish by ICDs and need multiple criteria as they are stable (unlike AF), associated (unlike most VTs) with and onset which is sudden (unlike sinus tachycardia) and in the ventricle (unlike atrial tachycardia).

Case 5

A well classified 1:1 tachycardia

Patient

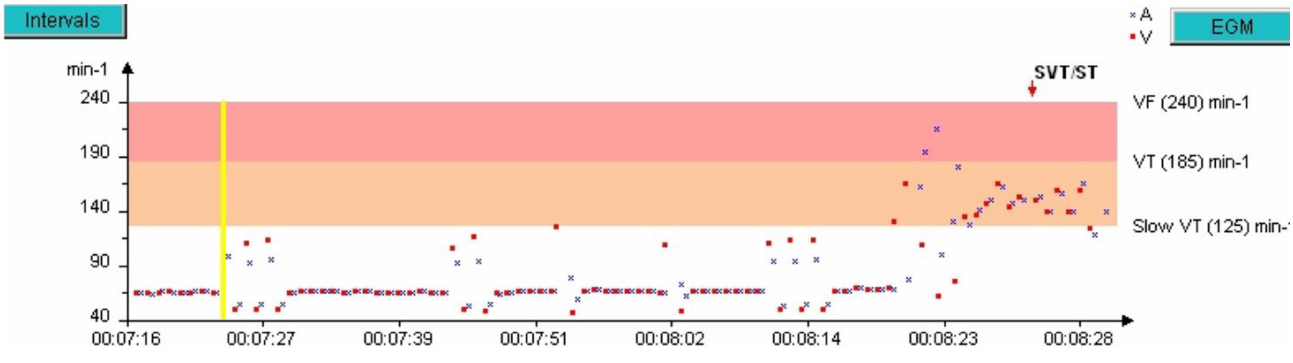
A 65-year-old man implanted with an INTENSIA DR dual-chamber defibrillator in secondary prevention for post-infarction dilated ischemic heart disease with highly altered ejection fraction, stage III heart failure and narrow QRS.

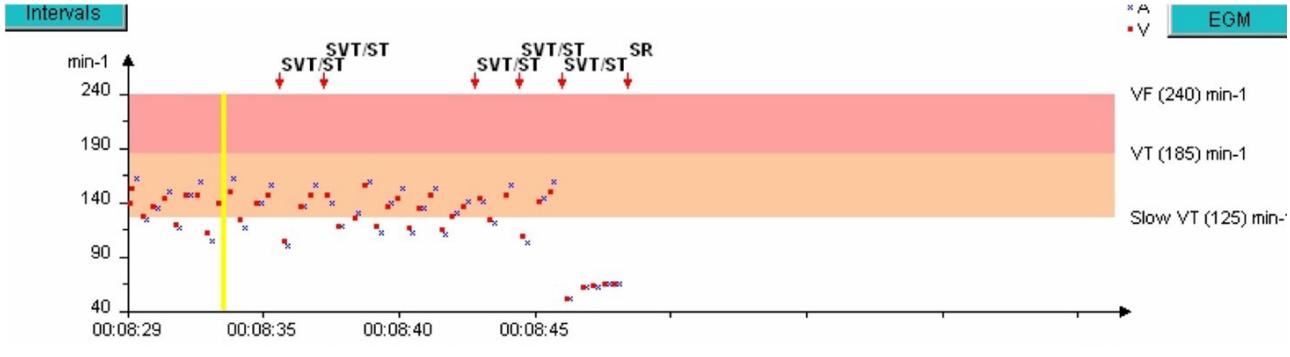
Programming

3 zones with :

1. A Slow zone starting at 125/min, 30 persistence cycles, with ATP and shock sequences
2. A VT zone starting at 185/min
3. A VF zone starting at 240/min

Rate interval plot

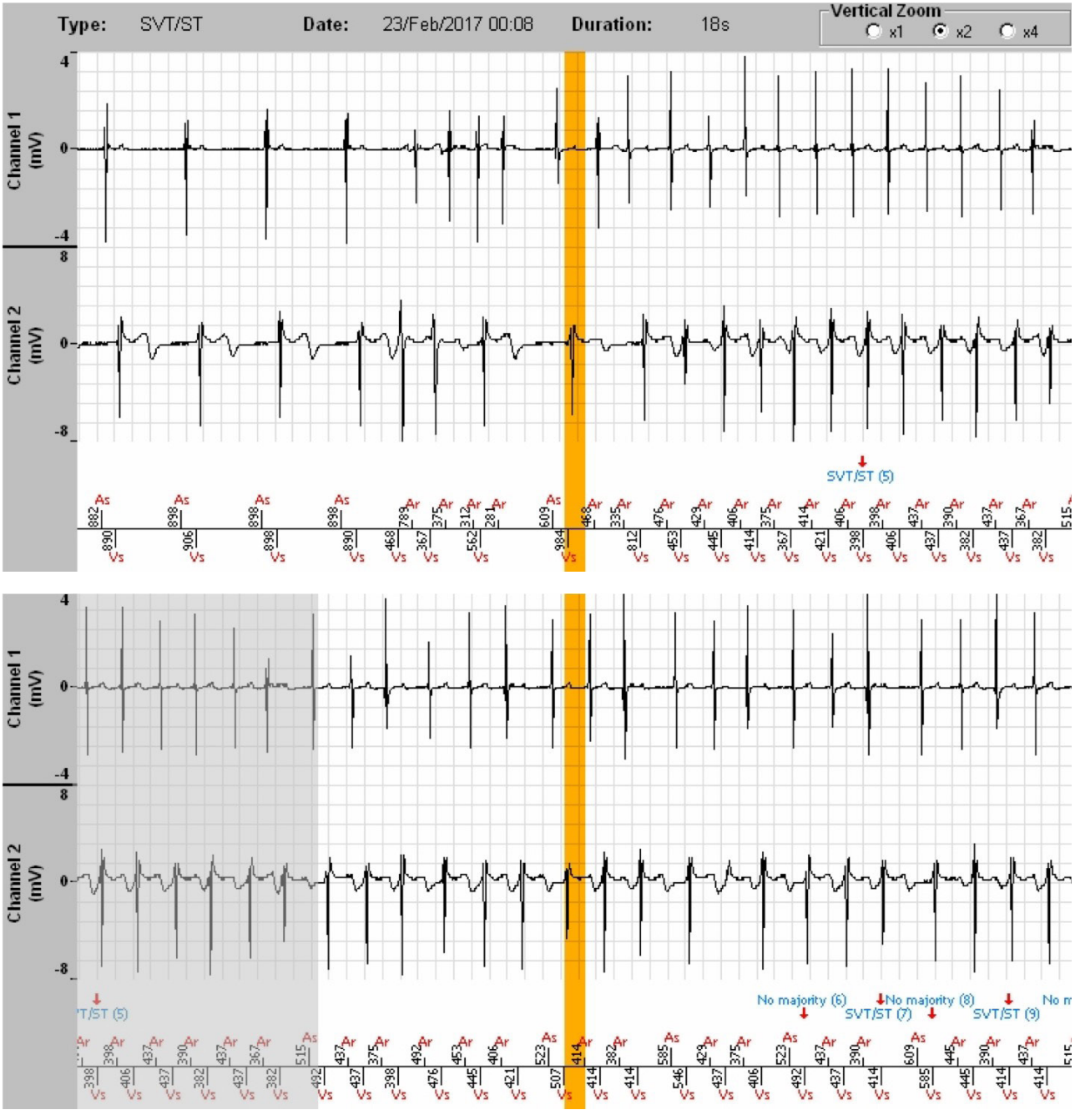


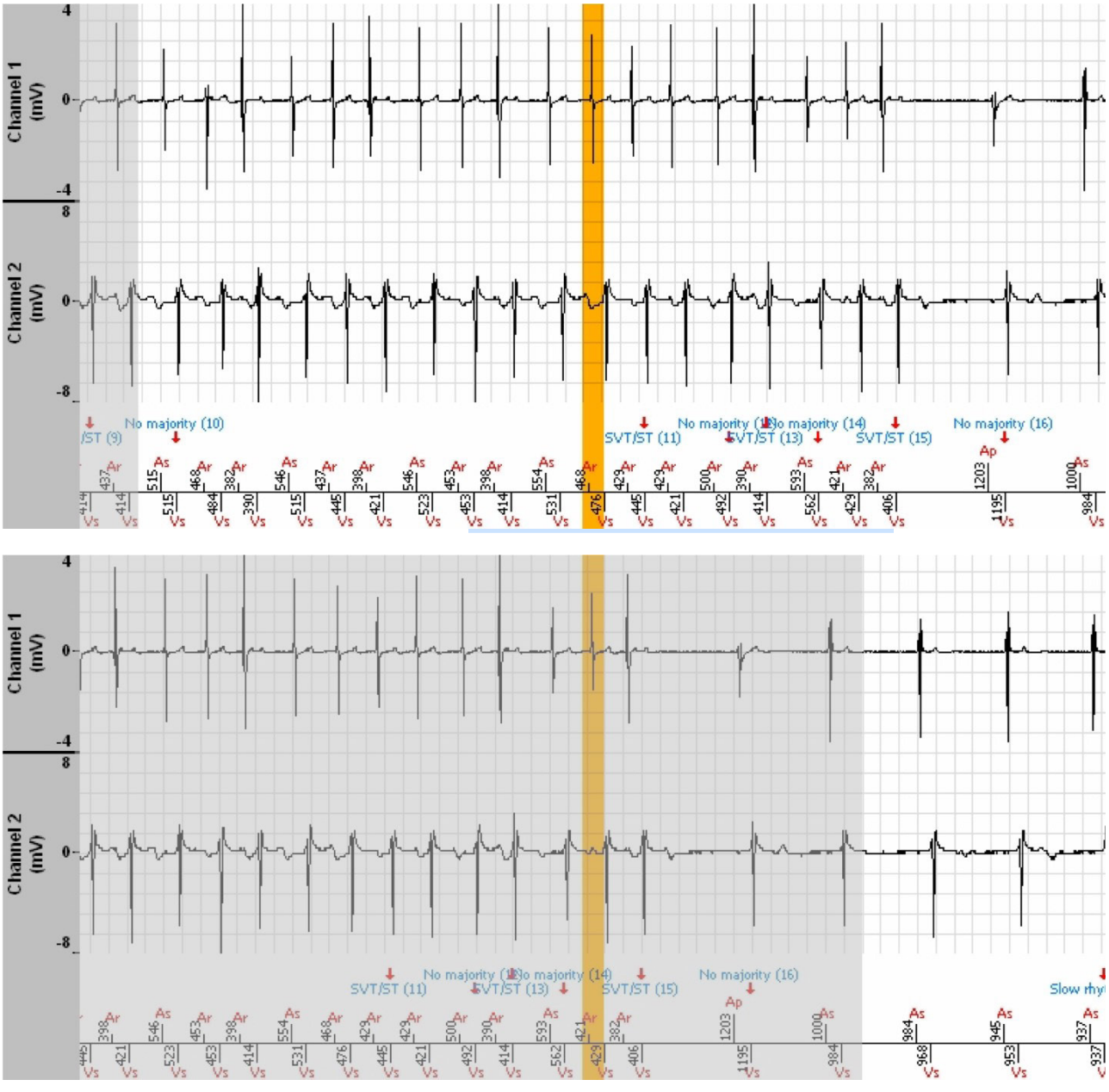


Case 5

EGM

The shaded areas are the portions of the EGM that are the repetitions of the end of the previous image.





Which are the correct statements ?

1 A 2:1 conducted atrial tachycardia

2 A bi-tachycardia

3 Atrial tachycardia with 1:1 AV association

4 Appropriate defibrillator response

5 Inappropriate response

Case 5

Interpretation

- The tachogram reveals both atrial and ventricular premature contractions during conducted sinus rhythm.
- The tachycardia is preceded by a ventricular triplet with probable retrograde conduction, followed by an immediate destabilisation of the atrial rhythm which initiates an unstable atrial tachycardia and reflected in the ventricle, leading to the diagnosis is SVT. Each variation of the P'P' interval induces the same variation of the corresponding RR interval. The tachycardia is well controlled by the atrium.
- The diagnosis is No majority when the rhythm enters or returns in the Slow zone (non Tachy) for at least 3 out of 8 cycles (but less than 6), then again becomes unstable with a diagnosis of SVT until termination of the episode.
- No therapy was induced.

Comments

- The rhythm is viewed as stable, 1:1, with A acceleration, hence the diagnosis of SVT.
- Of note: the atrial markers are either As or Ar during the entire episode. This signifies that the defibrillator is constantly suspicious of atrial arrhythmia identified by the Fallback Mode Switch algorithm that functions in parallel. The As markers appear when the Ar-As interval is greater than 500 ms. This is not specific to the defibrillator, but to the Fallback Mode Switch algorithm of all platforms of the brand, both pacemakers and defibrillators.

Correct answers - n° 3, 4

Take-home messages

The dual-chamber defibrillator primarily classifies tachycardias in the same manner as a single-chamber defibrillator, taking into account stability as first line analysis. In the absence of a morphology algorithm, the quality of the diagnoses is highly dependent on the quality of atrial sensing that is itself dependent on the atrial lead and the ability of the defibrillator to detect P waves outside of the refractory periods, hence highlighting the care duly required at the time of implantation of this atrial lead.

Case 6

Appropriate discrimination? Analyse everything!

Patient

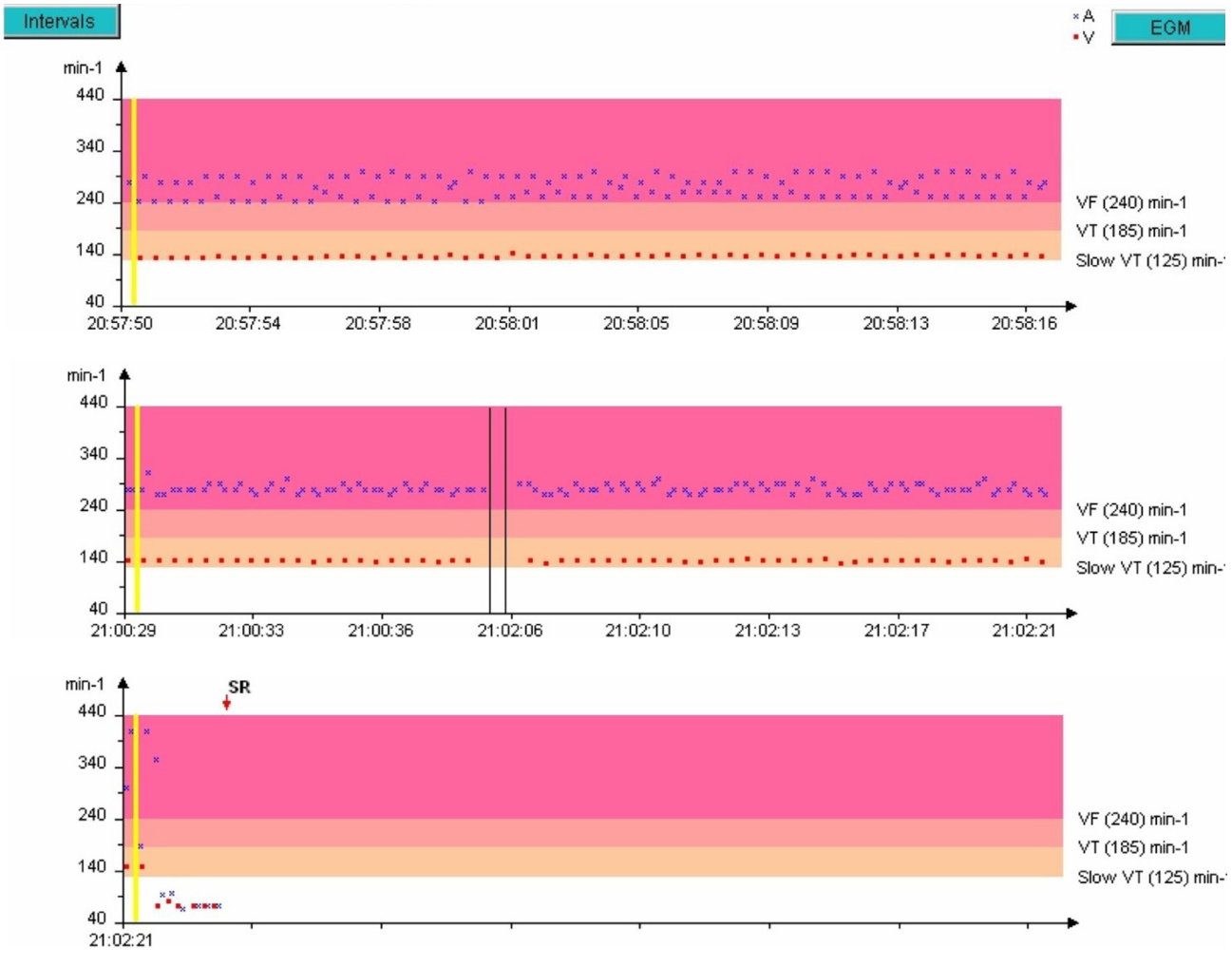
A 65-year-old man implanted with an INTENSIA DR dual-chamber defibrillator in secondary prevention for post-infarction dilated ischemic heart disease with highly altered ejection fraction, stage III heart failure and narrow QRS.

Programming

3 zones with:

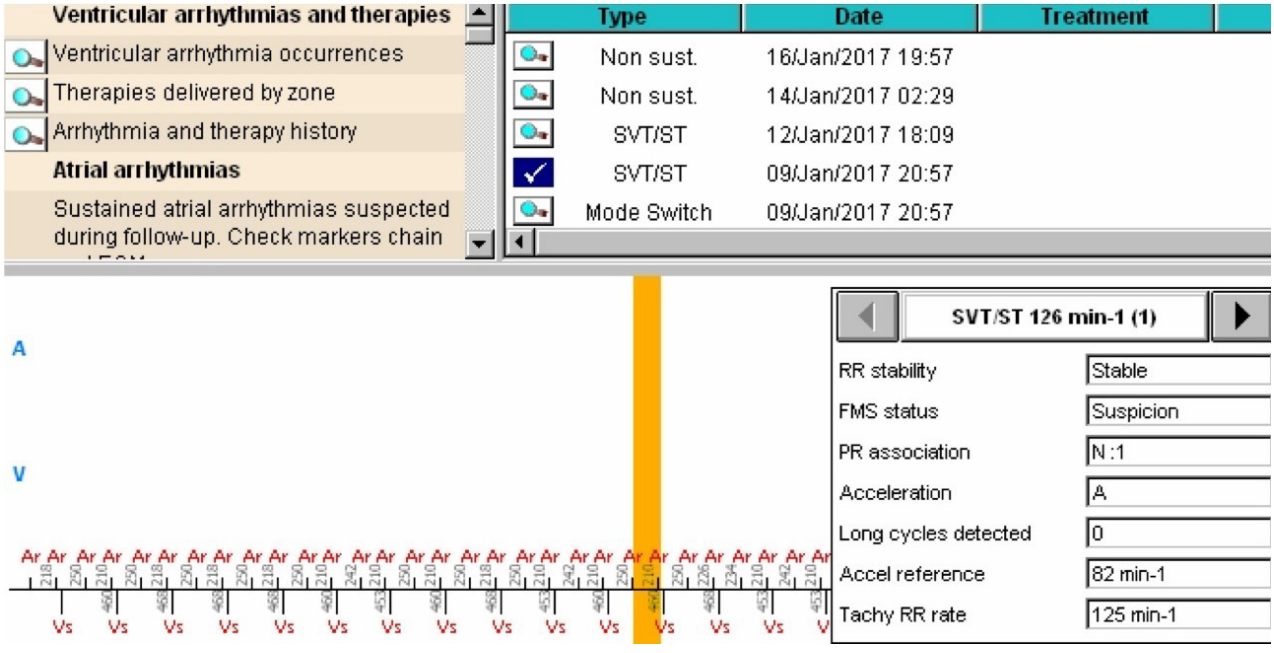
1. A Slow zone starting at 125/min, 30 persistence cycles, with ATP and shock sequences
2. A VT zone starting at 185/min
3. A VF zone starting at 240/min

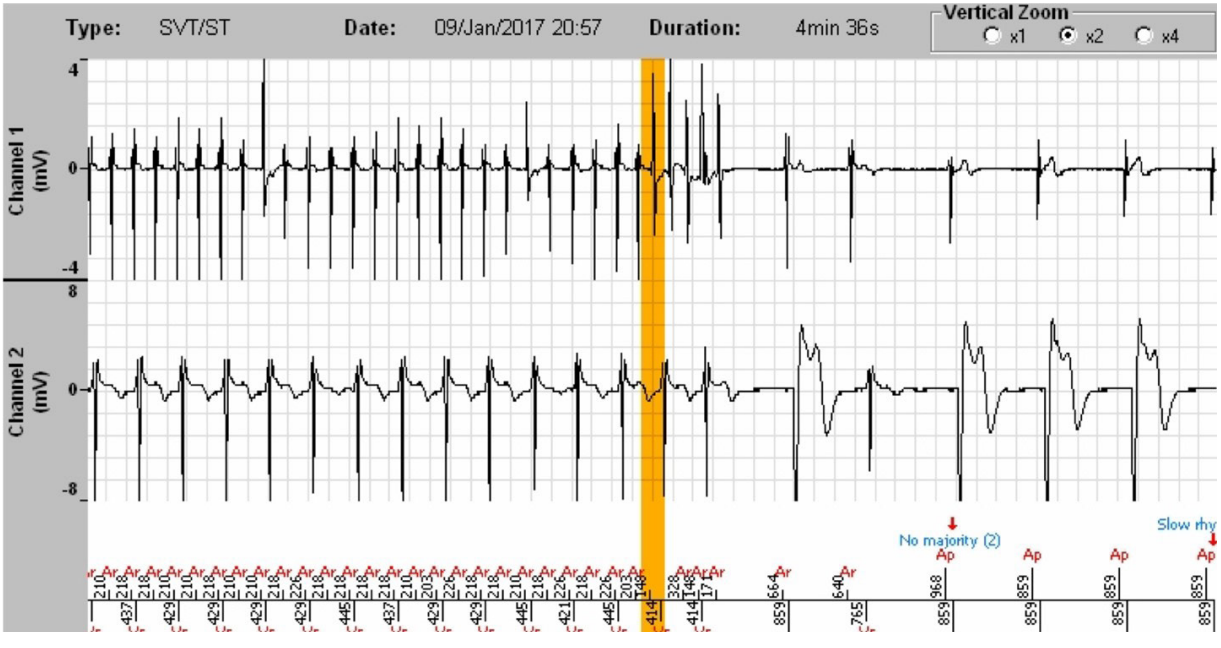
Rate interval plot



Case 6

EGM





What is your opinion?

1 A 2:1 conducted atrial tachycardia

2 A bi-tachycardia

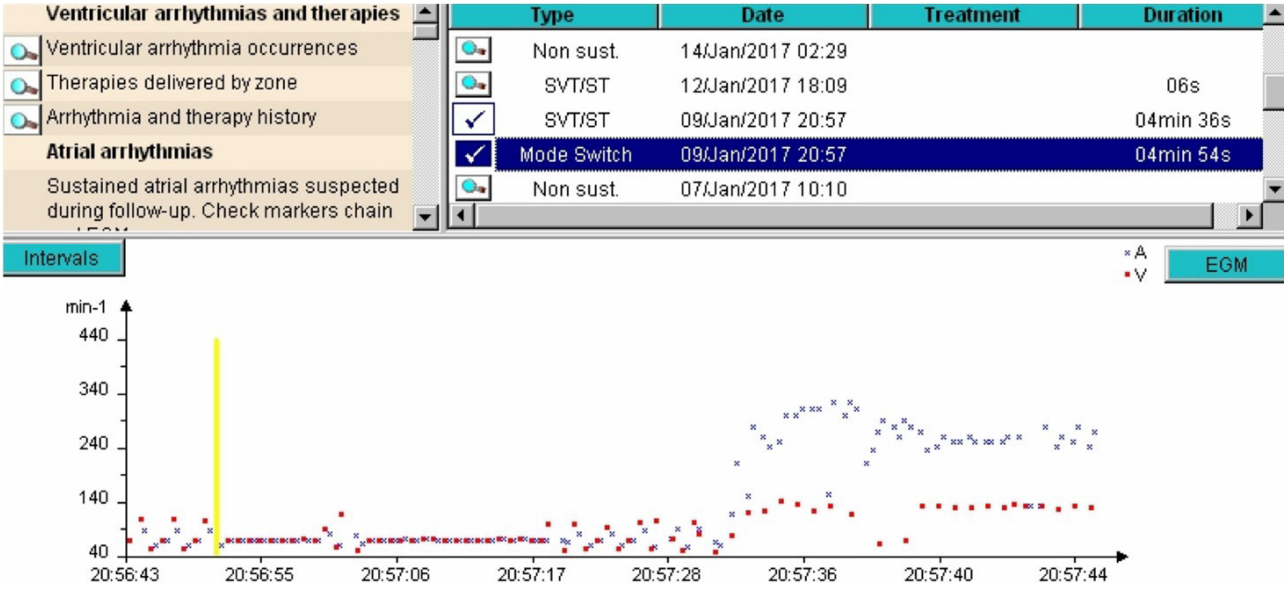
3 Impossible to make a diagnosis, the EGM of the onset of the arrhythmia is not available

4 Appropriate defibrillator response

5 Inappropriate response

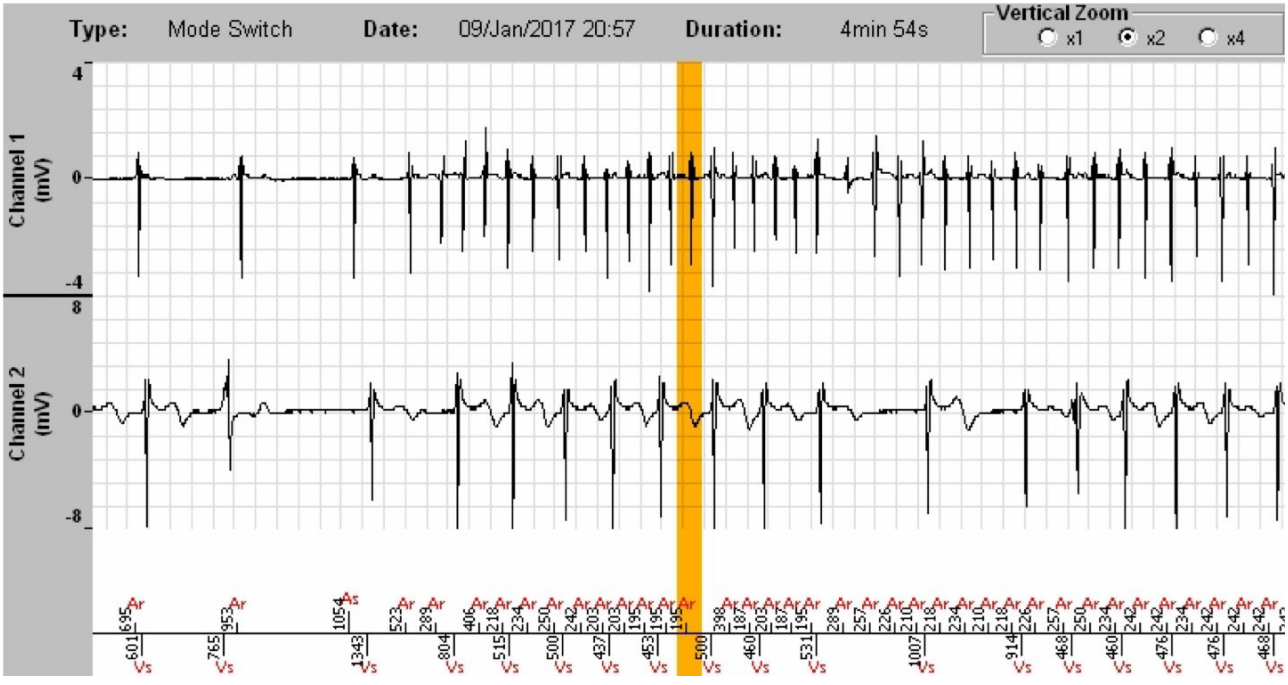
Interpretation

- The defibrillator documents a SVT episode in the list of stored episodes, whose duration was 4 minutes 36 seconds. The start time of the tachogram is 20:57:50. The onset of the tachycardia is not visible. The termination of the tachycardia can be analysed with a Slow Rhythm majority return that marks the end of the episode.
- The defibrillator documents a stable tachycardia with an N:1 (2:1) PR association, a sudden onset by way of an atrium, and is in mode switch (state of suspicion). The criteria that led to the diagnosis of SVT are therefore stability and N:1 PR association.
- In fact, by looking more closely at the list of stored episodes it is found that on the same day, and at the same time, a mode switch is reported which lasted 4 minutes and 54 seconds and thus covers the SVT episode reported at the same time. The beginning of the tachycardia is therefore analysable, but within the mode switch episode. Impractical, given the functioning principles of the Fallback Mode Switch and PARAD+ algorithms as well as the management of stored data. To summarise, the Fallback Mode Switch will identify an atrial arrhythmia after 28 ventricular cycles involving PACs while PARAD+ will recognise this same arrhythmia after 38 ventricular cycles (2 initial cycles not taken into account, 6 for the first majority and 30 for the persistence) with the criteria of SVT fulfilled. Moreover, the EGMs and markers are not “duplicable”, i.e. once the EGM/markers corresponding to the fallback mode switch criterion are memorised/stored, they are no longer usable for the next episode (in this instance, the SVT identified by PARAD+).



- In this instance, we can declare that the tachycardia is supraventricular. Following a phase of sinus rhythm instability linked to PVCs, the atrial tachycardia begins with variable AV conduction at 20:57:30, which causes the defibrillator to enter into suspicion of mode switch and then to actual mode switch. The ventricular rhythm becomes stable approximately 10 seconds after the onset. The continuation of the mode switch episode constitutes the episode labelled SVT.

Case 6



Comments

- The diagnosis was appropriate since the algorithm perfectly identified the onset of the tachycardia as being stable with N atrial events for 1 ventricular event (2:1 specifically). This is the essential element that allowed the diagnosis of SVT.
- The diagnosis of SVT was maintained until the spontaneous termination of the atrial arrhythmia.
- However, for the observer, it is necessary to retrieve the information in two different stored episodes: one pertaining to the pacing component of the defibrillator, the other pertaining to the discrimination algorithm of the defibrillator, which renders the reading quite difficult.
- The placement of the atrial lead of the MicroPort dual- and triple-chamber defibrillators requires meticulous care in order to limit as much as possible detection defects of the arrhythmic atrial signals which the algorithm needs for an effective discrimination.

Correct answers - n° 1, 4

Take-home messages

In the absence of visualisation of the onset of a tachycardia episode, it is necessary to look for this onset in another stored episode of the memorised list. This mainly concerns atrial arrhythmias, as in the present example, with the beginning of the arrhythmia most often found in the mode switch episodes since the Fallback Mode Switch algorithm is faster in classifying this type of arrhythmia than the PARAD+ discrimination algorithm, programmed with a persistence of more than 20 cycles. In other words, this happens when the device goes into switch mode before the end of the PARAD+ algorithm persistence.

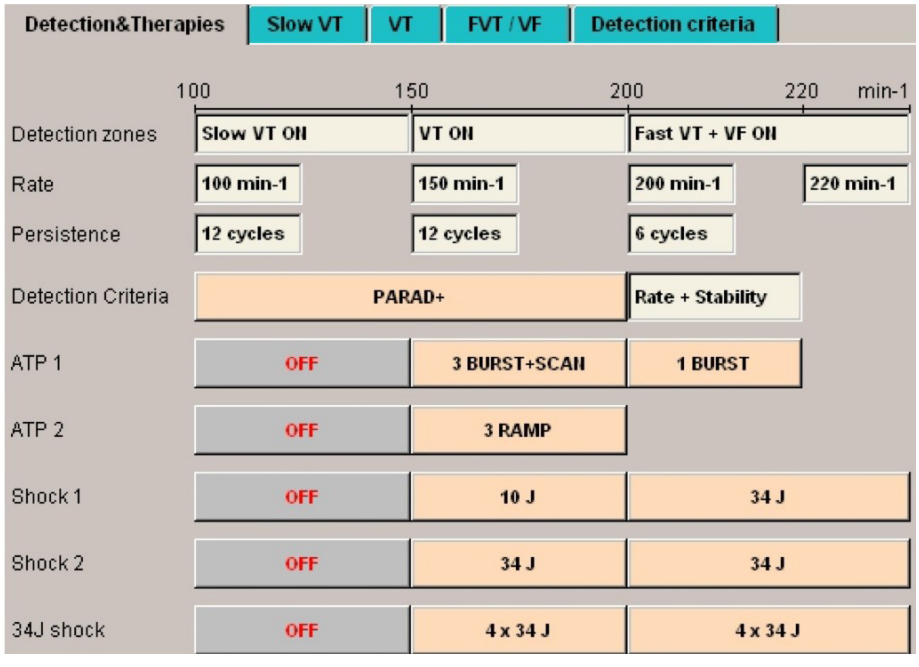
Case 7

Bitachycardia ?

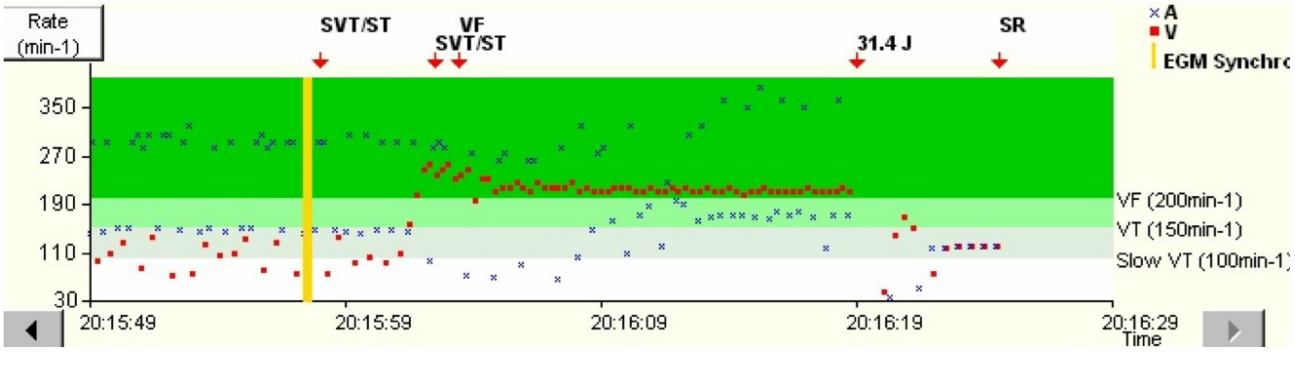
Patient

A 72-year-old man with a triple-chamber defibrillator for dilated heart disease with healthy coronary arteries, an ejection fraction of 28%, complete left bundle branch block, and optimal medical therapy. The patient has never experienced a VT until now, and is known with paroxysmal AF. The patient consults due to a loss of consciousness the day before.

Programming



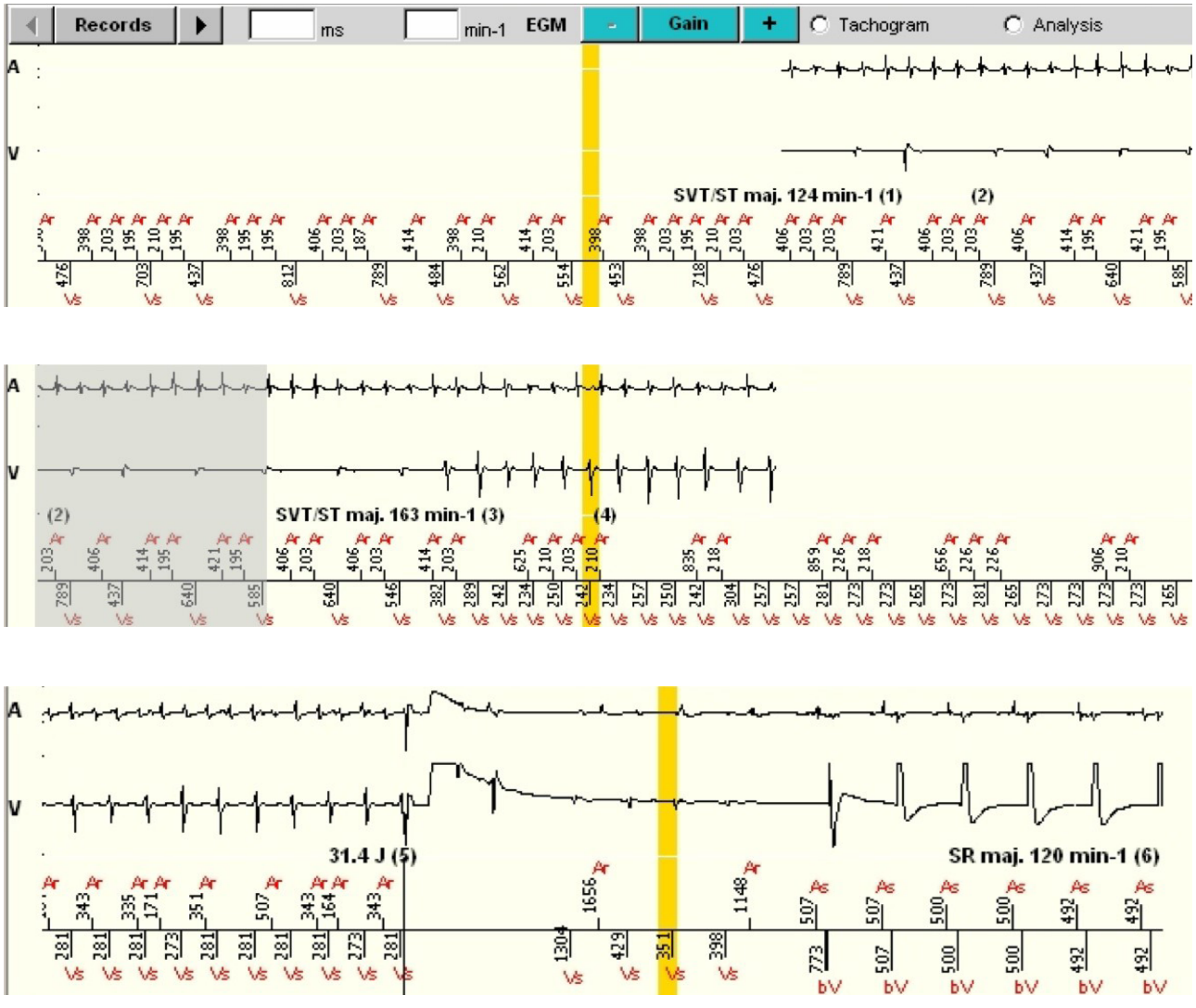
Interval plot



Case 7

EGM

The shaded areas are the portions of the EGM that are the repetitions of the end of the previous image.



What is your opinion?

1 There is ventriculo-atrial crosstalk at the beginning of the tracing

2 There is an atrial tachycardia at the beginning of the tracing

3 There are detection errors during the atrial tachycardia

4 The VF is relatively stable and a Fast ATP burst should have been triggered

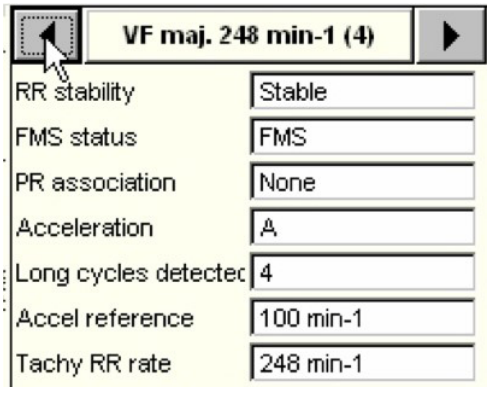
5 The device works perfectly

Interpretation

- The patient presents a sustained atrial rhythm disorder with variable conduction to the ventricle with cycles oscillating between the Slow and VT zones, such that a SVT diagnosis is proposed, and appropriate. Not all atrial cycles are visible since those in the post-ventricular atrial blanking are not detected.
- A tachycardia begins in the VF zone at 248 per minute, triggering an effective 31.4 Joule shock. This is a ventricular tachycardia and not a ventricular fibrillation given that the cycles tend to slow down over time (about 280ms at the time of the shock).
- Following 6 slow cycles out of 8, the episode is terminated.
- The atrial tachycardia has disappeared, the rhythm is associated. The shock terminated both the atrial tachycardia and VT simultaneously.

Comments

- The episode begins since 6 out of 8 cycles are in the Slow VT zone, although the rhythm is unstable and the tachycardia is classified as SVT.
- When the tachycardia begins and enters in the VF zone, no discrimination criterion is applied. Only the rate criterion will induce a VF-type therapy.



- At annotation (4), the diagnosis of VF is made and the programmed persistence of 6 cycles is initiated.
- Since the ventricular arrhythmia is 248 per minute when the persistence is reached, it is a shock that is directly issued and not an ATP burst for Fast VT which would only be applied if the rate had been between 200 and 220 per minute with strict stability as programmed. However, the EGM shows that the VT stabilises with regular cycles at about 280ms at the time of the shock. If the Fast VT zone had been set to 255bpm with a persistence of 20 cycles as recommended in primary prevention, an ATP could have been initiated (the rhythm has indeed become stable at the 20th cycle), with a good likelihood of termination.
- At the end of the persistence, the charging of the capacitors, although not noted by this former platform of the brand, begins.
- After a 1-second post-shock blanking during which two premature contractions occur that are not detected, the 4 ventricular events which are also premature contractions remain in the tachycardia zones. It takes the 6 associated As-BiV cycles to complete the episode (6 ventricular paced cycles).

- There is simultaneous termination of the atrial tachycardia and the VT. This situation represents a danger in a patient who is not being treated with an anticoagulant, and also represents a contraindication for the induction/termination of a VF with a test shock.

Correct answers - n° 2, 5

Take-home messages

No discrimination when the tachycardia is in the VF zone (Fast VT zone included). The stability criterion in the Fast VT zone is only used to decide whether or not to deliver an ATP before the charging of the capacitors.

Inducing and terminating a VF with a shock test in a non-anticoagulated AF patient is contraindicated if the absence of intracardiac thrombosis is not verified, and a flash anticoagulation has not been administered.

Case 8

Stabilisation of a tachycardia against a backdrop of atrial arrhythmia; a very difficult diagnosis

Patient

A 70-year-old man with a PLATINIUM DR dual-chamber implanted in secondary prevention for post-infarction ischemia with an ejection fraction of 20% and narrow QRS. The patient consults after presenting numerous episodes on telecardiology follow-up.

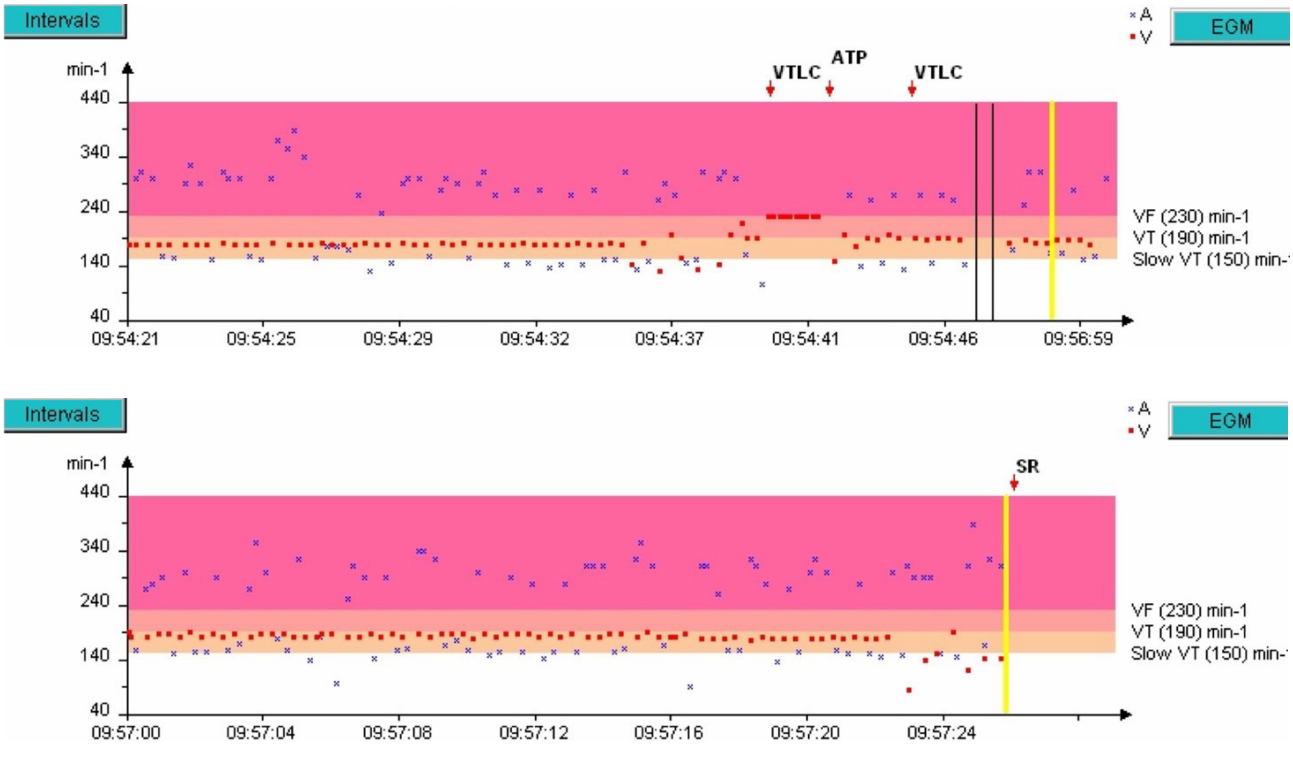
Programming

3 zones avec :

1. A Slow VT monitoring zone, without therapy, starting at 150/min with a persistence of 30 cycles
2. A VT zone starting at 190/min with a first line of therapies consisting of ATP
3. A VF zone starting at 230/min

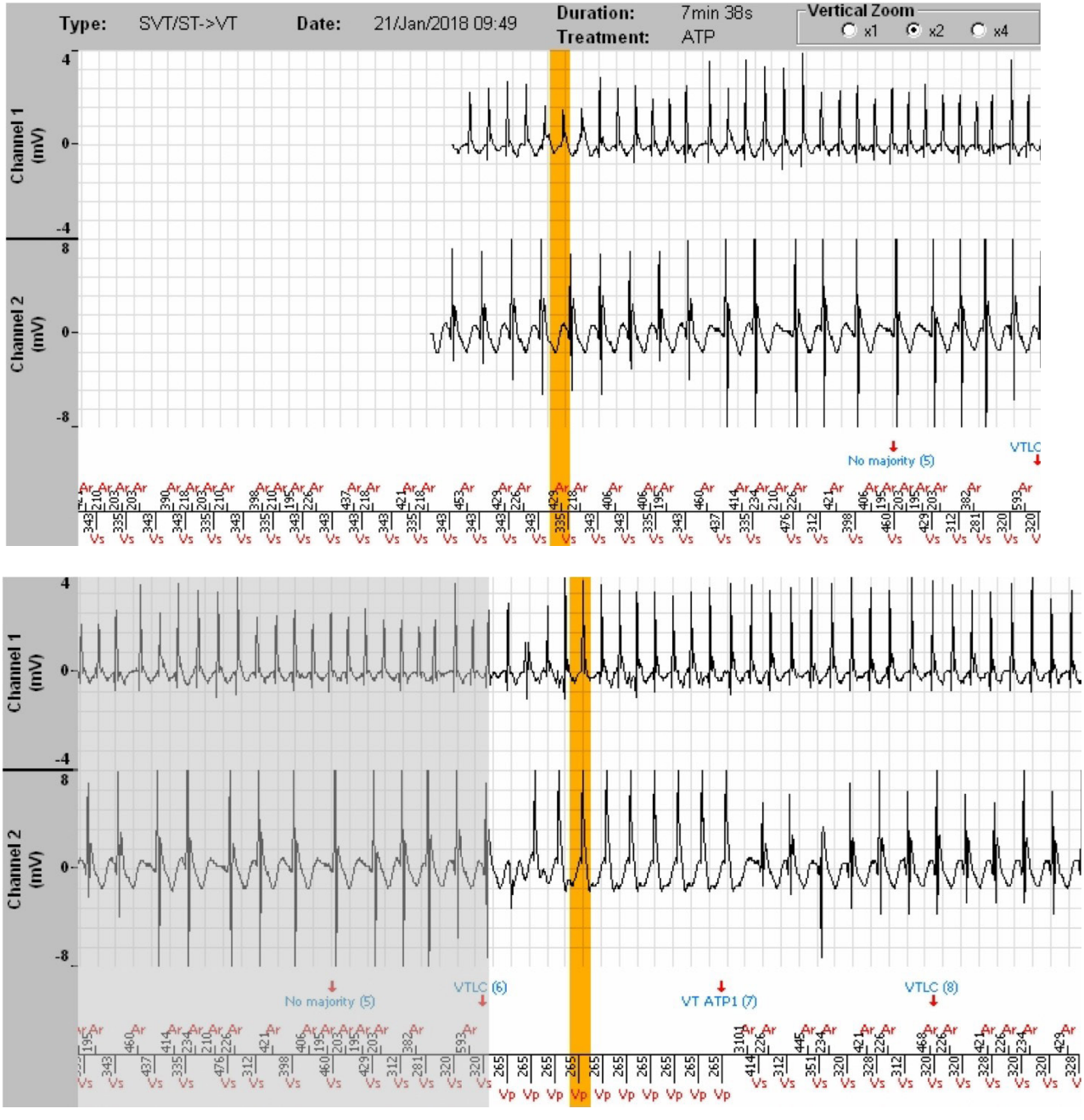
Rate interval plot

The episode lasted 7 minutes and 38 seconds and the tachogram below shows only the last 3 minutes. During the preceding 4 minutes 30 seconds, the ventricular rate is perfectly stable in the Slow VT zone.



Case 8

EGM



Which are the correct answers?

1 The patient is in AF and the ATP is inappropriate

2 The patient is experiencing Slow VT

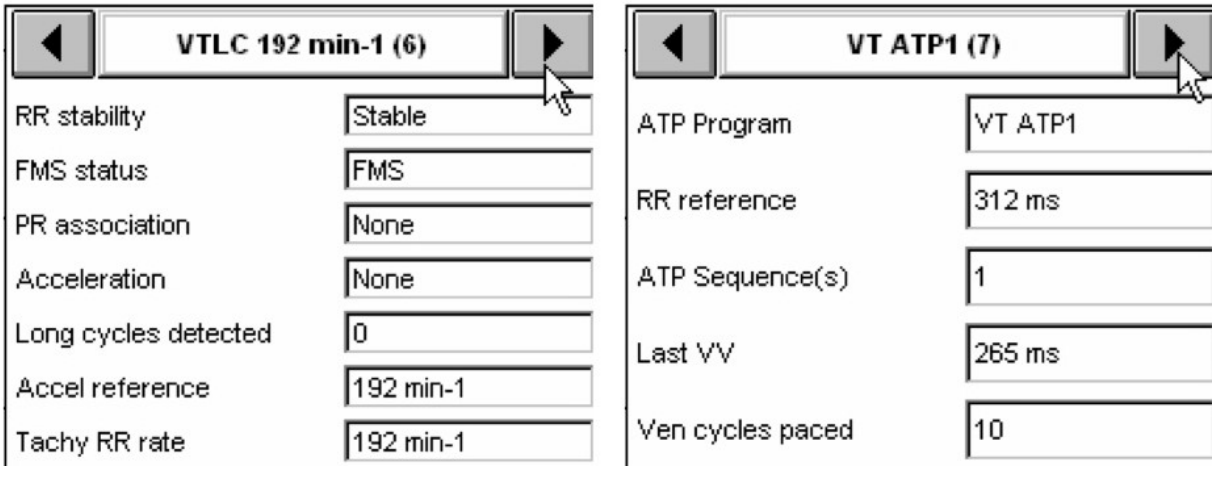
3 The ATP is ineffective

4 The ATP is delivered in the VT zone

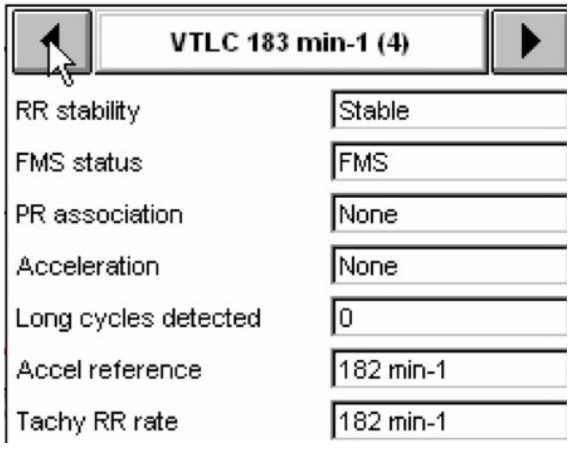
5 The functioning of the defibrillator is satisfactory

Interpretation

- All stored episodes comprise AF. We can therefore expect regularisation phases of ventricular rhythm with incorrect temporary diagnoses of VT.
- This episode, which lasts 7 minutes and 38 seconds, shows a stable ventricular rhythm (335 to 343 ms) in a Slow VT zone, and the defibrillator diagnoses a Slow VT at the beginning of the episode (tachogram and EGM not shown at the time of the diagnosis).
- No therapy is programmed in the Slow VT zone, hence no surprise in the fact that the Slow VT continues.
- Then, suddenly, the rhythm becomes unstable (starting at the orange vertical bar) with cycles whose coupling interval is in the Slow zone (non Tachy) for at least 3 out of 8 cycles (but less than 6), which leads to annotation n°5 « No majority ». This majority maintains the VT persistence counter (no reset to zero, no increment).



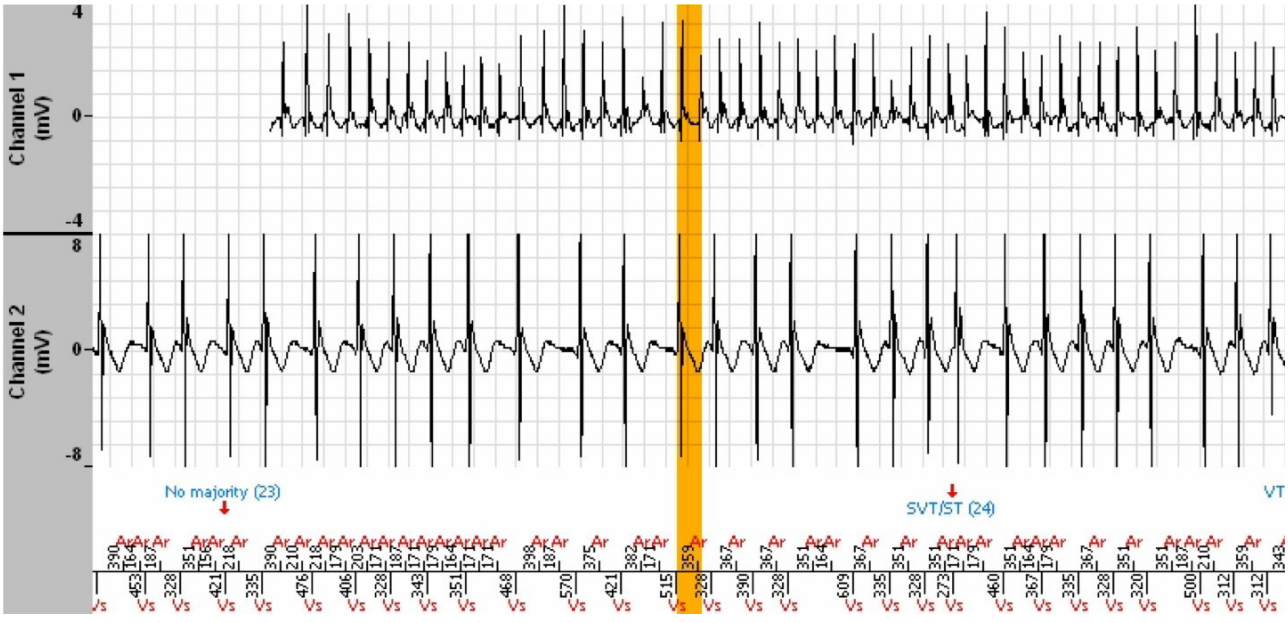
- Then appears an acceleration in rate which leads the tachycardia into the VT zone (annotation n°6). The incrementation of the VT persistence counter had begun during the Slow VT phase, and the VT counter reached the programmed persitence shortly thereafter. The persistence being reached and the average rate of the last 4 Tachy/VF cycles in the VT zone induce a VT zone ATP (annotation n°7).



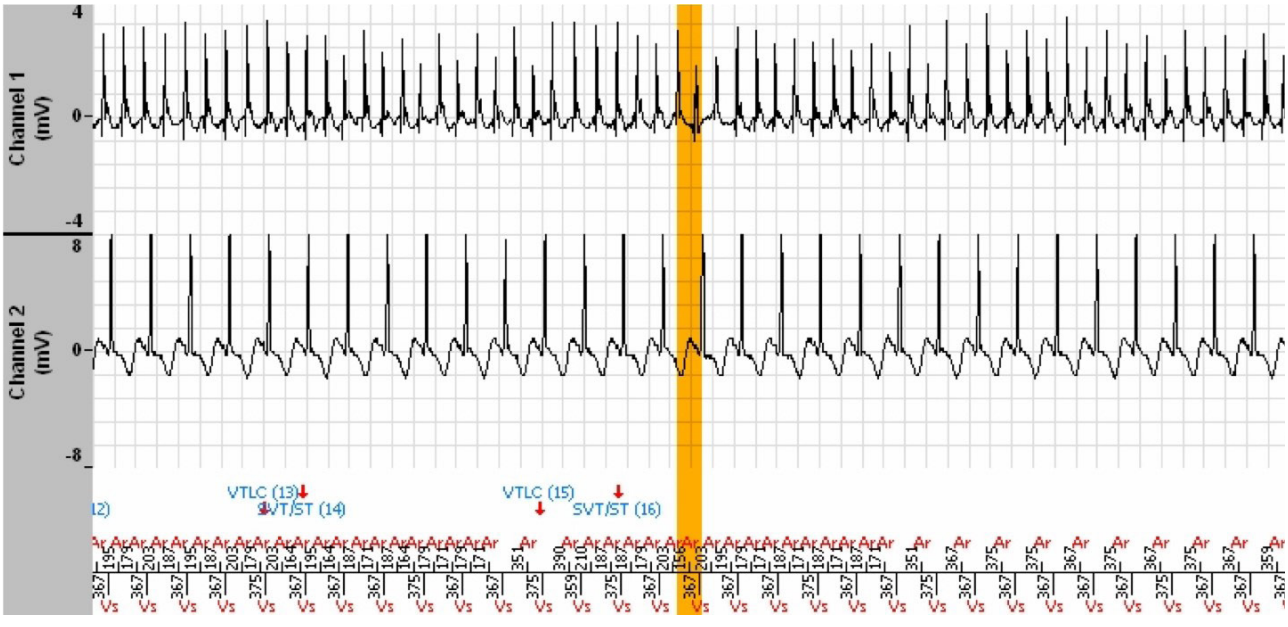
- Indeed, annotation n°4 revealed a diagnosis of VT in the VT zone that had begun to increment the VT persistence counter.
- The ATP does not terminate the tachycardia, which returns to the Slow VT zone with perfect stability, with no defibrillator intervention for the remaining 3 minutes, until

the sudden slowing of the rate and termination of the episode.

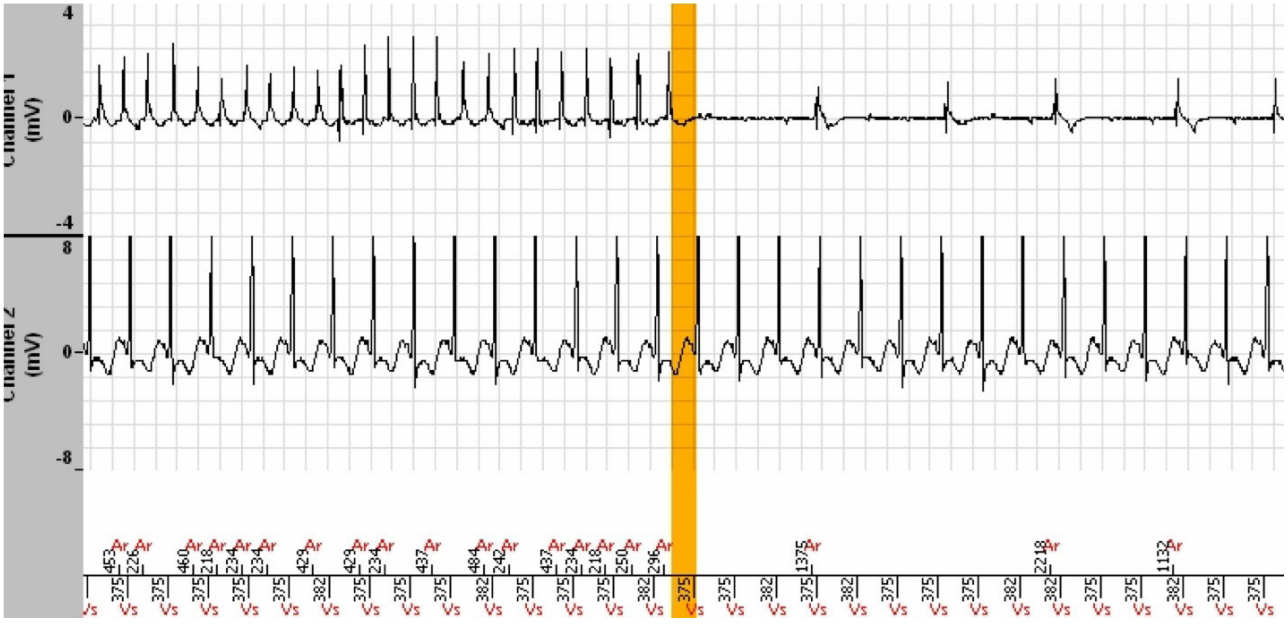
- However, is this treated tachycardia truly a VT or a tachycardia conducted to the ventricles and accelerated by the AF? The answer lies (perhaps) in the analysis of the other memorised episodes.



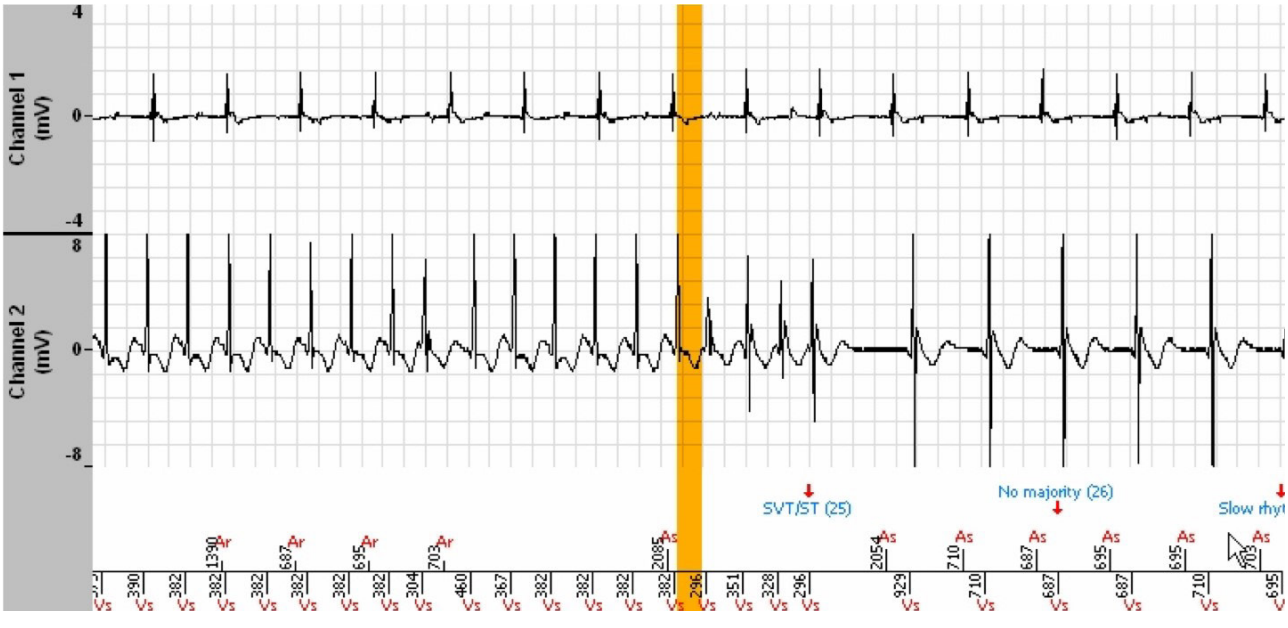
- In this EGM, it is indisputably a conducted AF with irregular ventricular rhythm, appropriately diagnosed as SVT.



- In this other EGM, of another episode labelled Slow VT, the tachycardia is perfectly stable, monomorphic and of very different morphology compared to the ventriculograms of the conducted AF.



- Evidence that this latter EGM does indeed show ventricular tachycardia lies in the observation of the continuation of this tachycardia whereas the AF has terminated spontaneously.



- When the ventricular tachycardia terminates, we find the conducted PR sinus rhythm combination. Note the morphology of the QRS in sinus rhythm which corresponds to that of the conducted AF cycles, and to that of the 11 cycles that follow the orange bar of the EGM of our clinical case. Those cycles which precede the orange bar and those that follow the ATP have a different morphology (less amplitude), which evokes a VT. The morphology of this VT is also different from the obvious VT of the episode shown above.
- The interpretation of the tracing of this clinical case is thus the following (subject to discussion): The tachycardia is a Slow VT which terminates, followed by ventricular cycles conducted by the AF which enter the VT zone, completing the persistence

initiated well before, and induce an ATP which results in the return of the Slow VT. This Slow VT is different from that of another episode, revealed by the two EGMs above.

Correct answers - n° 1, 2, 3, 4

Comments

The interpretation of this tracing is particularly difficult and, as usual, one must read all of the memory data before arriving to any conclusion.

The PARAD+ algorithm would undoubtedly gain in specificity if a morphological analysis function was added.

Take-home messages

A correct diagnosis can only result from a meticulous analysis of all of the information stored by the device.

The statistics, the evolution curves of the parameters and all EGMs must be analysed.

The « Analysis » function of the EGMs is a valuable tool for understanding the functioning of the device and for determining the necessary reprogramming.

Chapter 4 : Oversensing

Ventricular sensitivity control

1 - Principles

The purpose of the Automatic Ventricular Sensitivity Control function is to improve sensing of ventricular fibrillation (VF): a high sensitivity of the device must be applied during VF since most VF signals are of low amplitude (often amplitudes less than 3 mV), and also to avoid sensing of the T wave both in sinus rhythm and during arrhythmias.

One of the challenges of improving VF detection is that the signal amplitude is much lower during VF than in sinus rhythm and the difference in amplitude from one beat to the next can vary.

Another challenge is to avoid sensing of T waves, the amplitude of the filtered T waves is generally less than that of the R waves (the amplitude of the T wave is of the order of 25% of the R amplitude). Pre-clinical studies have shown that the maximum amplitude of these T waves is less than 25% of R waves after filtering.

2 - Filtering

The system used in pacemakers and cardiac defibrillators for the selection or non-selection of a signal is based on filtering techniques. All devices use amplifiers designed to detect events whose frequency varies between an upper limit and a lower limit: the bandwidth. Any event whose frequency is outside these limits will not be taken into account by the device. For MicroPort defibrillators, the ICD bandwidth is 25 to 80 Hz (at -3 dB), and is centered at 55 Hz. Filtering thus allows discriminating T waves, R waves or PACs. On the other hand, given that the filter limits are not completely vertical, it is possible that the circuit detects events outside its bandwidth, if their amplitudes are sufficiently significant. A classic but rare example of this type of oversensing is the sensing and recognition by the defibrillator of the T wave as being an R wave (recycling on the T wave).

3 - Ventricular sensing

For the Automatic Sensitivity Control function, only R waves are filtered and adjusted before being analysed for detection. After filtering, the T waves are attenuated and the signal obtained is rendered positive, in order to detect positive and negative slopes.

At first, a non-programmable absolute refractory period of 95 ms is applied after the sensing of the R-wave.

During the first 64 ms of this period, the implant still measures the amplitude of the R wave. The maximum amplitude of the R waves that the implant can measure is capped at 6 mV for this function.

For the ongoing cycle, the sensitivity will change as a function of the amplitude of the R wave measured in the first 64 ms. It can never go below the programmed sensitivity.

During the 95-156 ms interval following the sensing of the R wave:

- If the amplitude of the sensed R wave was greater than 6 mV, a sensitivity of 3 mV is applied (3 mV = 50% of 6 mV),
- If the amplitude of the sensed R wave was less than 1.6 mV, a sensitivity of 0.4 mV (the programmed sensitivity) is applied (0.4 mV = 25% of 1.6 mV),
- Between 1.6 and 6 mV, the applied sensitivity is between 25 and 50% of the measured R-wave. The sensitivity is calculated linearly in this interval: [1.6 mV; 6 mV] -> [25%; 50%].

These settings allow avoiding the multiple sensing of wide R waves and to sense the R waves in VF.

In the 156-500 ms interval following the sensing of the R wave, the sensitivity is set at 25% of the amplitude of the measured R wave (never below the programmed sensitivity). This setting was implemented to reject the T waves.

The following table illustrates how the device sets the sensitivity value for the 2 plateaux proportionally to the amplitude of the measured R wave. The greater the amplitude of the R wave, the lower the sensitivity of the device (i.e. high sensitivity value).

Ex. amplitude of the measured R wave (mV)	Sensitivity applied for the 1st 95-156 ms threshold (in % of the R wave)	Sensitivity applied for the 2nd 156-500 ms threshold (in % of the R wave)
6 and +	50	25
5	44	25
4	39	25
3	32	25
2	27	25
1.6	25	25

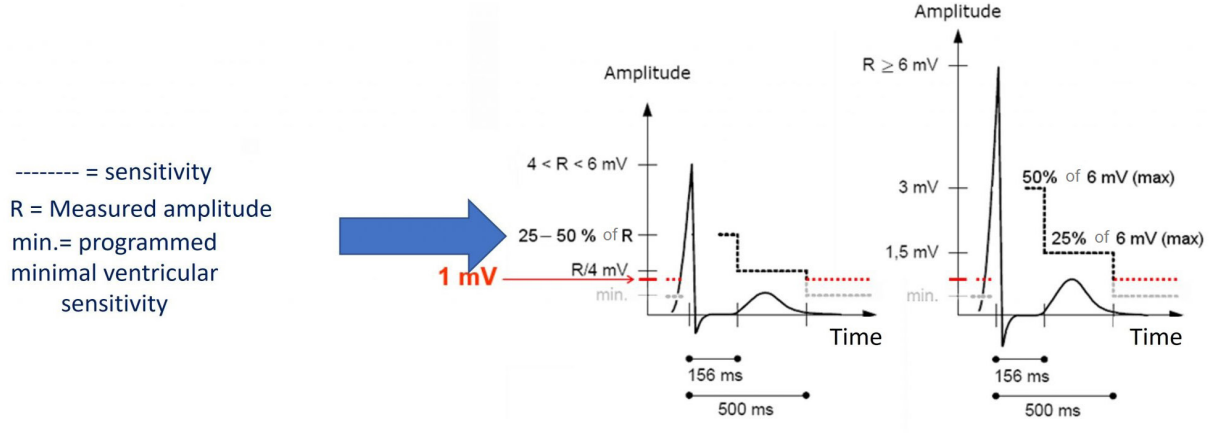
Thus, during much of the cycle (after 156 ms), ventricular sensitivity is comprised between 1.5 mV and the programmed sensitivity value in the event of a complex measured at an amplitude greater than 4 mV.

After 500 ms following the sensing of the R wave, and until the end of the cycle, the sensitivity returns to the programmed value or to 1mV (not configurable) according to certain conditions.

If all of the following conditions are fulfilled:

- the programmed ventricular sensitivity value is less than 1 mV, and
- the device does not detect a short cycle (VF/Fast VT zone) over the last six cycles, and
- the measured amplitude is greater than or equal to 4 mV

then, the V detection threshold is set at 1 mV after the second threshold; i.e. after 500 ms.



Ventricular sensitivity control

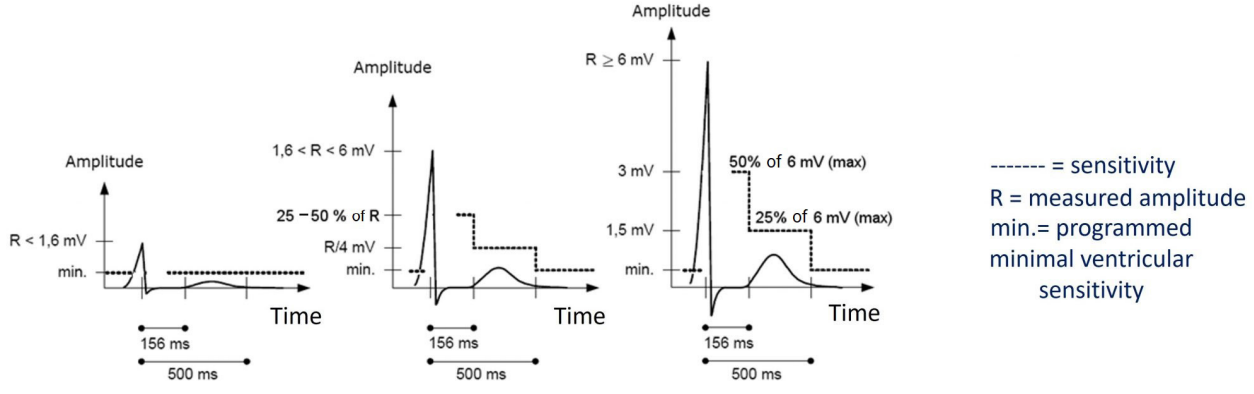
In sinus rhythm and in the VT zone, the lowest detection limit will be 1 mV and will cover any background noise (myopotential). During this period, the V sensitivity will mostly be 1 mV.

In case of a short coupling interval or weak detection, the lowest detection threshold will decrease to the programmed sensitivity (0.4 mV nominal).

If one of the following conditions is fulfilled:

- the device detects at least one short cycle (VF/Fast VT zone) over the last six cycles, or
- the measured R-wave amplitude is less than 4 mV (not applicable for the 3rd diagram)

then, the V detection threshold is set to the programmed sensitivity after the second plateau ; i.e. after 500 ms.

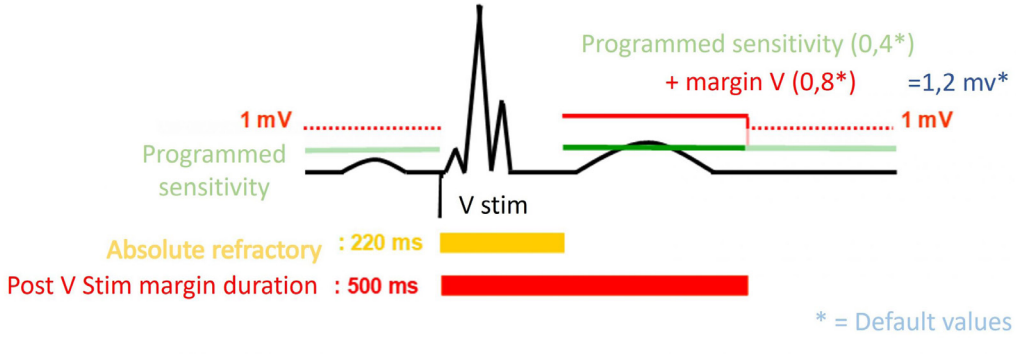


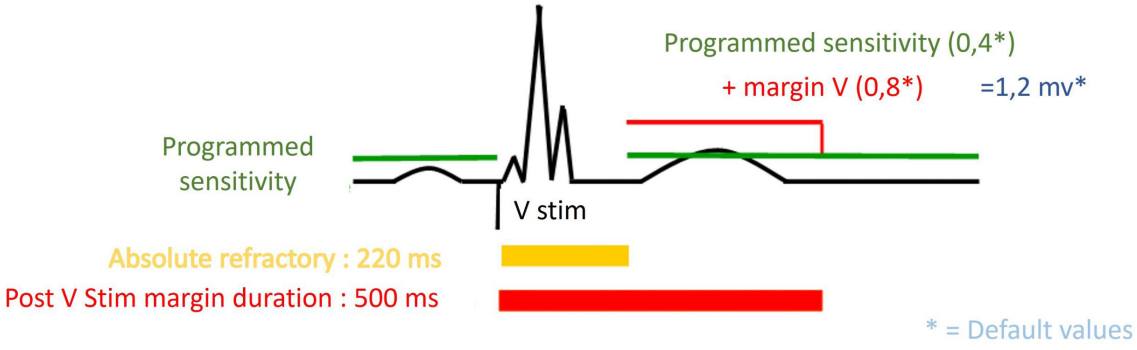
4 - Ventricular pacing

After ventricular pacing, there is an “automatic” management of the sensitivity. At first, an absolute non-programmable 220 msec refractory period is applied after the ventricular pacing. An additional sensitivity margin is programmable (nominal 0.8 mV) for the period between 220 ms and 500 ms post-ventricular pacing, this is the “V margin Post-V pacing”. This is a value added to the programmed ventricular sensitivity for this period. The goal is to “cover” broader T-waves in the case of ventricular pacing in general. After this 500 ms period, ventricular sensitivity automatically returns to 1 mV or the programmed sensitivity if the following conditions are fulfilled:

- the V programmed sensitivity is programmed > 1 mV, and
- if one or more short cycle (cycle in Fast VT/VF zone) was detected over the last six cycles

then the detection threshold V is set at 1 mV after 500 ms.





If there is at least one short cycle (fast VT/VF zone) in the last six cycles, then the V detection threshold is set to the programmed sensitivity after 500 ms.

5 - Programming

The Automatic Sensitivity Control is fully automatic. In case of difficulty linked to ventricular detection, the only parameter that can be adjusted is ventricular sensitivity.

There is only one possible setting in the case of ventricular pacing. This is the " V margin post-V pacing" parameter. See the chapter on automatic management of post-ventricular pacing sensitivity. You will need to open the "Expert parameters" and choose "A and V Detection". The "V Margin post-V pacing" parameter is then accessible. By default, knowing that its value is 0.8 mV and the ventricular sensitivity is 0.4 mV, the applied post-ventricular pacing ventricular sensitivity for the period from 220 ms to 500 ms is 1.2 mV.

Atrial Sensitivity Control

The control of atrial sensitivity enables avoiding R-wave crosstalk (or far-field sensing), both in sinus rhythm and during tachycardias. It is coupled with an automatic prolongation of the refractory periods after ventricular events. The 2 strategies are often combined.

1 - Implemented strategies for managing crosstalk of ventricular activity in the atrial channel.

Since the atrial channel has a high nominal sensitivity (0.4 mV programmed sensitivity) and by definition short refractory periods, the sensing quality on this channel has been put to the test particularly in situations of crosstalk or far-field sensing (R or V sensing in the A channel). Different solutions have been studied and applied to improve sensing on the atrial channel..

2 - Programming

Several settings are available to improve the quality of atrial sensing. Two parameters affect the value of the applied A sensitivity: "A Sensitivity" and "A margin post R or V". Two parameters affect the duration of the absolute atrial refractory period: the "Post V Atrial Refractory Period" and the "Post R Atrial Refractory Period".

3 - Situation where the ventricular event is preceded by atrial sensing

- In the case of ventricular detection preceded by atrial sensing, after the absolute refractory period (45 ms), the value of the applied sensitivity is the programmed sensitivity (0. 4 mV) incremented by the “A margin Post R or V ” (0.4 mV) for 30 ms*+ 97 ms
- In the case of ventricular pacing preceded by atrial sensing, after the absolute refractory period (80 ms), the value of the applied sensitivity is the programmed sensitivity (0. 4 mV) incremented by the “A margin Post R or V ” (0.4 mV) for 30 ms *+ 62 ms.

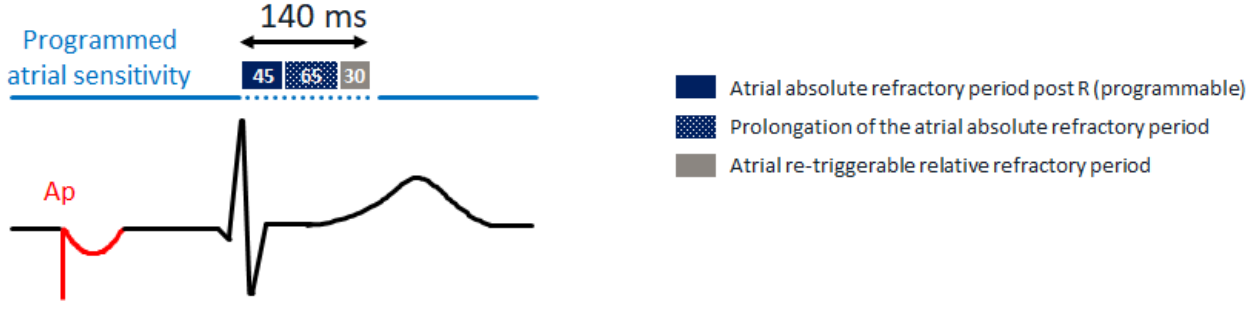
* Re-triggerable relative refractory period.

4 - Situation of PVC

- In the case of a PVC, after the absolute refractory period (45 ms), the value of the applied sensitivity is the programmed sensitivity (0.4 mV) incremented by the “A Margin post R or V” (0.4 mV) for 30 ms *+ 97 ms.

5 - Situation where the ventricular event is preceded by atrial pacing

- In the case of ventricular detection preceded by atrial pacing, the absolute refractory period (45 ms) is prolonged by 65 ms and by the re-triggerable relative refractory period (30 ms).



Note: In AAI-SafeR mode, in the case of ventricular detection preceded by atrial pacing, the absolute atrial refractory periods are not prolonged and the atrial sensitivity margin is not added. Only the absolute refractory period (45 ms) prolonged by the re-triggerable relative refractory period (30 ms) is applied.

- In the case of ventricular pacing, preceded by atrial pacing, the absolute refractory period (80 ms) is prolonged by 65 ms and by the re-triggerable relative refractory period (30 ms). The "A sensitivity control" is carried out over a total of 175 ms (80+65+30) after the sensing of the R-wave.

Oversensing situations

An oversensing of events detected by the defibrillation ventricular lead can occur and is added to the normal sensing of the R-wave. This results in false diagnoses of ventricular arrhythmia with the possible triggering of inappropriate and dangerous therapies. (At the atrial level, oversensing can also lead to either a false diagnosis of atrial arrhythmia and thus an inappropriate mode switch, or an additional degree of artificial PR association which, concomitant with a stable and dissociated VT, leads to a diagnosis of SVT).

There are two types of oversensing: those that are intrinsic, via the sensing of cardiac events of atrial origin (P waves, atrial tachycardia waves) or of ventricular origin (double sensing of R waves, T waves), and those that are extrinsic, via the sensing of non-cardiac bodily potentials (pectoral or diaphragmatic myopotentials), or lead fracture potentials, or extracorporeal potentials (external or fortuitous interference (50 Hz line, for example), or by the use of medical equipment (magnetic or electric or electromagnetic field of a diagnostic or therapy apparatus (electrotherapy, diathermy knife, for example)).

In all instances, the number of detected events per cardiac cycle is in excess and will result in two consequences: i) a consequence on cardiac pacing with an inhibition in pacing which, in a device-dependent patient, leads to a cardiac pause and its ensuing clinical course as a function of the duration of the pause; ii) a consequence on defibrillation, with false diagnoses of ventricular arrhythmia leading to unexpected shocks, which in turn can trigger true cardiac arrhythmias. Shocks are often iterative as long as the cause of this oversensing has not been removed. The use of a magnet should thus be reminded and whose action will be to suspend any detection of arrhythmia and all therapies as long as it applied next to the defibrillator case.

The suspicion of an oversensing-type activity, whether intrinsic or extrinsic, is evoked by the pattern exhibited by the tachogram of the recorded episode.

Intrinsic Oversensing

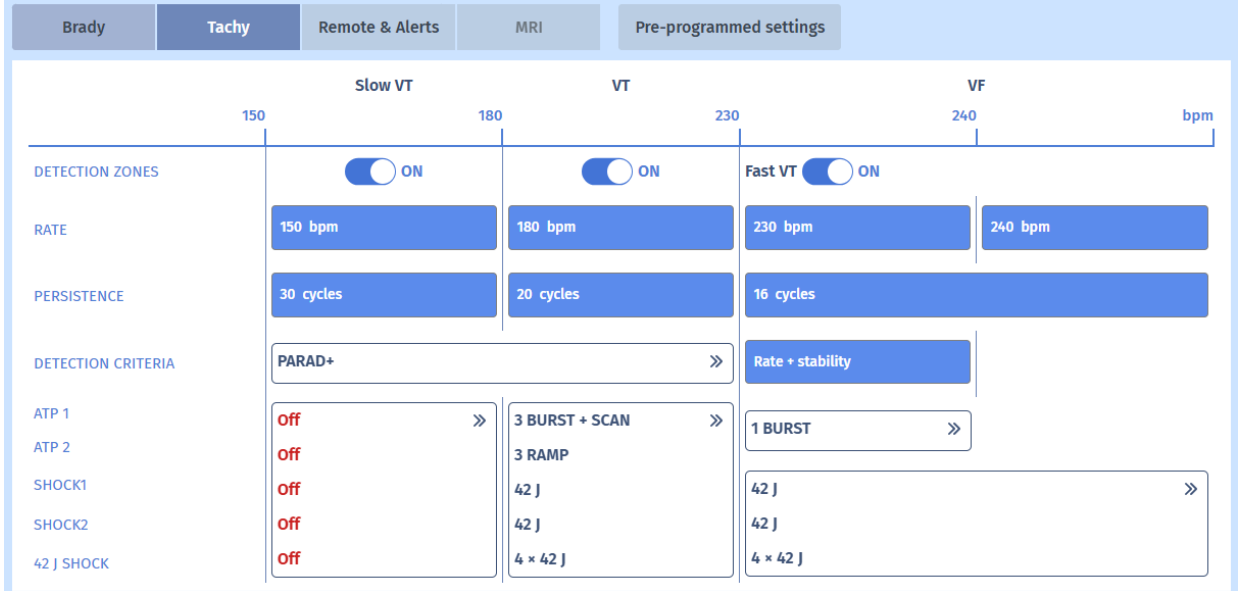
The sensing of P or T waves, or the double counting of R waves will cause oversensing for fixed intervals relative to the QRS detection signal, corresponding to the P or T wave onset times, or an intra-QRS interval. This results in a characteristic « railroad track » pattern which quite easily evokes this type of artifact whose type will be detailed by the electrograms. Clinically, in addition to the consequences of untimely triggered therapies in the absence of any arrhythmia, such oversensing at the ventricular level incurs a recycling of the pacemaker, and in a bradycardia patient, the pacing rate will be slow on the surface ECG, i.e. slower than what should normally be observed.

Case 1

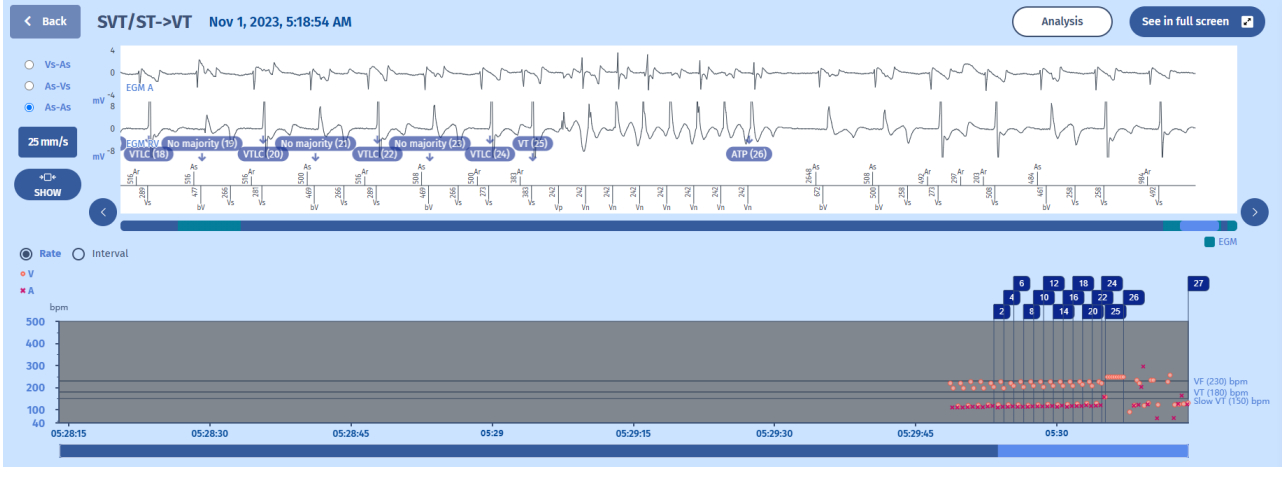
T-wave oversensing

Patient

54 year old patients with dilated cardiomyopathy and left bundle branch block, implanted with a CRT-D, comes in for a regular device check-up.



EGM



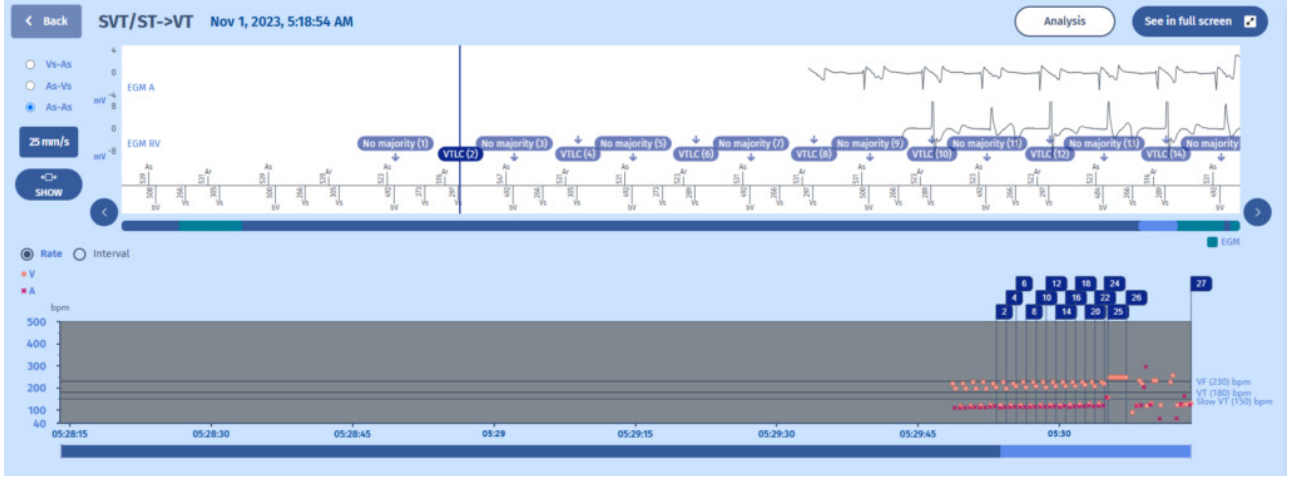
Which of the following answers is correct?

1 The T-wave oversensing is after paced ventricular events in this case

2 T-wave oversensing is quite common in MicroPort defibrillators

3 T-wave oversensing is often a problem of small R-waves, not tall T-waves, like in this case

4 The T-wave oversensing is after sensed ventricular events in this case



Rate interval plot

A typical feature of T-wave oversensing is that it creates a typical pattern with very short cycles (R-to-T) and short cycles (T-to-R). This creates a typical “railtrack track” pattern on the rate interval plot which is associated with oversensing of physiological signals (P-wave, R-wave or such as in this case T-wave oversensing). The pattern will suddenly appear and disappear and has only very slight variations in rate while the underlying rhythm is often sinus tachycardia (in order for the short cycles to be short enough to cross the VT zone).

EGM

The baseline rhythm is atrial sensing (sinus tachycardia) and biventricular pacing. Throughout the episode, we see a certain pattern. It begins with oversensed T-waves after biventricular pacing. These short cycles disable the delivery of biventricular pacing after the following atrial cycle and we see intrinsic atrioventricular conduction. The cycle thereafter does again allow biventricular tracking and we again see T-wave oversensing. This pattern repeats itself during acceleration of sinus rhythm which also makes the cycle after T-wave oversensing fast enough to fill the VT counter. Interestingly, the rhythm is considered stable as the majority (6/8) is indeed stable. We see many VTLC markers without therapy because the slow cycles change the diagnosis to “No majority” and they also extend the persistence (part of the PARAD+ algorithm). As there are no “SVT/ST” or “Slow rhythm” majorities, the persistence is never reset. Suddenly, because of the appearance of a premature atrial complex (PAC), the PARAD+ find AV association and follows a different path (VTLC -> VT). The slow cycles no longer extend the persistence which is filled (never set to 0 by SVT or slow rhythm markers) and an ATP is delivered.

Correct answer - n° 5

Comments

T-wave oversensing is extremely rare in MicroPort devices even though it is still a common phenomenon across other ICD platforms. The engineers have succeeded in filtering out the T-waves so that they are rarely oversensed these days. While it is true that in most cases of T-wave oversensing (across all ICD platforms), there is an association with small amplitude R-waves and increased risk of T-wave oversensing due to the adaptive sensitivity in ICDs (more sensitive during the cycle after small R-waves), However, this is not the case in the current patient as the R-waves are of significant amplitude (>15 mV). In addition, the oversensed T-waves are only to be found after biventricular paced events, which is very uncommon for tachycardia episodes. Pacing may indeed alter the morphology and amplitude of T-waves but rarely causes inappropriate therapies because of the low rate at which pacing occurs, limited also by the higher upper tracking rate. For a MicroPort ICD to deliver inappropriate therapy (a single ATP burst in this case), we must reach 6 out of 8 cycles in the VT zone. During biventricular pacing with T-wave oversensing, we only expect 4 out of 8 cycles to be within the VT zone as the R-T interval is very short (260-270 ms in this case) and the T-R interval is not. This is one of the main reasons why majority is set at 75% (6 out of 8) for the VT and VF counters, it protects the patient against inappropriate therapy due to T-wave oversensing. However, when the patient’s sinus rhythm accelerates beyond a certain heart rate, the T-R intervals shorten and may cross the VT zone. We can see that the patient’s heart rate is indeed >110/min and the VT counter is filled. Slow cycles prolong the onset of therapy because their presence leads to a classification of the rhythm as ‘No Majority’, which does not influence the VT persistence counter.In this patient, there is a single episode of T-wave oversensing among many episodes of true ventricular arrhythmia. There were no programming changes made.

Solutions for T-wave oversensing are not abundant. Changing the sensitivity is often the first thought but it may also impair the ability of the ICD to adequately detect VF signals, especially when the R-wave amplitude is low. Changing the zones will most often not help as the VT/VF counters are filled at high rate (including in this case). The true danger of T-wave oversensing is that it may deliver a shock on the T-wave (the ICD considering it to be a fast ventricular event on which it should deliver the shock), with potential catastrophic results (inducing a true VF which may be hard to defibrillate). In some companies with higher risk of T-wave oversensing there are other programming changes to be considered (changing the sensing vector, changing the adaptive sensing parameters) but in some cases, a new RV lead needs to be placed to solve the issue.

Message

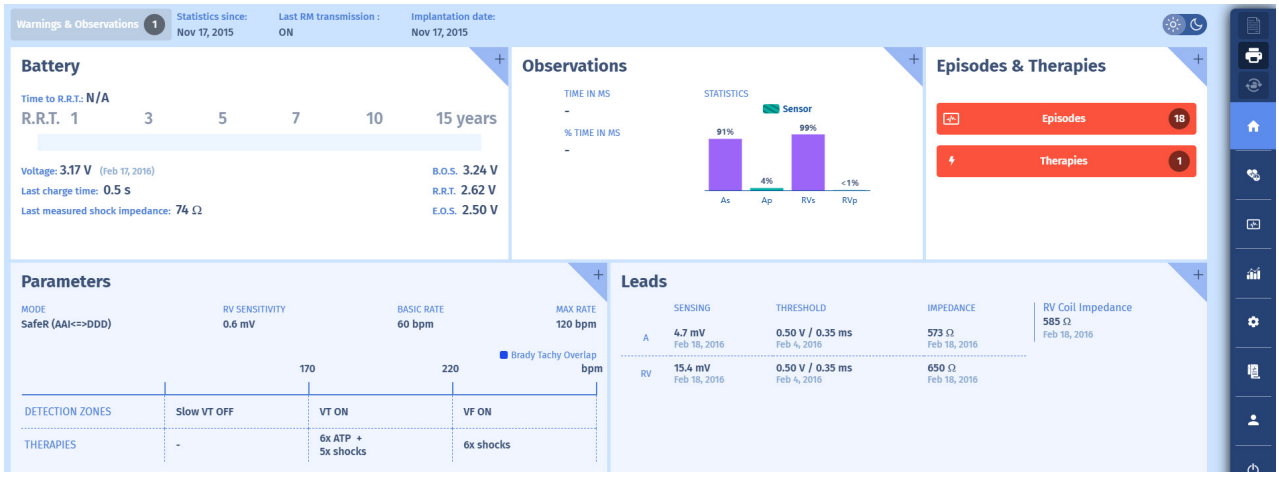
T-wave oversensing is extremely rare in MicroPort devices but needs to be timely recognized and managed even though programming options are mostly limited.

Case 2

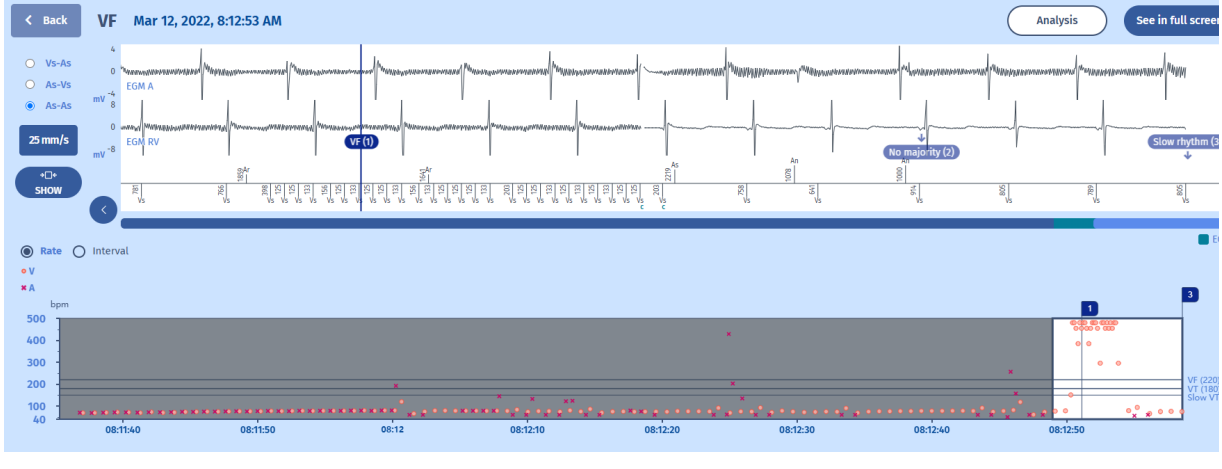
Aborted charge

Patient

70-year old patient with ischemic cardiomyopathy implanted with a dual chamber ICD comes into office for a device check-up.



EGM



Why did the capacitors charge in this episode?

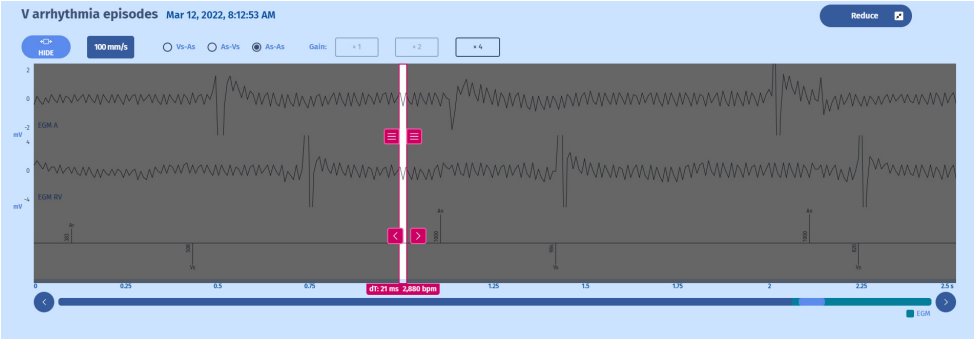
1 There was T-wave oversensing
2 There was P-wave oversensing
3 There was R-wave double counting
4 Due to 50 Hz interference
5 Due to diaphragm oversensing

Rate interval plot

In the beginning there is slow atrial and ventricular rhythm with some isolated fast events. Suddenly there is an extremely fast rhythm with ventricular cycles so high in the VF zone that they are close to the blanking period. We see a sudden-ON and sudden-OFF phenomenon. These aspects are typical for interference from an external source, probably the electrical grid (50 Hz noise).

EGM

When we look closely to the EGM, we see a very fast organized signal within a certain bandwidth (no clipping) on both the atrial and the ventricular channel. When we zoom (100 mm/sec), we can see that the “cycle length” of this signal is around 20 ms, making it a 50 Hz signal, typical for the electrical grid in Europe.



Correct answer - n° 4

Comments

The electrical grid is associated with a 50 Hz signal (in Europe, in the USA it is 40 Hz) which may be oversensed by ICDs when the patient is in contact. This may occur when the patient is in skin contact with the powergrid. Often because of insufficient isolated electrical appliances or through wet surfaces which are somehow connected to the electricity. While there are filters in place which attempt to avoid oversensing of these extremely fast signals, there is still a risk of inappropriate therapy. Since these signals may have significant amplitude and are always extremely fast, altering the sensitivity or the zones is often of little use. The only solution is to interrogate the patient on what activities were performed during the oversensing episode, in an attempt to identify the source. This activity (for example cleaning a poorly isolated caravan) should then be avoided in the future. Remote monitoring is perfect for this, as these episodes may be transmitted as an alert, and the remote monitoring staff may interrogate the patient soon after the episode, increasing the possibility that the patient remembers the activity. While oversensing of 50 Hz may be associated with an inappropriate shock (not so much ATP because too fast), the patient will most often stop the activity at once, eliminating the risk of suffering from multiple shocks.

Message

It is important to recognize these typical patterns of 50 Hz, in order to quickly identify and exclude the source, as these episodes have a high risk of inappropriate shock (very fast and ample signals).

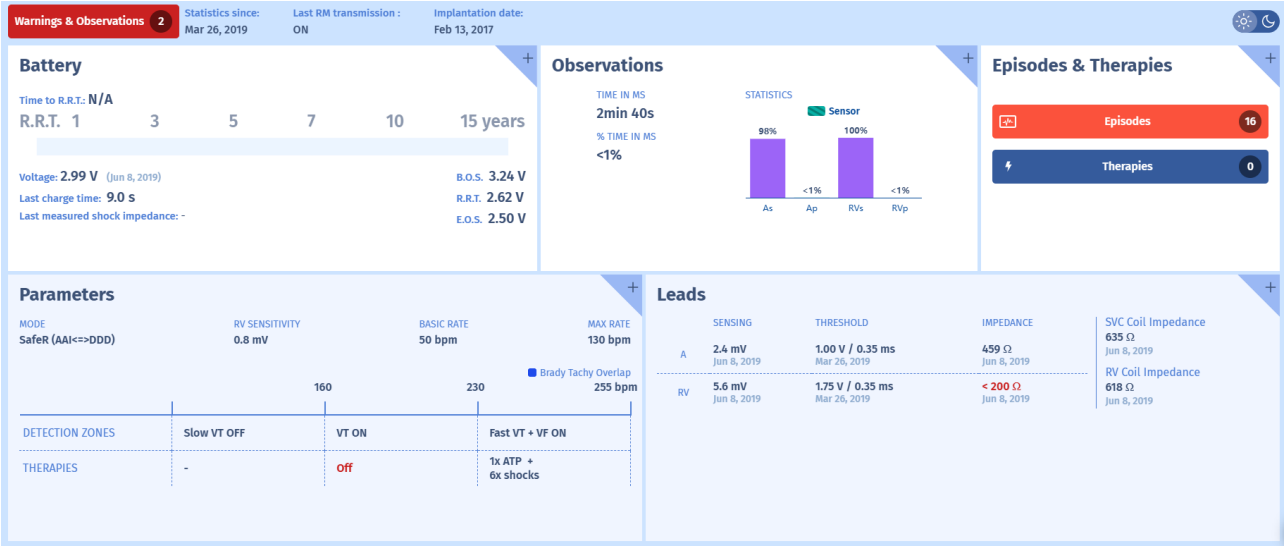
Case 3

Lead dysfunction

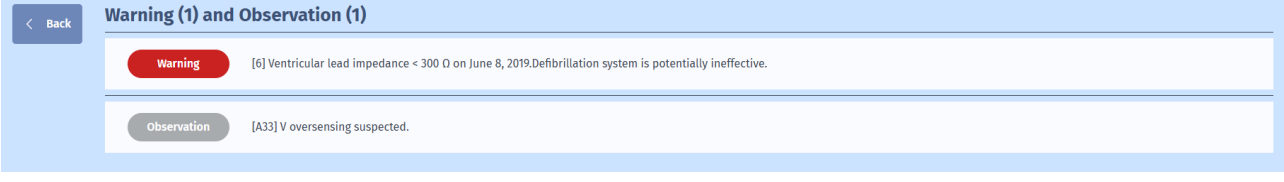
Patient

A 68-year old patient with ischemic cardiomyopathy has been implanted with a dual chamber ICD (Platinium DR). He presents for a routine check-up. He claims not to have any symptomes and not to have felt any ICD shocks.

Programmer Screen



Warning screen

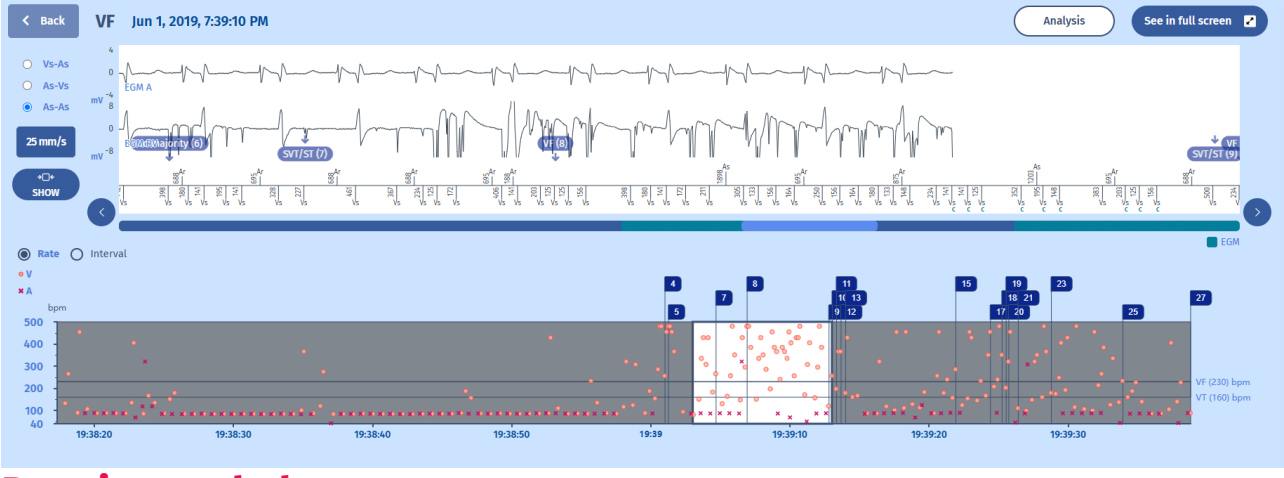


What does this signify?

1 RV lead conductor fracture

2 RV lead insulation breach

3 Episodes of ventricular arrhythmia



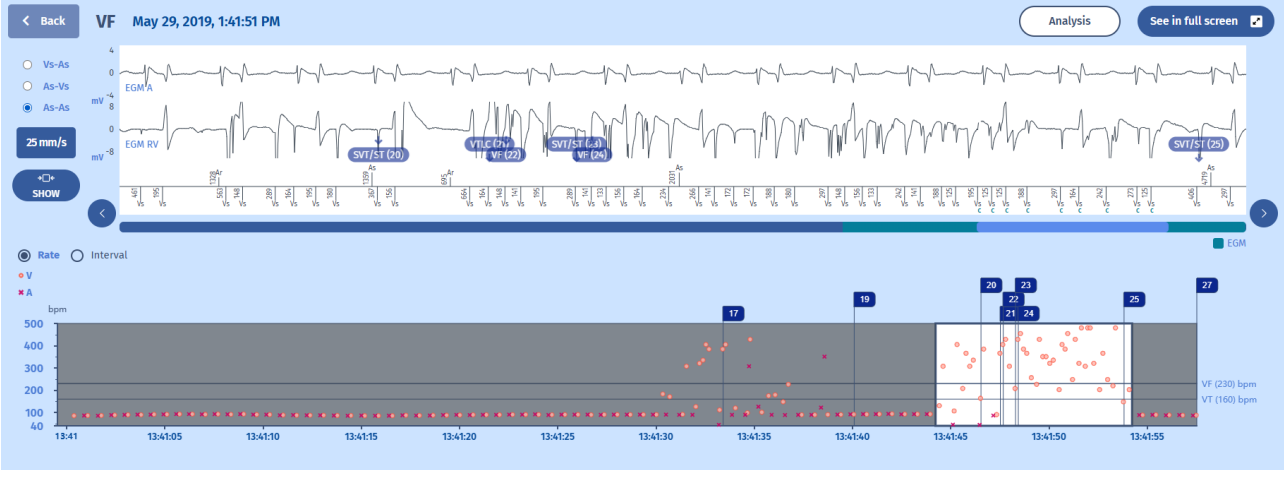
Rate interval plot

- We see a cloud of ventricular intervals which is non-physiological
- Also intervals over 400 beats per minute are highly unlikely to be physiological
- Various diagnoses are made by the ICD: there are multiple diagnoses of SVT/ST, VF and SR

EGM

- The underlying rhythm is sinus rhythm with spontaneous atrial events (As) conducted to the ventricule (Vs)
- The ventricular channel is saturated with artefacts; they are very sharp signals with varying amplitudes and cycle lengths
- The VF counter is filled but resets because of diagnosis of SVT/ST
- The VF counter is then filled with maintenance of the VF majority and charge of the capacitors (C markers)
- We already know from the Overview screen that no therapies were delivered during any episode

EGM 2 (older episode)



- This episode was registered a week before the first shown EGM
- It is a similar tracing with detection of VF and charge of the capacitors
- Also here, the noise stops during the charge and the charge is aborted
- This episode is shorter than the episode a week later; which shows a process often seen in lead failure, progressive prolongation of noise. Noise progression towards inaproppriate therapies may occur within 24 hours but it may also take days, weeks or even months.

Correct answer - n° 2

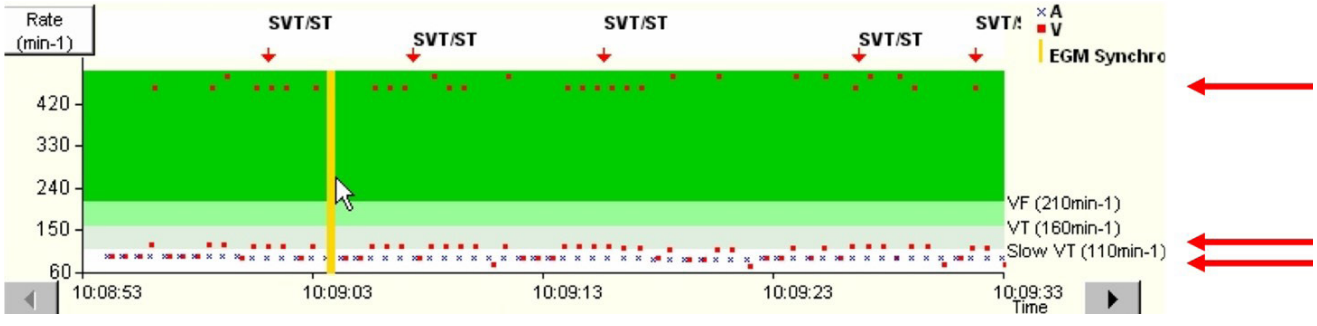
Comments

Luckily for the patient, the noise is intermittent and stops before the delivery of inappropriate therapies. Preventing inappropriate therapies in case of lead failure is a priority for the ICD companies. The combination of programming changes (extending counters, activating discriminators, activating dedicated algorithms) and remote monitoring (examination of non-sustained episodes, non-treated sustained episodes, impedance changes) have resulted in a significant decline in inappropriate therapies for lead failure. When lead failure is suspected, certain maneuvers may exacerbate lead noise to confirm the diagnosis. Examples are arm movements, deep breathing and pocket manipulation (certainly in case of insulation breach). A chest X-ray is often performed which may reveal lead fracture but can also serve for planning of the lead extraction or lead implantation procedure. When lead failure has been confirmed, ICD therapies need to be deactivated and in case of pacemaker dependency; the pacemaker programmed accordingly (for example asynchronous pacing in VOO mode to avoid inappropriate inhibition). Then within a short delay, a new lead should be implanted while abandoning or when possible, extracting the faulty lead.

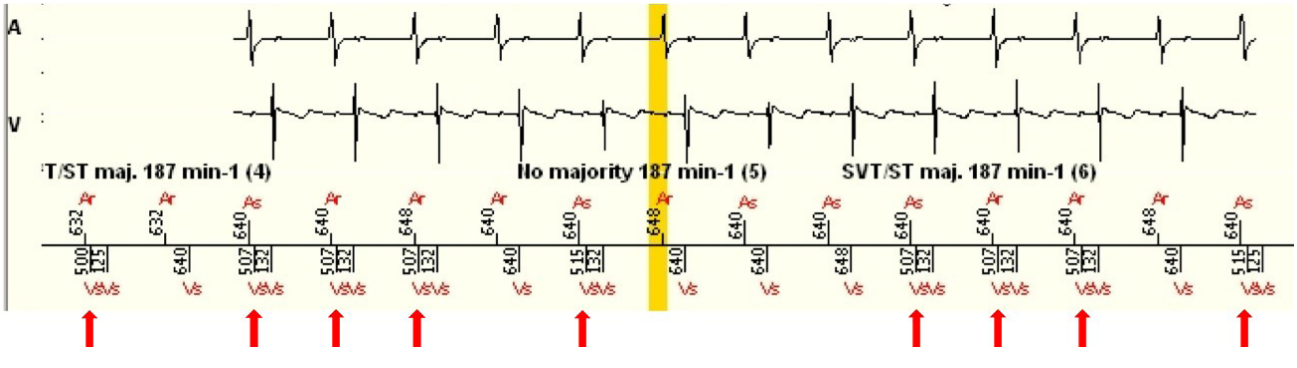
Case 4

Oversensing of the P waves

This case is even rarer, namely P-wave oversensing by the defibrillation lead. This is a routine follow-up examination in an asymptomatic patient implanted with an integrated bipolar defibrillation lead, in which the shock electrode of the ventricular defibrillation lead is involved in the ventricular detection of the defibrillator. « Non-sustained » tachycardias are recorded in the device memory.



The tachogram exhibits a characteristic triple railroad track pattern with RR, PR, and RP intervals.



The EGM reveals the cause of this oversensing.

1 The concordance between the ventricular markers and the visible P waves can readily be seen on the ventricular electrogram, the latter of which correspond well with the P waves of the atrial electrogram.

2 For this integrated bipolar defibrillation lead, this phenomenon is related to a positioning of the shock electrode of the defibrillator ventricular lead that is too close

to the tricuspid valve, and thus able to « pick up » the atrial signals.

3 This risk is all the more significant if the right ventricle is small, and the distal end of the defibrillation lead is placed in the anterior or infundibular septal area. The proximal part of the shock electrode is therefore straddling the tricuspid ring.

4 Here again, in the event of sinus acceleration and of atrial rhythm disturbances, false VT/VF diagnoses may occur and trigger dangerous inappropriate therapies.

5 This problem can be solved by decreasing the ventricular sensitivity, but at the risk of under-detection of ventricular fibrillation. If the sensitivity is decreased, we recommend performing a VF induction to verify the proper VF detection quality in this downgraded configuration.

Take-home message

When placing a ventricular defibrillation lead, the absence of oversensing of signals other than QRS, P-waves and T-waves should be controlled, which would thus require a repositioning of the defibrillation lead, which is difficult to perform later during the follow-up.

Case 5

Extracardiac oversensing

Patient

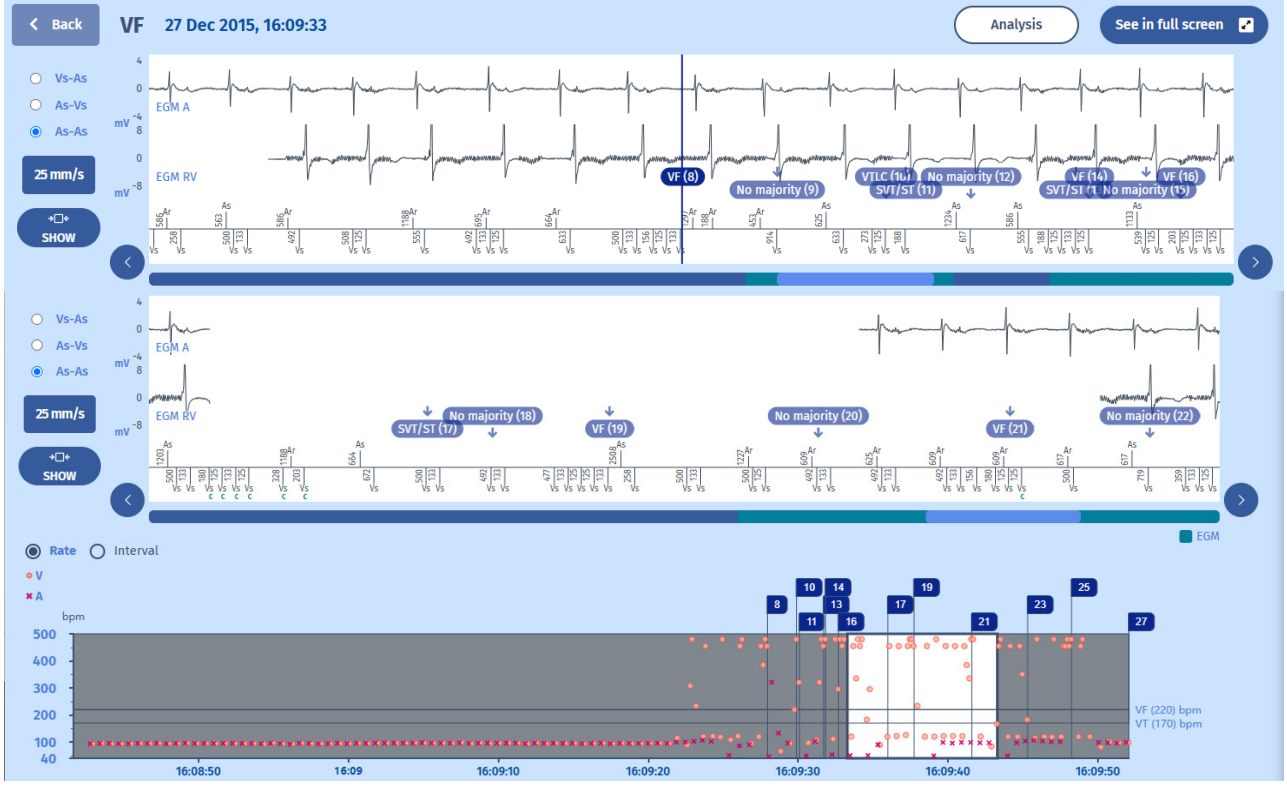
In this example, the patient was recently implanted in primary prevention for obstructive hypertrophic heart disease. He experienced a sudden syncope, has a family history of sudden death (father and brother), a subaortic obstruction measured at 74 mmHg at rest and 120 mmHg at exercise, a septal thickness of 24 mm, no ventricular bursts on Holter monitoring, but a significant septal fibrosis on MRI. A genetic study is in progress.

Given the above, the patient received a dual-chamber system in an attempt to reduce subaortic obstruction while simultaneously protecting against ventricular arrhythmia disorders. The right ventricular lead was thus placed at the apex of the RV, with continuous pacing by the device to reverse the ventricular activation sequence and minimise the obstruction on ejection. The pre-discharge follow-up control is quite satisfactory as well as the chest radiograph.

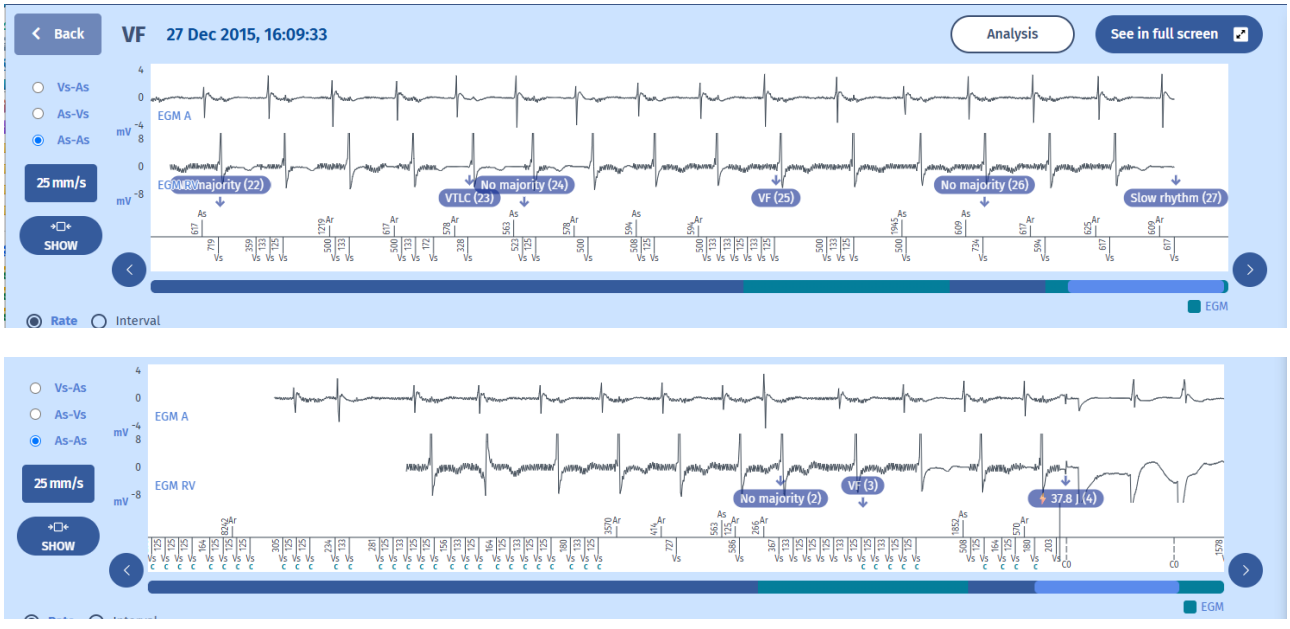
We quickly receive a telemedicine alert because the patient received a maximal shock for VF. The patient is recalled immediately for consultation. No symptoms occurred prior the shock which surprised the patient while attempting to retrieve an object that had slipped under the seat of his car! The leads work perfectly.

Programming

A VT zone is programmed starting at 180/min with a persistence of 12 cycles and a VF zone starting at 230/min with a fast VT section of 230 to 255/min with a burst followed by shocks, and a VF section with maximum shock directly.



Case 5



What is the most probable diagnosis ?

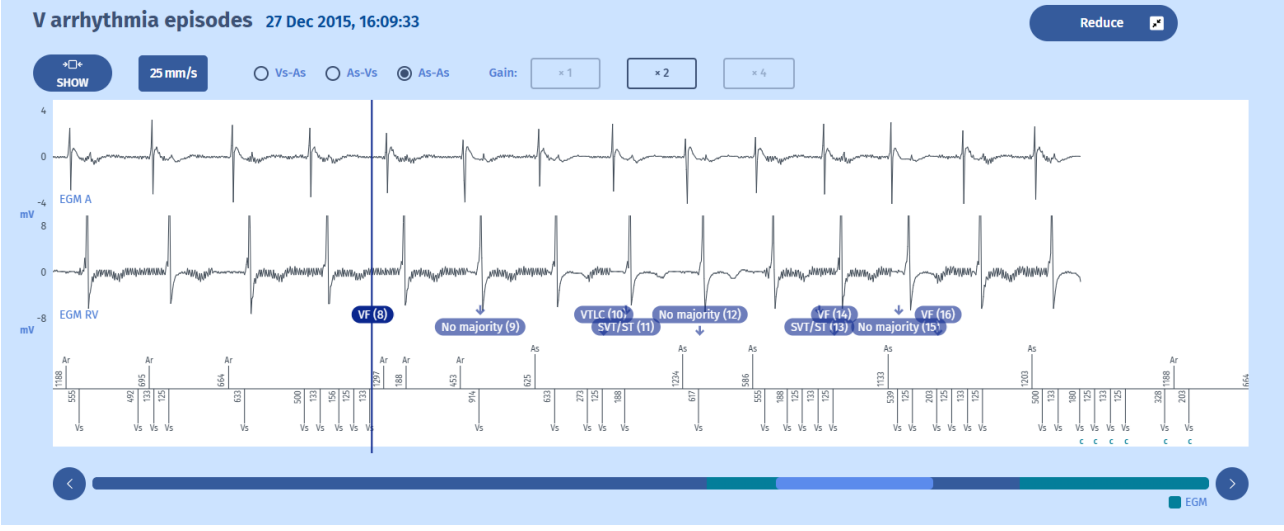
1 VT which the shock did not terminate

2 RV lead fracture

3 50 Hz

4 Diaphragmatic myopotentials

5 External interference



Interpretation

1 Using the EGM « Zoom » function to amplify and expand the tracing make EGMs much easier to interpret.

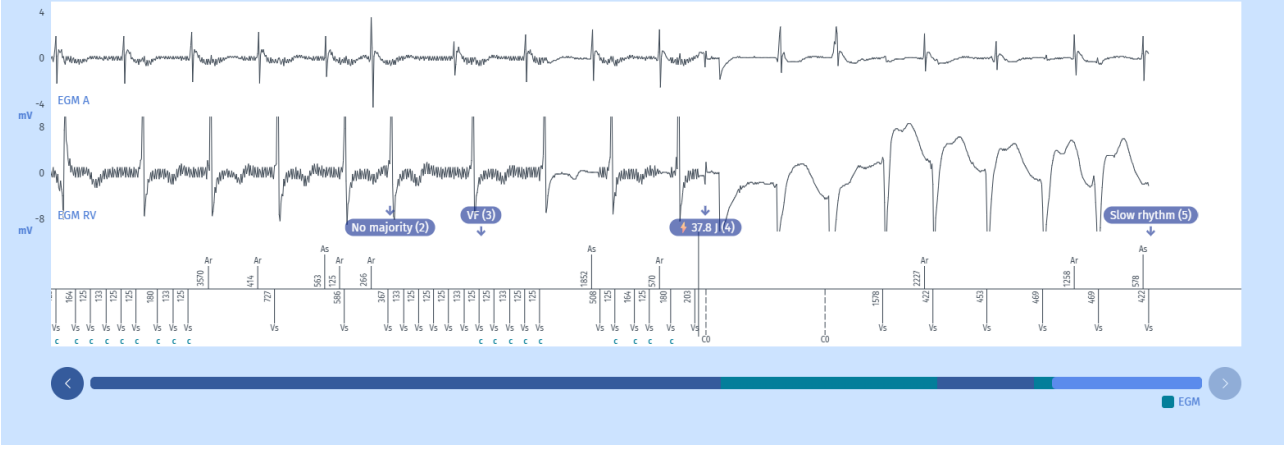
2 It is clear that the ventricular detections with very short RR intervals do not correspond to any ventriculogram on the ventricular EGM. It is therefore oversensing.

3 Many RR intervals have a duration of 125 ms which is the value of the post-ventricular ventricular blanking. Such values are not physiological but correspond either to external interference, a 50 Hz current, myopotentials, a lead facture, or a connection fault.

4 Analysis of the morphology of the oversensing on the EGM is therefore essential. By expanding the Case, we see that the line is thick on the ventricular EGM, but also to a certain degree on the atrial signal. This phenomenon can correspond to an external interference, a 50 Hz current, diaphragmatic-type myopotentials, although likely not pectoral, but certainly not to a lead fracture or a lack of connection which would cause chaotic potentials of large amplitude. In addition, the manipulation of the defibrillator case through the skin, which could not be aggressive given the very recent implantation procedure, does not induce any aberrant signal on the EGM in real-time. The circumstances surrounding of occurrence of the shock do not evoke exposure to external interference or a 50 Hz current. Hence, myopotentials? Counter movements of the arm, which are also painful, do not give rise to any anomaly.

5 On the other hand, the intermittent and sometimes regular nature of the appearance of the aberrant signals and the reproduction of the phenomenon on both leads through deep breathing during the consultation signal the diagnosis of myopotentials of diaphragmatic origin! A control image reveals that the ventricular lead is in its proper position, placed along the anterior aspect of the RV, while the atrial lead has moved to the anterior and lateral side of the RA, next to the right hemidiaphragm! Hence the reason for the observed artefacts in the form of a thick line appearing on the atrial EGM when the patient performs deep respiratory movements, an event reproducible in consultation. The atrial signals are, however, not of sufficient amplitude to be detected.

Case 5



We can also observe that the charging of the capacitors was not homogeneous, the process being interrupting upon the appearance of slow cycles causing the absence of majority. The charging of the capacitors resumes as soon as the majority becomes VF again. At the end of the charge, the next cycle being in the VF zone, the shock is delivered. However, in this instance, a slow ventricular tachycardia was induced, detected outside of the VT or VF zone, such that the episode terminates due to the diagnosis of « Slow Rhythm », while the tachycardia continues. We do not know how long the latter persisted. The patient states he remained asymptomatic.

Correct answer - n° 4

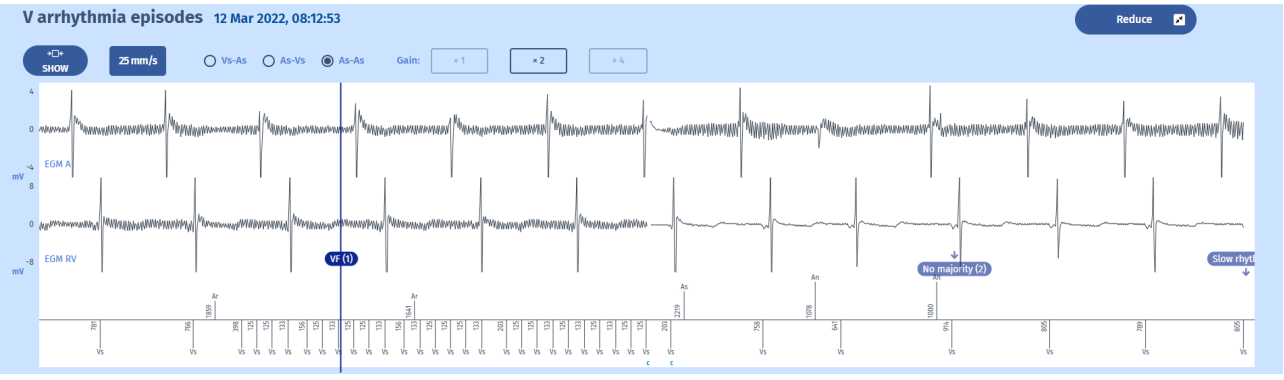
Take-home message

When extrinsic oversensing is suspected, it is imperative to thoroughly analyse the entire EGM in order to characterise the signals as well as perform systematic provocative manoeuvres in concomitance with the analysis of the cardiac signal in real time by the programmer in the "EGM" test screen. The interview of the patient is essential to identify the situation at the origin of this oversensing. The use of the RF communication function facilitates these tests by eliminating the programming head.

Finally, if the phenomenon is observed within the first few days or weeks after implantation, a connection problem should be suspected. However, after several months or years, this latter hypothesis is no longer plausible.

Case 6

Oversensing of signals generated by the 50 Hz line current



This episode corresponds to the sensing of a 50Hz line current. It is noted that the current is mainly sensed by the ventricular lead with signals detected at the limit of the post-ventricular ventricular blanking value, i.e. 125 ms. The atrial channel reveals the occurrence of the same interference, and moreover the sinus signals do not all appear to be detected they are properly managed by relative retriggerable refractory periods of 30 ms since they do not always give rise to markers. The current generates low-amplitude signals and on both leads simultaneously.

A diagnosis of VF is initiated, which triggers the persistence followed by the start of a capacitor charge noted C. This is because the noise management function is automatically disabled (for 15 cycles) as soon as a cycle < 406 ms (and > 190ms) is sensed, in order to improve sensing and give priority to arrhythmia detection. After these 15 cycles, noise management is reactivated, i.e. retriggerable refractory periods of 30 ms + Ventricular sensitivity interaction which suppresses the oversensing on the chain of markers and thus prevents the inappropriate shock from being delivered.

Take-home message

It is essential to determine the origin of the interference in order to avoid inappropriate shock and the inhibition of cardiac pacing if the patient is pacemaker-dependent.

In the event of discovery of this phenomenon after a tele-transmission, an immediate discussion is necessary with the patient to eliminate the source of this interference because, later on, the patient will no longer remember. Of course, a setting adjustment of the device is not possible to hide these interferences.

In addition, the patient should be reminded of the dangers of any therapy that involves the use of electrical current through the body.

By increasing the programmed persistence, the charging of the capacitors could be avoided.

It is necessary to analyse all recorded arrhythmia episodes because, as in this example, the mode switches attributed to interferences during the first follow-up have now become actual atrial arrhythmias in the second follow-up. You must review all stored episodes!

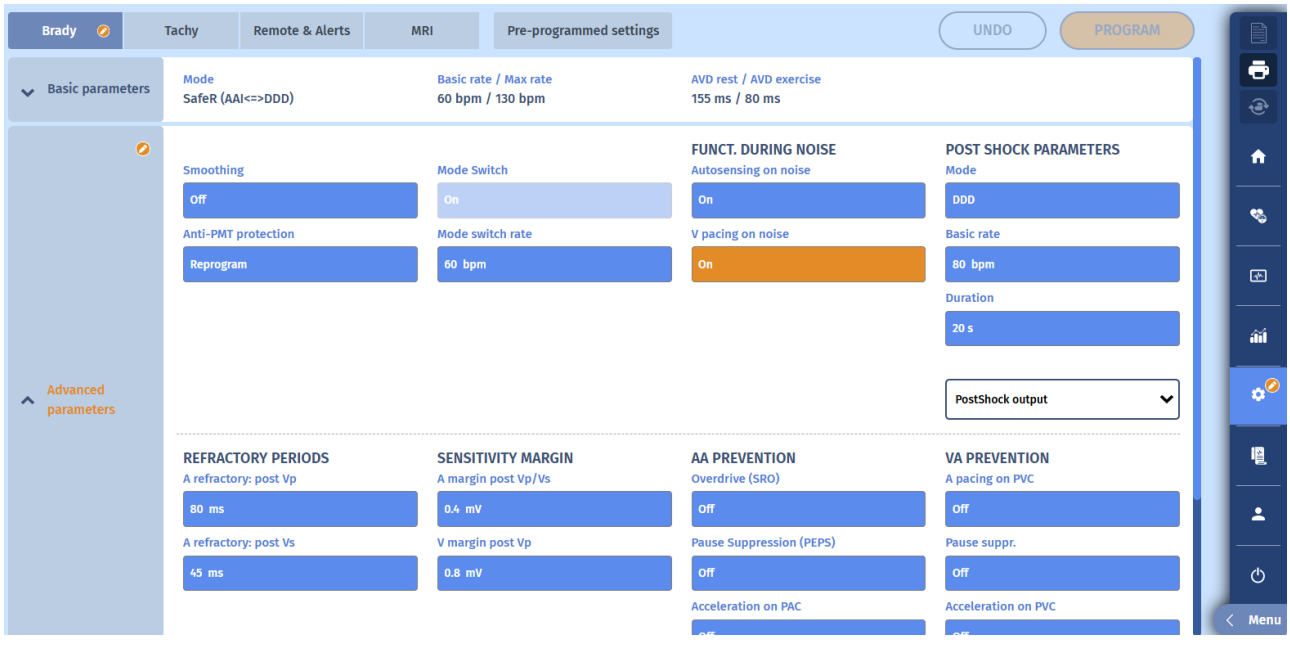
Case 7

Oversensing from the use of a electrocautery knife

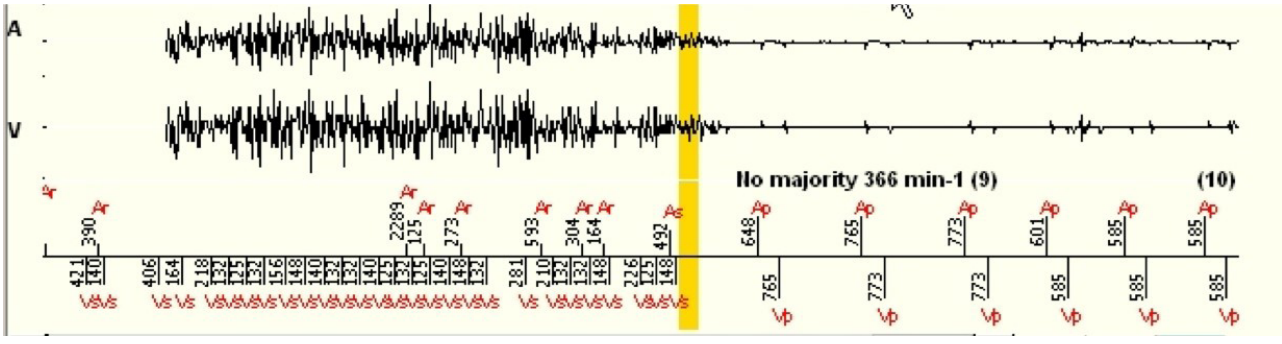
Another form of interference is the current induced by a diathermy knife in the vicinity or not of a defibrillator. The current is detected on all channels, the signals are chaotic, and of variable amplitude.

The same risks are to be feared (inappropriate shock, and inhibition of pacing in device-dependent patients). However, the solution is extremely simple: during the use of the diathermy knife, just apply a magnet next to the defibrillator case which will inhibit both the detection of arrhythmias as well as therapies.

The pacing function is not changed on the latest MicroPort models (Platinium). On previous platforms, pacing was delivered in DDD or VVI mode according to the permanent pacing mode programmed at the magnet rate depending on the state of wear of the battery (96/min at the beginning of life (Beginning Of Service) and 8O/min at the time of replacement (Recommended Replacement Time)). In contrast, for pacemaker-dependent patients only, there is a function that allows pacing when noise (electrical interference with a rate greater than 16 Hz) is detected and properly managed, i.e. masked by the automatic retriggering of refractory periods (30 ms). At the end of the escape interval, if the refractory periods continue to be retriggered, pacing is delivered. This corresponds to functioning in asynchronous mode (risk-free for a pacemaker-dependent patient). The programmed mode is restored as soon as the interference is no longer detected. This function is accessible from the “Settings” screen, “Brady” tab, in the “Advanced Settings” section. After clicking on “Functioning during noise”, it will be necessary to activate the “V pacing on noise”.



Oversensing



Take-home message

1. To avoid the harmful effect of a diathermy knife on the defibrillator, you must apply a magnet next to the device.
2. To regain all functions, simply remove the magnet.
3. In pacing-dependent patients, program the “V Pacing on noise” feature to avoid inhibition during noise
4. The patient must be informed.

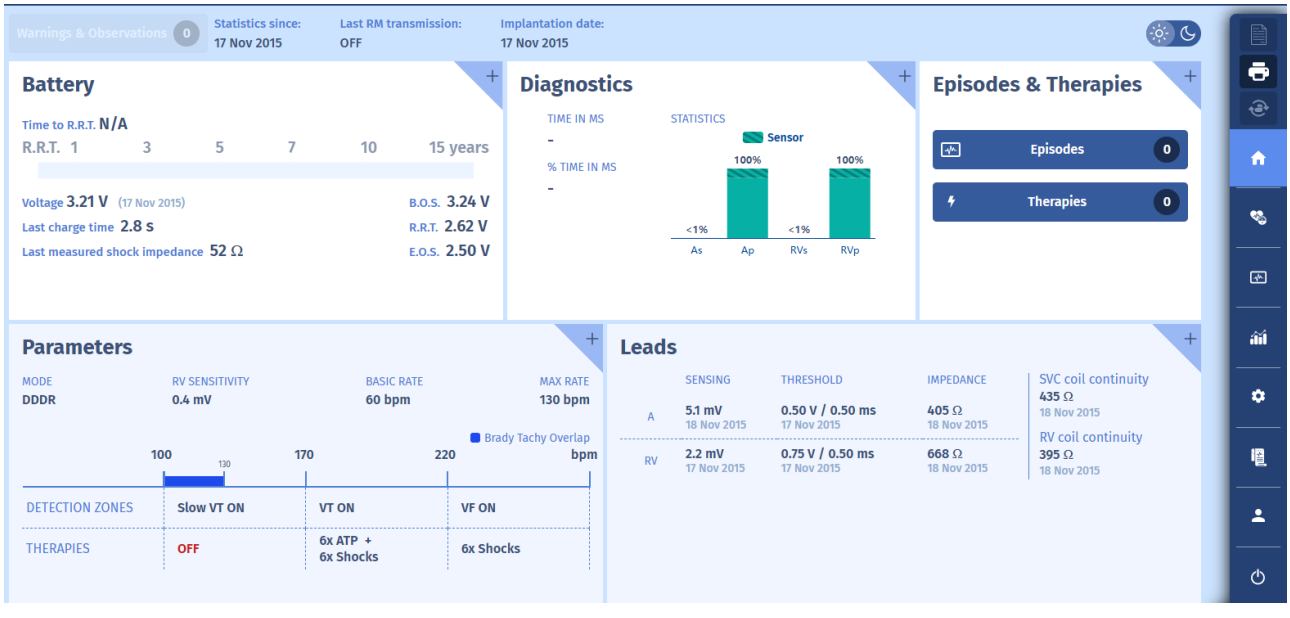
Case 8

An emergency!

Patient

The patient was implanted for primary prevention of obstructive hypertrophic cardiomyopathy (resting gradient: 80 mmHg). He is asymptomatic, but note the sudden death of two of his brothers, one of whom also had OHCM, with ventricular tachycardia bursts, a genetic mutation, and significant septal fibrosis at MRI. The defibrillator is dual-chamber given that the patient is bradycardic under beta-blocker therapy, and in the hope that the DDD pacing from the RV with complete RV capture while maintaining atrial systole will decrease the obstruction in the long term.

A follow-up control was conducted on day 1, and deemed satisfactory.



Are you satisfied with the follow-up control ?

1 No, the shock impedance is too low

2 Yes, completely

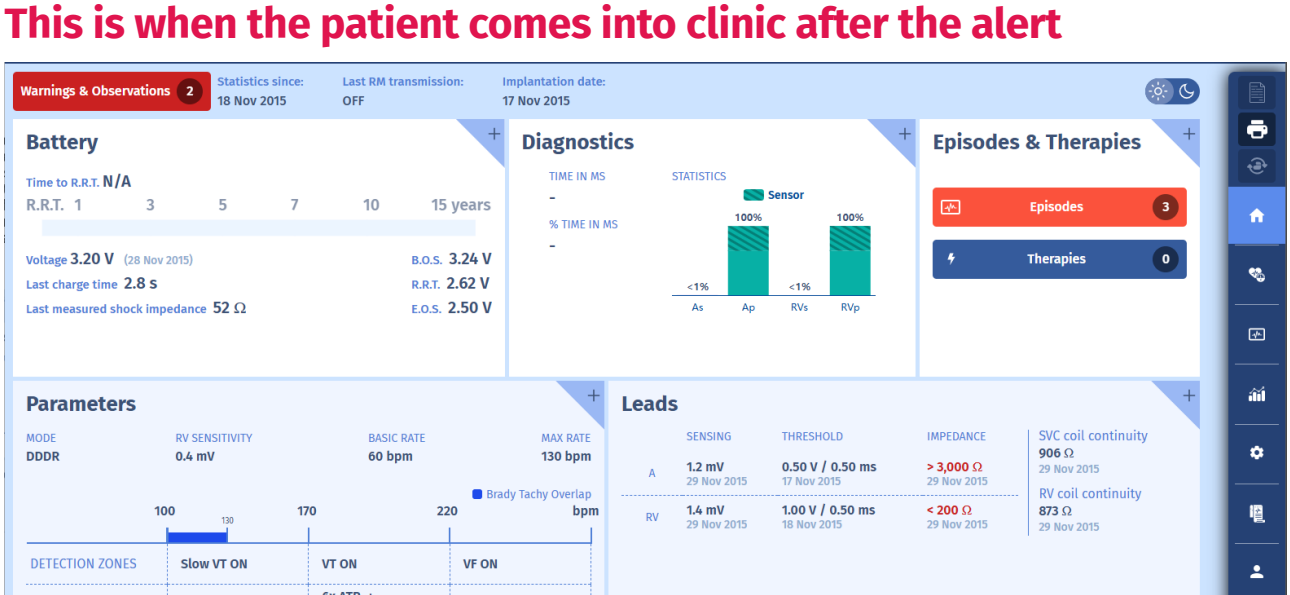
3 No, ventricular sensing is 2.2 mV

4 No, a shock is recorded, which is why a shock impedance value is provided

5 No, I am not satisfied with the impedance values of the shock electrodes

However, two weeks later, a telemedicine alert was transmitted.

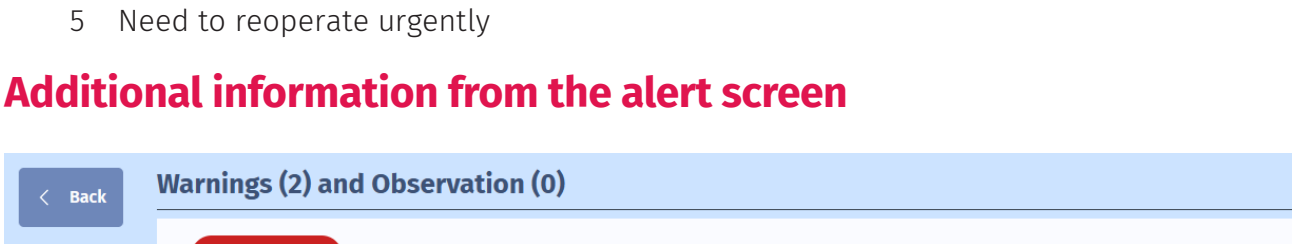
This is when the patient comes into clinic after the alert



What is your opinion (1) ?

1. A nonsustained ventricular fibrillation episode occurred
2. The atrial lead is fractured
3. The ventricular pacing/sensing lead is fractured
4. The shock electrode conductor is fractured
5. Need to reoperate urgently

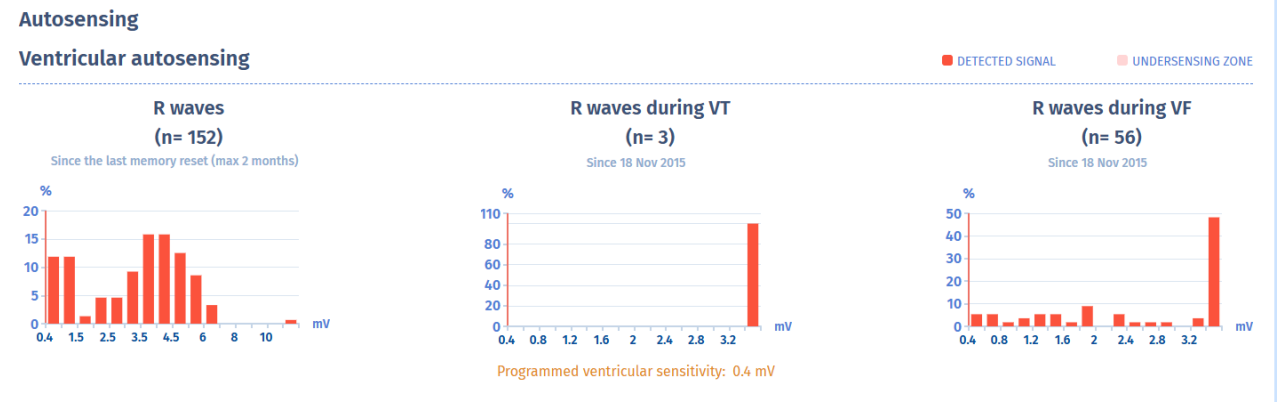
Additional information from the alert screen



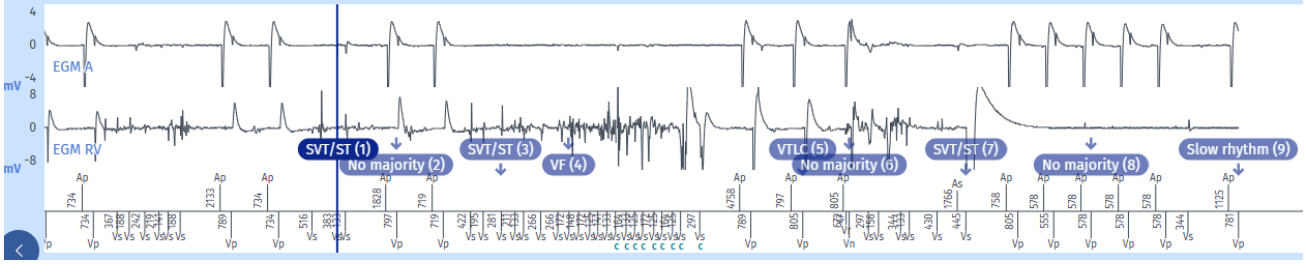
Case 8

Lead sensing and impedance trends

Ventricular signal amplitudes



EGM saved into the memory of the device as «VF»



What is your opinion (2) ?

1 The drop in ventricular impedance is consistent with the increase in atrial impedance and the drop in P wave amplitude

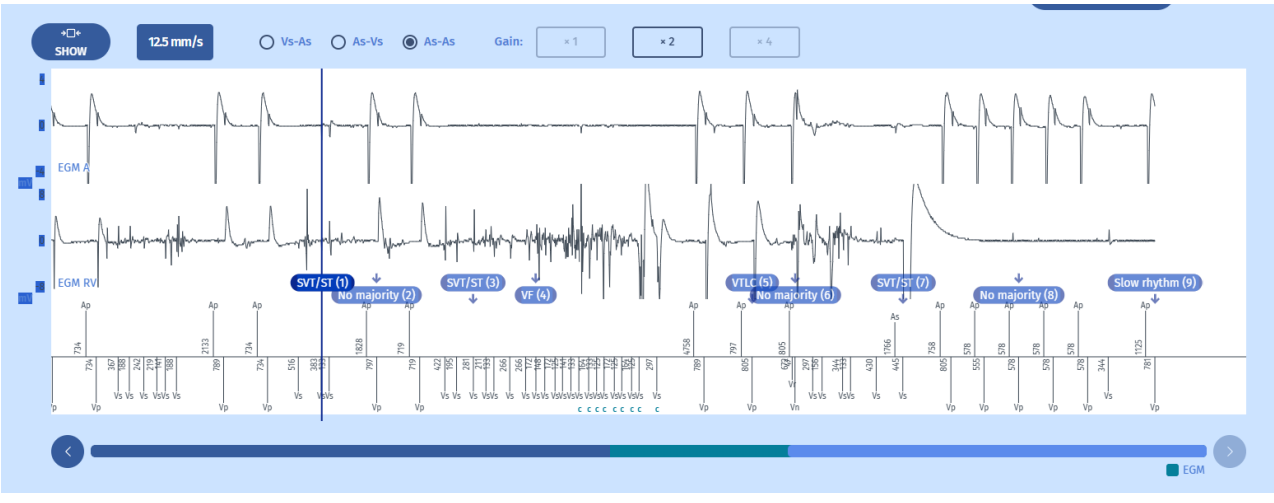
2 Both leads are damaged

3 The device does not sense R-waves since only 152 R waves have been detected

4 The VF episode corresponds to RV lead fracture signals

5 If the artifacts persist, the risk is an inappropriate shock

Episode recorded during the emergency follow-up, after manipulation of the defibrillator case through the skin



Interpretation

1. At the first follow-up control, 24 hours after defibrillator placement, ventricular sensing is low at 2.2 mV. This parameter must be re-assessed after a few days, although if the detection value remains very low or decreases again, it will be necessary to discuss the repositioning of the ventricular lead. A minimum value of 5 mV is allowed for the amplitude of the R wave at the time of lead placement.
2. The teletransmission initiated an alert due to abnormalities in measured lead impedances. The atrial impedance exceeded the upper limit of 3000 Ohm, signalling a fractured conductor, and the ventricular lead exceeded the lower limit of 200 Ohm, signalling an internal insulation fracture.
3. These anomalies occurred at the same time on both leads and suggest a mechanical aggression on the two leads, probably related to a traumatic lead fixation given their occurrence soon after the installation of the device.
4. The problem cannot be a connection fault at the level of the defibrillator case, since in this instance, the impedances of the two leads would be beyond the maximum values.
5. Only 152 R-waves were sensed since the defibrillator is constantly pacing. R-waves in VF and

VT are fracture artifacts and can have a very large amplitude.

6. These artifacts occurring in runs lead to false VF diagnoses, which induces capacitor charges.
7. It is necessary to reoperate urgently and change the two leads. In the meantime, the therapies are inactivated.
8. The handling of the material through the skin « finished off » the leads. The last electrogram no longer reveals any physiological signal, and the artifacts saturate the atrial channel.

Correct answers:

Follow-up : 3

Opinion n°1 : 2 and 5

Opinion n°2 : 1, 2, 4 and 5

Comments

- The observed lead fracture potentials call for a rapid reintervention since the time lapse between the first electrical signs of fracture (such as an out-of-norm impedance and/or aberrant, non-physiological and very fast ventricular signals such as those of our example), and complete fracture and/or triggering of shocks can be very short.
- For the defibrillator, other than the placing of a magnet next to the defibrillator case, the risk is an inappropriate, repetitive and uncontrollable shock, which must lead to an urgent consultation; for the pacemaker, the risk is the inhibition of cardiac pacing and the resulting asystole in a device-dependent patient.
- In both cases, the situation is very dangerous.
- Should the reoperation involve the extraction of the lead? The answer is difficult. Lead extraction is only recommended in instances of infection of the material. In the absence of infection, extraction adds its own risks (vein tearing, cardiac perforation with tamponade, tricuspid valve tear with concurrent major cardiac insufficiency, etc.) that can lead to immediate and precarious restorative cardiac surgery. On the other hand, however, the now-surplus material no longer hinders the venous circuit or the cardiac chambers. Therefore? … If the lead has recently been placed (less than two years), it can be extracted and indeed be removed by simple unscrewing and careful traction. Beyond this timeframe, our tendency is not to extract the lead, and to add the new lead, making sure that the two shock electrodes do not touch each other so as to avoid that in the event of shock therapy, some of the energy will be diverted to the abandoned lead.

Message

A defibrillation lead fracture necessitates an urgent response: a reoperation for a change of material.

Chapter 5 : Remote monitoring

Transmission 1

Shocks disabled

You receive the following transmission:

MicroPort CRM

PLATINIUM SonR CRT-D 1811

Alert report **Sent: 28-Nov-2021 - 02:55**

SHOCK DISABLED

THERAPIES	
Tachy Therapies	None
Arrhythmia history	No Events
% biV pacing	100 %

DEVICE MANAGEMENT	
Battery	OK
Leads	OK
Coils	YELLOW

WARNINGS

- **[A30] SHOCK OFF 27/Nov/2021.**

Observations

- No observation detected

THERAPIES SUMMARY [Since last report: 20-Nov-2021]

TACHY THERAPIES AND EPISODES

	Slow VT	VT	FVT+VF	SVT->VT	Total		SVT/ST
Episodes	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Treated)	0
ATP	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
Shocks	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
Shocks 42J	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	

BRADY THERAPIES

As	52 %	Vs	0 %
Ap	48 %	Vp	100 %
PMT	0		
ModeSwitch	0		
Time in MS	0s		

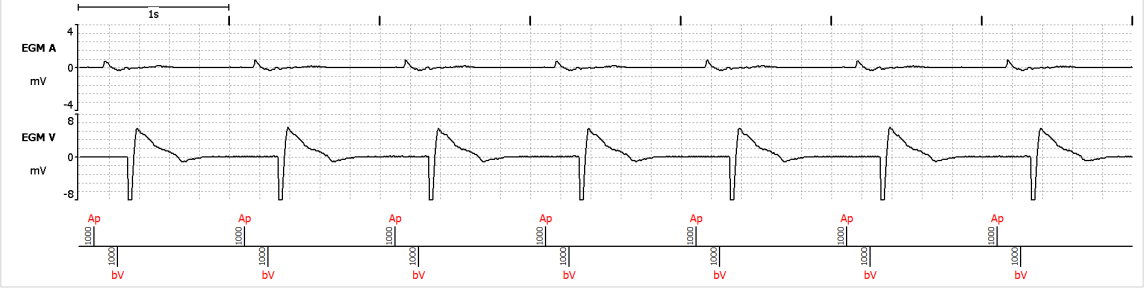
DEVICE MANAGEMENT SUMMARY

BATTERY Voltage **2.92V** Time to RRT

R.R.T. 1 3 5 7 9 12 Years

		Impedance (ohms)	Detection (mV)	Threshold (V @ ms)	Output (V @ ms)
LEADS	A	543	4.9	0.50 0.35	2.00 0.35
	RV	996	13.0	3.50 0.50	5.00 0.50
	LV	748		1.25 0.35	2.50 0.35
COILS	RV Coil	628			
	SVC Coil	642			

REAL TIME EGM



TACHY THERAPIES AND EPISODES

BTO 150 185 230 255

Zones	Slow VT ON	VT ON	Fast VT + VF ON	SVT->VT	Total		SVT/ST
Episodes	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Treated)	0
ATP	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
Shocks	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
42J Shock	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	

Detection	PARAD+	PARAD+	Rate + Stability
ATP 1	Off	Off	Off
ATP 2	Off	Off	
Shock 1	Off	Off	Off
Shock 2	Off	Off	Off
42J Shock	Off	Off	Off

Last shock	-
Impedance (ohms)	-
Charge time (s)	-
Energy (J) prog./deliv.	-/-
Total shocks/charges since implant	0/3
Deleterious ATP	0
Non-sustained episodes	0

VENTRICULAR ARRHYTHMIA HISTORY

No new episodes detected since last follow-up

ATRIAL ARRHYTHMIA HISTORY

No new episodes detected since last follow-up

Which statement is correct?

1 The shocks are disabled in the VT zone

2 The shocks are disabled in the VF zone

3 The shocks are disabled in all tachycardia zones

Explications

In contemporary ICDs with continuous remote monitoring, deactivated therapies will be sent as an alert during the next transmission. The therapies may have been deactivated, for example before a surgical procedure in order to prevent inappropriate therapies (oversensing of noise). The healthcare professional may have inadvertently failed to reactivate the therapies after the procedure. The remote monitoring system hereby acts as a safeguard, a rapid reminder to switch back on the therapies. The remote monitoring clinic may act by requesting the patient to come into clinic to re-activate the therapies. Without remote monitoring, the patient is often not seen in-office for many months, exposing the patient to ventricular arrhythmias not treated by ICD therapies. In this case, the therapies were de-activated just before an MRI. Thanks to the alert received the following day, the patient could be reprogrammed correctly within a short time span.

Of course, in certain cases, it may have been decided that the therapies remain de-activated. This most often occurs in the context of advanced comorbidities associated with a significant reduction in life expectancy. During this shared decision-making process, it is important to note clearly in the hospital records that therapies have been de-activated intentionally.

When the therapies are left deactivated on purpose, in addition to keeping an adequate medical record, the remote monitoring alert “shock disabled” should be switched off.

Transmission 2

ATP delivered

You receive the following transmission:

MicroPort CRM

PLATINIUM DR 1540

Implant date: 21-Jun-2019

Alert report **Sent: 15-Jul-2021 - 10:32**

SEVERAL ALERTS RAISED

THERAPIES	
Tachy Therapies	Delivered
Arrhythmia history	Events
% V Sensing	99 %

DEVICE MANAGEMENT	
Battery	OK
Leads	OK
Coils	OK

WARNINGS

- No warning detected

Observations

- **[A28] AT/AF Daily Burden higher than 30 min: 1h 48min, 12/Jul/2021.**
- **[A41] ATP delivered on 14/Jul/2021.**
- Time spent in AAI mode: 99 %.Total of the ventricular pacing: 1 %
- Atrial arrhythmia number = 4
- Total time in Mode switch = 02h 26min (0.7%)
- The ventricular mean rate in mode switch is 65 min-1
- Number of treated arrhythmia episodes: 1

THERAPIES SUMMARY [Since last report: 30-Jun-2021]

TACHY THERAPIES AND EPISODES

	Slow VT	VT	FVT+VF	SVT->VT	Total		SVT/ST
Episodes	0(0)	1(1)	0(0)	0(0)	1(1)	ALL (Treated)	52
ATP	0(0)	1(1)	0(0)	0(0)	1(1)	ALL (Success)	
Shocks	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
Shocks 42J	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	

BRADY THERAPIES

As	1 %	Vs	99 %
Ap	98 %	Vp	1 %
PMT	0		
ModeSwitch	4		
Time in MS	2h 26min		

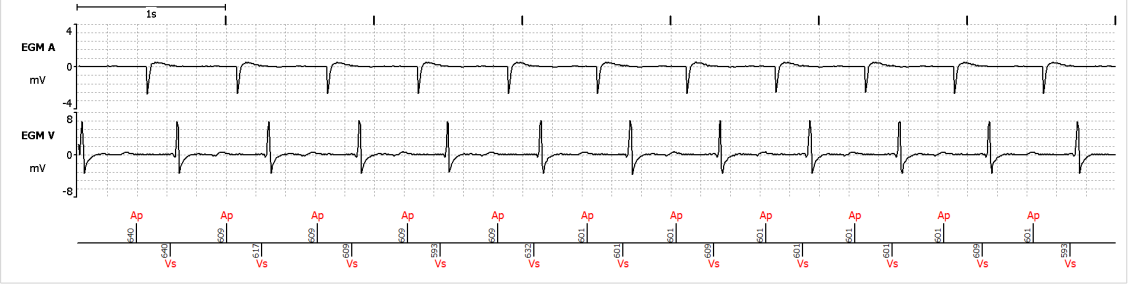
DEVICE MANAGEMENT SUMMARY

BATTERY Voltage **2.99V** Time to RRT

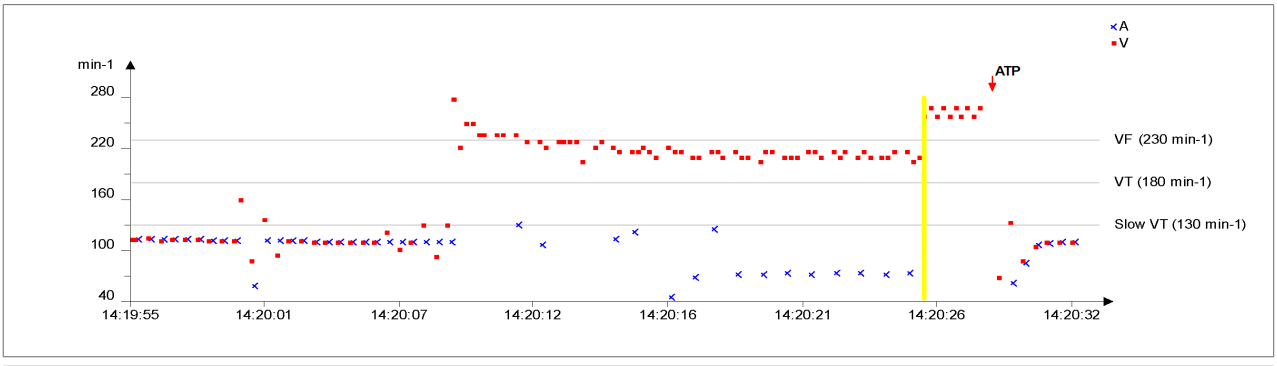
R.R.T. 1 3 5 7 **10** **15 Years**

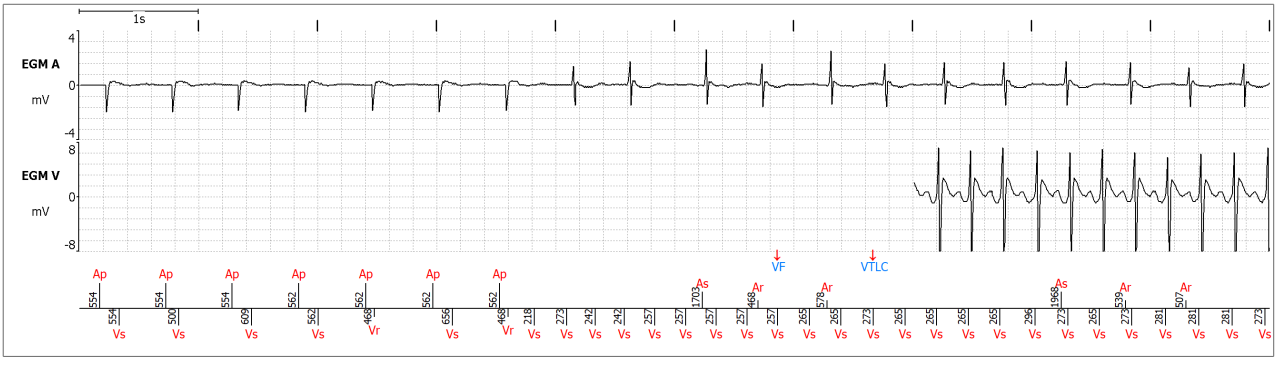
		Impedance (ohms)	Detection (mV)	Threshold (V @ ms)	Output (V @ ms)
LEADS	A	897	1.6	0.50 0.75	1.50 0.75
	V	340	11.0	1.00 0.35	2.00 0.35
COILS	RV Coil	269			

REAL TIME EGM

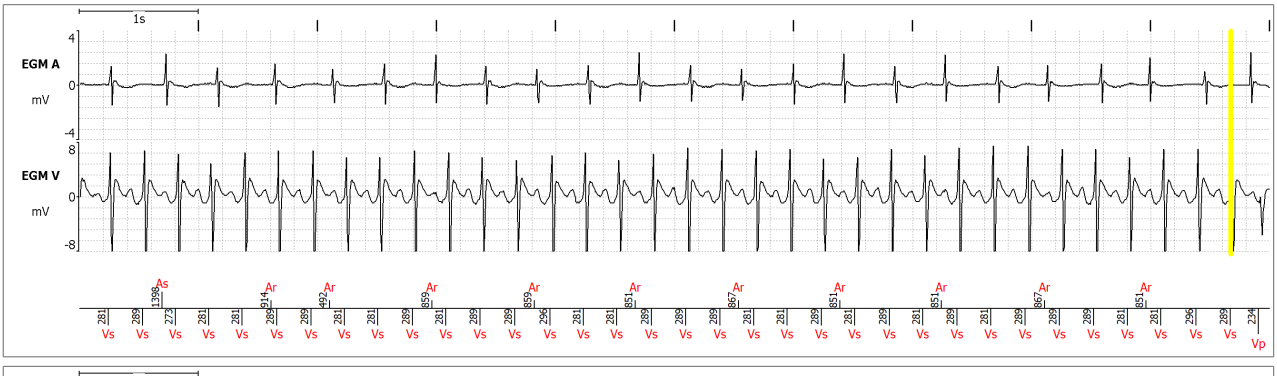


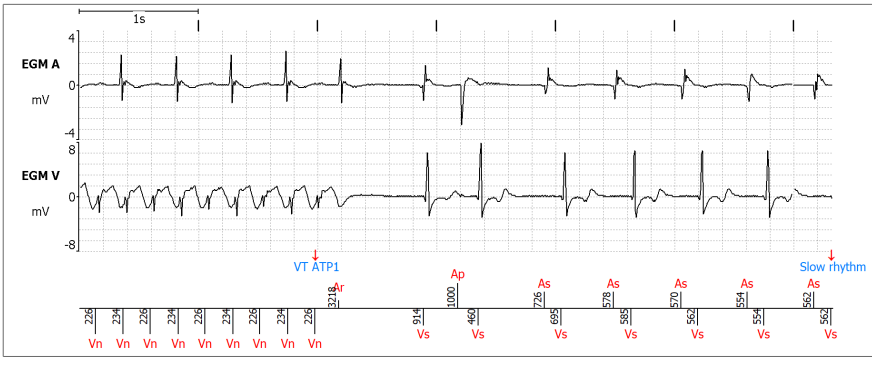
Rhythm: VT Duration: 6s TREATED: ATP





Rhythm: VT Duration: 6s TREATED: ATP





Transmission 2

Which of the following statements is correct?

1 As the overview screen suggests, this patient has atrial arrhythmias, not ventricular arrhythmias.

2 The VT is correctly sensed in the VT zone, which is programmed according to the guidelines

3 The VT is correctly sensed in the VT zone, but the detection is longer than usual.

4 It is actually a VF which is initially correctly labeled as VF, but then wrongfully labeled as VT

Explications

The transmission includes an episode showing a ventricular tachycardia at around 210 beats per minute. The sensing of ventricular events is correct and there are no signs of noise artifacts. After a few cycles in the VF zone, the VT stabilizes in the VT zone with correct classification (VTLC marker). However, it takes over ten seconds for the VT to be treated, as the persistence counter is programmed to 50 cycles, instead of the recommended 20 or 30 cycles. Then the ATP terminates the VT with success.

Next steps

Treated ventricular arrhythmias often need clinical action. After making sure the ICD and leads function properly, the clinical history of the patient should be collected to be able to understand why programming is different from the recommendations. In this case, it is because this young patient (50 years of age) implanted due to a dilated cardiomyopathy is known to have asymptomatic nonsustained VTs, even at high rates. It was previously decided to program longer persistence counters, in order to allow for the VT to self-terminate, and decrease the risk of deleterious ATPs (bursts or ramps which accelerate the VT into faster VT or VF). It is however recommended to call the patient to enquire whether the episode was symptomatic (especially if loss of consciousness occurred) which may require reprogramming the ICD.

The persistence counter is a compromise between the willingness to treat ventricular arrhythmia before it causes symptoms or accelerates into a more dangerous arrhythmia, and the willingness to reduce unnecessary therapys. It is important to note that successful ATP/shock does not mean that is was needed, as many ventricular arrhythmias self-terminate. This is a limitation of many (older) ICD studies. The ideal persistence is probably not to be defined for all patients, but rather at patient level, based on symptoms during the arrhythmias and the occurrence of non-sustained VTs.

Correct answer: 3

Transmission 3

Shocks delivered

You receive the following transmission. While two arrhythmias have occured, only the VF episode is shown.

MicroPort CRM

PLATINIUM DR 1510

Implant date: 01-Sep-2021

Alert report **Sent: 24-Sep-2023 - 23:35**

SEVERAL ALERTS RAISED

THERAPIES	
Tachy Therapies	Delivered
Arrhythmia history	Events
% V Sensing	100 %

DEVICE MANAGEMENT	
Battery	OK
Leads	OK
Coils	OK

WARNINGS

- No warning detected

Observations

- **[A41] ATP delivered on 24/Sep/2023.**
- **[A31] Shocks delivered, 24/Sep/2023.**
- Time spent in AAI mode: 100 %.Total of the ventricular pacing: 0 %
- Number of treated arrhythmia episodes: 2

THERAPIES SUMMARY

[Since last report: 07-Sep-2023]

TACHY THERAPIES AND EPISODES

	Slow VT	VT	FVT+VF	SVT->VT	Total		SVT/ST
Episodes	0(0)	0(0)	2(2)	0(0)	2(2)	ALL (Treated)	0
ATP	0(0)	0(0)	1(1)	0(0)	1(1)	ALL (Success)	
Shocks	0(0)	0(0)	1(1)	0(0)	1(1)	ALL (Success)	
Shocks 42J	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	

BRADY THERAPIES

As	94 %	Vs	100 %
Ap	1 %	Vp	0 %
PMT	0		
ModeSwitch	0		
Time in MS	0s		

DEVICE MANAGEMENT SUMMARY

Alert not available

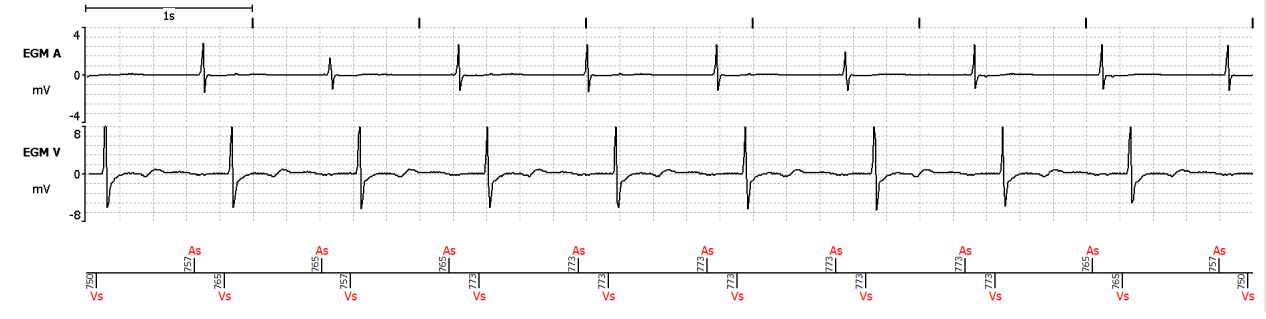
BATTERY

Voltage **3.03V** Time to RRT

R.R.T. 1 3 5 7 **10** **15 Years**

		Impedance (ohms)	Detection (mV)	Threshold (V @ ms)	Output (V @ ms)
LEADS	A	728	4.0	1.00 0.35	2.50 0.35
	V	455	15.4	1.00 0.35	2.50 0.35
COILS	RV Coil	376			

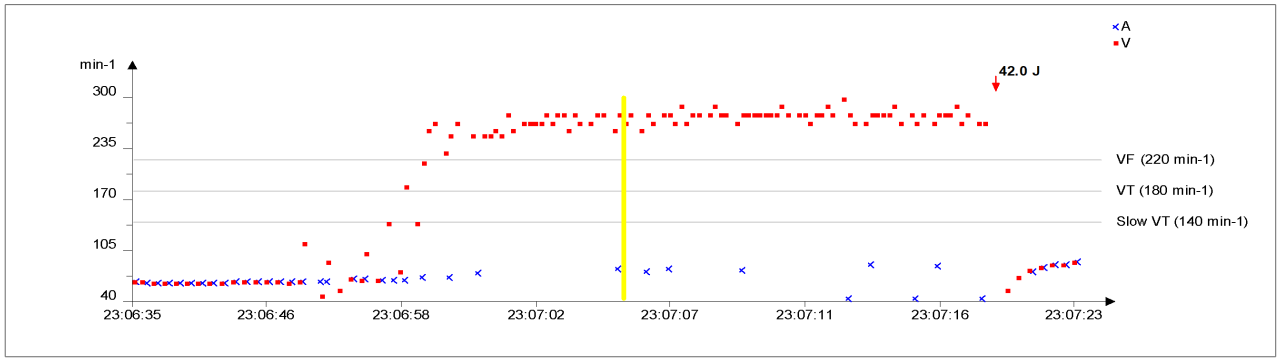
REAL TIME EGM

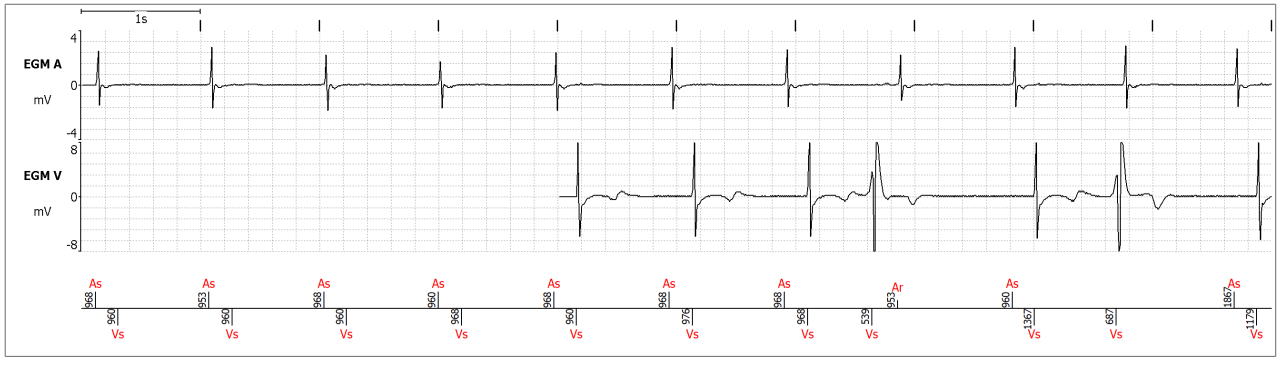


Transmission 3

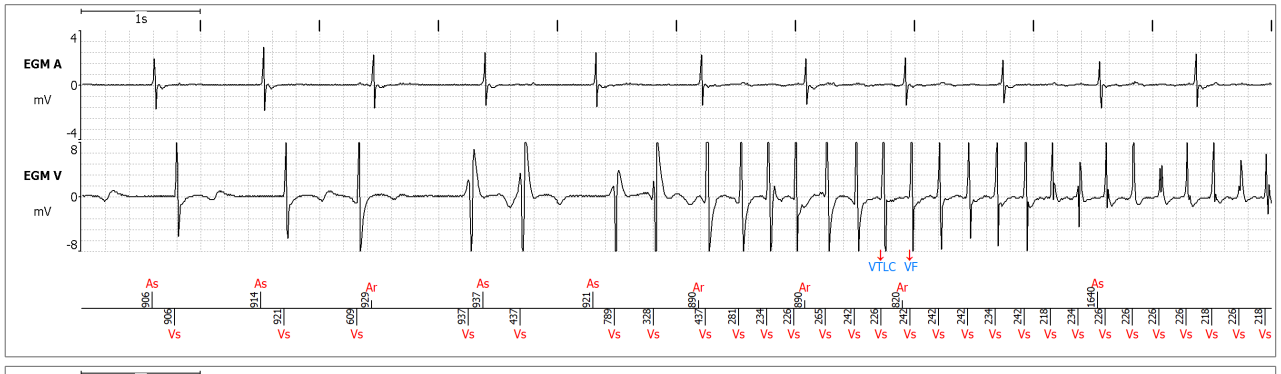
Bien que deux arythmies se soient produites, seul l'épisode de FV est montré.

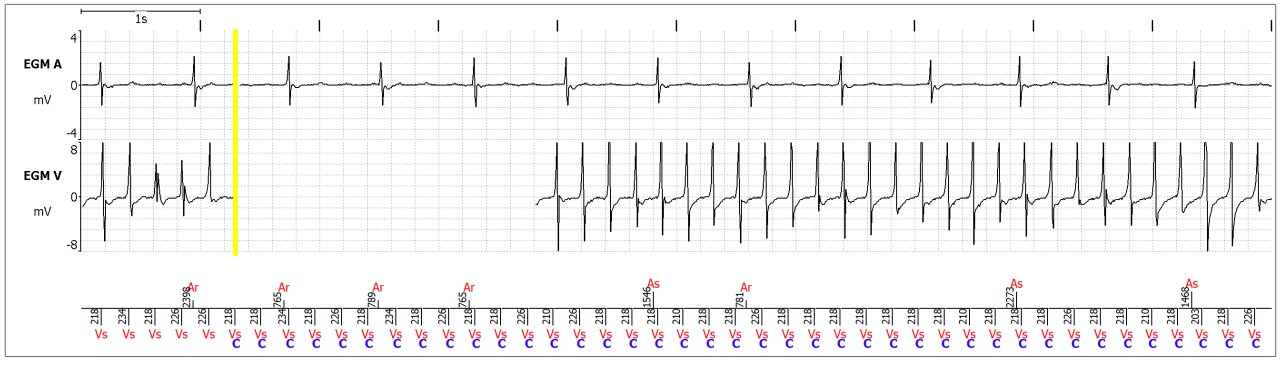
Rhythm: VF Duration: 18s TREATED: SHOCK 1 x 42.0J

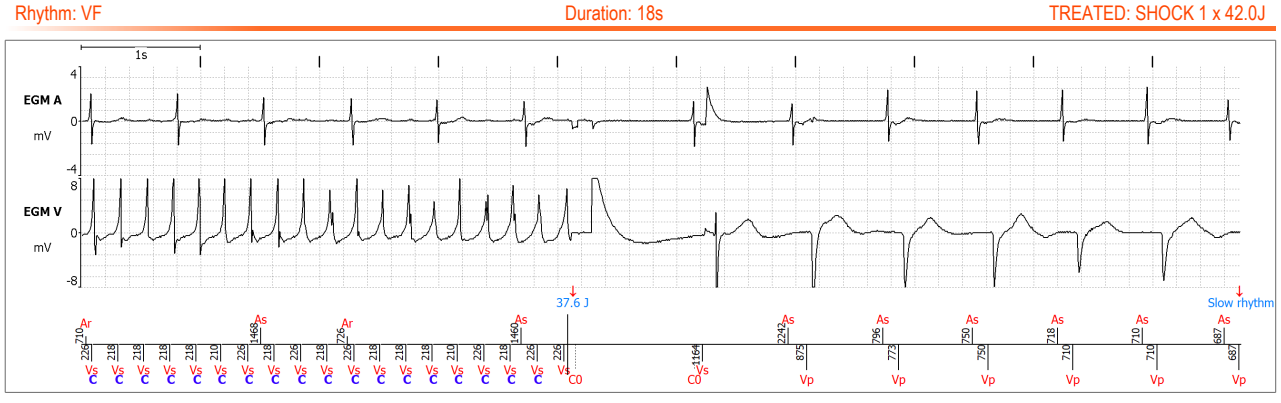




Rhythm: VF Duration: 18s TREATED: SHOCK 1 x 42.0J







Why was there no ATP delivered in the VF episode?

1 Because the ventricular rhythm is too fast, it is over the VF rate limit (255 bpm)

2 Because the ventricular rhythm is too irregular, it does not meet the stability threshold

3 Because it's not a ventricular arrhythmia, but something else

Explications

This patient has suffered from a VF episode which is shown at the end of the tansmission. According to the therapies summary, the episode was treated with success by a shock.

When looking at the episode, we see initial sinus rhythm with ventricular extrasystole. There is an increase in ventricular systoles with a sudden onset of a rapid ventricular arrythmia with cycles as short as 218 ms on the first strip. There are no signs of noise artifacts or of atrial arrhythmia. The VF majority is reached (blue VF marker) and the persistence counter starts. When the persistence counter is filled and the VF zone criteria are still met, the capacitors start to charge for the shock.

There is no ATP delivered as the ventricular events with a rate of around 270 bpm surpasses the FVT zone which is between 220 – 255 beats per minute. This is shown by the yellow marker area in the figure above. At the end of the charge, a 37.6 J shock is delivered which successfully terminates the arrhythmia. The first cycle following the shock is ignored and after 6 cycles slower than the slowest VT zone, the episode is terminated (blue marker Slow rhythm).

Next steps

When therapies have been delivered by an ICD, we need to make sure that the ICD is in good condition. The shock impedance is within range (66 Ohms), the lead senses properly (15.4 mV), the pacing impedance is normal (455 Ohms) and the real time EGM looks good (atrial and ventricular sensing). Most often, there are clinical consequences. The patient will be called into hospital respecting the driving restrictions imposed by national law. Cardiologists attempt to identify a possible trigger for the arrhythmia, such as ischemia, metabolic changes, changes in medication or co-existing disease. Often, the arrhythmia is caused by the underlying cardiac disease for which the patient was implanted with an ICD. In this case, cardiologists will evaluate the disease progression and attempt to optimize therapy. Patients with treated episodes will often be treated with anti-arrhythmia and/or ventricular ablation.

In this case, the patient was implanted because of ischemic heart disease and repeated coronoangiography revealed a new coronary lesion in the mainstem for which he was treated successfully with a stent.

Correct answer: 1

Transmission 4

Shock delivered

You receive the following transmission:

MicroPort CRM

GALI 4LV SonR CRT-D 2844

Implant date: 06-Apr-2022

Alert report **Sent: 10-Nov-2023 - 23:45**

SHOCK DELIVERED

THERAPIES	
Tachy Therapies	Delivered
Arrhythmia history	Events
% biV pacing	100 %

DEVICE MANAGEMENT	
Battery	OK
Leads	OK
Coils	OK

WARNINGS

- No warning detected

Observations

- **[A31] Shocks delivered, 9/Nov/2023.**
- [A28] AT/AF Daily Burden higher than 30 min: 59min 56s, 25/Sep/2023.
- Total time in Mode switch = 14min 32s (0.0%)
- In Fallback Mode Switch, the ventricular rate is paced at 98 %
- The ventricular mean rate in mode switch is 76 min-1
- Number of treated arrhythmia episodes: 1

THERAPIES SUMMARY [Since last report: 28-Sep-2023]

TACHY THERAPIES AND EPISODES

	Slow VT	VT	FVT+VF	SVT->VT	Total		SVT/ST
Episodes	0(0)	0(0)	1(1)	0(0)	1(1)	ALL (Treated)	0
ATP	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
Shocks	0(0)	0(0)	1(1)	0(0)	1(1)	ALL (Success)	
Shocks 42J	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	

BRADY THERAPIES

As	88 %	Vs	0 %
Ap	11 %	Vp	100 %
PMT	0		
ModeSwitch	7		
Time in MS	14min 32s		

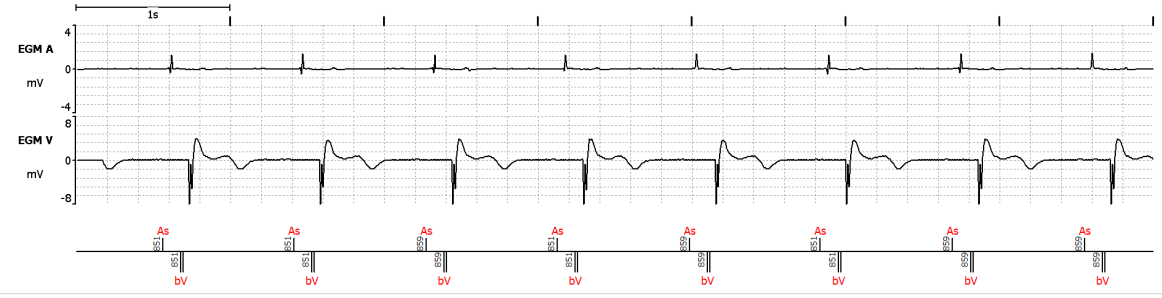
DEVICE MANAGEMENT SUMMARY Alert not available

BATTERY Voltage **2.91V** Time to RRT

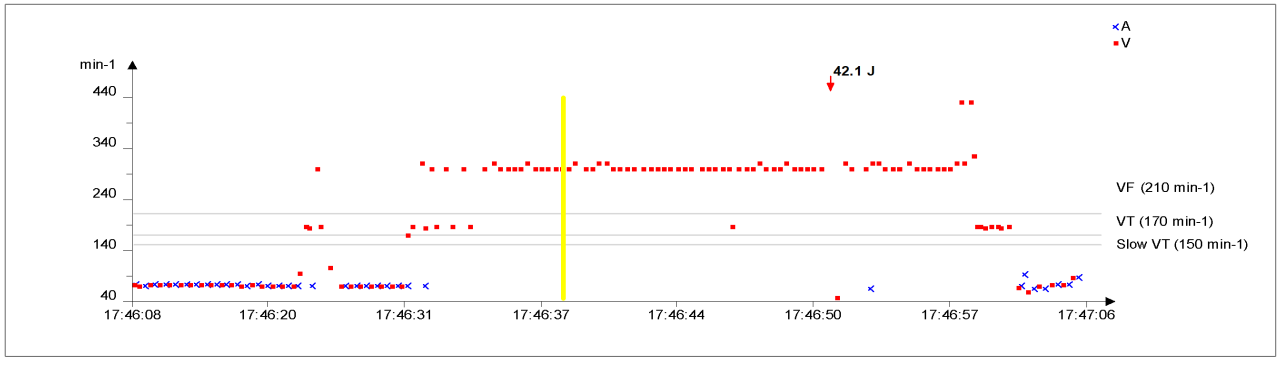
R.R.T. 1 3 5 7 9 12 Years

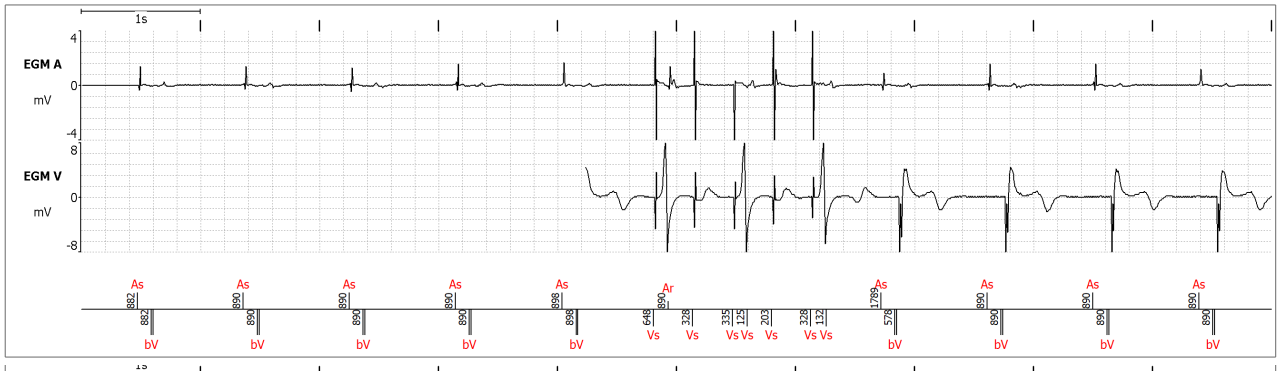
		Impedance (ohms)	Detection (mV)	Threshold (V @ ms)	Output (V @ ms)
LEADS	A	369	2.5	0.75 0.35	2.00 0.35
	RV	322	13.0	1.25 0.35	2.50 0.35
	LV	1053		2.25 0.35	2.75 0.35
COILS	RV Coil	265			

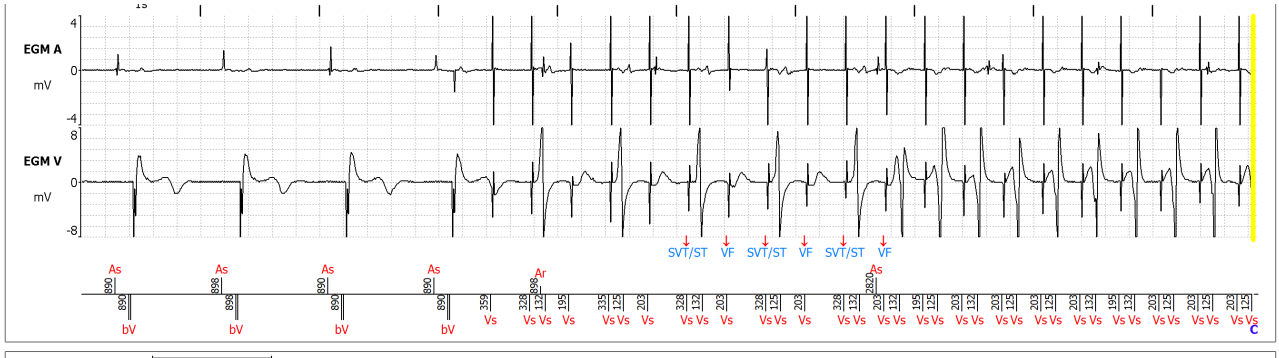
REAL TIME EGM

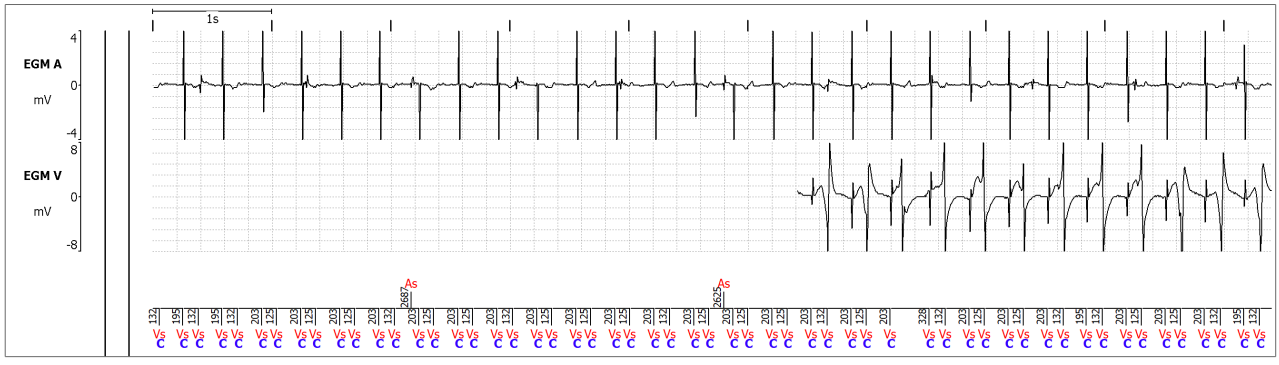


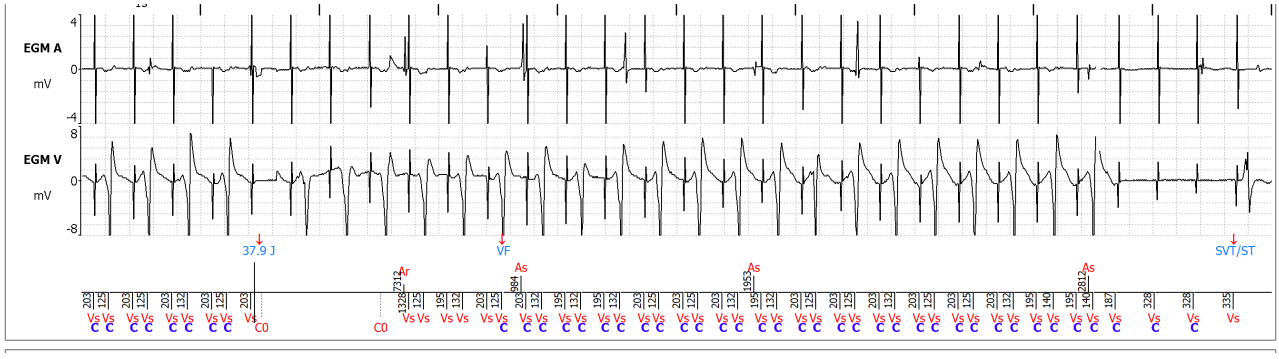
Rhythm: VF | Duration: 28s | TREATED: SHOCK 1 x 42.1J











Transmission 4

Which statement is correct?

1 Shock delivered because of ventricular fibrillation

2 Shock delivered because of oversensing of lead noise caused by RV lead dysfunction

3 Shock delivered because of oversensing of lead noise caused by EMI (electromagnetic interference)

4 Shock delivered because of oversensing of something else

Explications

The patient had a single episode in the VT/VF zone, an episode with the VF label and treated by a shock, which was delivered with success according to the ICD. When we look at the episode, we do not see the occurrence of a typical ventricular arrhythmia, but rather the alternance of very narrow noise artifacts (on both RV and atrial channels) followed by what looks like true ventricular events. They are in fact pacing artifacts (not generated by the ICD but by an external source) followed by ventricular capture. Note that some of the pacing spikes are not followed by ventricular events due to intermittent loss of capture. In case of intermittent loss of capture, only the pacing spikes are oversensed. This triggers the VT majority which is met (6 out of 8 ventricular intervals are in the VT zone) but as it is considered unstable, the label is SVT/ST. When all pacing spikes are followed by R waves, the double counting is persistent which fills the VF majority (6 out of 8) and we observe the VF label. After this VF label, the VF persistence is filled (20 events in the VF zone) and the charge begins (blue C). Throughout the charge, the oversensing (double counting) continues and the shock is delivered. As expected, it does not stop the oversensing as it is caused by something external. After a post-shock blanking of one second, the oversensing begins again with double-counting of ventricular rate (spike + R-wave) and the VF counter is filled again. There is no persistence counter for redetection, so the second charge begins. During the second charge, the oversensing decreases (due to loss of capture) and stops (due to termination of pacing by external source). The VF majority is lost and the charge is therefore stopped.

Next steps

When receiving an episode which shows pacing spikes not caused by the implanted device, medical records need to be examined to discover the source of the noise. In this case, the external pacing spikes were caused by rapid ventricular pacing during a transcatheter aortic valve implantation (TAVI/TAVR procedure). The ventricle is rapidly paced for a few seconds to prevent it from expelling the freshly implanted valve. As the TAVI procedure is becoming more and more common, these types of episodes are becoming quite frequent. Other sources of external pacing may be due to pacing maneuvres during ablation procedures or co-implants (like a leadless pacemaker). Most often these episodes are received only a few days later, as most patients do not have the remote monitoring transmitters in their room during hospitalisation. Also in this case, the VF episode was received 4 days after the event.

The device is functioning properly with correct sensing and pacing. No changes are needed in programming after receiving the alert. However, the medical team responsible for the intervention, which caused the inappropriate shock, should have disabled the therapies in this patient implanted with an ICD. The remote monitoring alert offers an opportunity to educate the colleagues performing TAVI procedures, and remember them to always disable therapies in ICD patients.

Transmission 5

Atrial lead impedance

You receive the following transmission

MicroPort CRM

PLATINIUM DR 1510

Follow up report

THERAPIES	
Tachy Therapies	None
Arrhythmia history	Events
% V Sensing	98 %

DEVICE MANAGEMENT	
Battery	OK
Leads	RED
Coils	OK

WARNINGS

- [A7] Atrial lead impedance > 2000 ohms: 2405, 2/Feb/2021, 3 Day Max Criterion.

Observations

- [A41] ATP delivered on 18/Dec/2020.
- Time spent in AAI mode: 97 %.Total of the ventricular pacing: 2 %
- Atrial arrhythmia number = 2
- Total time in Mode switch = 01min 03s (0.0%)
- In Fallback Mode Switch, the ventricular rate is paced at 83 %
- The ventricular mean rate in mode switch is 81 min-1

THERAPIES SUMMARY [Since last report: 19-Dec-2020]

TACHY THERAPIES AND EPISODES

	Slow VT	VT	FVT+VF	SVT->VT	Total		SVT/ST
Episodes	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Treated)	0
ATP	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
Shocks	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
Shocks 42J	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	

BRADY THERAPIES

As	16 %	Vs	98 %
Ap	84 %	Vp	2 %
PMT	0		
ModeSwitch	2		
Time in MS	1min 3s		

DEVICE MANAGEMENT SUMMARY

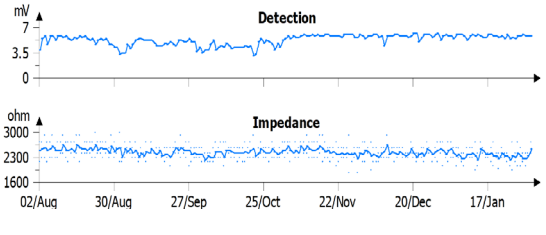
BATTERY Voltage **2.97V** Time to RRT

		Impedance (ohms)	Detection (mV)	Threshold (V @ ms)	Output (V @ ms)
LEADS	A	2403	5.6	3.00 0.35	4.50 0.35
	V	924	15.4	1.25 0.35	2.50 0.35
COILS	RV Coil	934			

DEVICE MANAGEMENT

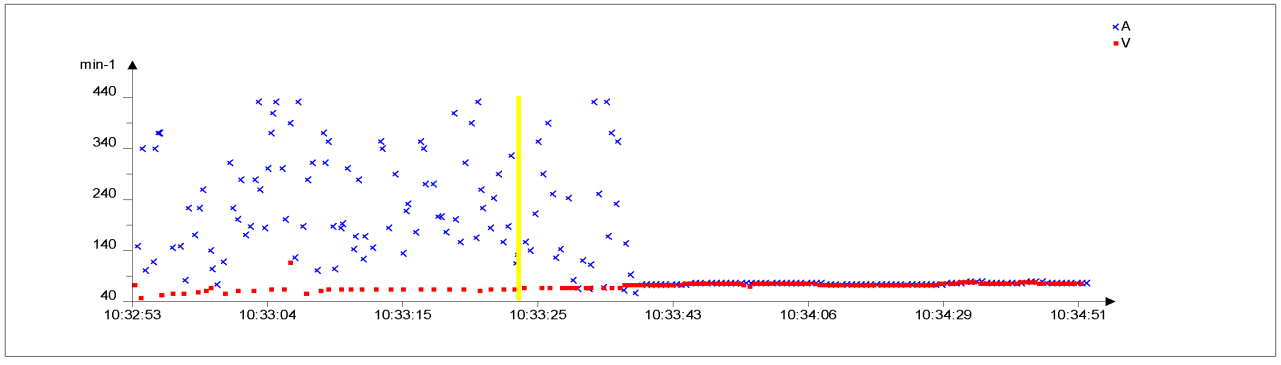
ATRIAL LEAD

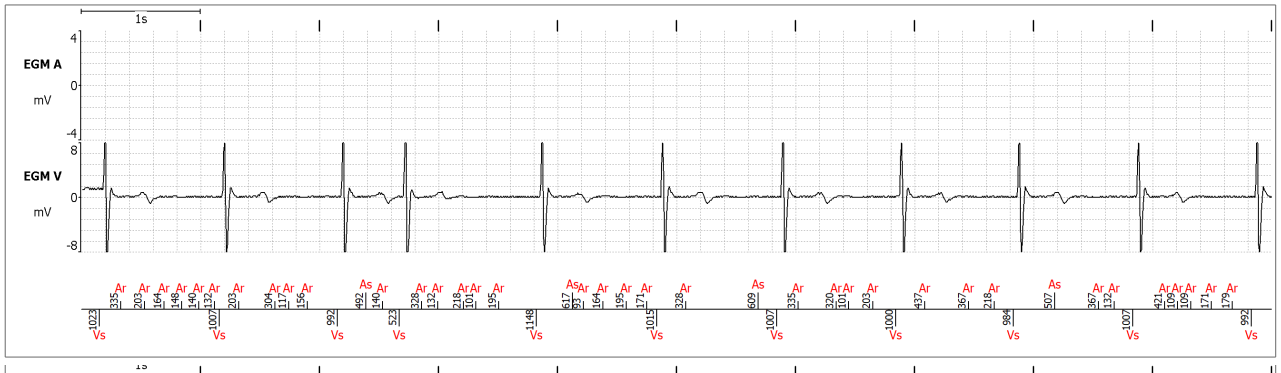
	Value	Measured on
P Waves (mV)	5.6	03-Feb-2021
Threshold (V @ ms)	3.00 0.35	24-Sep-2020
Output (V @ ms)	4.50 0.35	
Impedance (ohms)	2403	02-Feb-2021

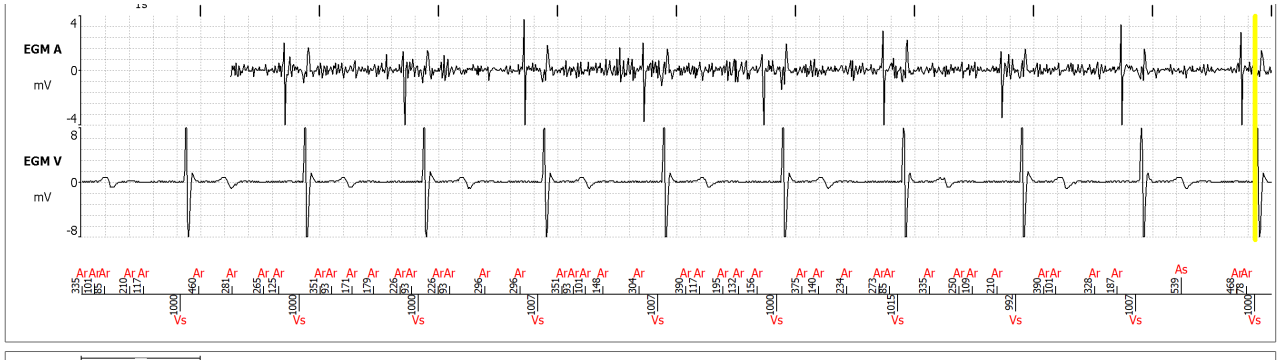


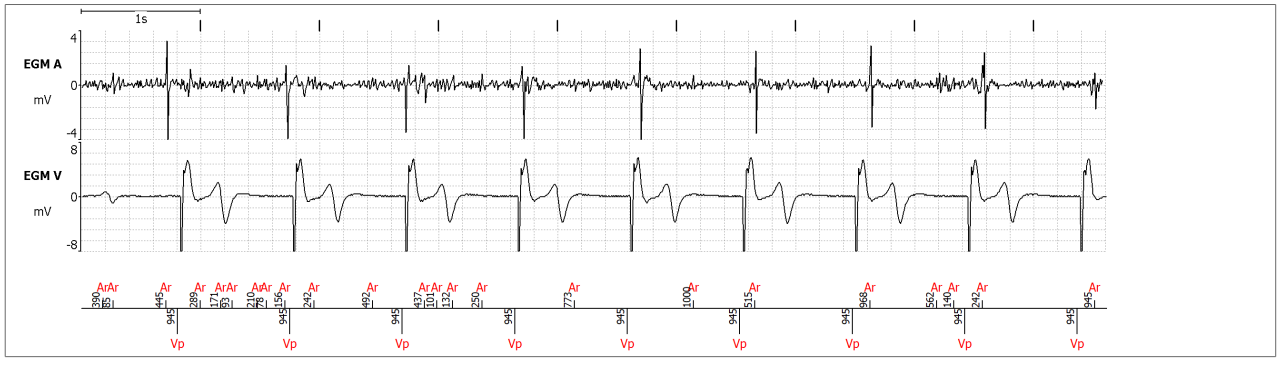
Transmission 5

Rhythm: Mode Switch | Duration: 32s | NOT TREATED









Which statement is correct?

1 The patient had episodes of paroxysmal atrial fibrillation

2 There is worsening of atrial lead dysfunction.

3 There is new atrial lead dysfunction

4 This patient is pacemaker dependant.

Explications

This transmission shows an “Atrial lead impedance” alert, which is triggered when the atrial lead impedance is below 200 Ohms or above 2000 Ohms. The last atrial impedance was 2403 Ohms. While a completely severed lead would result in an impedance of > 3000 Ohms, the value of 2403 Ohms is also clearly outside of the normal range (< 1000 Ohms). When looking at the trends, the high impedance has been around this value and stable for a few months. While sensing shows good values (5.6 mV), the atrial pacing threshold is very high (3V at 0.35ms). In this transmission, there are two Mode Switch episodes which show intermittent oversensing on the atrial channel. The oversensed signals are chaotic, with large amplitudes and are non-physiologic in nature. Together with the increased impedance and high pacing threshold, the lead noise confirms the diagnosis of atrial lead dysfunction.

Next steps

In patients with signs of atrial lead dysfunction, the diagnosis is often difficult as the lead still functions nearly all of the time and does not cause any symptoms. The clinical risks of an atrial lead dysfunction are obviously a lot lower than a dysfonctioning ventricular lead which is associated with multiple inappropriate therapies and syncope due to loss of ventricular capture. In ICDs, the atrial lead is often used for atrial pacing in patients with slow sinus rates or chronotropic incompetency, often aggravated by medical therapy in the context of their cardiomyopathy. This is also the case in this patient, who is paced in the atrium 84% of the time, mostly sensor-driven in Safer-R mode. Importantly, in ICD patients, proper functioning of the atrial lead is also important as it is part of the discrimination algorithm which differentiates between supraventricular and ventricular arrhythmias. In case of atrial lead dysfunction, tachycardias may be wrongly classified as ventricular or supraventricular. It is recommended to reprogram the discrimination algorithm (de-activate PARAD+) in case of suspected atrial lead dysfunction. The patient should be seen in-clinic to confirm the diagnosis (noise exacerbation maneuvers and X-ray), perform programming changes and discuss intervention. In this case, it was decided to add a new atrial lead and abandon the existing one (which is 18 years old).

Correct answer: 2

Transmission 6

Ventricular oversensing suspected

You receive the following transmission:

MicroPort™ CRM

GALI 4LV SonR CRT-D 2844

Alert report

V OVERSENSING SUSPECTED

THERAPIES	
Tachy Therapies	None
Arrhythmia history	Events
% biV pacing	98 %

DEVICE MANAGEMENT	
Battery	OK
Leads	OK
Coils	OK

WARNINGS

- No warning detected

Observations

- **[A33] V oversensing suspected.**
- Number of untreated arrhythmia episodes: 1

THERAPIES SUMMARY [Since last report: 08-Jul-2023]

TACHY THERAPIES AND EPISODES

	Slow VT	VT	FVT+VF	SVT->VT	Total		SVT/ST
Episodes	0(0)	0(0)	1(0)	0(0)	1(0)	ALL (Treated)	0
ATP	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
Shocks	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
Shocks 42J	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	

BRADY THERAPIES

Vs	2 %
Vp	98 %

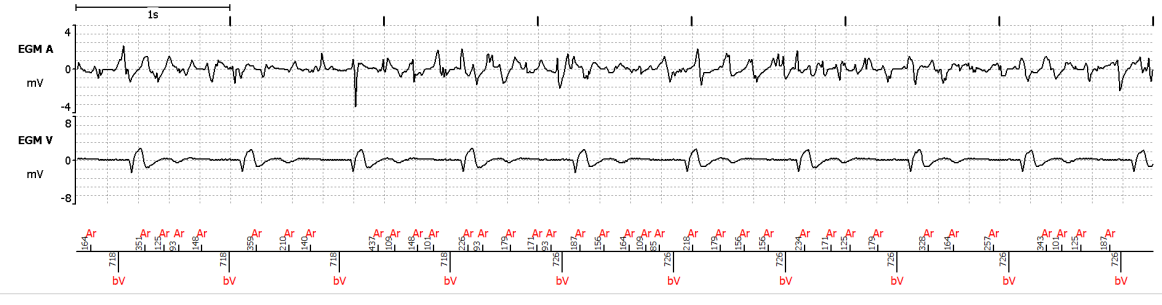
DEVICE MANAGEMENT SUMMARY Alert not available

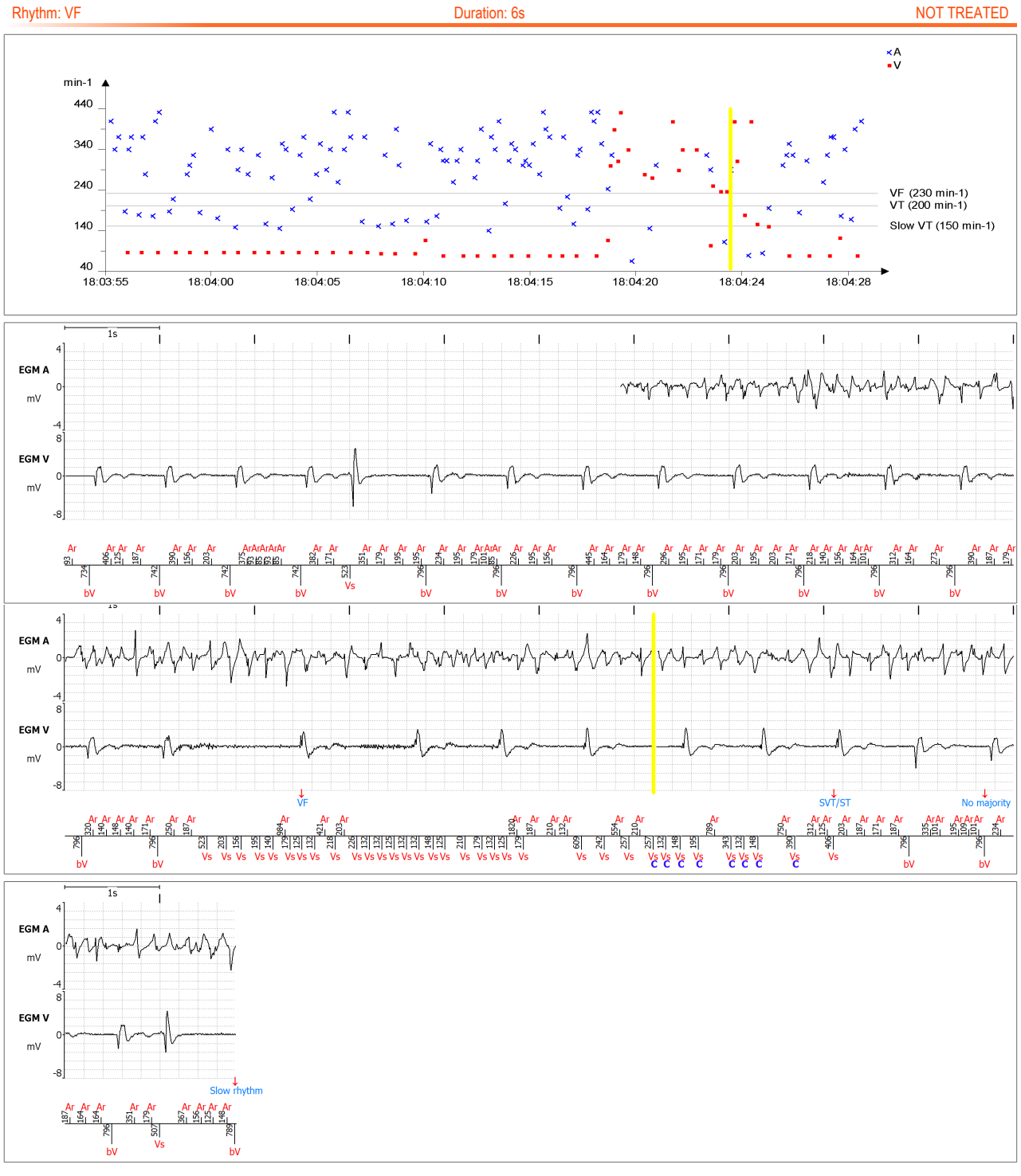
BATTERY Voltage **3.18V** Time to RRT

R.R.T. 1 3 5 7 9 12 Years

		Impedance (ohms)	Detection (mV)	Threshold (V @ ms)	Output (V @ ms)
LEADS	A	-	1.3	- -	
	RV	269	4.8	1.00 0.35	2.50 0.35
	LV	1017		1.00 0.35	2.50 0.35
COILS	RV Coil	287			

REAL TIME EGM





Which statement is correct?

1 Signs of lead dysfunction with aborted shock

2 Aborted shock due to oversensing of external noise

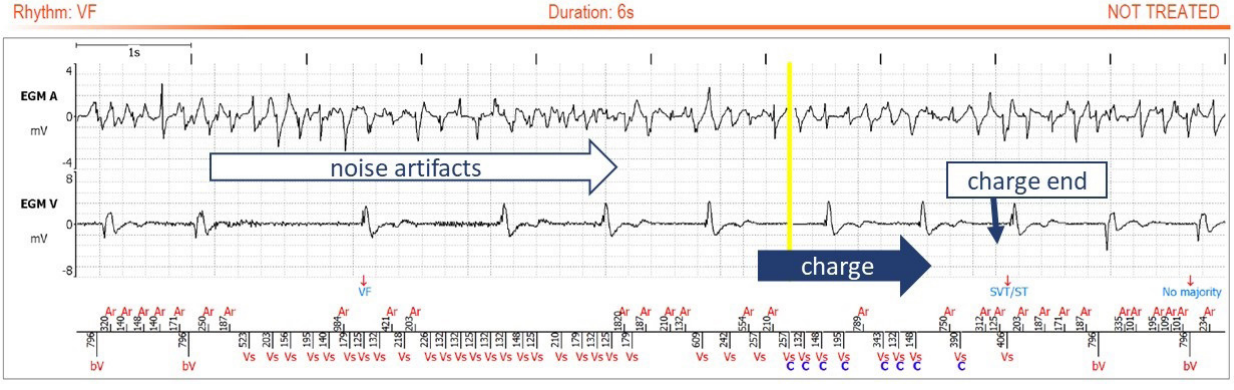
3 Episode of fast non-sustained ventricular tachycardia

4 Episode of atrial fibrillation with fast conducted ventricular response

Transmission 6

Explications

This transmission shows a “V oversensing suspected” alert, which is triggered when fast ventricular events (close to the blanking) are sensed, raising the suspicion of ventricular oversensing due to noise. In this transmission, there is a VF episode without therapy, which is also very suspicious for intermittent oversensing. When we look at the EGM, we see the sudden onset of a low-amplitude and very fast noise, resembling a 50 Hz signal. As the majority of the ventricular events is VF also throughout the persistence, the diagnosis of VF is made and the ICD begins to charge. Just after the onset of the charge, the noise stops and the VF majority is lost, stopping the charge.



Next steps

One of the major advantages of remote medicine is the ability to contact the patient soon after the registration of asymptomatic, but possibly clinically relevant episodes. This is the case for atrial and/or ventricular arrhythmias, but perhaps even more so for oversensing of noise caused by lead dysfunction or external noise. In this case, there is a suspicion of external noise, detected by the sensitive ventricular ICD lead. This type of noise is most often caused by patient-machine interaction such as during manipulation of poorly isolated tools which are connected to the power grid. A context of wet surfaces may exarcerbate the problem (e.g. in the kitchen or in a flooded basement). When contacting the patient within a day of the event, it is often possible to identify the source. When the episode is discovered during an in-clinic consultation, often weeks or months have passed, making it very challenging and often impossible for the patient to remember the source which may have caused the lead noise. After identification of the problem, the source needs to be avoided by the patient (ideally repaired or replaced by other tools) in order to prevent inappropriate therapies. When the source cannot be identified, it is possible to exclude other sources of noise such as lead dysfonction or diaphragm oversensing. In this case, the patient was manipulating a switch board in a flooded basement.

Correct answer: 2

Transmission 7

R.R.T.

You receive the following transmission:

MicroPort CRM

PARADYM RF DR

Alert report

BATTERY DEPLETION - R.R.T.

THERAPIES	
Tachy Therapies	None
Arrhythmia history	Events
% V Sensing	2 %

DEVICE MANAGEMENT	
Battery	RED
Leads	OK
Coils	OK

WARNINGS

- **[A25] R.R.T. (Recommended Replacement Time) detected 25/Jun/2021: plan device replacement.**

Observations

- Atrial arrhythmia number = 1
- Total time in Mode switch = 03min 06s (0.0%)
- The ventricular mean rate in mode switch is 66 min-1

THERAPIES SUMMARY [Since last report: 08-Apr-2021]

TACHY THERAPIES AND EPISODES

	Slow VT	VT	FVT+VF	SVT->VT	Total		SVT/ST
Episodes	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Treated)	0
ATP	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
Shocks	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
Shocks 42J	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	

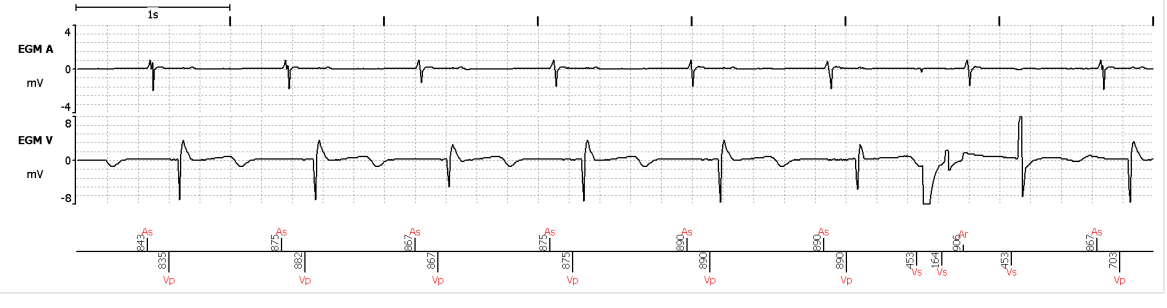
BRADY THERAPIES

As	11 %	Vs	2 %
Ap	88 %	Vp	98 %
PMT	0		
ModeSwitch	1		
Time in MS	3min 6s		

DEVICE MANAGEMENT SUMMARY

BATTERY	Voltage	2.66V			
		Impedance (ohms)	Detection (mV)	Threshold (V @ ms)	Output (V @ ms)
LEADS	A	513	2.5	0.75 0.35	2.00 0.35
	V	367	15.1	1.50 0.35	3.00 0.35
COILS	RV Coil	262			
	SVC Coil	277			

REAL TIME EGM



Transmission 7

What is the correct answer ?

1 Plan for generator change

2 Plan for generator change and addition of atrial lead

3 Plan for generator change and addition of right ventricular lead

4 Plan for generator change and addition of left ventricular lead

Explications

This transmission shows an R.R.T. (Recommended Replacement Time) alert meaning it's time to plan the device replacement. This is where remote monitoring may significantly decrease the amount of in-clinical visits. There is no more need to see patients more often when the battery shows a limited remaining duration. When the alert is received, the patient may be electively planned for a generator change, leaving ample time for additional investigation (such as echocardiography) when needed.

In this transmission however, there is also an abnormal real time EGM which shows non-physiological artifacts on the ventricular channel. This is not an alert as lead sensing, threshold and impedance measurements are all normal. But ICD lead dysfunction may be dangerous as it is associated with inappropriate shocks and loss of capture.

Next steps

This patient was admitted to the hospital soon after the transmission; as there was not only indication of a generator change, but also of lead revision. During interrogation, multiple "NSVT" episodes showed signs of RV lead dysfunction with oversensing of noise artifacts. Therefore the patient underwent not only generator change, but also addition of an RV ICD lead.

Correct answer: 3

Transmission 8

Lead Parameters Evaluation (LPE) RV alert

78-year old patient implanted with a dual chamber ICD (Talentia DF4 DR) four months prior because of dilated cardiomyopathy.

You receive the following transmission:

MicroPort™ CRM

TALENTIA DF4 DR 3540

Implant date: 23-Aug-2024

Alert report **Sent: 26-Dec-2024 - 00:34**

SEVERAL ALERTS RAISED

THERAPIES	
Tachy Therapies	None
Arrhythmia history	No Events
% V Sensing	5 %

DEVICE MANAGEMENT	
Battery	OK
Leads	RED
Coils	OK

WARNINGS

- [A44] V Threshold value is over the max tested amplitude (5.0 V) on 26/Dec/2024.
- **[A130] Lead Parameters RV alert was raised on 25/Dec/2024, (0 years, 4 months, and 2 days since implantation) for the following reason(s):**
- **↳ Right ventricular impedance has been considered too Low over the past week. Please refer to the corresponding RV impedance section for more information.**
- **↳ Right ventricular sensitivity has been considered too Low over the past week. Please refer to the corresponding RV sensitivity section for more information..**
- **↳ Right ventricular threshold has been considered too Highover the past week. Please refer to the corresponding RV threshold section for more information.**

Observations

- [A28] AT/AF Daily Burden higher than 6 h: 17h 7min, 17/Dec/2024.

THERAPIES SUMMARY [Since last report: 25-Dec-2024]

TACHY THERAPIES AND EPISODES

	Slow VT	VT	FVT+VF	SVT->VT	Total		SVT/ST
Episodes	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Treated)	0
ATP	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
Shocks	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	
Shocks 42J	0(0)	0(0)	0(0)	0(0)	0(0)	ALL (Success)	

BRADY THERAPIES

As	3 %	Vs	5 %
Ap	92 %	Vp	95 %
PMT	0		
ModeSwitch	0		
Time in MS	0s		

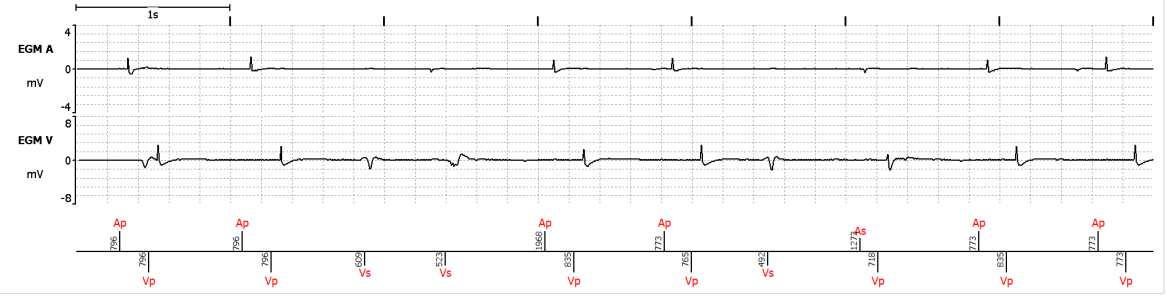
DEVICE MANAGEMENT SUMMARY

BATTERY Voltage **3.18V** Time to RRT

R.R.T. 1 3 **5** **7** 10 15 Years

		Impedance (ohms)	Detection (mV)	Threshold (V @ ms)	Output (V @ ms)
LEADS	A	425	1.0	1.25 0.35	3.50 0.35
	V	249	1.7	1.50 0.35	6.00 0.35
COILS	RV Coil	242			

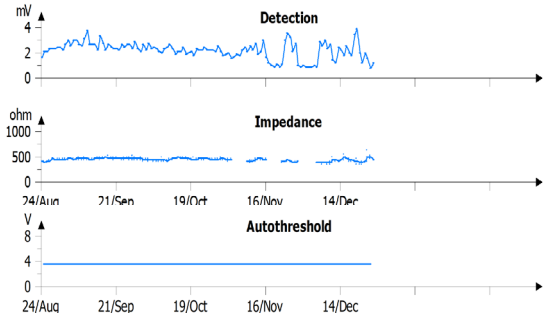
REAL TIME EGM



Transmission 8

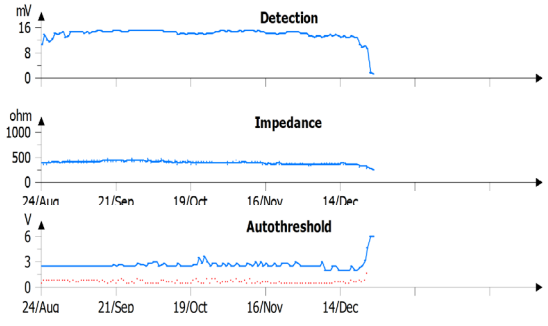
ATRIAL LEAD

	Value		Measured on
P Waves (mV)	1.0		26-Dec-2024
Threshold (V @ ms)	1.25	0.35	03-Sep-2024
Output (V @ ms)	3.50	0.35	
Impedance (ohms)	425		26-Dec-2024



V LEAD

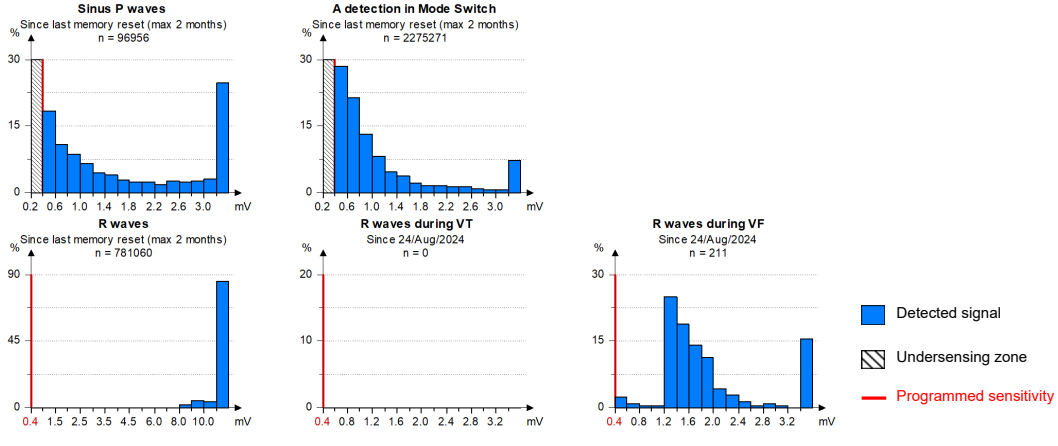
	Value		Measured on
R Waves (mV)	1.7		26-Dec-2024
Threshold (V @ ms)	1.50	0.35	24-Dec-2024
Output (V @ ms)	6.00	0.35	
Impedance (ohms)	249		26-Dec-2024



LEADS IMPLANTED

	Manufacturer	Model	SN	Implanted on
A	Medtronic	4076-45	BBL1724032	23-Aug-2024
V	Medtronic	6935M-55	TDL321224G	23-Aug-2024
RV Coil	-	-	-	23-Aug-2024
SVC Coil	-	-	-	23-Aug-2024

P & R WAVE AMPLITUDE DISTRIBUTION



What are the appropriate next steps?

1. Call the patient to the clinic in order to deactivate the therapies
2. Tell the patient not to drive to the clinic themselves
3. This appears to be a measurement error. Schedule a new transmission in a week.
4. Perfom lead testing in the clinic with arm and breathing manoeuvres
5. The RV lead most likely needs to be changed.

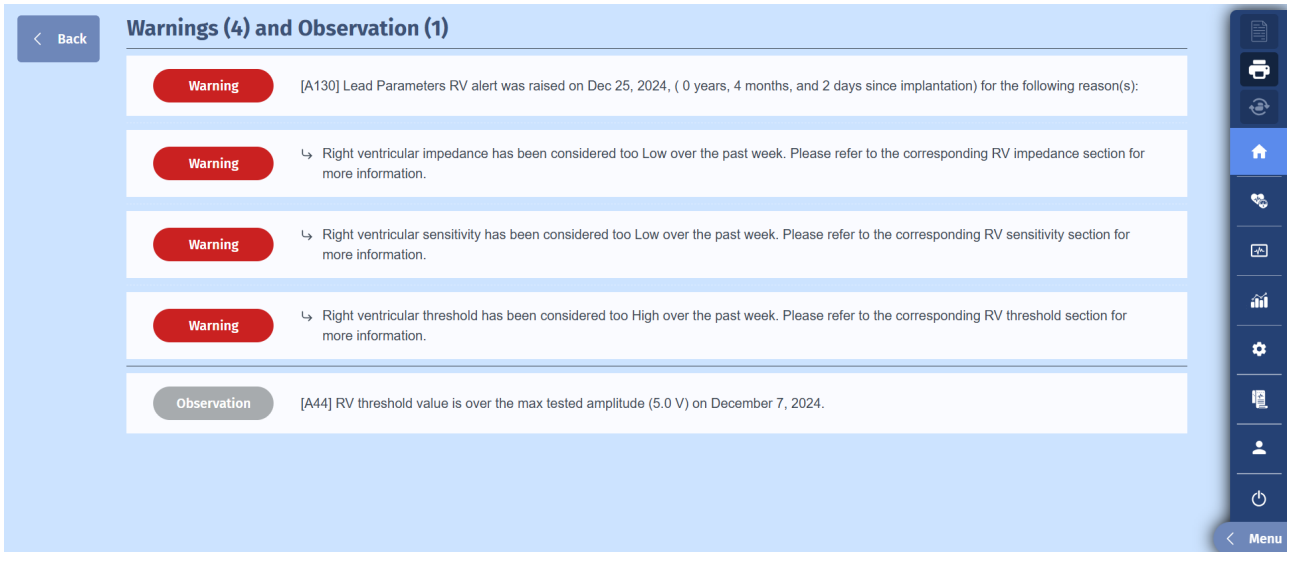
Clinical case

The patient was contacted and asked to come into the device clinic for a manual check-up. The 12-lead ECG showed ventricular escape rhythm and ventricular pacing spikes without capture. The patient had no new symptoms, NYHA II.

Interrogation

The overview screen shows abnormal sensing values for the RV, 0 episodes but multiple alerts (red button).

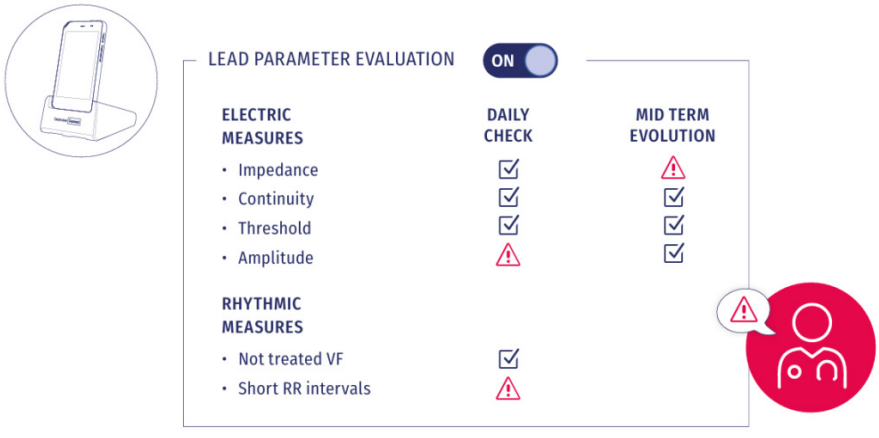
The alert list confirms the presence of the Lead Parameter Evaluation (LPE) alert based on changes in sensing amplitude, autothreshold and impedance. There is also an older alert for RV threshold only.



Lead parameter evaluation (LPE)

The Lead Parameter Evaluation (LPE) is an alert, which aims to enhance patient's protection through earlier lead failure detection. It is a multi-parametric algorithm which may trigger a red alert through an evaluation of daily lead checks (impedance, threshold, sensing) and other information (non treated VF episodes, short VV interval counter). In more details, the electrical settings assess daily lead impedance, coil continuity, lead pacing threshold and lead sensing amplitude. The rhythmic settings assess the daily number of non-treated episodes in VF rate zone and the daily number of short ventricular intervals (<= 180ms) outside an episode in VF rate zone. The LPE issues a lead alert if 1 electrical setting is abnormal for 3 days in a row, or 2 settings (electrical/electrical, or electrical/rhythmic) are abnormal in a 7-day window.

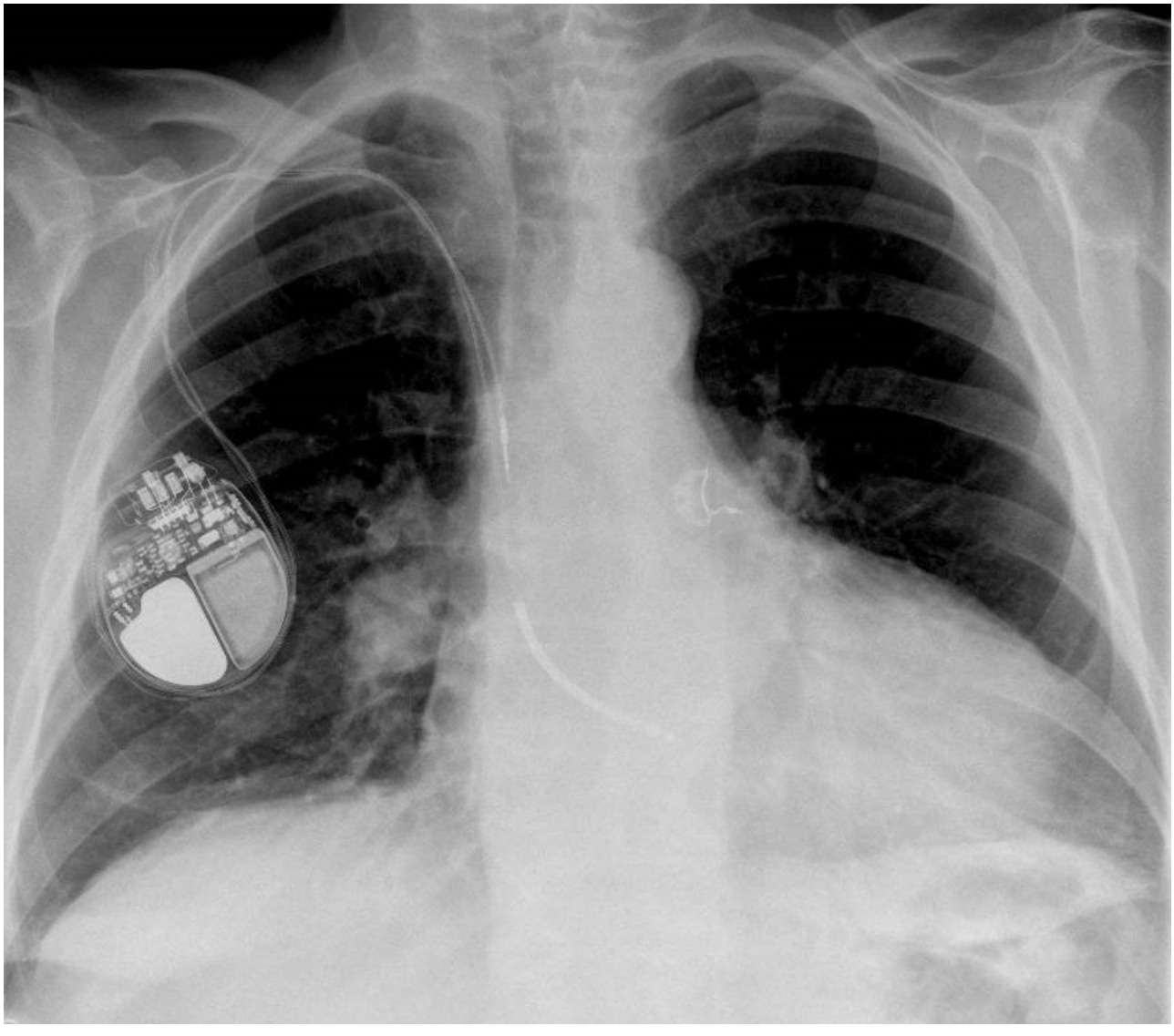
This alert, which could be considered one of the most important alerts for ICD patients, should always be associated with a rapid response, ensuring the patient is secure and not at risk for inappropraite and/or ineffective therapies.



Lead trends

The lead trends show that since a few days, the lead parameters had been deteriorating with low sensed values, high/out-of-range pacing thresholds and decreasing impedance. In fact, an alert had already been sent a few days earlier due to the inability to perform pacing threshold but review of the lead showed no other arguments for lead dysfunction at the time and careful remote evaluation had been continued. Because of high suspicion of RV lead dysfunction, the therapies were deactivated.

A chest X-ray was performed showing RA and RV lead displacement.



The next day, both leads were removed and new atrial and RV ICD leads were placed.

Correct answers: 1, 2, 4, 5

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